Abstract of the Madison Region’s Advanced Manufacturing Industry Cluster

April 2019

Abstract of the Madison Region's Advanced Manufacturing Industry Cluster

Prepared for
Madison Region Economic Partnership

Matt Kures
University of Wisconsin-Madison
Division of Extension
Center for Community and Economic Development

Craig Kettleson and Michael Gay

Madison Region Economic Partnership

Financial support provided by
Wisconsin Economic Development Corporation

This page is intentionally blank

Contents

List of Figures

Section 1

Section 2

Section 3

Introduction

Contemporary economic development strategies recognize that regional assets are the true drivers of employment and income growth. The Madison Region is endowed with many potential assets, including competitive industry concentrations; high levels of human and social capital; robust physical infrastructure; unique natural resources; and exceptional quality of life characteristics. While these assets influence many aspects of the regional economy, several are directly connected to the Advanced Manufacturing Industry Cluster.[1] Specifically, the Region has a diversity of firms engaged in a variety of advanced manufacturing niches; a robust innovation and entrepreneurial (I&E) ecosystem; world-class educational institutions; and extraordinary levels of human capital that contribute to a highly skilled labor force. The mere presence of these regional strengths, however, does not guarantee future prosperity and development of the advanced manufacturing cluster or the broader Region. Instead, the Madison Region must find ways to leverage these assets in innovative manners that build economic opportunities, but also maintain the Region's quality of life.

Over the past two decades, industry cluster initiatives have become a popular means for leveraging competitive assets in communities and regions. While a more in-depth discussion is provided below, industry clusters are geographically-concentrated businesses that are connected through: 1) the products they produce; 2) the supplies, services, infrastructure and technologies they require; and 3) a common labor force. In other words, industry clusters are "groups of industries closely related by skill, technology, supply, demand, and/or other linkages" (Delgado, Porter and Stern, 2014, p. 2). Importantly, industries in a cluster also share some level of common opportunities and threats. Developing an industry cluster strategy around the Region's advanced manufacturing industries provides one opportunity for addressing any potential opportunities and threats by ultimately making these industries more competitive.

The Madison Region certainly possesses the necessary components to further develop its advanced manufacturing cluster. However, Southern Wisconsin is by no means the only region attempting to build a cluster around its advanced manufacturing assets. Cities, regions and states across the nation are aggressively pursuing cluster opportunities in advanced industries such as machinery, electronic components, pharmaceuticals, advanced materials, and navigational, measurement and control instruments. Regions are also considering how their advanced manufacturing industries are being influenced by modern production technologies associated with Industry 4.0. *The challenge for the Madison Region is to build its advanced manufacturing cluster around its comparative advantages in a manner that differentiates itself from other advanced manufacturing related initiatives.* Accordingly, a primary goal of this abstract is to begin understanding the Region's advanced manufacturing cluster in a way that identifies its potential comparative advantages.

[1] The *Advance Now* economic development strategy formally identifies advanced manufacturing as a cluster initiative that holds promise for the Madison Region.

Understanding Industry Clusters

While industry clusters are popular as economic development strategies, cluster initiatives are often misunderstood and misused. Many economic development practitioners fail to understand how clusters operate from a theoretical perspective, leading to poor participation of cluster stakeholders and improper implementation. Consequently, identifying potential sources of comparative advantage for the Region's Advanced Manufacturing cluster requires a basic understanding of industry cluster theory. While potential cluster stakeholders do not need an in-depth knowledge of this theory, they should appreciate how cluster components interact with each other.

As previously suggested, industry clusters are groups of industries connected by skills, technologies, supply chains, demand sources and other linkages. More commonly, industry clusters are "geographic concentrations of interconnected companies, specialized suppliers, service providers, firms in related industries, and associated institutions (e.g. universities, standards agencies, trade associations) in a particular field that compete but also cooperate" (Porter 1998, p. 197). Several key terms in this definition provide guidance for this study of the Region's advanced manufacturing cluster:

- *Industry clusters involve interconnected companies, specialized suppliers, service providers, and firms in related industries* - The concept of clusters goes beyond the recognition of a single industry sector or classification. Clusters acknowledges important connections and relationships among industries and other business types that support each other through supply chains and service provision. In theory, the presence of these quality local suppliers and services creates efficiencies and increases firm competitiveness. For instance, nearby firms in the advanced manufacturing cluster might have shared infrastructure needs or require similar inputs in their supply chains that could be provided by local firms;

- *Industry clusters include associated institutions* – Industry clusters are not solely comprised of for-profit, private-sector firms. Industry clusters recognize the potential assistance and knowledge spillovers (transfers) that universities, trade associations, and government agencies can provide.[2] The participation of these institutions in cluster-based initiatives can provide research, workforce development, advocacy, and other support for cluster establishments. While the Madison Region Economic Partnership (MadREP) will be a key partner in developing the advanced manufacturing cluster, the initiative will also depend on support and participation from state agencies; other economic development organizations; local municipalities; educational institutions; workforce development entities; and non-profit enterprises that work with manufacturing-related businesses and talent;

- *Industry clusters have a geographic concentration* – Clusters and their associated components are concentrated in a distinct geographic area. Geographic concentration allows for increased interaction and efficiencies to be developed among companies in a cluster. While the exact geographic extent of a cluster will depend on a variety of factors, the geographic scope of a cluster relates to the distance in which informational, transactional, incentive, and other efficiencies occur (Porter, 2000). Accordingly, the geographic boundaries of clusters are defined by inter-company relationships and *not* political boundaries

[2] Knowledge transfers can also occur among individual firms in an industry cluster.

(Rosenfeld, 2001). While the geographic area for this cluster analysis is based on a pre-determined geography (see below), there may be instances where advanced manufacturing cluster opportunities extend into nearby areas (such as Milwaukee, the Fox Valley, Chicago or Minneapolis-St. Paul);

- *Industry cluster firms compete, but also cooperate* - Individual firms within an industry cluster are in competition with each other, but also exhibit a level of cooperation. Cooperation in an area allows firms to engage in activities such as joint-contract bidding; developing custom labor force training programs; coordinating research efforts; providing a unified voice on industry-wide issues; and improving their industry's visibility. The precondition of cooperation requires that private industry stakeholders, or industry champions, have a lead role in the potential success of industry clusters. *Without cooperation, a region does not have an industry cluster, but rather a simple industry concentration.* Broad participation of cluster firms in the Madison Region will be vital to the success of an advanced manufacturing cluster initiative. The true challenge is providing authentic incentives to firms and stakeholders to engage in cluster efforts.

Report Outline

Based on the preceding discussion, a successful advanced manufacturing cluster initiative will require: 1) considering the breadth and depth of industries in the advanced manufacturing cluster; 2) understanding characteristics of the Region's labor force or human capital; 3) identifying potential niches or opportunities for differentiating the Region's advanced manufacturing cluster; 4) enhancing the cluster's support and development ecosystem; and 5) developing key strategic initiatives to support the cluster in the Madison Region. To explore these cluster requirements, the remainder of this advanced manufacturing cluster abstract is organized as follows:

Section 1 – Advanced Manufacturing Industries in the Madison Region. Understanding the cluster in terms of its industry classifications is an important step to identifying initiatives to support and grow the Region's advanced manufacturing cluster. Advanced manufacturing measures of industry scale and scope include employment, location quotients, establishments, non-employers and productivity. Definitions of advanced manufacturing industries are further detailed in Section 1.

Section 2 – Advanced Manufacturing Human Capital. Section 2 focuses on advanced manufacturing talent, or human capital, by considering measures of the labor force's scale and scope. Talent is largely defined by using occupations. Specific measures of advanced manufacturing human capital include occupational concentrations, talent diversity, wage rates, age distributions, turnover rates and susceptibility to automation.

Section 3 – Advanced Manufacturing Cluster Support and Development Ecosystem. Section 3 examines other factors that contribute to the support and development of the Region's advanced manufacturing cluster including: broadband availability and distribution; regional assets that influence talent attraction and retention; international markets for advanced manufacturing products; purchasing patterns; business parks, certified and gold shovel sites, and speculative buildings; educational institutions; and support organizations that foster innovation and connect firms to resources.

As noted earlier, identifying potential niches or opportunities for differentiating the Region's advanced manufacturing cluster; and developing key strategic initiatives to support the cluster in the Madison Region are two important components of a cluster analysis. These components will be completed at a later date once this portion of the cluster analysis has generated conversation and feedback from key stakeholders in the Region's advanced manufacturing cluster.

Defining Advanced Manufacturing

As noted by the Brookings Institution, the nation's advanced industry sector is "characterized by its deep involvement with technology research and development (R&D) and STEM (science, technology, engineering, and math) workers. The sector encompasses 50 industries ranging from manufacturing industries such as automaking and aerospace to energy industries such as oil and gas extraction to high-tech services, such as computer software and computer system design, including for health applications. These industries encompass the nation's "tech" sector at its broadest and most consequential." (pg 2. Muro, Rothwell, Andes, Fikri, and Kulkarni, 2015).

This analysis focuses on manufacturing categories within the broader advanced industries sector. However, many other advanced industries are covered in MadREP's ICT, Bioscience and Health Care industry cluster abstracts. Furthermore, these industry categories are not necessarily exclusive. Many of the advanced manufacturing categories used in this analysis overlap with the Region's other key clusters.

For purposes of this analysis, advanced manufacturing includes the following industries. Section 1 of this analysis describes these industries in greater detail while Figure I.1 provides an outline of the advanced manufacturing cluster components.

Advanced Manufacturing Industries

- Chemical Manufacturing (NAICS 325)
- Plastics and Rubber Products Manufacturing (NAICS 326)
- Nonmetallic Mineral Product Manufacturing (NAICS 327)
- Primary Metal (NAICS 331)
- Fabricated Metal Product Manufacturing (NAICS 332)
- Machinery Manufacturing (NAICS 333)
- Computer and Electronic Product Manufacturing (NAICS 334)
- Electrical Equipment, Appliance, and Component Manufacturing (NAICS 335)
- Transportation Equipment Manufacturing (NAICS 336)

Also note that Medical Equipment and Supplies Manufacturing (NAICS 3391) could also be considered as part of the advanced manufacturing cluster. However, this industry is considered in detail in MadREP's Bioindustry Cluster Abstract.

Figure I.1 – Advanced Manufacturing Cluster Components

Key Advanced Manufacturing Subsectors

Chemical Manufacturing

- Basic chemicals
- Resin, synthetic rubber, and artificial synthetic fibers
- Pesticide, fertilizer, and other agricultural chemicals
- Pharmaceutical and medicine mfg.
- Paint, coating, and adhesives
- Soap, cleaning compounds and toilet preparations
- Other chemical products and preparations

Plastics and Rubber Products Manufacturing

- Plastics pipe, pipe fitting, and unlaminated profile shapes
- Laminated plastics plates, sheets and shapes
- Polystyrene foam products
- Urethane and other foam products
- Tire manufacturing
- Rubber and plastics hoses and belting
- Rubber product manufacturing for mechanical use

Nonmetallic Mineral Product Manufacturing

- Clay product and refractory mfg.
- Glass and glass products
- Cement and concrete products
- Lime and gypsum product
- Other nonmetallic mineral products

Primary Metal Manufacturing

- Iron and steel mills and ferroalloy mfg.
- Steel product mfg. from purchased steel
- Alumina and aluminum production and processing
- Foundries

Fabricated Metal Product Manufacturing

- Forging and stamping
- Architectural and structural metals
- Boiler, tank, and shipping containers
- Hardware
- Spring, wire and turned products
- Machine shops
- Coating, engraving, heat treating, and allied activities
- Other fabricated metal products

Machinery Manufacturing

- Agriculture, construction, and mining machinery
- Industrial machinery
- Commercial and service industry machinery
- Ventilation, heating, air-conditioning, and commercial refrigeration equipment
- Metalworking machinery
- Engine, turbine, and power transmission equipment
- Other general purpose machinery

Computer and Electronic Product Manufacturing

- Computer and peripheral equipment
- Communications equipment mfg.
- Audio and video equipment mfg.
- Semiconductor and other electronic component mfg.
- Navigational, measuring, electromedical, and control instruments mfg.

Electrical Equipment, Appliance, and Component Manufacturing

- Electric lighting equipment mfg.
- Household appliance mfg.
- Electrical equipment mfg.
- Other electrical equipment and component mfg.

Transportation Equipment Manufacturing

- Motor vehicle mfg.
- Motor vehicle body and trailer mfg.
- Motor vehicle parts mfg.
- Aerospace product and parts mfg.
- Other transportation equipment mfg.

Key Advanced Manufacturing Subsectors and Niches

Composite Materials

- Artificial and synthetic fibers and filaments
- Glass and glass product manufacturing
- Cement and concrete product manufacturing

Bicycle Manufacturing

- Bicycles
- Bicycle components
- Bicycle accessories

Machinery

- Agriculture, construction & mining machinery
- Industrial machinery manufacturing
- Metalworking machinery manufacturing

Pharmaceuticals

- Medicinal and botanical mfg.
- Pharmaceutical preparation mfg.
- In-vitro diagnostic substance mfg.
- Biological product (except diagnostic) mfg.

Measuring and electromedical instruments

- Electromedical and electrotherapeutic apparatus mfg.
- Analytical laboratory instrument mfg.
- Irradiation apparatus mfg.

Figure I.1 (Continued) – Advanced Manufacturing Cluster Components

Advanced Manufacturing Talent

Production Occupations

- Inspectors, Testers, Sorters, Samplers, and Weighers
- Assemblers and Fabricators
- Welders, Cutters, Solderers, and Brazers
- Tool and Die Makers
- Metal and Plastic Cutting, Punching and Press Machine Setters, etc.
- Metal-Refining Furnace Operators and Tenders
- CNC Machine Tool Operators
- Sheet Metal Workers
- Chemical Equipment Operators and Tenders
- Coating, Painting, and Spraying Machine Setters, Operators, and Tenders
- Extruding, Forming, Pressing, and Compacting Machine Setters, etc.
- Packaging and Filling Machine Operators
- Mixing and Blending Machine Setters, etc.
- Machinists

Engineers, Computer and Technical Occupations

- Industrial Engineers
- Mechanical Engineers
- Electrical Engineers
- Materials Engineers
- Electronics Engineers, Except Computer
- Engineers, All Other
- Chemical Engineers
- Chemists
- Biomedical Engineers
- Electrical and Electronics Engineering Technicians
- Electricians
- Logisticians
- Mechanical Drafters
- Industrial Engineering Technicians
- Software Developers, Systems Software
- Software Developers, Applications
- Computer Systems Analysts

Transportation and Repair Occupations

- Industrial Machinery Mechanics
- Maintenance Workers, Machinery
- Maintenance and Repair Workers, General
- Shipping, Receiving, and Traffic Clerks
- Laborers and Freight, Stock, and Material Movers
- Production, Planning, and Expediting Clerks
- Heavy and Tractor-Trailer Truck Drivers
- Industrial Truck and Tractor Operators
- Crane and Tower Operators
- Bus and Truck Mechanics and Diesel Engine Specialists

Business, Management and Financial Occupations

- General and Operations Managers
- Architectural and Engineering Managers
- Natural Sciences Managers
- Industrial Production Managers
- First-Line Supervisors of Production and Operating Workers
- Compliance Officers
- Accountants and Auditors
- Bookkeeping, Accounting, and Auditing Clerks
- Market Research Analysts and Marketing Specialists
- Business Operations Specialists

Sales and Office Support Occupations

- Customer Service Representatives
- Office Clerks, General
- Secretaries and Administrative Assistants, Except Legal, Medical, and Executive
- Sales Representatives, Technical and Scientific Products
- Buyers and Purchasing Agents
- First-Line Supervisors
- Sales Representatives
- Office Support Occupations

Advanced Manufacturing Support and Development Ecosystem

- Specialized Financial, Legal and Professional Services
- Broadband
- Air, Truck and Rail Transportation
- Talent Attraction and Retention Factors (Lifestyle/Quality of Life, Housing)
- Industrial Locations/Industrial Parks
- Educational Institutions/R&D Funding
- Workforce Development Organizations
- Entrepreneurial Support (Organizations, Physical Spaces, Fabrication Labs, Mentor Programs and Technical Assistance, Networking, Capital, etc.)

Figure I.1 (Continued) – Advanced Manufacturing Cluster Components

Advanced Manufacturing Industry Supply Chains

Chemical, plastics and rubber products manufacturing

- Basic organic and inorganic chemicals
- Pharmaceutical preparation, botanicals and biological products
- In-vitro diagnostic substances
- Petrochemical and other chemical products and preparations
- Petroleum-based resins and other plastic feedstocks
- Refined petroleum products
- Machined, coated, engraved and heat treated metal products
- Plastic and chemical manufacturing machinery
- Synthetic dyes and pigments
- Industrial gases
- Adhesives
- Scientific r &d services
- Management, scientific, and technical consulting services
- Machinery, maintenance, leasing and repair services
- Paper and printing inks
- Printed and bare circuit assemblies
- Relay and industrial controls
- Oilseeds and processed animal and rendered byproducts
- Laminated/unlaminated paper and plastic materials, films and sheets
- Glass, paperboard, metal and plastic containers

Nonmetallic mineral product manufacturing

- Sand, gravel, clay and ceramic and refractory minerals
- Quarried stone
- Basic organic and inorganic chemicals
- Commercial and industrial machinery
- Paperboard containers
- Quarried other nonmetallic minerals
- Fabricated metal products
- Alkalies and chlorine products
- Paints and coatings
- Coating ,engraving, heat treating, and allied activities
- Scientific research and development services
- Adhesives
- Special tools, dies, jigs and fixtures
- Industrial gases
- Wood containers and pallets
- Machine shop services
- Plastic materials and resins
- Architectural, engineering and related services
- Plastic packaging materials
- Machinery repair services
- Hand tools

Primary and fabricated metal product manufacturing

- Semi-finished and finished metal products - iron and steel
- Semi-finished and finished products – aluminum
- Semi-finished and finished other metals (titanium, brass, copper and various alloys)
- Scrap, coal, ore
- Clay and non-clay refractory products
- Abrasives and plastics
- Industrial gases
- Chemical products and preparations
- Industrial machinery leasing and repair
- Industrial process instruments
- Metal cutting and formation tools
- Specialized tools, dies, jigs and fixtures
- Hand tools
- Plastic and paperboard packing

Machinery and transportation equipment manufacturing

- Motors, generators, engine equipment, speed changers and gears
- Machined, coated, stamped, extruded, engraved and heat treated metal products
- Tires, gaskets hoses, belts and other rubber products
- Laminated plastic plates, sheets and shapes and other plastic products
- Batteries, semiconductors, printed circuit assemblies, electrical connectors and relays
- Valves, fittings and bearings – plastic and metal
- Iron, steel, zinc, lead, aluminum, copper, and other ferrous and non-ferrous metals/alloys
- Paints, coatings, lubricants, abrasives, adhesives and other industrial chemicals
- Metal cutting & forming machine tools/other machine tools
- Industrial gases
- Material handling equipment
- Industrial controls and industrial process instruments
- Scientific r &d services
- Management, scientific, and technical consulting services
- Machinery, maintenance, leasing and repair services
- Printed and bare circuit assemblies
- Relay and industrial controls
- Specialized tools, dies, jigs and fixtures

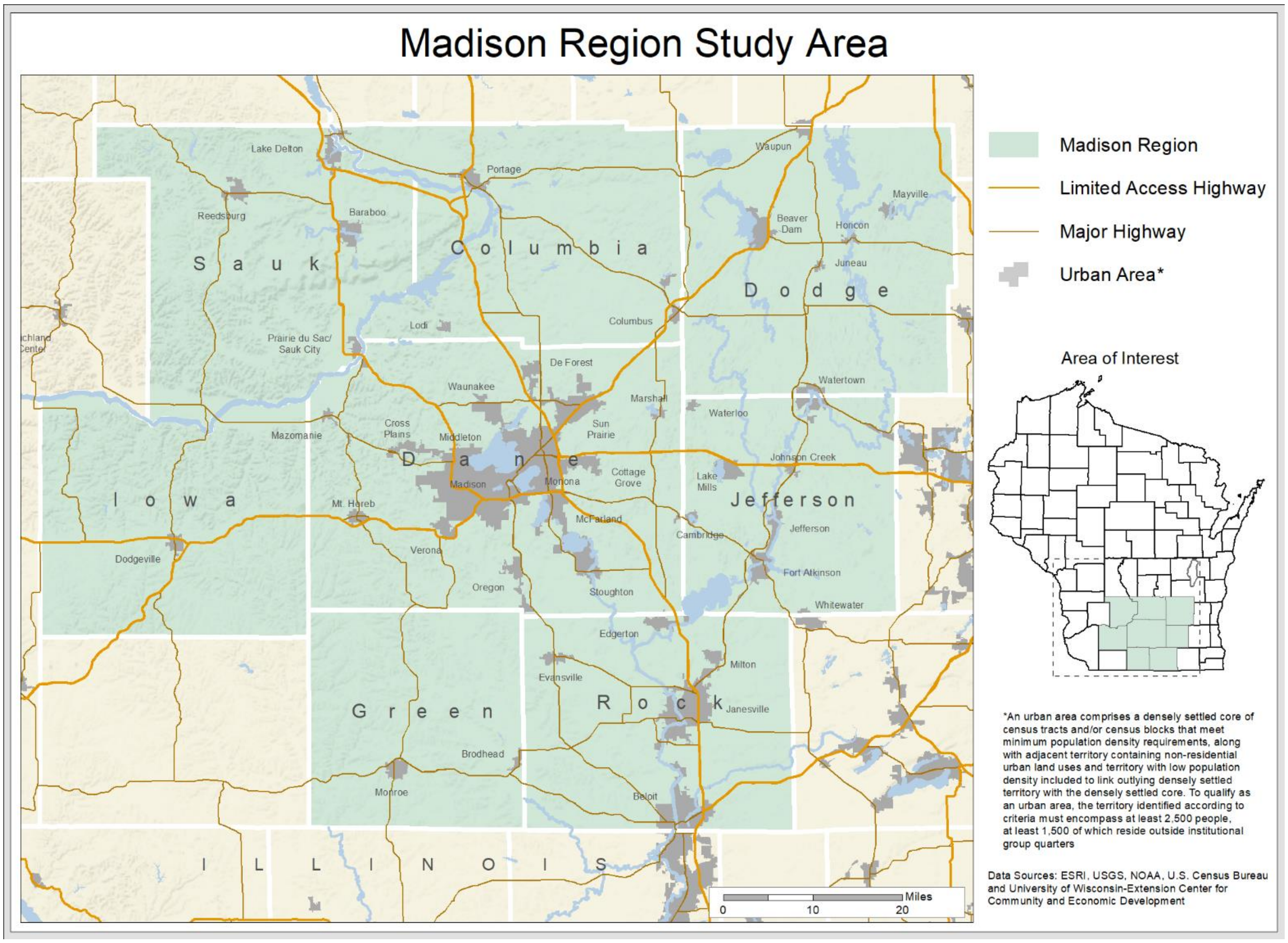
Computer and electronic product manufacturing and electrical equipment, appliance, and component manufacturing

- Computer terminals, storage devices and peripheral equipment
- Software
- Scientific research and development services
- Semiconductor and related devices
- Printed circuit assemblies (electronic assemblies)
- Bare printed circuit boards
- Communication and energy wires and cables
- Electron tubes
- Relay and industrial controls
- Electronic capacitors, resistors, coils, transformers, and other inductors
- Measuring and controlling devices
- Crowned, forged, stamped, and sintered metals
- Plates and fabricated structural products, metal and plastic
- Coated, engraved, heat treated products
- Rolled, drawn, extruded and alloyed metals
- Paperboard containers
- Custom roll formed metals
- Electronic connectors and other electronic components
- Plastics materials and resins
- Industrial gases
- Paints, coatings, lubricants, abrasives, adhesives and other industrial chemicals

Study Area

The advanced manufacturing study area used in this analysis is the eight-county Madison Region served by MadREP (Figure I.2). Specifically, the Madison Region consists of Columbia, Dane, Dodge, Green, Iowa, Jefferson, Rock, and Sauk counties. Columbia, Dane, Green and Iowa counties are part of the Madison metropolitan statistical area (MSA) while Rock County is part of the Janesville-Beloit MSA. These MSA definitions will become important units of analysis in portions of this analysis of the advanced manufacturing cluster. Importantly, the Madison Region's geographic location also allows access to the significant metro areas of Milwaukee, Chicago and the Twin Cities.

Figure I.2 – Madison Region Study Area



Readers of this abstract should note that the broad appeal of cluster initiatives often leads to high expectations for results. Despite all of the proposed benefits to regions and firms, it is important to recognize that the success of clusters as an economic development strategy is uncertain, even when fully understood and properly implemented. While examples of successful cluster initiatives exist, empirical evidence on the ability of clusters to increase competitiveness, generate job growth, and produce new economic activity is being actively debated among researchers (for examples see: Palazuelos, 2005; McDonald et al, 2007; Motoyama, 2008; Woodward, 2012; and Delgado et al, 2014). Nonetheless, the lack of conclusive evidence does not mean that regions should abandon cluster initiatives. Clusters can succeed with proper guidance and participation. Furthermore, industry clusters remain beneficial as a framework for analyzing advanced manufacturing industries as they can identify the potential connections and synergies among firms in the Region.

Finally, this analysis recognizes that it cannot capture every element and aspect of the advanced manufacturing cluster. The cluster is constantly evolving and will continue to change at a rapid pace. Accordingly, this analysis is intended to be consistently revisited and updated and this report is intended to be a living document. Readers are welcome to suggest opportunities for improvement and amendments.

This page is intentionally blank

Section 1 – Advanced Manufacturing Industries in the Madison Region

As noted in the Introduction, the Madison Region's advanced manufacturing industry cluster encompasses a diversity of manufacturing subsectors that provide significant economic contributions. Each individual firm in the advanced manufacturing cluster has unique characteristics and community impacts. However, advanced manufacturing firms also complement one another on a Regional basis in terms of their needs for talent, infrastructure, supply chains and other forms of support that create a competitive manufacturing ecosystem. Importantly, many of these industries also face a number of common opportunities and challenges that could be addressed through shared approaches to workforce and industrial development. To better understand the scale and scope of the Madison Region's advanced manufacturing industries, the following section considers the cluster from a variety of industry perspectives including measures of:

- Employment;
- Location quotients;
- Establishments;
- Non-employers; and
- Productivity

Again, this analysis relies on a modified version of manufacturing categories that are defined as "advanced industries" by the Brookings Institution Advanced Industries Project (2015). These industries include:

- Chemical Manufacturing (NAICS 325)
- Plastics and Rubber Products Manufacturing (NAICS 326)
- Nonmetallic Mineral Product Manufacturing (NAICS 327)
- Primary Metal (NAICS 331)
- Fabricated Metal Product Manufacturing (NAICS 332)
- Machinery Manufacturing (NAICS 333)
- Computer and Electronic Product Manufacturing (NAICS 334)
- Electrical Equipment, Appliance, and Component Manufacturing (NAICS 335)
- Transportation Equipment Manufacturing (NAICS 336)

In addition to the broad categories of advanced manufacturing, the Madison Region also has a number of specific niches in advanced manufacturing such as composite materials; bicycling manufacturing; several categories of machinery; navigational, measuring, electromedical, and control instruments; and pharmaceuticals. While these niches are not examined in detail as part of this analysis, they will be assessed in greater depth by MadREP at a future date. Importantly, several of these niches overlap with the ICT, bioscience and health care industry clusters and provide opportunities for cross-cluster development.

Advanced Manufacturing Industry Descriptions

The following industry descriptions examine the scope of products and activities associated with each category of advanced manufacturing. The industry descriptions are supplied by the U.S. Census Bureau, while establishment, employment and GDP figures are provided by the Bureau of Labor Statistics and Bureau of Economic Analysis.

Chemical Manufacturing (NAICS 325)

The chemical manufacturing industry is based on the transformation of organic and inorganic raw materials by a chemical process and the formulation of products. In 2017, the United States had 18,157 chemical manufacturing establishments with 820,728 total employees. Overall, the industry accounted for $388 billion in gross domestic product or 2.1% of the national GDP. Large and concentrated centers of chemical manufacturing include Houston, Chicago, Philadelphia, San Francisco, and Indianapolis (Figure 1.1). The top 50 MSAs by total number of establishments are available in Appendix 1A, which includes the Madison MSA. The MSA had 69 and the Region 89 chemical manufacturing establishments in 2017 (Figure 1.17).

The industry distinguishes between the production of basic chemicals from the production of intermediate and end products produced by further processing of basic chemicals that make up the remaining industry groups. Specifically, the chemical manufacturing industry can be further categorized according to:

- Basic chemical manufacturing;
- Resin, synthetic rubber, and artificial synthetic fibers and filaments manufacturing;
- Pesticide, fertilizer, and other agricultural chemical manufacturing;
- Pharmaceutical and medicine manufacturing;
- Paint, coating, and adhesive manufacturing;
- Soap, cleaning compound, and toilet preparation manufacturing;
- Other chemical product and preparation manufacturing.

Figure 1.1 – Top 10 MSAs by Total Employment in Chemical Manufacturing and an LQ > 1.25*

- Houston-The Woodlands-Sugar Land, TX MSA
- Chicago-Naperville-Elgin, IL-IN-WI MSA
- Philadelphia-Camden-Wilmington, PA-NJ-DE-MD MSA
- San Francisco-Oakland-Hayward, CA MSA
- Indianapolis-Carmel-Anderson, IN MSA
- St. Louis, MO-IL MSA
- Cincinnati, OH-KY-IN MSA
- Cleveland-Elyria, OH MSA
- Kingsport-Bristol-Bristol, TN-VA MSA
- Oxnard-Thousand Oaks-Ventura, CA MSA

*Note that several metro areas with suppressed data could also likely be included on this list. Please see Appendix 1A.

Sources: Bureau of Labor Statistics and Authors' Calculations

Plastics and Rubber Products Manufacturing (NAICS 326)

The U.S. plastic and rubber products manufacturing industry is comprised of over 13,199 establishments and 714,339 employees producing $83 billion in GDP (0.4% of the national GDP). Notable employment centers include Chicago, Detroit, Minneapolis, Riverside (CA) and Charlotte. Milwaukee is also included in the top 10

(Figure 1.2). The top 50 MSAs by total number of establishments are available in Appendix 1A. The MSA had 31 and the Region 64 plastics and rubber products manufacturing establishments in 2017 (Figure 1.17).

Plastics manufacturing accounts for the largest component of this subsector and produces a variety of products including bags, bottles, films, sheets, shapes, pipes and foams. These products are often used as inputs in other manufacturing categories, medical products, construction or final products sold directly to consumers. Specific types of plastics include: Polyethylene terephthalate (PET, or sometimes PETE), High-density or low-density polyethylene (HDPE or LDPE), Linear low-density polyethylene (LLDPE), Polyvinyl chloride (PVC/vinyl), Polypropylene (PP), Polystyrene (PS) and Polylactic acid (PLA). Production process include injection molding, compression molding, and additive applications (3D printing).

Figure 1.2 – Top 10 MSAs by Total Employment in Plastics and Rubber Products Manufacturing and an LQ > 1.25*

- Chicago-Naperville-Elgin, IL-IN-WI MSA
- Detroit-Warren-Dearborn, MI MSA
- Minneapolis-St. Paul-Bloomington, MN-WI MSA
- Riverside-San Bernardino-Ontario, CA MSA
- Charlotte-Concord-Gastonia, NC-SC MSA
- Cleveland-Elyria, OH MSA
- Akron, OH MSA
- Milwaukee-Waukesha-West Allis, WI MSA
- Elkhart-Goshen, IN MSA
- Rochester, NY MSA

*Note that several metro areas with suppressed data could also likely be included on this list. Please see Appendix 1A.

Sources: Bureau of Labor Statistics and Authors' Calculations

Nonmetallic Mineral Product Manufacturing (NAICS 327)

The nonmetallic mineral product manufacturing industry transforms mined or quarried nonmetallic minerals, such as sand, gravel, stone, clay, and refractory materials, into products for intermediate or final consumption. Nationally, the industry includes 16,335 establishments employing 409,775 employees. Nonmetallic mineral product manufacturing accounts for $54 billion in GDP or 0.3% of the national gross domestic product. Processes used include grinding, mixing, cutting, shaping, and honing. Metro areas with a specialization and significant employment level in nonmetallic mineral products include Riverside, Pittsburgh, Columbus, Vineland-Bridgeton (NJ) and Dayton (Figure 1.3). The top 50 MSAs by total number of establishments are available in Appendix 1A. The MSA had 32 and the Region 71 nonmetallic mineral product manufacturing establishments in 2017 (Figure 1.17).

Figure 1.3 – Top 10 MSAs by Total Employment in Nonmetallic Mineral Product Manufacturing and an LQ > 1.25*

- Riverside-San Bernardino-Ontario, CA MSA
- Pittsburgh, PA MSA
- Columbus, OH MSA
- Vineland-Bridgeton, NJ MSA
- Dayton, OH MSA
- Worcester, MA-CT MSA
- Grand Rapids-Wyoming, MI MSA
- Tulsa, OK MSA
- Birmingham-Hoover, AL MSA
- Buffalo-Cheektowaga-Niagara Falls, NY MSA

*Note that several metro areas with suppressed data could also likely be included on this list. Please see Appendix 1A.

Sources: Bureau of Labor Statistics and Authors' Calculations

Heat is often used in the process and chemicals are frequently mixed to change the composition, purity, and chemical properties for the intended product. For example, glass is produced by heating silica sand to the melting point (sometimes combined with cullet or recycled glass) and then drawn, floated, or blow molded to the desired shape or thickness. Refractory materials are heated and then formed into bricks or other shapes for use in industrial applications.

The industry includes establishments that manufacture bricks, refractories, ceramic products, and glass and glass products, such as plate glass and containers. Also included are cement and concrete products, lime, gypsum and other nonmetallic mineral products including abrasive products, ceramic plumbing fixtures, statuary, cut stone products, and mineral wool. The products are used in a wide range of activities from construction and heavy and light manufacturing to articles for personal use.

Mining, beneficiating, and manufacturing activities often occur in a single location. Separate receipts will be collected for these activities whenever possible. When receipts cannot be broken out between mining and manufacturing, establishments that mine or quarry nonmetallic minerals, beneficiate the nonmetallic minerals, and further process the nonmetallic minerals into a more finished manufactured product are classified based on the primary activity of the establishment. A mine that manufactures a small amount of finished products is classified in Sector 21, Mining, Quarrying, and Oil and Gas Extraction. An establishment that mines whose primary output is a more finished manufactured product is classified in the Manufacturing sector.

Primary Metal (NAICS 331)

In 2011, the domestic primary metal manufacturing industry accounted for 5,495 establishments employing 369,382 individuals. The industry contributed $54 billion in gross domestic product, or 0.3% of the nation's total GDP. Large and specialized metro areas for primary metal manufacturing include Chicago, Pittsburgh, Youngstown, Cleveland and Detroit. Milwaukee is also found in the Top 10 metro areas based on these criteria (Figure 1.4). The top 50 MSAs by total number of establishments are available in Appendix 1A. The MSA had 10 and the Region 17 primary metal manufacturing establishments in 2017 (Figure 1.17).

Industries in the primary metal manufacturing subsector smelt and/or refine ferrous and nonferrous metals from ore, pig or scrap, using electrometallurgical and other process metallurgical techniques. Establishments in this subsector also manufacture metal alloys and superalloys by introducing other chemical elements to pure metals. The output of smelting and refining, usually in ingot form, is used in rolling, drawing, and extruding operations to make sheet, strip, bar, rod, or wire, and in molten form to make castings and other basic metal products.

Figure 1.4 – Top 10 MSAs by Total Employment in Primary Metal Manufacturing and an LQ > 1.25*

- Chicago-Naperville-Elgin, IL-IN-WI MSA
- Pittsburgh, PA MSA
- Youngstown-Warren-Boardman, OH-PA MSA
- Cleveland-Elyria, OH MSA
- Detroit-Warren-Dearborn, MI MSA
- St. Louis, MO-IL MSA
- Cincinnati, OH-KY-IN MSA
- Birmingham-Hoover, AL MSA
- Milwaukee-Waukesha-West Allis, WI MSA
- Reading, PA MSA

*Note that several metro areas with suppressed data could also likely be included on this list. Please see Appendix 1A.

Sources: Bureau of Labor Statistics and Authors' Calculations

Primary manufacturing of ferrous and nonferrous metals begins with ore or concentrate as the primary input. Establishments manufacturing primary metals from ore and/or concentrate remain classified in the primary smelting, primary refining, or iron and steel mill industries regardless of the form of their output. Establishments primarily engaged in secondary smelting and/or secondary refining recover ferrous and nonferrous metals from scrap and/or dross. The output of the secondary smelting and/or secondary refining industries is limited to shapes such as ingot or billet that will be further processed. Recovery of metals from scrap often occurs in establishments that are primarily engaged in activities, such as rolling, drawing, extruding, or similar processes. Specific categories of primary metal manufacturing include:

- Iron and Steel Mills and Ferroalloy Manufacturing;
- Steel Product Manufacturing from Purchased Steel;
- Alumina and Aluminum Production and Processing;
- Nonferrous Metal (except Aluminum) Production and Processing;
- Foundries;

Fabricated Metal Product Manufacturing (NAICS 332)

The national fabricated metal product manufacturing industry included almost 58,000 establishments in 2017. With 1.42 million employees, it is one of the largest manufacturing subsectors in terms of total employment. The industry contributed $148 billion in GDP or 0.8% of the national gross domestic product. The nearby metro areas of Chicago, Milwaukee and Sheboygan are all notable employment centers for fabricated metal product manufacturing (Figure 1.5). The top 50 MSAs by total number of establishments are available in Appendix 1A. The MSA had 96 and the Region 253 fabricated metal product manufacturing establishments in 2017 (Figure 1.17).

Establishments in the fabricated metal product manufacturing industry transform metal into intermediate or end products other than machinery, computers and electronics, and metal furniture. Establishments may also treat metals and metal formed products fabricated elsewhere. Important fabricated metal processes are forging, stamping, bending, forming, and machining, used to shape individual pieces of metal; and other processes, such as welding and assembling, used to join separate parts together. Establishments in this subsector may use one of these processes or a combination of these processes.

Figure 1.5 – Top 10 MSAs by Total Employment in Fabricated Metal Product Manufacturing and an LQ > 1.25*

- Chicago-Naperville-Elgin, IL-IN-WI MSA
- Houston-The Woodlands-Sugar Land, TX MSA
- Detroit-Warren-Dearborn, MI MSA
- Cleveland-Elyria, OH MSA
- Milwaukee-Waukesha-West Allis, WI MSA
- Hartford-West Hartford-East Hartford, CT MSA
- Pittsburgh, PA MSA
- Cincinnati, OH-KY-IN MSA
- Grand Rapids-Wyoming, MI MSA
- Sheboygan, WI MSA

*Note that several metro areas with suppressed data could also likely be included on this list. Please see Appendix 1A.

Sources: Bureau of Labor Statistics and Authors' Calculations

Within manufacturing there are other establishments that make the same products made by this subsector; only these establishments begin production further back in the production process. These establishments have a more integrated operation. For instance, one establishment may manufacture steel, draw it into wire, and make wire products in the same establishment. Such operations are classified in the Primary Metal Manufacturing subsector. Specific categories of fabricated metal product manufacturing industry are based on similar combinations of processes used to make products and include:

- Forging and Stamping;
- Cutlery and Handtool Manufacturing;
- Architectural and Structural Metals Manufacturing;
- Boiler, Tank, and Shipping Container Manufacturing;
- Hardware Manufacturing;
- Spring and Wire Product Manufacturing;
- Machine Shops; Turned Product; and Screw, Nut, and Bolt Manufacturing;
- Coating, Engraving, Heat Treating, and Allied Activities;
- Other Fabricated Metal Product Manufacturing;

Machinery Manufacturing (NAICS 333)

The machinery manufacturing industry creates end products that apply mechanical force to perform work. In 2017, machinery manufacturing accounted for 30,101 establishments and almost 1.1 million employees in the United States. It also contributed $148 billion to the national GDP (0.8% of total GDP). Specialized employment centers with a large number of employees include the metro areas of Detroit, Minneapolis, Milwaukee, Cleveland and Grand Rapids (Figure 1.6). The top 50 MSAs by total number of establishments are available in Appendix 1A. The MSA had 78 and the Region 131 machinery manufacturing establishments in 2017 (Figure 1.17).

Some important processes for the manufacture of machinery are forging, stamping, bending, forming, and machining that are used to shape individual pieces of metal. Processes, such as welding and assembling are used to join separate parts together. Although these processes are similar to those used in metal fabricating establishments, machinery manufacturing is different because it typically employs multiple metal forming processes in manufacturing the various parts of the machine. Moreover, complex assembly operations are an inherent part of the production process.

Figure 1.6 – Top 10 MSAs by Total Employment in Machinery Manufacturing and an LQ > 1.25*

- Detroit-Warren-Dearborn, MI MSA
- Minneapolis-St. Paul-Bloomington, MN-WI MSA
- Milwaukee-Waukesha-West Allis, WI MSA
- Cleveland-Elyria, OH MSA
- Grand Rapids-Wyoming, MI MSA
- St. Louis, MO-IL MSA
- Charlotte-Concord-Gastonia, NC-SC MSA
- Tulsa, OK MSA
- Peoria, IL MSA
- Cincinnati, OH-KY-IN MSA

*Note that several metro areas with suppressed data could also likely be included on this list. Please see Appendix 1A.

Sources: Bureau of Labor Statistics and Authors' Calculations

Establishments specialize in making machinery designed for particular applications. Accordingly, design is considered when defining industries and industry groups that make machinery for different applications. A broad distinction exists between machinery that is generally used in a variety of industrial applications (i.e., general purpose machinery) and machinery that is designed to be used in a particular industry (i.e., special purpose machinery):

General purpose machinery

- Ventilation, Heating, Air Conditioning (HVAC), and Commercial Refrigeration Equipment
- Manufacturing; Metalworking Machinery Manufacturing;
- Engine, Turbine, and Power Transmission Equipment Manufacturing;
- Other General Purpose Machinery Manufacturing.

Special purpose machinery

- Agricultural, Construction, and Mining Machinery Manufacturing;
- Industrial Machinery Manufacturing;
- Commercial and Service Industry Machinery Manufacturing.

Computer and Electronic Product Manufacturing (NAICS 334)

Industries in the Computer and Electronic Product Manufacturing subsector group establishments that manufacture computers, computer peripherals, communications equipment, and similar electronic products, and establishments that manufacture components for such products. The industry includes 19,939 establishments and just over 1 million employees nationally. The industry generates $287 billion in gross national product which accounts for 1.6% of the nation's GDP. Important employment centers include San Jose, Los Angeles, Boston, Dallas and Minneapolis (Figure 1.7). The top 50 MSAs by total number of establishments are available in Appendix 1A. The MSA had 53 and the Region 58 computer and electronic product manufacturing establishments in 2017 (Figure 1.17).

Industries in Computer and Electronic Product Manufacturing have been combined in the same manufacturing subsector due to the economic significance they have attained. Specifically, their rapid growth suggests that they will become even more important to the economies of all three North American countries in the future, and in addition their manufacturing processes are fundamentally different from the manufacturing processes of other machinery and equipment. The design and use of

Figure 1.7 – Top 10 MSAs by Total Employment in Computer and Electronic Product Manufacturing and an LQ > 1.25*

- San Jose-Sunnyvale-Santa Clara, CA MSA
- Los Angeles-Long Beach-Anaheim, CA MSA
- Boston-Cambridge-Newton, MA-NH MSA
- Dallas-Fort Worth-Arlington, TX MSA
- Minneapolis-St. Paul-Bloomington, MN-WI MSA
- San Francisco-Oakland-Hayward, CA MSA
- San Diego-Carlsbad, CA MSA
- Austin-Round Rock, TX MSA
- Palm Bay-Melbourne-Titusville, FL MSA
- Raleigh, NC MSA

*Note that several metro areas with suppressed data could also likely be included on this list. Please see Appendix 1A.

Sources: Bureau of Labor Statistics and Authors' Calculations

integrated circuits and the application of highly specialized miniaturization technologies are common elements in the production technologies of the Computer and Electronic Product Manufacturing subsector.

As technology in this subsector is continually evolving, the computer and electronic product subsector is defined in a manner with will help capture these new products. However, the industry currently includes several specific categories:

- Computer and peripheral equipment manufacturing;
- Communications equipment manufacturing;
- Audio and video equipment manufacturing;
- Semiconductor and other electronic component manufacturing;
- Navigational, measuring, electromedical, and control instruments manufacturing;
- Manufacturing and reproducing magnetic and optical media.

Electrical Equipment, Appliance, and Component Manufacturing (NAICS 335)

Industries in the Electrical Equipment, Appliance, and Component Manufacturing subsector manufacture products that generate, distribute and use electrical power. With 8,053 establishments and 385,778 employees, the industry is one of the smaller durable manufacturing categories in terms of employment. **T**he industry accounts for $56 billion or 0.3% of the nation's gross domestic product. Notable employment centers include Chicago, Nashville, Louisville, Cleveland and Pittsburgh. While the Madison MSA has fewer establishments than many other MSAs, it is included in the top 10 here largely due to the presence of the **SUB-ZERO Group (Figure 1.8).** The top 50 MSAs by total number of establishments are available in Appendix 1A. The MSA had 15 and the Region 20 electrical equipment, appliance and component manufacturing establishments in 2017 (Figure 1.17).

Figure 1.8 – Top 10 MSAs by Total Employment in Electrical Equipment, Appliance, and Component Manufacturing and an LQ > 1.25*

- Chicago-Naperville-Elgin, IL-IN-WI MSA
- Nashville-Davidson--Murfreesboro--Franklin, TN MSA
- Louisville-Jefferson County, KY-IN MSA
- Cleveland-Elyria, OH MSA
- Pittsburgh, PA MSA
- Grand Rapids-Wyoming, MI MSA
- Racine, WI MSA
- Asheville, NC MSA
- Cleveland, TN MSA
- Madison, WI MSA

*Note that several metro areas with suppressed data could also likely be included on this list. Please see Appendix 1A.

Sources: Bureau of Labor Statistics and Authors' Calculations

The industry is composed of several categories making a diversity of products:

- *Electric Lighting Equipment Manufacturing* - Produces electric lamp bulbs, lighting fixtures, and parts;
- *Household Appliance Manufacturing* - Makes both small and major electrical appliances and parts.
- *Electrical Equipment Manufacturing* - Production of goods, such as electric motors, generators, transformers, and switchgear apparatus;

- *Other Electrical Equipment and Component Manufacturing* – Makes devices for storing electrical power (e.g., batteries), for transmitting electricity (e.g., insulated wire), and wiring devices (e.g., electrical outlets, fuse boxes, and light switches).

Transportation Equipment Manufacturing

The transportation equipment manufacturing subsector produces equipment for transporting people and goods. While transportation equipment is a type of machinery, an entire manufacturing subsector is devoted to this activity because of its economic significance. As suggested, firms in the transportation equipment manufacturing industry use production processes similar to those of other machinery manufacturing establishments, including bending, forming, welding, machining and assembling parts into components and finished products. However, the fabrication of components and subassemblies and their further assembly into finished vehicles tends to be a more common production process than found in the machinery manufacturing subsector (NAICS 333).

Transportation equipment manufacturing categorizes establishments according to transportation modes (road, rail, air and water.) Motor vehicle parts are classified as a separate industry group within transportation equipment manufacturing given their importance to the subsector. Furthermore, parts manufacturing requires less assembly and establishments that manufacture only parts are not as vertically integrated as those that make complete vehicles. Note that motor vehicle equipment not designed for highway operation (e.g., agricultural equipment, construction equipment, and materials handling equipment) is classified in the appropriate NAICS subsector based on the type and use of the equipment (typically under NAICS 333 – Machinery Manufacturing).

Figure 1.9 – Top 10 MSAs by Total Employment in Transportation Equipment Manufacturing and an LQ > 1.25*

- Detroit-Warren-Dearborn, MI MSA
- Seattle-Tacoma-Bellevue, WA MSA
- Dallas-Fort Worth-Arlington, TX MSA
- Elkhart-Goshen, IN MSA
- Nashville-Davidson--Murfreesboro--Franklin, TN MSA
- Wichita, KS MSA
- Virginia Beach-Norfolk-Newport News, VA-NC MSA
- Cincinnati, OH-KY-IN MSA
- St. Louis, MO-IL MSA
- Louisville-Jefferson County, KY-IN MSA

*Note that several metro areas with suppressed data could also likely be included on this list. Please see Appendix 1A.

Sources: Bureau of Labor Statistics and Authors' Calculations

Nationwide, the transportation equipment manufacturing industry accounted for almost 15,000 establishments and 1.65 million employees in 2017. Large, specialized employment centers include Detroit (automobiles), Seattle (aerospace), Dallas (aerospace), Elkhart (trailers and RVs) and Nashville (automobiles). The top 50 MSAs by total number of establishments are available in Appendix 1A. The MSA had 15 and the Region 32 transportation equipment manufacturing establishments in 2017 (Figure 1.17).

As previously noted, the industry is segmented into categories based on types of vehicles and parts including: Motor Vehicle Manufacturing; Motor Vehicle Bodies and Trailers; Motor Vehicle Parts; Aerospace Product and Parts Manufacturing; Railroad Rolling Stock Manufacturing; Ship and Boat Building; and Other Transportation Equipment*;*

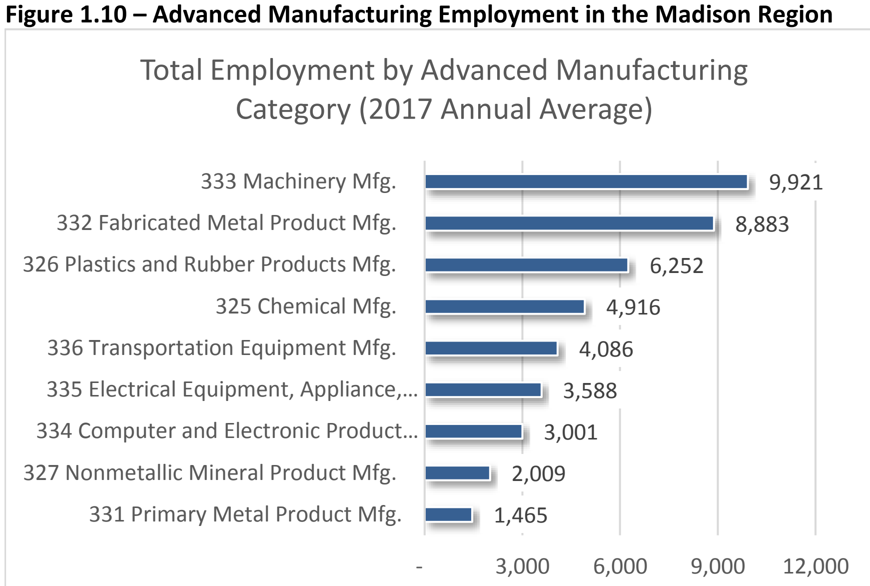
Advanced Manufacturing Employment

In 2017, advanced manufacturing accounted for over 44,100 jobs in the Madison Region (Figure 1.10), or almost 16% of all advanced manufacturing jobs in the State of Wisconsin. Machinery manufacturing (9,921 employees), fabricated metal products (8,883) and plastics and rubber product manufacturing (6,252) are the Region's largest advanced manufacturing employment categories, followed by chemicals (4,916), transportation equipment (4,086), and electrical equipment, appliance and component manufacturing (3,588). Not surprisingly, the two most populous counties of Dane County and Rock County have the largest number of advanced manufacturing jobs. However, advanced manufacturing has a significant footprint throughout all counties in the Region.

When considering employment trends in advanced manufacturing, it is important to account for the long term trajectory of jobs in the overall manufacturing sector. Nationally, total employment in the manufacturing sector (i.e. all manufacturing jobs, not just advanced manufacturing), currently remains 33% below its employment level in 1970 (Figure 1.11). Wisconsin and the Madison Region have fared better than the national trend as the state and Region posted strong employment gains between the early 1980s and the late 1990s.

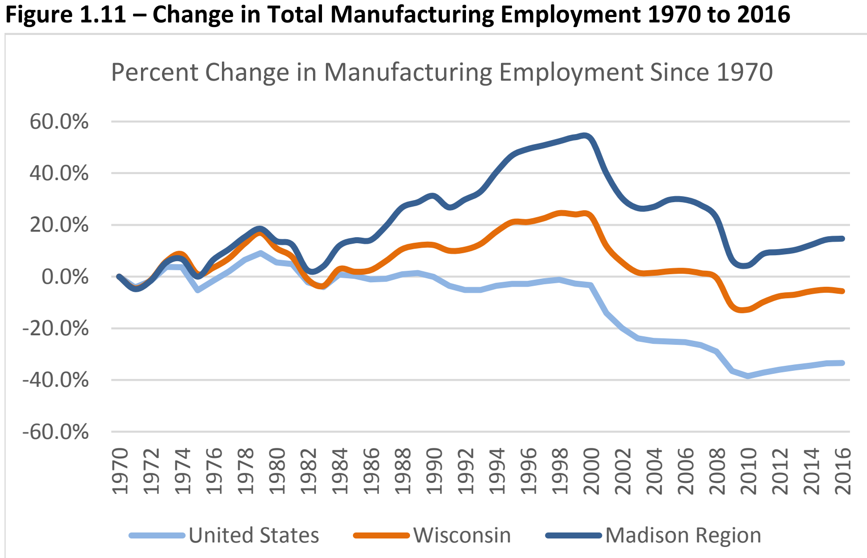
Since the year 2000, however, manufacturing employment in both the state and Region has declined dramatically. Severe employment declines occurred after both the 2001 recession and the 2007 recession and have yet to rebound to prior levels. In fact, is unlikely that employment in the manufacturing sector will return to the peaks found in the late 1990s for a variety of reasons including increasing output per worker,

Figure 1.10 – Advanced Manufacturing Employment in the Madison Region



Source: U.S. Census Bureau LEHD, U.S. Bureau of Labor Statistics and Authors' Calculations. Some figures are estimated.

Figure 1.11 – Change in Total Manufacturing Employment 1970 to 2016



Source: U.S. Bureau of Economic Analysis and Authors' Calculations.

automation and global competition. *While individual firms and portions of the manufacturing sector likely will experience employment gains, these overall trends should serve as a caution to using manufacturing employment as a metric for gauging the health of manufacturing in the Madison Region.*

Employment changes for each advanced manufacturing category are considered in Figure 1.12. *Note that employment data for primary metal manufacturing is suppressed in a manner that precludes a long-term analysis of change in the Madison Region.* Employment trends in advanced manufacturing suggest several similarities and differences when compared to trends in the overall manufacturing sector:

- Nationally, employment in every category of advanced manufacturing is either somewhat below or well below employment levels from the year 2000. However, chemical manufacturing and electrical equipment, appliance and component manufacturing in the Madison Region have added employment over the last two decades. These changes are largely driven by pharmaceutical manufacturing and appliance manufacturing respectively in the Region;

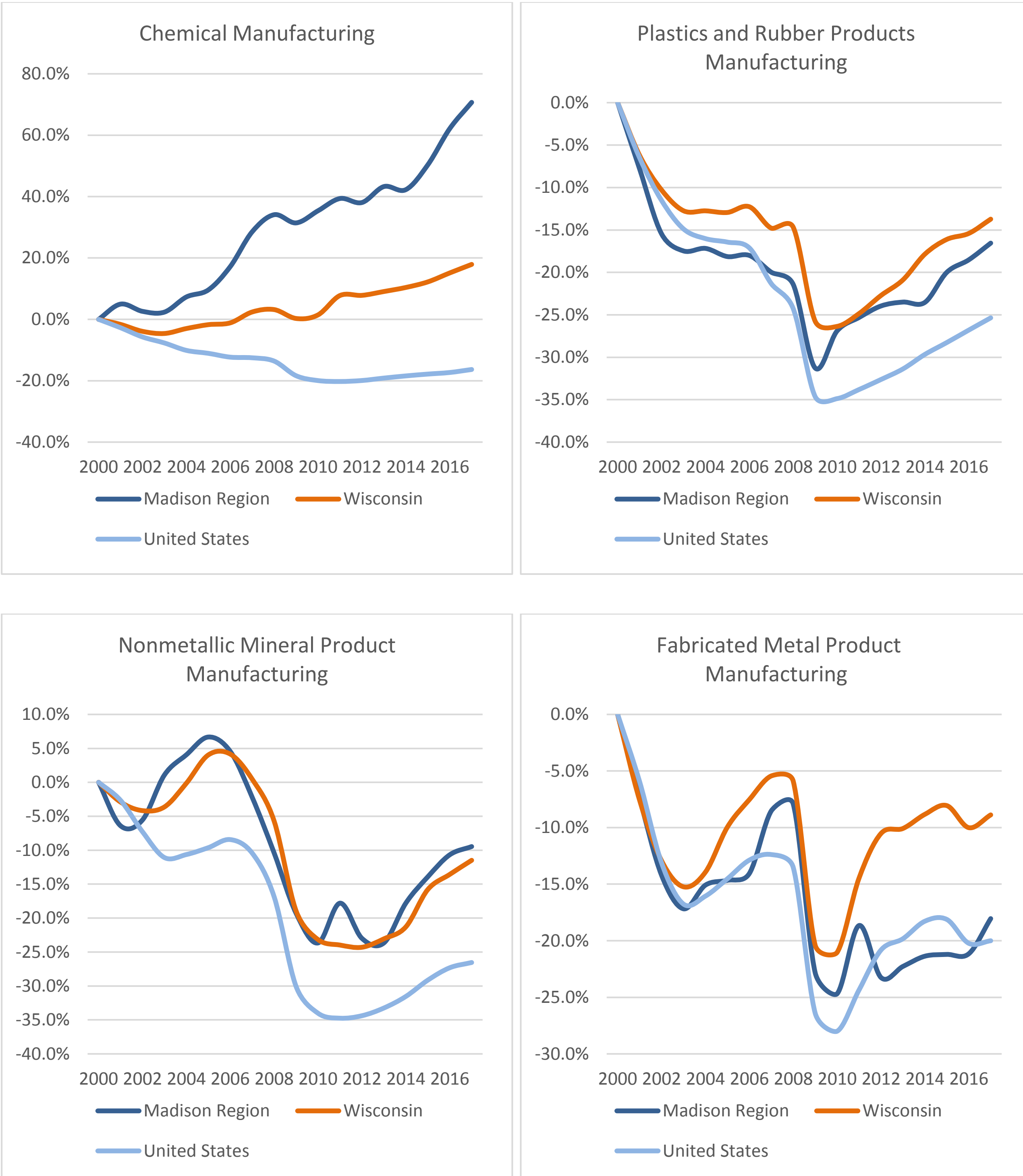
- The employment trends demonstrate the cyclical nature of advanced manufacturing. Specifically, employment in the industry is highly influenced by periods of national and global economic growth and decline;

- Despite long term employment trends, plastics manufacturing, nonmetallic mineral manufacturing and machinery manufacturing in the Madison Region have made notable employment gains since the end of the Great Recession. With the exception of machinery manufacturing, employment levels in these categories of advanced manufacturing have also increased in the State of Wisconsin;

- Employment in fabricated metal product manufacturing grew rapidly in the State of Wisconsin during the period following the Great Recession. However, the Madison Region did not experience the same levels of growth in this category of advanced manufacturing, suggesting the need for further analysis of this industry in the Region;

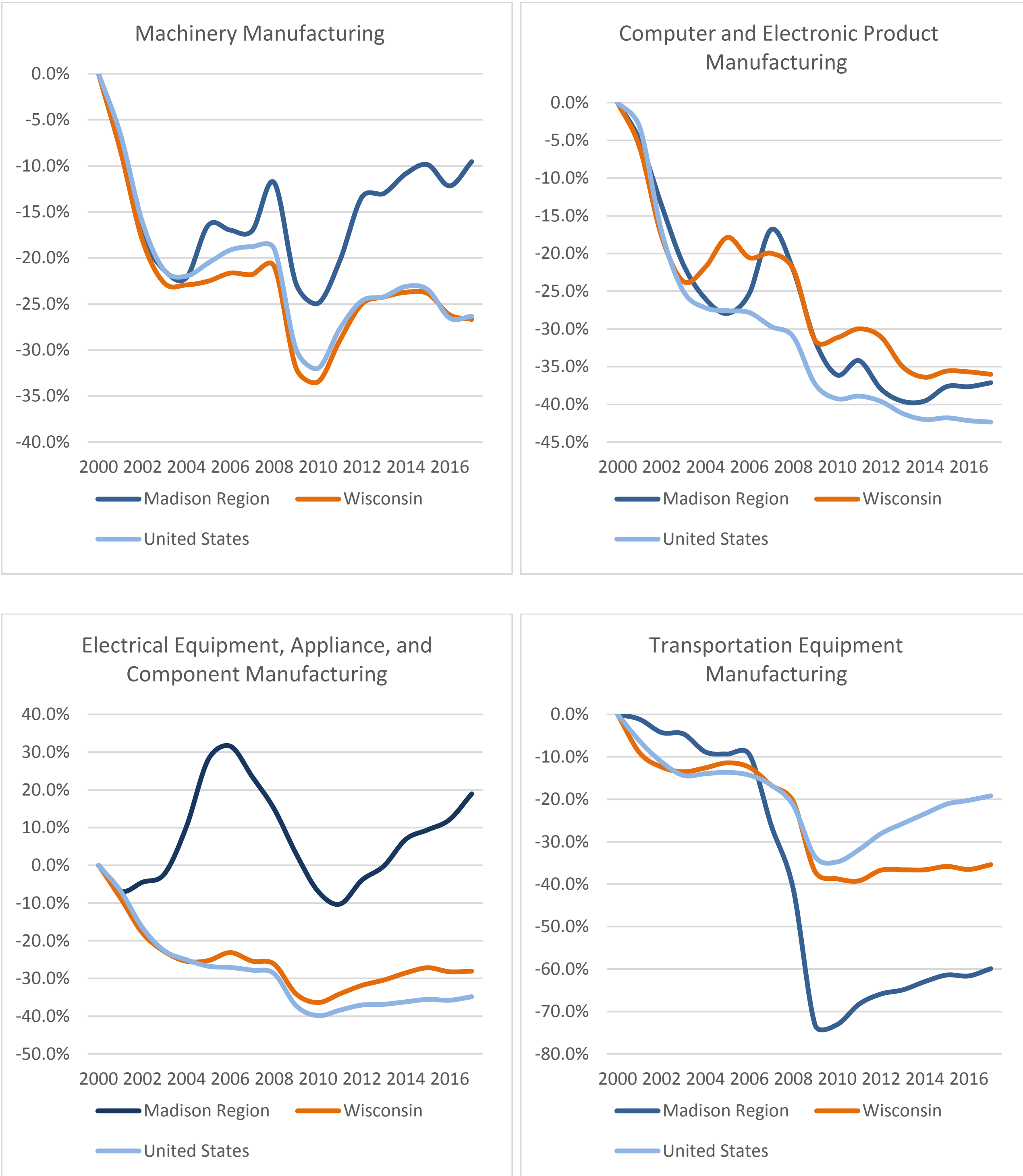
- The Region's large decline in transportation equipment manufacturing employment is largely attributed to the shuttering of the General Motors assembly plant in Janesville.

Figure 1.12 – Change in Advanced Manufacturing Employment 2000 to 2017 (Percent Change Since 2000)



Source: U.S. Census Bureau LEHD, U.S. Bureau of Labor Statistics and Authors' Calculations. Some figures are estimated.

Figure 1.12 (Continued) – Change in Advanced Manufacturing Employment 2000 to 2017 (Percent Change Since 2000)



Source: U.S. Census Bureau LEHD, U.S. Bureau of Labor Statistics and Author's Calculations. Some figures are estimated.

Location Quotients

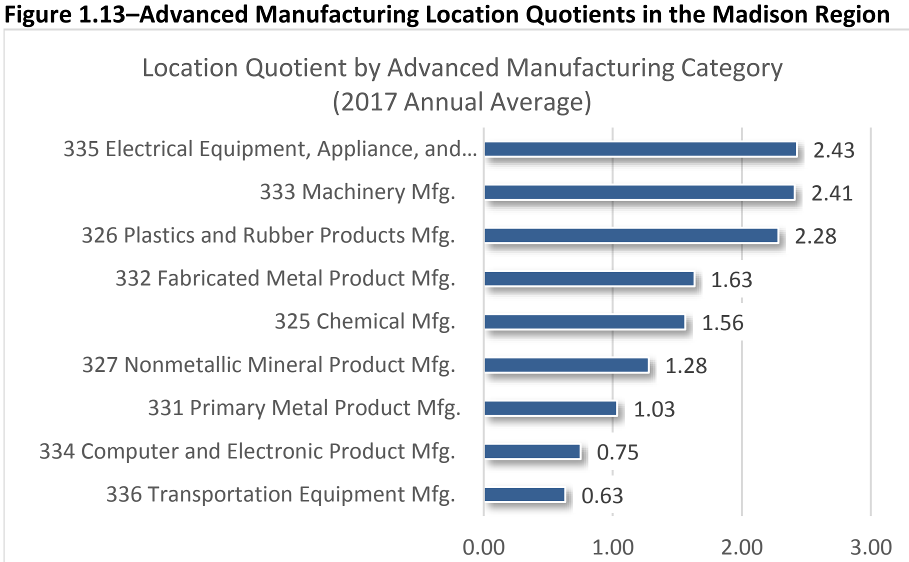
Location quotients provide another means of analyzing advanced manufacturing employment in the Madison Region. A location quotient (LQ) is calculated by comparing a category of advanced manufacturing's share of local employment to the category's share of overall national employment:

$$\textit{Location Quotient (LQ) For advanced manufacturing} = \frac{\dfrac{\text{Advanced manufacturing employment in the Region}}{\text{Total employment in the Region (all industries)}}}{\dfrac{\text{Advanced manufacturing national employment}}{\text{Total national employment (all industries)}}}$$

The critical value for a location quotient is 1.0. An LQ of 1.0 means an area has the *same* proportion of local employment in an industry as the nation. An LQ *greater* than 1.0 denotes that an area's share of employment in a given industry is more than its national share. Conversely, an LQ *less* than 1.0 indicates an area's employment in an industry is below the national percentage. Due to accuracy issues with employment data, location quotients between 0.75 and 1.25 are generally considered not to be significantly different from 1.0. [3]

Location quotients greater than 1.25 are important as they imply that an area has a specialization in a given industry. More specifically, an LQ greater than 1.25 suggests that an industry is producing more goods or services than can be consumed locally. These goods and services are in turn exported out of the Region, connecting the area to external economies and bringing outside dollars into local communities (i.e. they have an export-orientation). In contrast, an LQ less than 0.75 suggests that local industries are not meeting demand (demand is greater than supply) and the good or service must be imported into the Region.

Figure 1.13–Advanced Manufacturing Location Quotients in the Madison Region



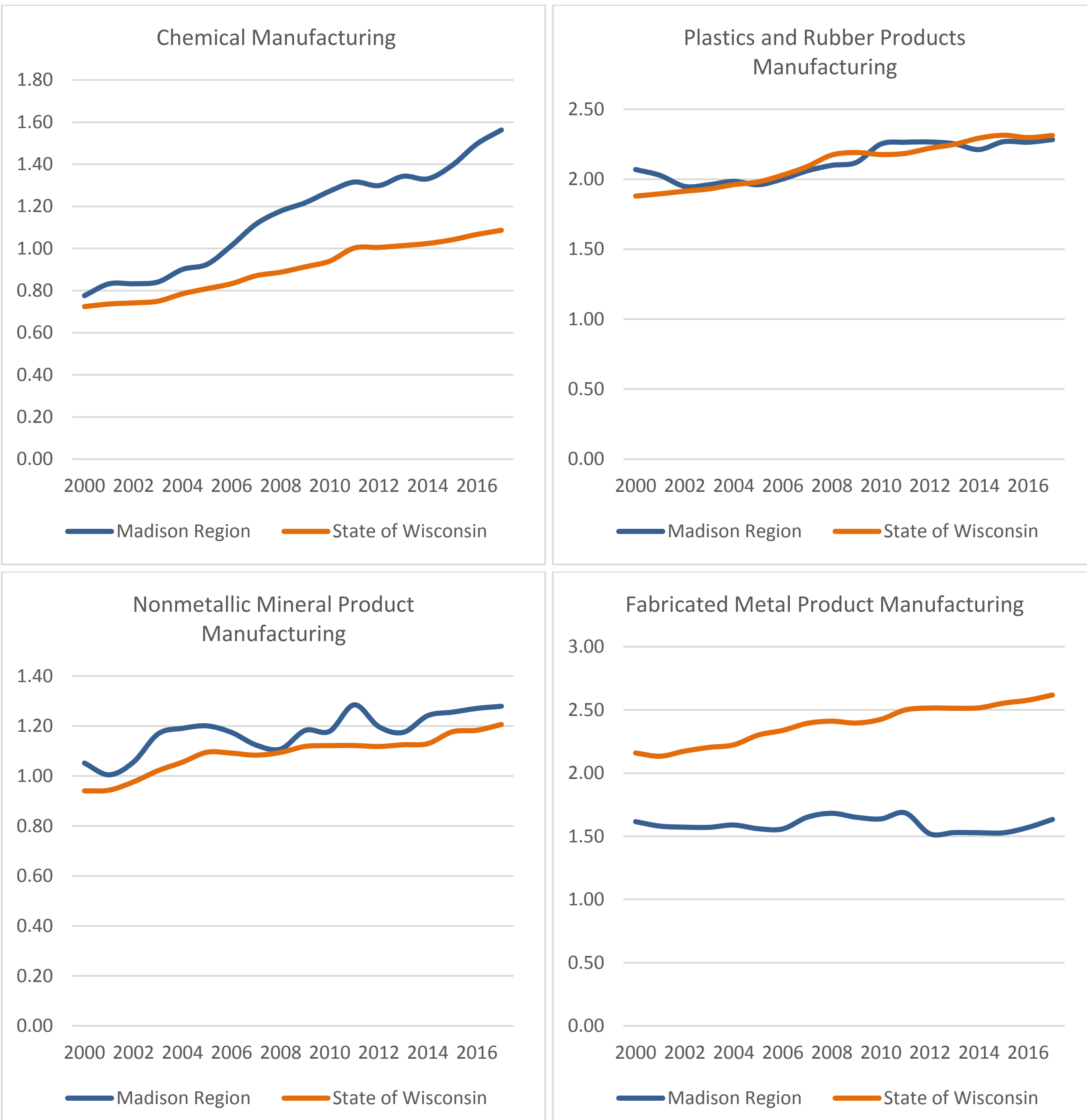
Source: U.S. Census Bureau LEHD, U.S. Bureau of Labor Statistics and Author's Calculations. Some figures are estimated.

With the exception of primary metal products, computer and electronic product manufacturing and transportation equipment, every category of advanced manufacturing has a location quotient above 1.25 in the Madison Region (Figure 1.13). Electrical equipment appliance and component manufacturing (LQ = 2.43), machinery manufacturing (2.41) and plastic and rubber products have the largest LQs in the Region with each of these advanced manufacturing categories showing location quotients above 2.25.

[3] Differences in local demand preferences compared to national conditions, or the efficiency of a local industry, have the potential to skew the results of a location quotient analysis.

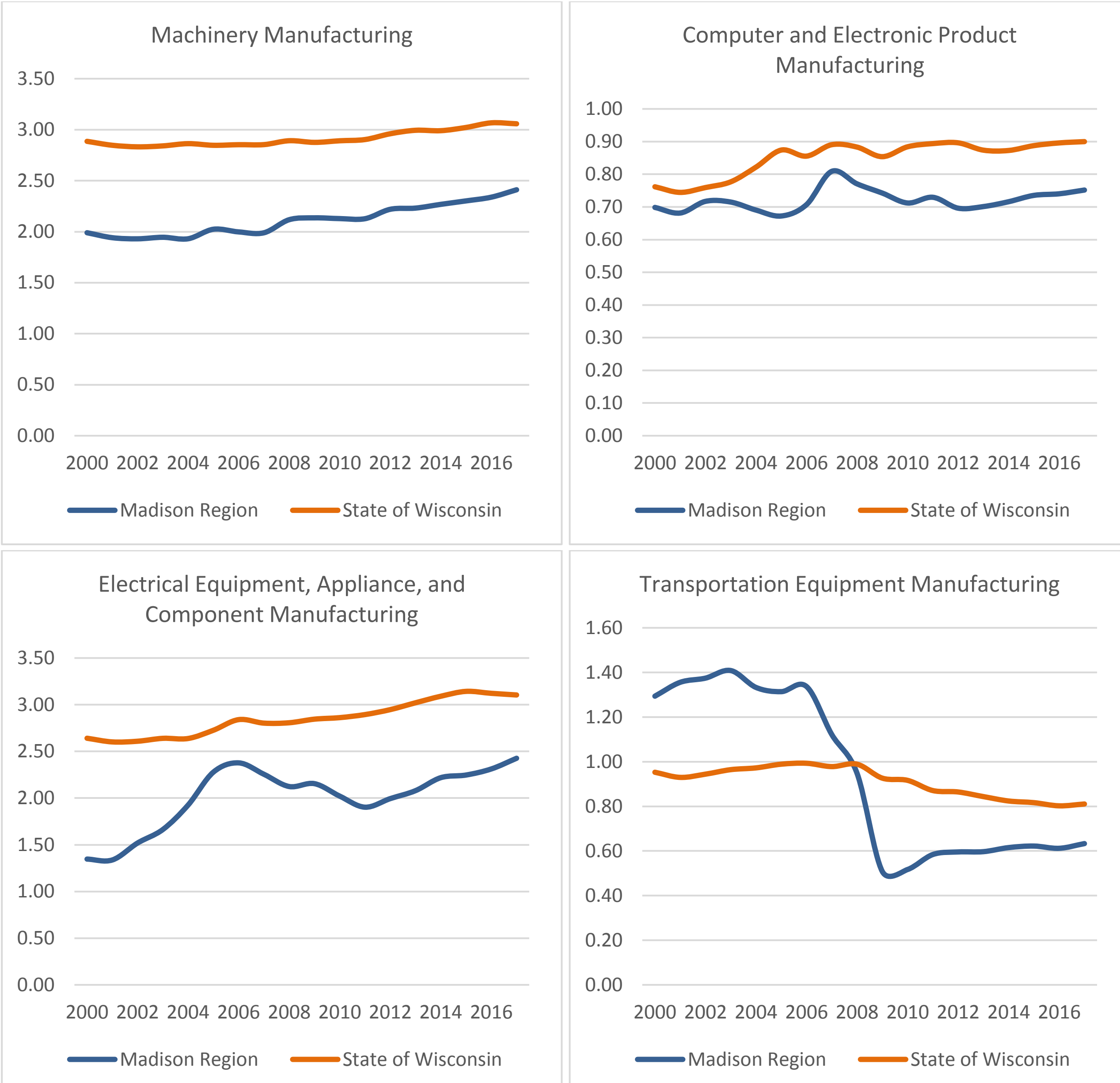
When considering trends in advanced manufacturing location quotients, both the Madison Region and the State of Wisconsin have experienced long term increases in location quotient values in several categories (Figure 1.14). Some of the increases in location quotients are due to employment gains in a category. For instance, the location quotient for chemical manufacturing in the Madison Region has grown from 0.80 in 2000 to 1.56 in 2017. This gain is largely due to the industry's growth in the region. However, other LQ increases are due to employment in the Madison Region declining at a slower rate than the nation. For instance, employment in plastics and rubber product manufacturing has declined in the Region and the nation. However, the slower rate of decline in the Madison Region has caused the industry's location quotient to grow.

Figure 1.14 – Change in Advanced Manufacturing Location Quotients 2000 to 2017



Source: U.S. Census Bureau LEHD, U.S. Bureau of Labor Statistics and Author's Calculations. Some figures are estimated.

Figure 1.14 (Continued) – Change in Advanced Manufacturing Location Quotients 2000 to 2017



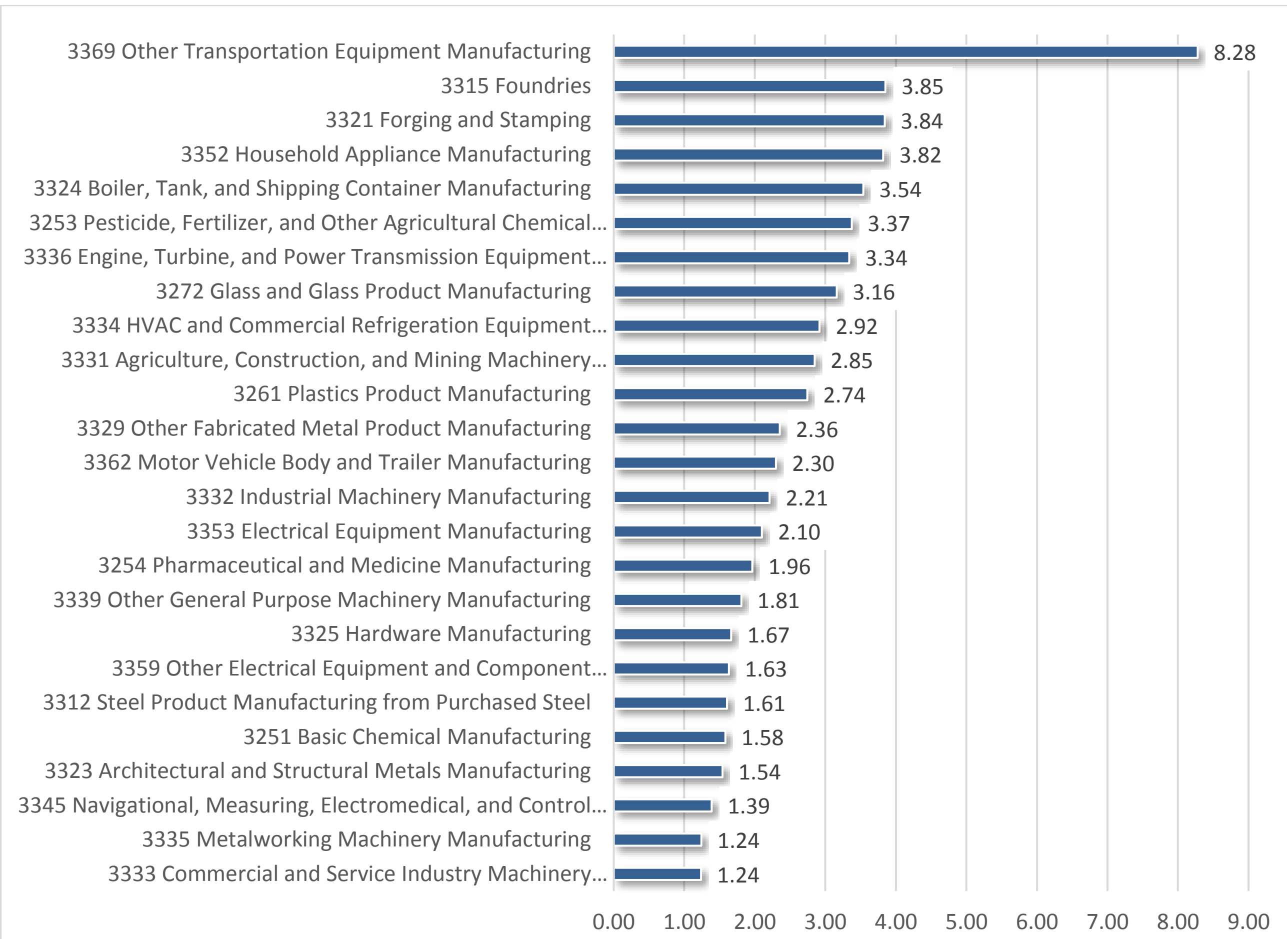
Source: U.S. Census Bureau LEHD, U.S. Bureau of Labor Statistics and Author's Calculations. Some figures are estimated.

As with employment trends, advanced manufacturing location quotient trends for the Madison Region show a number of similarities and differences to trends in the State of Wisconsin. Computer and electronic product manufacturing and transportation equipment manufacturing are the two only two industries in the Region and the state with location quotients below 1.0. However, computer and electronic manufacturing has had LQs consistently below 1.0 while transportation equipment manufacturing had a value above 1.0 and dropped below this threshold in 2009. Again, part of this decline can be attributed to changes at Janesville's General Motors facility, but not entirely.

Most other categories of advanced manufacturing in the Madison Region and the State of Wisconsin have experienced increases in their location quotients since the end of the Great Recession. An exception in the Madison Region is fabricated metal product manufacturing. While fabricated metal product manufacturing enjoyed a consistent growth in its statewide location quotient, little to no growth has been found in the Madison Region. Given the magnitude of this sector in the Madison Region, further exploration of this difference may be an important strategic initiative for MadREP.

While location quotients for each category of advanced manufacturing provide some insights to regional strengths, LQs for more detailed industries within advanced manufacturing provide additional perspectives on potential niches in the region. Specifically, the Madison Region has 25 subcategories of advanced manufacturing with location quotients at or above ~1.25 (Figure 1.15).The largest LQ is for “other transportation equipment manufacturing” despite the overall transportation equipment manufacturing category with a location quotient below 1.0. This large LQ reflects the presence of bicycle manufacturers in the region including Trek and Pacific Cycle.

Figure 1.15 – Madison Region Detailed Advanced Manufacturing Location Quotients



Source: IMPLAN

The Region also has strengths in several categories of fabricated metal products, despite the broader category trailing the state in measures of employment and location quotient growth. Furthermore, the Region has notable assets across many categories of machinery manufacturing as well as foundries and pharmaceuticals. Several categories with large location quotients, such as household appliance manufacturing and motor vehicle body and trailer manufacturing are driven by one or two large employers, such as the SUB-ZERO Group and Stoughton Trailer. In all, these LQs reinforce the presence of the niches noted earlier in Section 1.

Establishments and Non-Employers

As of 2016, 735 advanced manufacturing establishments are located in the eight-county Madison Region (Figure 1.17). The largest number of firms are found in fabricated metal products (253 establishments) followed by machinery manufacturing (131). Subcategories of advanced manufacturing with notable numbers include machine shops; architectural and structural metals manufacturing; and metalworking machinery manufacturing, which reinforce the importance of metal fabrication in the Region. With 57 establishments, plastics product manufacturing also accounts for a significant presence in the Madison Region. The concentration of navigational, measuring, electromedical, and control instruments manufacturing and pharmaceutical manufacturing establishments partly reflect the presence of the bioscience industry cluster in the Region and are also considered in MadREP's Bioscience Industry Abstract.

As noted earlier, several categories of advanced manufacturing are dominated by one or two large employers. Nonetheless, only 15 advanced manufacturing establishments in the Madison Region have 500 or more employees. Another 99 establishments employ 100 to 499 employees and are distributed across all categories of advanced manufacturing. However, the majority of establishments are smaller enterprises with fewer than 100 employees. These firms are often overlooked by economic development policies and incentives that target larger establishments for business recruitment and workforce development activities. Instead, the needs of smaller firms may vary and often require different types of support in the form of access to capital and technical assistance.

A specific type of firm often overlooked by economic and business development activities is Stage 2 firms, or so-called second-stage companies (Figure 1.16). Stage 2 companies are distinct from other firms as they have survived the start-up process, but also reached a position where the complexity of running the company has exceeded the capacity of one owner or CEO. More formal operational structures and strategy may be needed to continue growth and evolve into the next stage of business. However, the time, expertise and revenue are often unavailable within the firm to support these changes (Edward Lowe Foundation, 2012). Due to their unique position, these firms often fall between economic development efforts that look to generate start-ups and those that work with the retention and attraction of larger firms. These firms may provide opportunities for growth in the Madison Region, particularly through programs such as Economic Gardening.™

Figure 1.16 – Business Stages

- *Self-Employed/Non-Employer (1 employee)* - Includes small-scale business activity that can be conducted in homes as well as sole proprietorships;
- *Stage 1 (2-9 employees)* – Includes partnerships, lifestyle businesses and startups. This stage is focused on defining a market, developing a product or service, obtaining capital and finding customers;
- *Stage 2 (10-99 employees)* - At this phase, a company typically has a proven product, and survival is no longer a daily concern. Companies begin to develop infrastructure and standardize operational systems. Leaders delegate more and wear fewer hats;
- *Stage 3 (100-499 employees)* - Expansion is a hallmark at this stage as a company broadens its geographic reach, adds new products and pursues new markets. Stage 3 companies introduce formal processes and procedures, and the founder is less involved in daily operations and more concerned with managing culture and change;
- *Stage 4 (500 or more employees)* – By Stage 4, an organization dominates its industry and is focused on maintaining and defending its market position. Key objectives are controlling expenses, productivity, global penetration and managing market niches.

Source: Edward Lowe Foundation

Figure 1.17 – Madison Region Establishments by Employment Size in Advanced Manufacturing (2016)

NAICS	Description	Total Establishments	Establishments by Number of Employees			
			1 to 9 Emp.	10 to 99 Emp.	100 to 499 Emp.	500 or More Emp.
325	**Chemical Manufacturing**	**89**	**32**	**46**	**10**	**1**
3251	Basic chemical manufacturing	11	4	7	0	0
3252	Resin, artificial synthetic fibers & filaments mfg.	10	3	5	2	0
3253	Pesticide, fertilizer and other ag. chemical mfg.	6	3	1	2	0
3254	Pharmaceutical and medicine manufacturing	32	7	19	5	1
3255	Paint, coating, and adhesive manufacturing	5	2	3	0	0
3256	Soap, cleaning compound &toilet prep mfg.	16	7	9	0	0
3259	Other chemical product and preparation mfg.	9	6	2	1	0
326	**Plastics and Rubber Products Manufacturing**	**64**	**16**	**33**	**15**	**0**
3261	Plastics product manufacturing	57	14	30	13	0
3262	Rubber product manufacturing	7	2	3	2	0
327	**Nonmetallic Mineral Product Manufacturing**	**71**	**37**	**30**	**4**	**0**
3271	Clay product and refractory manufacturing	5	3	2	0	0
3272	Glass and glass product manufacturing	10	3	4	3	0
3273	Cement and concrete product manufacturing	43	23	19	1	0
3274	Lime and gypsum product manufacturing	1	1	0	0	0
3279	Other nonmetallic mineral product manufacturing	12	7	5	0	0
331	**Primary Metal Manufacturing**	**17**	**5**	**6**	**5**	**1**
3311	Iron and steel mills and ferroalloy manufacturing	2	2	0	0	0
3312	Steel product manufacturing from purchased steel	1	0	0	1	0
3313	Alumina and aluminum production and processing	3	1	1	1	0
3315	Foundries	11	2	5	3	1
332	**Fabricated Metal Product Manufacturing**	**253**	**124**	**100**	**28**	**1**
3321	Forging and stamping	20	4	12	3	1
3322	Cutlery and handtool manufacturing	3	0	3	0	0
3323	Architectural and structural metals manufacturing	58	23	29	6	0
3324	Boiler, tank, and shipping container manufacturing	12	4	3	5	0
3325	Hardware manufacturing	1	0	1	0	0
3326	Spring and wire product manufacturing	1	1	0	0	0
3327	Machine shops; turned product; & screw mfg.	100	57	36	7	0
3328	Coating, engraving, heat treating & allied activities	21	12	7	2	0
3329	Other fabricated metal product manufacturing	37	23	9	5	0

Source: U.S. Census Bureau County Business Patterns

Figure 1.17 (Continued) – Madison Region Establishments by Employment Size in Advanced Manufacturing (2016)

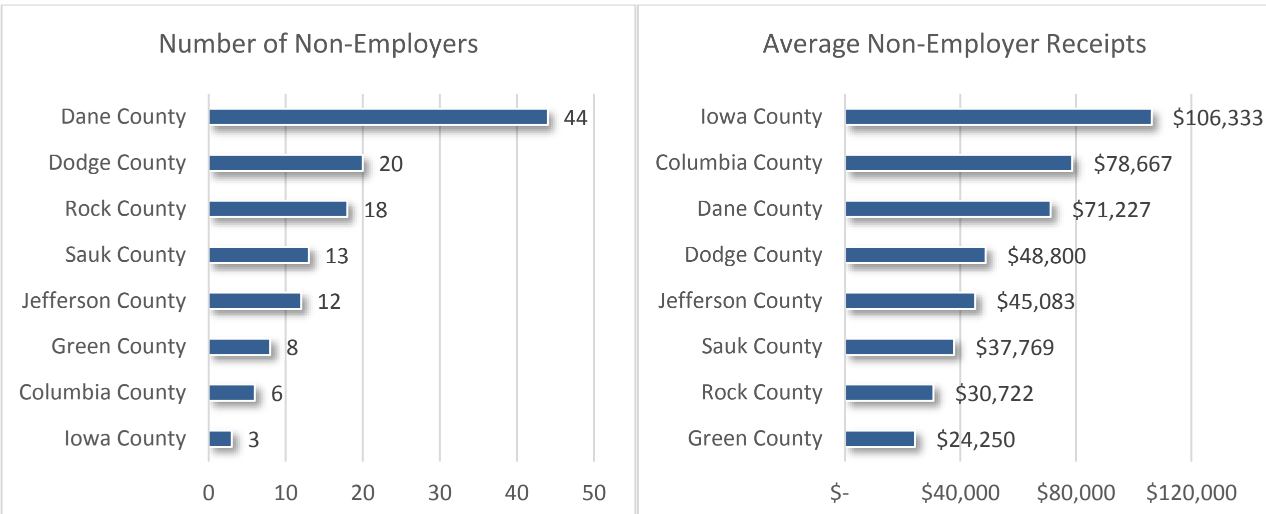
NAICS	Description	Total Establishments	Establishments by Number of Employees			
			1 to 9 Emp.	10 to 99 Emp.	100 to 499 Emp.	500 or More Emp.
333	**Machinery Manufacturing**	**131**	**35**	**73**	**21**	**2**
3331	Agriculture, construction & mining machinery	18	5	7	4	2
3332	Industrial machinery manufacturing	17	4	11	2	0
3333	Commercial and service industry machinery	13	1	10	2	0
3334	HVAC and commercial refrigeration equipment	9	0	6	3	0
3335	Metalworking machinery manufacturing	38	15	22	1	0
3336	Engine, turbine & power transmission equipment	5	1	2	2	0
3339	Other general purpose machinery manufacturing	31	9	15	7	0
334	**Computer and Electronic Product Manufacturing**	**58**	**20**	**26**	**9**	**3**
3341	Computer & peripheral equipment manufacturing	3	2	0	1	0
3342	Communications equipment manufacturing	3	1	1	1	0
3343	Audio and video equipment manufacturing	3	1	2	0	0
3344	Semiconductor and other electronic components	17	5	12	0	0
3345	Navigation, measuring, electromedical & controls	32	11	11	7	3
335	**Electrical Equipment, Appliance & Component**	**20**	**7**	**6**	**3**	**4**
3351	Electric lighting equipment manufacturing	4	1	1	1	1
3352	Household appliance manufacturing	4	1	1	0	2
3353	Electrical equipment manufacturing	8	4	2	1	1
3359	Other electrical equipment and components	4	1	2	1	0
336	**Transportation Equipment Manufacturing**	**32**	**15**	**10**	**4**	**3**
3361	Motor vehicle manufacturing	1	1	0	0	0
3362	Motor vehicle body and trailer manufacturing	8	3	2	2	1
3363	Motor vehicle parts manufacturing	19	9	7	2	1
3364	Aerospace product and parts manufacturing	1	0	1	0	0
3369	Other transportation equipment manufacturing	3	2	0	0	1
	Total for All Advanced Manufacturing	**677**	**271**	**304**	**90**	**12**

Source: U.S. Census Bureau County Business Patterns

Non-Employers

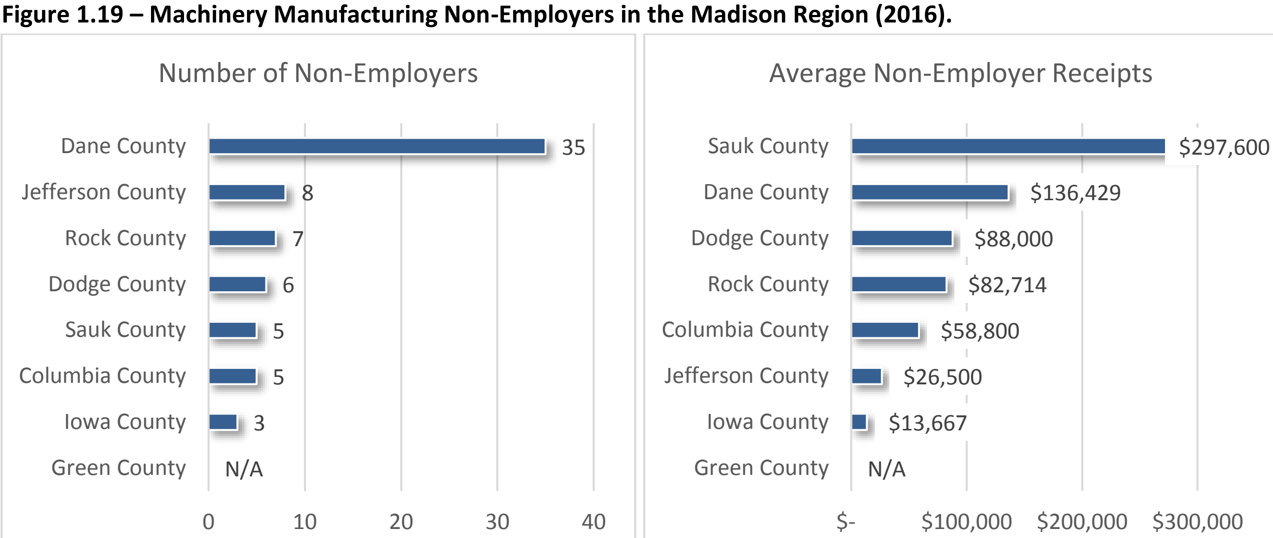
The establishment figures in Figure 1.17 do not include firms classified as *non-employers*. Non-employers are sole-proprietors who may have small enterprises located at home or elsewhere. Non-employer figures originate from tax return information collected by the Internal Revenue Service and provide some perspective on the so-called "gig" economy. Unlike other sectors in the Madison Region's economy, the number of non-employers in advanced manufacturing are somewhat limited. Notable exceptions are fabricated metal product manufacturing with 124 non-employers (Figure 1.18) and machinery manufacturing with 69 non-employers in the Region (Figure 1.19). While some of these firms have small levels of annual receipts and may only provide secondary sources of incomes to their owners, other non-employers may be an overlooked source of nascent entrepreneurs looking to grow their business with proper support.

Figure 1.18 – Fabricated Metal Product Manufacturing Non-Employers in the Madison Region (2016).



Source: U.S. Census Bureau Non-employer Statistics

Figure 1.19 – Machinery Manufacturing Non-Employers in the Madison Region (2016).



Source: U.S. Census Bureau Non-employer Statistics

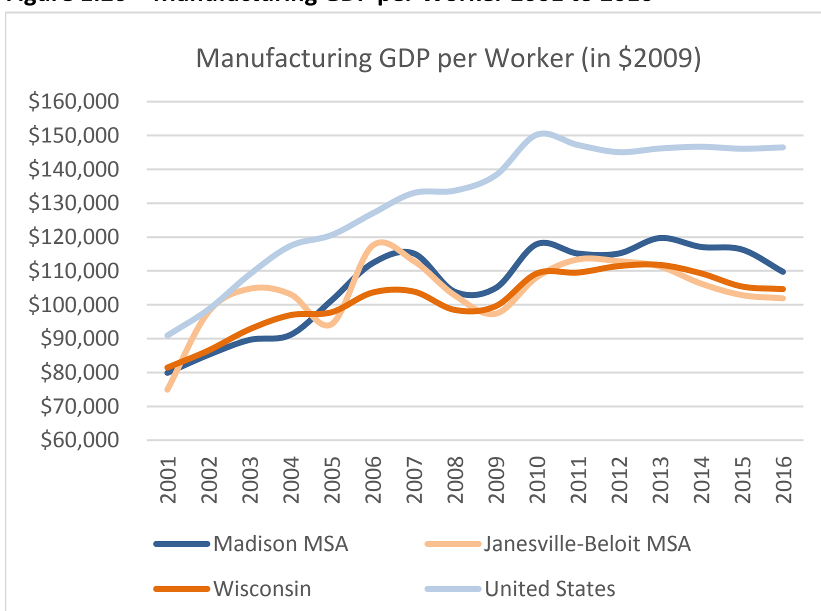
The number of small manufacturers in the Region is partly reflective of the high costs to entry and scaling often found in the manufacturing industry. That is, the capital costs associated with starting a new manufacturing firm or scaling up an existing small firm tend to be much higher in the manufacturing sector than other portions of the economy. However, the capital barriers to manufacturing are diminishing, partly due to new technologies (such as additive manufacturing) and an emphasis on physical spaces that provide the necessary equipment for prototyping and refining new products (such as maker spaces). Accordingly, support for entrepreneurship and startups in manufacturing deserve the attention and focus that are given to other industry clusters in the Madison Region.

Advanced Manufacturing Productivity Trends

As noted throughout this analysis, manufacturing continues to be a large, but evolving component of both the Regional and state economy. One of the more remarkable recent changes in manufacturing has been fluctuations in productivity. As noted earlier in this section, manufacturing employment in the nation and Wisconsin have declined since 1970. Nonetheless, when measured in terms of gross domestic product, manufacturing grew by 44% over the same period. These long term gains in GDP are due to greater levels of productivity in the industry. More recently, however, productivity levels have remained flat and even declined in some instances.

Productivity can be affected by various factors including advances in technology or equipment, economies of scale, or higher skilled workers. Unfortunately the data needed to perform a detailed analysis of advanced manufacturing productivity is unavailable for the Madison Region or even the State of Wisconsin.[4] However, GDP per worker provides a basic proxy for comparing productivity across time and across geographies. When comparing GDP per worker for all manufacturing sectors combined (i.e. not just advanced manufacturing), GDP per worker experienced strong growth nationally throughout the 2000s (Figure 1.20) However, this national growth in GDP per worker was strongly influenced by productivity growth in the computer and electronic component manufacturing subsector. When removing the influence of this sector, national productivity growth rates are much lower.

Figure 1.20 – Manufacturing GDP per Worker 2001 to 2016



Source: Bureau of Economic Analysis and Author's Calculations

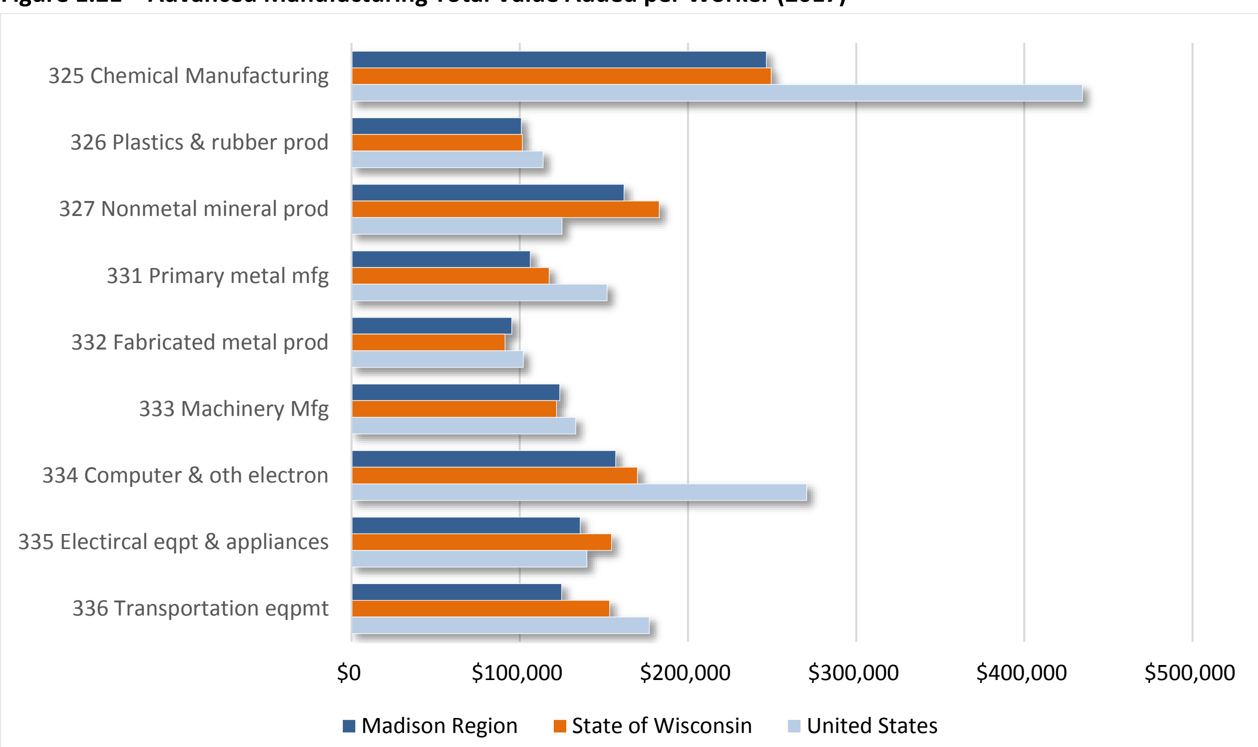
[4] Measures of multifactor productivity are available for manufacturing industries at the national level, but not at the state level. Furthermore, true productivity measures of GDP per worker should be measured on an output per hour worked basis. Again, these types of measures are not available below the national level of analysis.

The State of Wisconsin, the Madison MSA and the Janesville-Beloit MSA are much less dependent on computer and electronic component manufacturing. Accordingly, it is not surprising that growth in GDP per worker is much lower than the national rates of the 2000s. More concerning than these lower growth rates is the flattening or decline in GDP per worker since 2010 across all areas in Figure 1.20. These declines suggest that manufacturers are producing less with the same amount of inputs or the same amount with more inputs.

Ultimately, these changes to productivity are important for several reasons. First, productivity is one measure of competitiveness. That is, regions with higher levels of productivity can create greater levels of output with lower levels of inputs. Consequently, these regions can generate greater returns to manufacturing firms. Second, the returns to manufacturing firms from higher productivity can be distributed to regions in several manners. Higher profits can be reinvested in a firm through capital investments. Owners of the firms can earn higher levels of proprietor income or generate higher dividends for shareholders. Consumers of the products produced by manufacturing firms may see lower prices. Furthermore, employees of the firm may experience higher wages. Regardless of how the returns from higher productivity are distributed, greater gains in productivity often lead to greater income in a region.

Productivity can also be estimated for advanced manufacturing categories in the Madison Region. In this case, the basic measure of productivity is total value added per worker, which is largely analogous to GDP per worker. As with productivity in the overall manufacturing industry, productivity values for advanced manufacturing categories in the Madison Region are largely similar to those of the State of Wisconsin (Figure 1.21). Nonetheless, these values trail those of the United States in every category except nonmetallic mineral manufacturing. These figures also show that levels of total value added per worker vary by industry with chemical manufacturing showing the greatest values and fabricated metal products having the lowest.

Figure 1.21 – Advanced Manufacturing Total Value Added per Worker (2017)



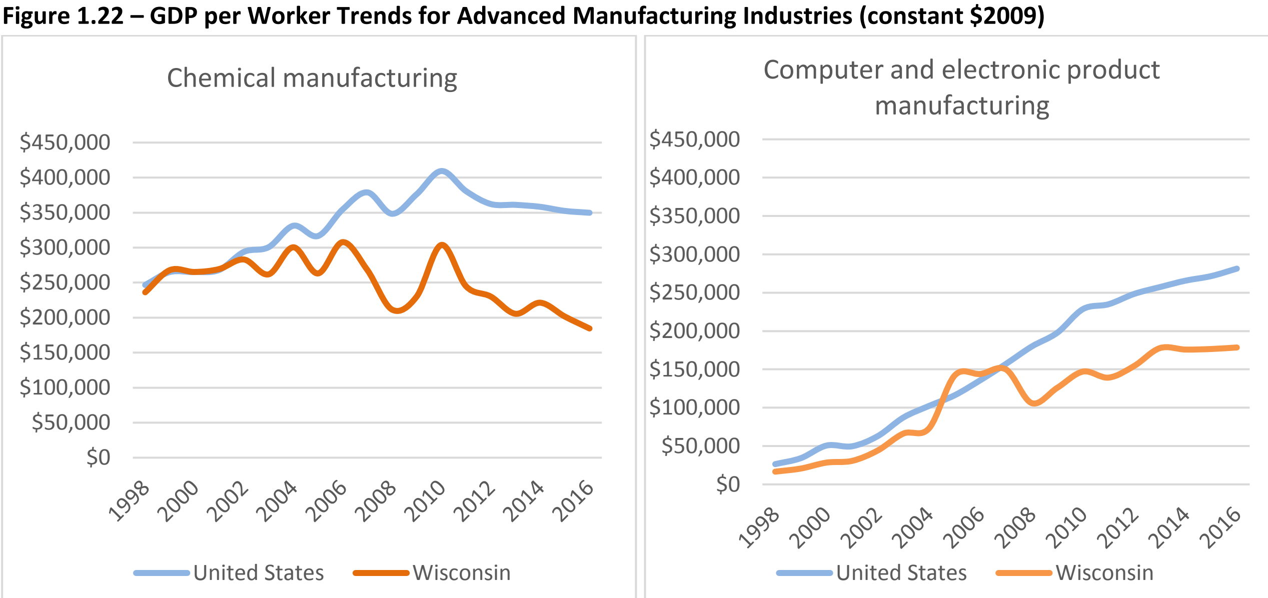
Source: IMPLAN

Unfortunately, productivity values cannot be tracked over time for individual categories of advanced manufacturing in the Madison Region. However, GDP per worker trends for advanced manufacturing categories in the State of Wisconsin do provide some important perspectives on how these industries have changed over the past several decades. While there may be some variations between values in the Madison Region and the State of Wisconsin, it is unlikely that local trends will vary dramatically given the prior comparisons of GDP per worker and total value added per worker.

As suggested by the data in Figure 1.21, two categories with the highest values per worker are chemical manufacturing and computer and electronic component manufacturing. In the late 1990s, GDP per worker values for both of these industries were similar in the State of Wisconsin and the United States. However, the United States experienced greater increases in GDP per worker between 2000 and 2010 than the State of Wisconsin, suggesting that Wisconsin has lower levels of productivity (Figure 1.22). However, GDP per worker values in chemical manufacturing have declined dramatically since 2010 in both the State of Wisconsin and the United States. More recently, GDP per worker values in computer and electronic component manufacturing have also slowed in the United States and remained stagnant in the State of Wisconsin.

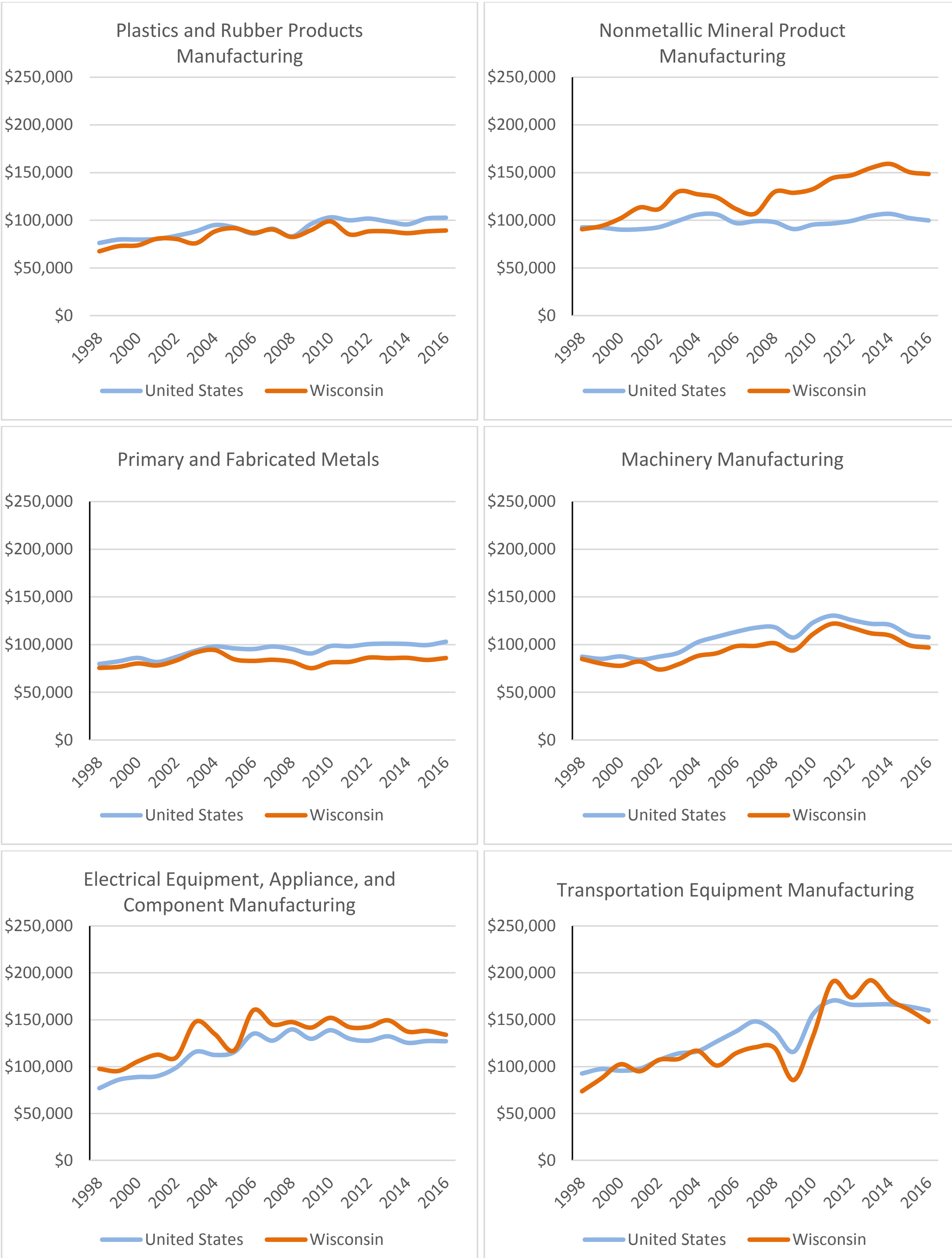
The remaining categories of advanced manufacturing have lower overall levels of GDP per worker. With the exception of nonmetallic mineral products, Wisconsin's trends in GDP per worker have largely followed those of the United States. Unfortunately, most categories of advanced manufacturing have seen very little growth in GDP per worker since 2010, with several industries actually declining in GDP per worker (Figure 1.22). These trends suggest that most advanced manufacturing categories are actually becoming *less* productive. *While the exact reasons for these declines are still being researched, it is likely that lower levels of capital investments and research expenditures are partly responsible*. Regardless, increasing productivity should be a key goal of manufacturing development initiatives both locally and statewide.

Figure 1.22 – GDP per Worker Trends for Advanced Manufacturing Industries (constant $2009)



Source: Bureau of Economic Analysis and Author's Calculations

Figure 1.22 (continued) – GDP per Worker Trends for Advanced Manufacturing Industries (constant $2009)



Source: Bureau of Economic Analysis and Author's Calculations

Conclusions and Summary

- The employment impacts of the Great Recession still linger in many categories of advanced manufacturing. However, broader employment declines in manufacturing started prior to 2007 with the nation, the State of Wisconsin and the Madison Region all experiencing drops beginning in the year 2000. Unfortunately, it is unlikely that the overall manufacturing sector will return to its employment peaks of the late 1990s. Despite these changes, the manufacturing sector is still a foundation of the Madison Region and individual firms and portions of the advanced manufacturing sector likely will experience employment gains. Nonetheless, these overall trends should serve as a caution to using manufacturing employment as the primary metric for evaluating the health of manufacturing in the Madison Region.

- Nationally, employment in every category of advanced manufacturing is either somewhat below or well below employment levels from the year 2000. However, chemical manufacturing and electrical equipment, appliance and component manufacturing in the Madison Region have added employment over the last two decades. These changes are largely driven by pharmaceutical manufacturing and appliance manufacturing respectively in the Region.

- The employment trends depicted in Section 1 also demonstrate the cyclical nature of advanced manufacturing. Specifically, employment in the industry is highly influenced by periods of national and global economic growth and decline.

- With the exception of primary metal products, computer and electronic product manufacturing and transportation equipment, every category of advanced manufacturing has a location quotient above 1.25 in the Madison Region. Electrical equipment appliance and component manufacturing (LQ = 2.43), machinery manufacturing (2.41) and plastic and rubber products (2.28) have the largest LQs in the Region with each of these advanced manufacturing categories showing location quotients above 2.25.

- Both the Madison Region and the State of Wisconsin have experienced long term increases in location quotient values in several categories. Some of the increases in location quotients are due to employment gains in a category, such as those found in chemical manufacturing. In contrast, other LQ increases, such as those found in plastics manufacturing, are due to employment in the Madison Region declining at a slower rate than the nation.

- The majority of advanced manufacturing establishments in the Madison Region are smaller enterprises with fewer than 100 employees. These firms are often overlooked by economic development policies and incentives that target larger establishments for business recruitment and workforce development activities. Instead, the needs of smaller firms may vary and often require different types of support in the form of access to capital, physical spaces, labor force development and technical assistance. These needs are particularly relevant to smaller firms or start-ups looking to scale operations. A number of second stage manufacturing firms may also benefit from participation in Economic Gardening programs.

- Flat or declining productivity is one of the biggest challenges facing advanced manufacturing across the Region, state and nation. Increasing productivity should be a key goal of manufacturing development initiatives both locally and statewide. These efforts will likely vary within each category of advanced manufacturing, but could be broadly supported through increased capital investment, workforce development initiatives, and increases in R&D that ideally result in new products and markets.

Appendix 1A – Top 50 Metropolitan Statistical Areas for Advanced Manufacturing Categories (Ranked by Total Establishments in 2017)

Chemical Manufacturing (NAICS 325)

Metropolitan Statistical Area	Number of Establishments	Total Employment	Employment Location Quotient
New York-Newark-Jersey City, NY-NJ-PA MSA	969	S	S
Los Angeles-Long Beach-Anaheim, CA MSA	780	27,275	0.80
Chicago-Naperville-Elgin, IL-IN-WI MSA	635	37,093	1.45
Houston-The Woodlands-Sugar Land, TX MSA	578	38,301	2.31
Philadelphia-Camden-Wilmington, PA-NJ-DE-MD MSA	406	26,920	1.71
Atlanta-Sandy Springs-Roswell, GA MSA	405	10,759	0.73
Dallas-Fort Worth-Arlington, TX MSA	375	14,619	0.74
Miami-Fort Lauderdale-West Palm Beach, FL MSA	337	5,298	0.37
San Francisco-Oakland-Hayward, CA MSA	237	20,384	1.51
Boston-Cambridge-Newton, MA-NH MSA	233	13,437	0.89
Detroit-Warren-Dearborn, MI MSA	217	8,993	0.83
St. Louis, MO-IL MSA	204	12,482	1.66
Charlotte-Concord-Gastonia, NC-SC MSA	202	S	S
Minneapolis-St. Paul-Bloomington, MN-WI MSA	199	8,724	0.81
San Diego-Carlsbad, CA MSA	191	9,020	1.10
Cleveland-Elyria, OH MSA	188	10,581	1.84
Cincinnati, OH-KY-IN MSA	177	11,713	1.98
Phoenix-Mesa-Scottsdale, AZ MSA	173	5,304	0.47
Riverside-San Bernardino-Ontario, CA MSA	166	4,432	0.54
Seattle-Tacoma-Bellevue, WA MSA	153	2,861	0.26
Portland-Vancouver-Hillsboro, OR-WA MSA	148	2,675	0.40
Tampa-St. Petersburg-Clearwater, FL MSA	142	4,050	0.56
Denver-Aurora-Lakewood, CO MSA	141	3,182	0.39
Washington-Arlington-Alexandria, DC-VA-MD-WV MSA	137	6,623	0.37
Kansas City, MO-KS MSA	133	5,857	1.00
Pittsburgh, PA MSA	124	4,533	0.72
Baltimore-Columbia-Towson, MD MSA	123	5,457	0.72
Baton Rouge, LA MSA	113	S	S
Milwaukee-Waukesha-West Allis, WI MSA	108	4,872	1.03
Memphis, TN-MS-AR MSA	97	4,282	1.23
Salt Lake City, UT MSA	97	S	S
Nashville-Davidson--Murfreesboro--Franklin, TN MSA	96	3,147	0.59
Louisville-Jefferson County, KY-IN MSA	93	3,013	0.83
San Juan-Carolina-Caguas, PR MSA	91	13,746	3.85
Orlando-Kissimmee-Sanford, FL MSA	91	2,263	0.33
Columbus, OH MSA	88	6,859	1.18
New Orleans-Metairie, LA MSA	88	S	S
Indianapolis-Carmel-Anderson, IN MSA	82	16,411	2.88
Richmond, VA MSA	82	5,219	1.44
Akron, OH MSA	82	3,965	2.16
Austin-Round Rock, TX MSA	80	S	S
Buffalo-Cheektowaga-Niagara Falls, NY MSA	78	4,958	1.61
Providence-Warwick, RI-MA MSA	78	S	S
Greenville-Anderson-Mauldin, SC MSA	76	4,847	2.19
San Jose-Sunnyvale-Santa Clara, CA MSA	76	S	S
Allentown-Bethlehem-Easton, PA-NJ MSA	72	3,393	1.68
Madison, WI MSA	**69**	**S**	**S**
Worcester, MA-CT MSA	61	3,215	1.46
San Antonio-New Braunfels, TX MSA	61	1,624	0.29
Beaumont-Port Arthur, TX MSA	60	S	S

Source: U.S. Bureau of Labor Statistics Quarterly Census of Employment and Wages   S = Supressed

Plastics and Rubber Products Manufacturing (NAICS 326)

Metropolitan Statistical Area	Number of Establishments	Total Employment	Employment Location Quotient
Chicago-Naperville-Elgin, IL-IN-WI MSA	567	32,308	1.45
Los Angeles-Long Beach-Anaheim, CA MSA	541	20,655	0.69
New York-Newark-Jersey City, NY-NJ-PA MSA	464	17,548	0.38
Minneapolis-St. Paul-Bloomington, MN-WI MSA	247	12,926	1.37
Dallas-Fort Worth-Arlington, TX MSA	245	13,258	0.77
Philadelphia-Camden-Wilmington, PA-NJ-DE-MD MSA	233	10,540	0.77
Riverside-San Bernardino-Ontario, CA MSA	225	9,800	1.37
Atlanta-Sandy Springs-Roswell, GA MSA	221	15,077	1.18
Houston-The Woodlands-Sugar Land, TX MSA	220	10,099	0.70
Detroit-Warren-Dearborn, MI MSA	208	13,558	1.44
Miami-Fort Lauderdale-West Palm Beach, FL MSA	157	2,768	0.22
Cleveland-Elyria, OH MSA	154	7,600	1.52
Boston-Cambridge-Newton, MA-NH MSA	137	7,100	0.54
Charlotte-Concord-Gastonia, NC-SC MSA	129	8,302	1.44
St. Louis, MO-IL MSA	120	6,710	1.03
Akron, OH MSA	116	7,068	4.43
Portland-Vancouver-Hillsboro, OR-WA MSA	116	S	S
Cincinnati, OH-KY-IN MSA	114	5,893	1.14
Milwaukee-Waukesha-West Allis, WI MSA	111	5,812	1.42
Phoenix-Mesa-Scottsdale, AZ MSA	107	3,287	0.33
Grand Rapids-Wyoming, MI MSA	105	S	S
San Francisco-Oakland-Hayward, CA MSA	99	2,617	0.22
Pittsburgh, PA MSA	98	S	S
Seattle-Tacoma-Bellevue, WA MSA	96	3,984	0.41
Denver-Aurora-Lakewood, CO MSA	96	3,079	0.43
Tampa-St. Petersburg-Clearwater, FL MSA	96	S	S
Kansas City, MO-KS MSA	93	4,294	0.84
San Diego-Carlsbad, CA MSA	91	2,605	0.37
Worcester, MA-CT MSA	88	4,471	2.34
Providence-Warwick, RI-MA MSA	86	S	S
Columbus, OH MSA	82	S	S
Indianapolis-Carmel-Anderson, IN MSA	80	3,731	0.75
Greenville-Anderson-Mauldin, SC MSA	79	S	S
Elkhart-Goshen, IN MSA	78	5,790	8.72
Salt Lake City, UT MSA	78	S	S
Nashville-Davidson--Murfreesboro--Franklin, TN MSA	77	4,071	0.88
Louisville-Jefferson County, KY-IN MSA	67	5,310	1.68
Rochester, NY MSA	63	5,338	2.13
Hartford-West Hartford-East Hartford, CT MSA	60	S	S
Orlando-Kissimmee-Sanford, FL MSA	56	1,641	0.28
Buffalo-Cheektowaga-Niagara Falls, NY MSA	55	4,141	1.54
Hickory-Lenoir-Morganton, NC MSA	55	3,872	5.17
Erie, PA MSA	54	4,415	7.32
Baltimore-Columbia-Towson, MD MSA	54	2,249	0.34
Greensboro-High Point, NC MSA	53	4,621	2.66
Dayton, OH MSA	53	2,967	1.62
Memphis, TN-MS-AR MSA	49	1,621	0.54
Allentown-Bethlehem-Easton, PA-NJ MSA	48	S	S
Las Vegas-Henderson-Paradise, NV MSA	47	1,684	0.35
Jacksonville, FL MSA	47	970	0.30

Source: U.S. Bureau of Labor Statistics Quarterly Census of Employment and Wages S = Supressed

The Madison had 31 establishments and ranked 78th

Nonmetallic Mineral Products Manufacturing (NAICS 327)

Metropolitan Statistical Area	Number of Establishments	Total Employment	Employment Location Quotient
New York-Newark-Jersey City, NY-NJ-PA MSA	530	9,074	0.35
Chicago-Naperville-Elgin, IL-IN-WI MSA	446	S	S
Los Angeles-Long Beach-Anaheim, CA MSA	336	7,054	0.41
Dallas-Fort Worth-Arlington, TX MSA	320	S	S
Miami-Fort Lauderdale-West Palm Beach, FL MSA	316	5,952	0.83
Atlanta-Sandy Springs-Roswell, GA MSA	265	7,359	1.01
Houston-The Woodlands-Sugar Land, TX MSA	263	6,446	0.78
Philadelphia-Camden-Wilmington, PA-NJ-DE-MD MSA	200	S	S
Riverside-San Bernardino-Ontario, CA MSA	185	6,604	1.61
Pittsburgh, PA MSA	170	5,037	1.60
Phoenix-Mesa-Scottsdale, AZ MSA	167	4,826	0.85
Tampa-St. Petersburg-Clearwater, FL MSA	161	3,098	0.87
Washington-Arlington-Alexandria, DC-VA-MD-WV MSA	159	2,926	0.33
Boston-Cambridge-Newton, MA-NH MSA	155	2,710	0.36
Seattle-Tacoma-Bellevue, WA MSA	153	5,176	0.94
Portland-Vancouver-Hillsboro, OR-WA MSA	146	S	S
Charlotte-Concord-Gastonia, NC-SC MSA	145	S	S
San Francisco-Oakland-Hayward, CA MSA	143	3,049	0.45
Minneapolis-St. Paul-Bloomington, MN-WI MSA	135	4,640	0.86
St. Louis, MO-IL MSA	132	3,312	0.88
Denver-Aurora-Lakewood, CO MSA	131	4,573	1.11
Orlando-Kissimmee-Sanford, FL MSA	128	3,179	0.93
Cleveland-Elyria, OH MSA	121	2,646	0.92
Detroit-Warren-Dearborn, MI MSA	121	S	S
Birmingham-Hoover, AL MSA	116	2,424	1.74
Nashville-Davidson--Murfreesboro--Franklin, TN MSA	106	3,333	1.25
Kansas City, MO-KS MSA	104	2,881	0.98
San Antonio-New Braunfels, TX MSA	98	3,207	1.13
Cincinnati, OH-KY-IN MSA	97	2,395	0.81
Indianapolis-Carmel-Anderson, IN MSA	94	3,529	1.24
Baltimore-Columbia-Towson, MD MSA	90	S	S
Columbus, OH MSA	86	4,558	1.57
Austin-Round Rock, TX MSA	82	S	S
Providence-Warwick, RI-MA MSA	82	S	S
Las Vegas-Henderson-Paradise, NV MSA	78	2,280	0.83
San Diego-Carlsbad, CA MSA	77	1,447	0.35
Jacksonville, FL MSA	77	S	S
Salt Lake City, UT MSA	73	1,761	0.88
Buffalo-Cheektowaga-Niagara Falls, NY MSA	71	2,317	1.51
Tulsa, OK MSA	70	2,445	2.02
Oklahoma City, OK MSA	70	S	S
Louisville-Jefferson County, KY-IN MSA	69	1,457	0.80
Milwaukee-Waukesha-West Allis, WI MSA	69	S	S
New Orleans-Metairie, LA MSA	65	1,127	0.73
Allentown-Bethlehem-Easton, PA-NJ MSA	64	1,999	1.99
Worcester, MA-CT MSA	61	2,860	2.61
Raleigh, NC MSA	61	S	S
Memphis, TN-MS-AR MSA	58	1,061	0.61
San Jose-Sunnyvale-Santa Clara, CA MSA	57	1,875	0.60
Sacramento--Roseville--Arden-Arcade, CA MSA	56	1,919	0.70

Source: U.S. Bureau of Labor Statistics Quarterly Census of Employment and Wages S = Supressed

The Madison MSA had 39 establishments and ranked 72nd

Primary Metal Manufacturing (NAICS 331)

Metropolitan Statistical Area	Number of Establishments	Total Employment	Employment Location Quotient
Chicago-Naperville-Elgin, IL-IN-WI MSA	233	25,656	2.23
Los Angeles-Long Beach-Anaheim, CA MSA	228	7,324	0.48
New York-Newark-Jersey City, NY-NJ-PA MSA	174	4,361	0.18
Houston-The Woodlands-Sugar Land, TX MSA	135	3,555	0.48
Detroit-Warren-Dearborn, MI MSA	121	6,649	1.36
Pittsburgh, PA MSA	116	10,524	3.70
Cleveland-Elyria, OH MSA	101	6,969	2.69
Dallas-Fort Worth-Arlington, TX MSA	98	6,304	0.71
Philadelphia-Camden-Wilmington, PA-NJ-DE-MD MSA	84	4,484	0.63
Riverside-San Bernardino-Ontario, CA MSA	76	4,519	1.22
Providence-Warwick, RI-MA MSA	75	S	S
Youngstown-Warren-Boardman, OH-PA MSA	67	7,071	13.10
Atlanta-Sandy Springs-Roswell, GA MSA	67	4,558	0.69
Miami-Fort Lauderdale-West Palm Beach, FL MSA	56	725	0.11
Minneapolis-St. Paul-Bloomington, MN-WI MSA	55	4,127	0.85
Cincinnati, OH-KY-IN MSA	54	5,293	1.99
St. Louis, MO-IL MSA	52	5,549	1.64
Milwaukee-Waukesha-West Allis, WI MSA	49	4,690	2.21
Phoenix-Mesa-Scottsdale, AZ MSA	49	2,038	0.40
Boston-Cambridge-Newton, MA-NH MSA	46	1,123	0.17
Birmingham-Hoover, AL MSA	44	5,259	4.19
Portland-Vancouver-Hillsboro, OR-WA MSA	43	S	S
San Francisco-Oakland-Hayward, CA MSA	43	S	S
Charlotte-Concord-Gastonia, NC-SC MSA	38	3,466	1.16
Akron, OH MSA	35	1,481	1.80
Denver-Aurora-Lakewood, CO MSA	35	S	S
Louisville-Jefferson County, KY-IN MSA	34	2,004	1.23
Salt Lake City, UT MSA	33	S	S
Seattle-Tacoma-Bellevue, WA MSA	33	S	S
Tampa-St. Petersburg-Clearwater, FL MSA	33	S	S
Reading, PA MSA	31	4,138	9.41
Tulsa, OK MSA	31	1,476	1.36
New Haven-Milford, CT MSA	30	1,774	1.90
Canton-Massillon, OH MSA	30	S	S
Columbus, OH MSA	28	1,528	0.58
Nashville-Davidson--Murfreesboro--Franklin, TN MSA	26	2,284	0.95
Kansas City, MO-KS MSA	26	625	0.24
Fort Wayne, IN MSA	26	S	S
Grand Rapids-Wyoming, MI MSA	26	S	S
San Diego-Carlsbad, CA MSA	25	626	0.17
Indianapolis-Carmel-Anderson, IN MSA	24	2,293	0.89
Buffalo-Cheektowaga-Niagara Falls, NY MSA	24	1,657	1.19
Lancaster, PA MSA	23	2,798	4.59
Niles-Benton Harbor, MI MSA	23	1,424	8.95
Dayton, OH MSA	22	768	0.81
Knoxville, TN MSA	21	1,944	2.01
Toledo, OH MSA	21	1,325	1.76
Orlando-Kissimmee-Sanford, FL MSA	21	325	0.11
Baltimore-Columbia-Towson, MD MSA	20	695	0.20
Syracuse, NY MSA	20	S	S

Source: U.S. Bureau of Labor Statistics Quarterly Census of Employment and Wages S = Supressed

The Madison MSA had 10 establishments and ranked 94th

Fabricated Metal Product Manufacturing (NAICS 332)

Metropolitan Statistical Area	Number of Establishments	Total Employment	Employment Location Quotient
Los Angeles-Long Beach-Anaheim, CA MSA	2,700	63,827	1.08
Chicago-Naperville-Elgin, IL-IN-WI MSA	2,403	65,337	1.48
New York-Newark-Jersey City, NY-NJ-PA MSA	1,964	34,213	0.38
Houston-The Woodlands-Sugar Land, TX MSA	1,757	48,098	1.68
Detroit-Warren-Dearborn, MI MSA	1,369	34,736	1.85
Dallas-Fort Worth-Arlington, TX MSA	1,082	28,635	0.84
Minneapolis-St. Paul-Bloomington, MN-WI MSA	1,041	S	S
Cleveland-Elyria, OH MSA	990	27,036	2.72
Philadelphia-Camden-Wilmington, PA-NJ-DE-MD MSA	908	18,956	0.70
Boston-Cambridge-Newton, MA-NH MSA	857	19,867	0.76
Riverside-San Bernardino-Ontario, CA MSA	659	14,046	0.99
Miami-Fort Lauderdale-West Palm Beach, FL MSA	652	9,583	0.39
Milwaukee-Waukesha-West Allis, WI MSA	632	21,918	2.69
Seattle-Tacoma-Bellevue, WA MSA	604	12,102	0.63
Pittsburgh, PA MSA	598	14,183	1.30
Atlanta-Sandy Springs-Roswell, GA MSA	595	14,579	0.58
Phoenix-Mesa-Scottsdale, AZ MSA	589	14,974	0.76
Portland-Vancouver-Hillsboro, OR-WA MSA	588	S	S
San Jose-Sunnyvale-Santa Clara, CA MSA	555	10,391	0.97
San Francisco-Oakland-Hayward, CA MSA	533	9,789	0.42
Hartford-West Hartford-East Hartford, CT MSA	531	15,593	2.56
Charlotte-Concord-Gastonia, NC-SC MSA	500	12,624	1.10
Cincinnati, OH-KY-IN MSA	497	13,868	1.36
Tulsa, OK MSA	471	S	S
St. Louis, MO-IL MSA	453	S	S
Tampa-St. Petersburg-Clearwater, FL MSA	411	6,608	0.53
San Diego-Carlsbad, CA MSA	406	7,173	0.51
Grand Rapids-Wyoming, MI MSA	402	13,495	2.49
Denver-Aurora-Lakewood, CO MSA	392	6,824	0.48
Indianapolis-Carmel-Anderson, IN MSA	386	S	S
Providence-Warwick, RI-MA MSA	360	S	S
Salt Lake City, UT MSA	307	5,151	0.75
New Haven-Milford, CT MSA	302	7,076	1.97
Kansas City, MO-KS MSA	290	8,174	0.80
Rochester, NY MSA	286	7,019	1.41
Birmingham-Hoover, AL MSA	284	6,275	1.30
Columbus, OH MSA	284	S	S
Dayton, OH MSA	276	6,557	1.80
Buffalo-Cheektowaga-Niagara Falls, NY MSA	272	6,955	1.30
Akron, OH MSA	268	6,722	2.12
Worcester, MA-CT MSA	252	6,182	1.63
Rockford, IL MSA	244	7,113	5.03
Nashville-Davidson--Murfreesboro--Franklin, TN MSA	244	7,059	0.77
Orlando-Kissimmee-Sanford, FL MSA	236	3,349	0.28
Oklahoma City, OK MSA	232	5,425	0.92
Louisville-Jefferson County, KY-IN MSA	231	7,622	1.21
Baltimore-Columbia-Towson, MD MSA	226	4,015	0.31
Lafayette, LA MSA	223	3,036	1.58
Austin-Round Rock, TX MSA	214	3,789	0.39
Washington-Arlington-Alexandria, DC-VA-MD-WV MSA	210	3,359	0.11

Source: U.S. Bureau of Labor Statistics Quarterly Census of Employment and Wages S = Supressed

The Madison MSA had 96 establishments and ranked 101st

Machinery Manufacturing (NAICS 333)

Metropolitan Statistical Area	Number of Establishments	Total Employment	Employment Location Quotient
Chicago-Naperville-Elgin, IL-IN-WI MSA	1,353	35,852	1.07
Detroit-Warren-Dearborn, MI MSA	1,100	33,180	2.34
Los Angeles-Long Beach-Anaheim, CA MSA	1,096	22,744	0.51
New York-Newark-Jersey City, NY-NJ-PA MSA	792	14,951	0.22
Houston-The Woodlands-Sugar Land, TX MSA	788	S	S
Minneapolis-St. Paul-Bloomington, MN-WI MSA	486	20,015	1.41
Dallas-Fort Worth-Arlington, TX MSA	483	S	S
Cleveland-Elyria, OH MSA	470	15,326	2.04
Milwaukee-Waukesha-West Allis, WI MSA	426	19,114	3.10
Philadelphia-Camden-Wilmington, PA-NJ-DE-MD MSA	409	S	S
Miami-Fort Lauderdale-West Palm Beach, FL MSA	388	5,396	0.29
Grand Rapids-Wyoming, MI MSA	331	13,454	3.29
Atlanta-Sandy Springs-Roswell, GA MSA	309	8,339	0.44
Charlotte-Concord-Gastonia, NC-SC MSA	308	12,204	1.41
Boston-Cambridge-Newton, MA-NH MSA	301	S	S
Riverside-San Bernardino-Ontario, CA MSA	300	6,590	0.61
Tampa-St. Petersburg-Clearwater, FL MSA	269	5,764	0.61
San Francisco-Oakland-Hayward, CA MSA	261	8,732	0.49
Cincinnati, OH-KY-IN MSA	258	10,717	1.38
Pittsburgh, PA MSA	256	9,973	1.21
Phoenix-Mesa-Scottsdale, AZ MSA	236	5,669	0.38
St. Louis, MO-IL MSA	232	12,886	1.31
Rochester, NY MSA	220	S	S
Portland-Vancouver-Hillsboro, OR-WA MSA	213	9,411	1.09
San Diego-Carlsbad, CA MSA	210	8,553	0.80
Tulsa, OK MSA	209	11,278	3.56
Seattle-Tacoma-Bellevue, WA MSA	209	7,801	0.54
San Jose-Sunnyvale-Santa Clara, CA MSA	197	10,312	1.27
Akron, OH MSA	187	5,282	2.20
Hartford-West Hartford-East Hartford, CT MSA	181	6,026	1.31
Dayton, OH MSA	179	8,187	2.97
Indianapolis-Carmel-Anderson, IN MSA	178	S	S
Kansas City, MO-KS MSA	174	5,645	0.73
Rockford, IL MSA	165	7,308	6.82
Oklahoma City, OK MSA	161	S	S
Providence-Warwick, RI-MA MSA	148	2,710	0.52
Lafayette, LA MSA	147	3,647	2.51
Salt Lake City, UT MSA	147	S	S
Orlando-Kissimmee-Sanford, FL MSA	143	5,705	0.64
Buffalo-Cheektowaga-Niagara Falls, NY MSA	141	4,866	1.21
Nashville-Davidson--Murfreesboro--Franklin, TN MSA	138	3,046	0.44
Denver-Aurora-Lakewood, CO MSA	138	S	S
Louisville-Jefferson County, KY-IN MSA	137	6,046	1.27
Greenville-Anderson-Mauldin, SC MSA	124	8,092	2.79
Columbus, OH MSA	120	6,952	0.91
New Haven-Milford, CT MSA	115	2,305	0.85
Worcester, MA-CT MSA	113	S	S
Sacramento--Roseville--Arden-Arcade, CA MSA	108	2,243	0.31
Baltimore-Columbia-Towson, MD MSA	106	S	S
Toledo, OH MSA	98	2,795	1.28

Source: U.S. Bureau of Labor Statistics Quarterly Census of Employment and Wages S = Supressed

The Madison MSA had 78 establishments and ranked 61st

Computer and Electronic Product Manufacturing (NAICS 334)

Metropolitan Statistical Area	Number of Establishments	Total Employment	Employment Location Quotient
Los Angeles-Long Beach-Anaheim, CA MSA	1,267	74,170	1.71
New York-Newark-Jersey City, NY-NJ-PA MSA	904	39,523	0.59
San Jose-Sunnyvale-Santa Clara, CA MSA	874	112,383	14.26
Chicago-Naperville-Elgin, IL-IN-WI MSA	711	S	S
Boston-Cambridge-Newton, MA-NH MSA	638	46,797	2.45
San Francisco-Oakland-Hayward, CA MSA	552	28,688	1.67
San Diego-Carlsbad, CA MSA	455	27,756	2.67
Dallas-Fort Worth-Arlington, TX MSA	446	41,493	1.66
Minneapolis-St. Paul-Bloomington, MN-WI MSA	362	36,615	2.67
Philadelphia-Camden-Wilmington, PA-NJ-DE-MD MSA	361	S	S
Houston-The Woodlands-Sugar Land, TX MSA	322	14,408	0.69
Washington-Arlington-Alexandria, DC-VA-MD-WV MSA	321	13,558	0.60
Miami-Fort Lauderdale-West Palm Beach, FL MSA	319	7,243	0.40
Phoenix-Mesa-Scottsdale, AZ MSA	289	S	S
Portland-Vancouver-Hillsboro, OR-WA MSA	279	S	S
Seattle-Tacoma-Bellevue, WA MSA	277	13,605	0.97
Atlanta-Sandy Springs-Roswell, GA MSA	245	8,434	0.45
Detroit-Warren-Dearborn, MI MSA	238	S	S
Austin-Round Rock, TX MSA	207	25,797	3.62
Tampa-St. Petersburg-Clearwater, FL MSA	179	9,538	1.05
Baltimore-Columbia-Towson, MD MSA	174	12,101	1.26
Salt Lake City, UT MSA	169	S	S
Denver-Aurora-Lakewood, CO MSA	159	5,818	0.56
Orlando-Kissimmee-Sanford, FL MSA	159	4,375	0.51
Pittsburgh, PA MSA	148	S	S
Riverside-San Bernardino-Ontario, CA MSA	145	4,096	0.39
Cleveland-Elyria, OH MSA	139	5,906	0.81
Manchester-Nashua, NH MSA	133	11,050	7.57
Milwaukee-Waukesha-West Allis, WI MSA	128	9,158	1.53
Oxnard-Thousand Oaks-Ventura, CA MSA	126	5,242	2.25
Raleigh, NC MSA	123	12,324	2.83
Rochester, NY MSA	117	10,253	2.80
Boulder, CO MSA	115	8,222	6.32
Providence-Warwick, RI-MA MSA	115	5,118	1.02
Sacramento--Roseville--Arden-Arcade, CA MSA	104	4,813	0.69
Albuquerque, NM MSA	99	4,047	1.50
New Haven-Milford, CT MSA	98	3,536	1.34
Cincinnati, OH-KY-IN MSA	98	S	S
Palm Bay-Melbourne-Titusville, FL MSA	96	13,038	8.71
Charlotte-Concord-Gastonia, NC-SC MSA	93	3,202	0.38
St. Louis, MO-IL MSA	91	3,364	0.35
Kansas City, MO-KS MSA	83	5,421	0.73
Hartford-West Hartford-East Hartford, CT MSA	82	3,545	0.79
Bridgeport-Stamford-Norwalk, CT MSA	82	3,101	1.02
Boise City, ID MSA	80	10,433	4.70
Columbus, OH MSA	80	2,641	0.36
Indianapolis-Carmel-Anderson, IN MSA	77	3,375	0.47
Santa Maria-Santa Barbara, CA MSA	75	3,350	2.34
Tucson, AZ MSA	71	2,124	0.81
Buffalo-Cheektowaga-Niagara Falls, NY MSA	70	3,196	0.82

Source: U.S. Bureau of Labor Statistics Quarterly Census of Employment and Wages S = Supressed

The Madison MSA had 53 establishments and ranked 53rd

Electrical Equipment, Appliance and Component Manufacturing (NAICS 335)

Metropolitan Statistical Area	Number of Establishments	Total Employment	Employment Location Quotient
Los Angeles-Long Beach-Anaheim, CA MSA	489	14,703	0.92
New York-Newark-Jersey City, NY-NJ-PA MSA	360	10,223	0.41
Chicago-Naperville-Elgin, IL-IN-WI MSA	344	19,183	1.59
Detroit-Warren-Dearborn, MI MSA	164	S	S
Dallas-Fort Worth-Arlington, TX MSA	160	5,826	0.63
Houston-The Woodlands-Sugar Land, TX MSA	156	5,713	0.73
Miami-Fort Lauderdale-West Palm Beach, FL MSA	149	1,994	0.30
San Francisco-Oakland-Hayward, CA MSA	135	3,974	0.62
Boston-Cambridge-Newton, MA-NH MSA	134	5,283	0.75
Philadelphia-Camden-Wilmington, PA-NJ-DE-MD MSA	123	4,024	0.54
Atlanta-Sandy Springs-Roswell, GA MSA	122	7,284	1.06
Minneapolis-St. Paul-Bloomington, MN-WI MSA	105	4,943	0.97
Tampa-St. Petersburg-Clearwater, FL MSA	98	S	S
San Jose-Sunnyvale-Santa Clara, CA MSA	96	3,388	1.16
Cleveland-Elyria, OH MSA	94	5,236	1.94
San Diego-Carlsbad, CA MSA	91	2,068	0.54
Charlotte-Concord-Gastonia, NC-SC MSA	91	S	S
Milwaukee-Waukesha-West Allis, WI MSA	90	S	S
Riverside-San Bernardino-Ontario, CA MSA	88	3,238	0.84
Phoenix-Mesa-Scottsdale, AZ MSA	83	S	S
Pittsburgh, PA MSA	80	5,168	1.74
St. Louis, MO-IL MSA	78	3,640	1.03
Seattle-Tacoma-Bellevue, WA MSA	76	1,883	0.36
Portland-Vancouver-Hillsboro, OR-WA MSA	66	S	S
Providence-Warwick, RI-MA MSA	66	S	S
Cincinnati, OH-KY-IN MSA	62	3,239	1.16
Austin-Round Rock, TX MSA	59	2,333	0.88
Washington-Arlington-Alexandria, DC-VA-MD-WV MSA	56	S	S
Orlando-Kissimmee-Sanford, FL MSA	49	S	S
Nashville-Davidson--Murfreesboro--Franklin, TN MSA	48	8,314	3.32
Baltimore-Columbia-Towson, MD MSA	48	1,487	0.42
Hartford-West Hartford-East Hartford, CT MSA	45	2,407	1.45
Denver-Aurora-Lakewood, CO MSA	44	1,219	0.31
Kansas City, MO-KS MSA	43	1,007	0.36
Worcester, MA-CT MSA	42	2,128	2.06
Indianapolis-Carmel-Anderson, IN MSA	41	930	0.35
Salt Lake City, UT MSA	40	1,406	0.75
Oxnard-Thousand Oaks-Ventura, CA MSA	39	1,286	1.49
Grand Rapids-Wyoming, MI MSA	38	4,055	2.76
Sacramento--Roseville--Arden-Arcade, CA MSA	38	S	S
Greenville-Anderson-Mauldin, SC MSA	37	S	S
Raleigh, NC MSA	37	S	S
New Haven-Milford, CT MSA	36	1,268	1.30
Jacksonville, FL MSA	33	1,218	0.69
Tulsa, OK MSA	32	2,052	1.80
Buffalo-Cheektowaga-Niagara Falls, NY MSA	31	2,261	1.56
Birmingham-Hoover, AL MSA	31	953	0.73
Richmond, VA MSA	31	S	S
Bridgeport-Stamford-Norwalk, CT MSA	30	2,239	1.99
Virginia Beach-Norfolk-Newport News, VA-NC MSA	29	739	0.37

Source: U.S. Bureau of Labor Statistics Quarterly Census of Employment and Wages S = Supressed

The Madison MSA had 15 establishments and ranked 81st

Transportation Equipment Manufacturing (NAICS 336)

Metropolitan Statistical Area	Number of Establishments	Total Employment	Employment Location Quotient
Los Angeles-Long Beach-Anaheim, CA MSA	728	61,644	0.90
Detroit-Warren-Dearborn, MI MSA	561	109,541	5.04
Miami-Fort Lauderdale-West Palm Beach, FL MSA	440	9,582	0.33
Dallas-Fort Worth-Arlington, TX MSA	307	49,664	1.26
Chicago-Naperville-Elgin, IL-IN-WI MSA	278	19,130	0.37
Seattle-Tacoma-Bellevue, WA MSA	275	85,288	3.84
New York-Newark-Jersey City, NY-NJ-PA MSA	260	7,766	0.07
Riverside-San Bernardino-Ontario, CA MSA	215	8,203	0.50
Phoenix-Mesa-Scottsdale, AZ MSA	185	16,844	0.74
San Diego-Carlsbad, CA MSA	181	20,011	1.22
Atlanta-Sandy Springs-Roswell, GA MSA	178	15,018	0.51
Cleveland-Elyria, OH MSA	149	13,350	1.16
Philadelphia-Camden-Wilmington, PA-NJ-DE-MD MSA	146	S	S
Tampa-St. Petersburg-Clearwater, FL MSA	144	S	S
Elkhart-Goshen, IN MSA	141	35,799	23.42
Wichita, KS MSA	141	27,401	8.30
Houston-The Woodlands-Sugar Land, TX MSA	140	4,983	0.15
Charlotte-Concord-Gastonia, NC-SC MSA	136	10,331	0.78
Portland-Vancouver-Hillsboro, OR-WA MSA	135	6,723	0.51
Hartford-West Hartford-East Hartford, CT MSA	125	S	S
St. Louis, MO-IL MSA	116	22,735	1.51
Cincinnati, OH-KY-IN MSA	106	23,493	1.98
Minneapolis-St. Paul-Bloomington, MN-WI MSA	105	2,641	0.12
Grand Rapids-Wyoming, MI MSA	101	S	S
Indianapolis-Carmel-Anderson, IN MSA	98	14,847	1.30
San Francisco-Oakland-Hayward, CA MSA	98	13,028	0.48
Nashville-Davidson--Murfreesboro--Franklin, TN MSA	97	28,086	2.63
Kansas City, MO-KS MSA	97	16,509	1.40
Boston-Cambridge-Newton, MA-NH MSA	93	S	S
Jacksonville, FL MSA	90	4,408	0.59
Denver-Aurora-Lakewood, CO MSA	87	7,828	0.47
San Antonio-New Braunfels, TX MSA	85	12,204	1.07
Orlando-Kissimmee-Sanford, FL MSA	81	S	S
Virginia Beach-Norfolk-Newport News, VA-NC MSA	80	26,103	3.08
Columbus, OH MSA	75	14,228	1.22
Oklahoma City, OK MSA	71	5,161	0.76
Salt Lake City, UT MSA	71	2,646	0.33
Port St. Lucie, FL MSA	68	1,898	1.18
Dayton, OH MSA	68	S	S
Providence-Warwick, RI-MA MSA	68	S	S
Tulsa, OK MSA	65	5,344	1.10
Knoxville, TN MSA	63	9,420	2.19
Milwaukee-Waukesha-West Allis, WI MSA	63	4,570	0.48
Palm Bay-Melbourne-Titusville, FL MSA	63	3,806	1.61
Louisville-Jefferson County, KY-IN MSA	59	22,227	3.06
Toledo, OH MSA	59	14,930	4.46
New Orleans-Metairie, LA MSA	59	2,491	0.40
Greenville-Anderson-Mauldin, SC MSA	59	S	S
Charleston-North Charleston, SC MSA	57	12,055	3.19
Washington-Arlington-Alexandria, DC-VA-MD-WV MSA	56	1,492	0.04

Source: U.S. Bureau of Labor Statistics Quarterly Census of Employment and Wages S = Supressed

The Madison MSA had 15 establishments and ranked 157th

This page is intentionally blank

Section 2 – Advanced Manufacturing Human Capital

As mentioned in the Introduction, all industry clusters depend on access to pools of human capital or skilled labor. While human capital is often measured in terms of the educational attainment acquired by the region's labor force, education provides an incomplete perspective on a worker's knowledge and abilities as it only captures differences in vertical skills, or the amount of skill possessed by people. That is, a person's level of education does not specify the types of individual skills and talents that people possess (Marigee, Blum, and Strange, 2009). Instead, this analysis partially uses occupations to measure human capital. Occupations group employees by the common set of activities, technologies and tasks that they perform. Accordingly, occupations provide a better measure of the skills an employee offers, regardless of an individual's educational attainment or industry of employment. Specific measures of advanced manufacturing human capital include occupational concentrations, talent diversity, age distribution, automation susceptibility and employment churn.

Advanced Manufacturing Occupational Structure

Advanced manufacturing broadly involves a diversity of occupations related to production, installation, transportation, engineering, repair and sales. However, a more detailed examination of occupations can be considered using the Standard Occupational Classification (SOC) which classifies occupations based on job duties, skills, education, and/or training requirements. To examine specific occupations concentrated in each advanced manufacturing category, the 30 largest occupations by total employment are listed for each subsector in Figures 2.1 to 2.9. *Note that these figures are based on the national occupational distributions for advanced manufacturing as reported by the Bureau of Labor Statistics (BLS). Local occupational structures likely will vary in sub-categories of advanced manufacturing and within individual firms.* Nonetheless, the overall national distributions provide a starting point for determining the occupations that are commonly important to these industries.

Information on regional specialization for each occupation is provided by an occupational location quotient calculated for both the Madison and Janesville-Beloit metropolitan statistical areas (MSAs).[5] Each occupation's annual average wages in the metro areas are also provided alongside the industry's national average wage to provide some perspective on pay rates. While these MSAs only cover five counties in the study area, detailed occupational figures are not available for other counties in the Madison Region. Nonetheless, the wage rates found in the five counties covered in this analysis are likely indicative of wages in the Region's overall labor market.

Each occupation also is assigned a *Job Zone* from the Occupational Information Network (O*NET). Job zones provide information on the usual types of preparation and time needed for given occupations within an industry. Occupations in Job Zone 1 have lower preparation requirements while occupations in Job Zone 5 require the largest amount of preparation (see Appendix 2A). In addition to insights on training needs for individual occupations, the distribution of occupations by Job Zones for each advanced manufacturing subsector provides perspectives on the overall training and skill requirements of the industry as a whole.

[5] Section 1 provides an overview of location quotients.

Figure 2.1 - Chemical Manufacturing Occupations by Share of Industry Employment – Top 30 Occupations (2017)

SOC	Occupation Title	Job Zone	Percent of Industry Employment	Madison MSA LQ	Janesville-Beloit MSA LQ	U.S. Annual Average Wage	Madison MSA Annual Avg. Wage	Janesville-Beloit MSA Annual Avg. Wage
51-9011	Chemical Equipment Operators and Tenders	2	8.15%	1.57	2.44	$51,050	$42,080	$59,690
51-9111	Packaging and Filling Machine Operators and Tenders	2	6.16%	1.63	1.82	$33,460	$33,200	$38,110
51-9023	Mixing and Blending Machine Setters, Operators, and Tenders	2	6.02%	2.01	1.88	$40,030	$36,730	$37,640
51-1011	First-Line Supervisors of Production and Operating Workers	2	4.12%	1.22	1.7	$71,750	$58,670	$61,580
19-2031	Chemists	4	3.56%	N/A	N/A	$79,810	$68,850	N/A
51-8091	Chemical Plant and System Operators	2	3.28%	1.29	4.29	$62,250	$43,980	$57,680
51-9061	Inspectors, Testers, Sorters, Samplers, and Weighers	2	3.22%	0.99	1.63	$45,850	$38,020	$32,170
19-4031	Chemical Technicians	3	2.74%	2.07	N/A	$53,410	$43,910	N/A
49-9041	Industrial Machinery Mechanics	3	2.43%	0.64	1.38	$58,850	$51,420	$54,850
49-9071	Maintenance and Repair Workers, General	3	2.11%	1.16	1.12	$49,760	$41,330	$35,500
53-7062	Laborers and Freight, Stock, and Material Movers, Hand	2	2.02%	0.74	1.33	$33,690	$32,460	$29,150
11-1021	General and Operations Managers	4	1.91%	0.82	0.66	$149,830	$125,630	$110,390
51-2098	Assemblers and Fabricators, All Other	2	1.87%	1.13	1.68	$31,570	$32,260	$30,850
17-2112	Industrial Engineers	4	1.73%	0.97	1.15	$94,490	$76,900	$77,180
41-4012	Sales Reps, Wholesale & Mfg., Except Tech/Scientific Products	4	1.69%	1.17	1.86	$77,800	$67,600	$63,350
43-5071	Shipping, Receiving, and Traffic Clerks	2	1.69%	0.79	1.51	$38,110	$35,100	$37,120
11-3051	Industrial Production Managers	4	1.68%	1.24	1.32	$120,140	$108,840	$125,810
17-2041	Chemical Engineers	4	1.59%	2.56	3.26	$112,310	$104,370	$110,740
41-4011	Sales Reps, Wholesale and Mfg., Technical/Scientific Products	4	1.47%	0.83	N/A	$90,910	$72,770	$108,340
43-4051	Customer Service Representatives	2	1.28%	1.4	1.55	$42,080	$37,680	$36,640
43-9061	Office Clerks, General	2	1.06%	1.25	1.15	$37,780	$36,430	$34,060
43-5061	Production, Planning, and Expediting Clerks	3	1.04%	0.68	0.73	$54,130	$48,290	$45,430
13-1199	Business Operations Specialists, All Other	3	1.00%	1.27	0.25	$87,220	$64,370	$63,200
51-9012	Separating, Filtering, Clarifying & Precipitating Machine Operators	2	1.00%	1.95	N/A	$45,760	$40,550	N/A
43-6014	Secretaries and Administrative Assistants	3	0.97%	0.5	0.43	$41,970	$38,880	$34,970
53-7051	Industrial Truck and Tractor Operators	2	0.95%	0.68	1.79	$38,020	$34,950	$34,750
13-2011	Accountants and Auditors	4	0.93%	1.23	0.73	$78,500	$68,030	$67,340
51-9199	Production Workers, All Other	2	0.93%	0.24	N/A	$39,890	$31,210	$28,820
53-3032	Heavy and Tractor-Trailer Truck Drivers	2	0.91%	0.82	1.87	$47,280	$48,020	$44,020
51-9198	Helpers--Production Workers	2	0.85%	0.35	0.67	$30,080	$33,300	$30,560

Source: Bureau of Labor Statistics, O*NET and Author's Calculations

Figure 2.2 - Plastics and Rubber Products Occupations by Share of Industry Employment – Top 30 Occupations (2017)

SOC	Occupation Title	Job Zone	Percent of Industry Employment	Madison MSA LQ	Janesville-Beloit MSA LQ	U.S. Annual Average Wage	Madison MSA Annual Avg. Wage	Janesville-Beloit MSA Annual Avg. Wage
51-4072	Molding, Coremaking & Casting Machine Operators, Metal & Plastic	2	10.4%	1.59	N/A	$31,800	$38,240	$42,590
51-2098	Assemblers and Fabricators, All Other, Including Team Assemblers	2	8.0%	1.13	1.68	$29,480	$32,260	$30,850
51-4021	Extruding and Drawing Machine Operators, Metal and Plastic	2	5.0%	0.80	5.87	$34,720	$33,720	$29,600
51-1011	First-Line Supervisors of Production and Operating Workers	2	4.6%	1.22	1.70	$57,850	$58,670	$61,580
51-9061	Inspectors, Testers, Sorters, Samplers, and Weighers	2	4.2%	0.99	1.63	$36,550	$38,020	$32,170
51-9041	Extruding, Forming, Pressing, and Compacting Machine Operators	2	3.8%	N/A	N/A	$34,500	N/A	N/A
53-7064	Packers and Packagers, Hand	2	2.9%	1.36	1.13	$26,500	$34,200	$29,640
51-9197	Tire Builders	2	2.9%	N/A	N/A	$42,810	N/A	N/A
53-7062	Laborers and Freight, Stock, and Material Movers, Hand	2	2.9%	0.74	1.33	$31,190	$32,460	$29,150
51-4031	Cutting, Punching, and Press Machine Operators, Metal and Plastic	2	2.3%	1.03	3.55	$32,670	$35,340	$37,350
49-9071	Maintenance and Repair Workers, General	3	2.3%	1.16	1.12	$45,120	$41,330	$35,500
43-5071	Shipping, Receiving, and Traffic Clerks	2	2.1%	0.79	1.51	$35,020	$35,100	$37,120
49-9041	Industrial Machinery Mechanics	3	2.0%	0.64	1.38	$51,290	$51,420	$54,850
51-9198	Helpers--Production Workers	2	2.0%	0.35	0.67	$29,160	$33,300	$30,560
51-4081	Multiple Machine Tool Operators, Metal and Plastic	2	1.9%	2.41	0.91	$33,090	$35,560	$38,840
41-4012	Sales Reps, Wholesale & Mfg., Except Tech/Scientific Products	4	1.8%	1.17	1.86	$68,970	$67,600	$63,350
51-9111	Packaging and Filling Machine Operators and Tenders	2	1.6%	1.63	1.82	$31,340	$33,200	$38,110
11-1021	General and Operations Managers	4	1.5%	0.82	0.66	$133,210	$125,630	$110,390
17-2112	Industrial Engineers	4	1.5%	0.97	1.15	$79,670	$76,900	$77,180
53-7051	Industrial Truck and Tractor Operators	2	1.5%	0.68	1.79	$34,390	$34,950	$34,750
11-3051	Industrial Production Managers	4	1.3%	1.24	1.32	$100,500	$108,840	$125,810
43-4051	Customer Service Representatives	2	1.3%	1.40	1.55	$41,320	$37,680	$36,640
51-4041	Machinists	3	1.2%	0.69	1.95	$39,090	$42,870	$44,060
51-4011	Computer-Controlled Machine Tool Operators, Metal and Plastic	3	1.1%	0.93	3.53	$36,820	$41,500	$44,060
51-9032	Cutting and Slicing Machine Setters, Operators, and Tenders	2	1.1%	0.94	N/A	$35,240	$34,830	N/A
51-9199	Production Workers, All Other	2	1.0%	0.24	N/A	$33,150	$31,210	$28,820
51-9023	Mixing and Blending Machine Setters, Operators, and Tenders	2	1.0%	2.01	1.88	$37,710	$36,730	$37,640
43-9061	Office Clerks, General	2	0.9%	1.25	1.15	$34,700	$36,430	$34,060
43-5061	Production, Planning, and Expediting Clerks	3	0.8%	0.68	0.73	$47,480	$48,290	$45,430
51-5112	Printing Press Operators	3	0.8%	2.05	2.36	$37,870	$40,520	$25,830

Source: Bureau of Labor Statistics, O*NET and Author's Calculations

Figure 2.3 - Nonmetallic Mineral Product Manufacturing Occupations by Share of Industry Employment – Top 30 Occupations (2017)

SOC	Occupation Title	Job Zone	Percent of Industry Employment	Madison MSA LQ	Janesville-Beloit MSA LQ	U.S. Annual Average Wage	Madison MSA Annual Avg. Wage	Janesville-Beloit MSA Annual Avg. Wage
53-3032	Heavy and Tractor-Trailer Truck Drivers	2	16.27%	0.82	1.87	$41,750	$48,020	$44,020
51-9195	Molders, Shapers, and Casters, Except Metal and Plastic	2	6.05%	1.02	N/A	$34,040	$37,660	N/A
51-2098	Assemblers and Fabricators, All Other, Including Team Assemblers	2	4.31%	1.13	1.68	$33,270	$32,260	$30,850
51-9041	Extruding, Forming, Pressing, and Compacting Machine Setters, etc.	2	4.29%	N/A	N/A	$37,370	N/A	N/A
51-1011	First-Line Supervisors of Production and Operating Workers	2	3.60%	1.22	1.70	$61,190	$58,670	$61,580
53-7062	Laborers and Freight, Stock, and Material Movers, Hand	2	3.49%	0.74	1.33	$31,680	$32,460	$29,150
51-9023	Mixing and Blending Machine Setters, Operators, and Tenders	2	3.11%	2.01	1.88	$38,420	$36,730	$37,640
41-4012	Sales Reps, Wholesale & Mfg., Except Tech/Scientific Products	4	2.69%	1.17	1.86	$64,230	$67,600	$63,350
51-9032	Cutting and Slicing Machine Setters, Operators, and Tenders	2	2.62%	0.94	N/A	$34,500	$34,830	N/A
51-9061	Inspectors, Testers, Sorters, Samplers, and Weighers	2	2.40%	0.99	1.63	$41,060	$38,020	$32,170
53-7051	Industrial Truck and Tractor Operators	2	2.19%	0.68	1.79	$36,680	$34,950	$34,750
51-9198	Helpers--Production Workers	2	2.16%	0.35	0.67	$31,580	$33,300	$30,560
11-1021	General and Operations Managers	4	2.06%	0.82	0.66	$117,790	$125,630	$110,390
49-9071	Maintenance and Repair Workers, General	3	2.03%	1.16	1.12	$45,370	$41,330	$35,500
51-9051	Furnace, Kiln, Oven, Drier, and Kettle Operators and Tenders	2	1.69%	1.29	N/A	$38,960	$32,710	N/A
43-9061	Office Clerks, General	2	1.62%	1.25	1.15	$35,000	$36,430	$34,060
51-9021	Crushing, Grinding, and Polishing Machine Setters, Operators, etc.	2	1.55%	N/A	N/A	$37,260	$30,650	N/A
49-9041	Industrial Machinery Mechanics	3	1.53%	0.64	1.38	$51,750	$51,420	$54,850
53-7064	Packers and Packagers, Hand	2	1.29%	1.36	1.13	$30,270	$34,200	$29,640
47-2061	Construction Laborers	2	1.22%	0.93	0.74	$33,630	$43,030	$47,810
49-3031	Bus and Truck Mechanics and Diesel Engine Specialists	3	1.20%	0.92	2.06	$45,230	$48,620	$52,130
51-9199	Production Workers, All Other	2	1.20%	0.24	N/A	$36,010	$31,210	$28,820
53-1048	First-Line Supervisors of Transportation & Material Moving Workers,		1.07%	0.70	0.92	$58,490	$52,020	$58,980
51-9111	Packaging and Filling Machine Operators and Tenders	2	1.03%	1.63	1.82	$35,310	$33,200	$38,110
11-3051	Industrial Production Managers	4	1.02%	1.24	1.32	$100,900	$108,840	$125,810
43-5032	Dispatchers, Except Police, Fire, and Ambulance	2	0.98%	0.69	0.80	$46,350	$44,770	$47,690
43-6014	Secretaries and Administrative Assistants	3	0.97%	0.50	0.43	$36,140	$38,880	$34,970
43-3031	Bookkeeping, Accounting, and Auditing Clerks	3	0.94%	1.06	1.38	$41,910	$39,610	$34,460
47-2073	Operating Engineers and Other Construction Equipment Operators	2	0.94%	0.80	1.49	$48,590	$66,650	$63,950
17-2112	Industrial Engineers	4	0.91%	0.97	1.15	$83,510	$76,900	$77,180

Source: Bureau of Labor Statistics, O*NET and Author's Calculations

Figure 2.4 - Primary Metal Product Manufacturing Occupations by Share of Industry Employment – Top 30 Occupations (2017)

SOC	Occupation Title	Job Zone	Percent of Industry Employment	Madison MSA LQ	Janesville-Beloit MSA LQ	U.S. Annual Average Wage	Madison MSA Annual Avg. Wage	Janesville-Beloit MSA Annual Avg. Wage
51-1011	First-Line Supervisors of Production and Operating Workers	2	4.7%	1.22	1.70	$63,830	$58,670	$61,580
51-4051	Metal-Refining Furnace Operators and Tenders	2	4.0%	N/A	N/A	$42,140	N/A	N/A
51-9061	Inspectors, Testers, Sorters, Samplers, and Weighers	2	3.9%	0.99	1.63	$41,360	$38,020	$32,170
51-4021	Extruding and Drawing Machine Setters, Operators, & Tenders	2	3.8%	0.80	5.87	$38,370	$33,720	$29,600
51-4072	Molding, Coremaking, and Casting Machine Setters, Operators, etc.	2	3.7%	1.59	N/A	$36,770	$38,240	$42,590
49-9041	Industrial Machinery Mechanics	3	3.7%	0.64	1.38	$52,650	$51,420	$54,850
51-4031	Cutting, Punching, and Press Machine Setters, Operators, etc.	2	3.6%	1.03	3.55	$35,980	$35,340	$37,350
51-4071	Foundry Mold and Coremakers	2	3.0%	2.64	N/A	$36,280	$36,240	N/A
51-4033	Grinding, Lapping, Polishing, and Buffing Machine Tool Setters, etc.	2	3.0%	1.03	2.07	$36,160	$35,980	$34,680
51-4023	Rolling Machine Setters, Operators, and Tenders, Metal and Plastic	2	2.9%	N/A	N/A	$43,250	N/A	N/A
49-9071	Maintenance and Repair Workers, General	3	2.6%	1.16	1.12	$48,160	$41,330	$35,500
51-9198	Helpers--Production Workers	2	2.6%	0.35	0.67	$31,530	$33,300	$30,560
51-4041	Machinists	3	2.5%	0.69	1.95	$39,910	$42,870	$44,060
53-7062	Laborers and Freight, Stock, and Material Movers, Hand	2	2.3%	0.74	1.33	$33,230	$32,460	$29,150
51-4081	Multiple Machine Tool Setters, Operators, and Tenders	2	2.1%	2.41	0.91	$37,420	$35,560	$38,840
53-7051	Industrial Truck and Tractor Operators	2	2.0%	0.68	1.79	$38,890	$34,950	$34,750
51-4052	Pourers and Casters, Metal	2	1.9%	N/A	N/A	$39,810	N/A	N/A
51-4121	Welders, Cutters, Solderers, and Brazers	3	1.8%	1.01	2.71	$41,790	$42,880	$42,110
43-5071	Shipping, Receiving, and Traffic Clerks	2	1.8%	0.79	1.51	$37,410	$35,100	$37,120
51-4011	Computer-Controlled Machine Tool Operators, Metal and Plastic	3	1.7%	0.93	3.53	$39,400	$41,500	$44,060
51-9199	Production Workers, All Other	2	1.7%	0.24	N/A	$44,080	$31,210	$28,820
17-2112	Industrial Engineers	4	1.5%	0.97	1.15	$79,830	$76,900	$77,180
41-4012	Sales Reps, Wholesale & Mfg., Except Tech/Scientific Products	4	1.5%	1.17	1.86	$74,750	$67,600	$63,350
51-2098	Assemblers and Fabricators, All Other, Including Team Assemblers		1.4%	1.13	1.68	$36,210	$32,260	$30,850
53-7021	Crane and Tower Operators	3	1.3%	N/A	N/A	$47,380	N/A	N/A
11-1021	General and Operations Managers	4	1.3%	0.82	0.66	$137,650	$125,630	$110,390
47-2111	Electricians	3	1.3%	0.85	1.13	$58,750	$54,930	$53,880
11-3051	Industrial Production Managers	4	1.2%	1.24	1.32	$105,080	$108,840	$125,810
49-9043	Maintenance Workers, Machinery	3	1.1%	0.92	2.51	$49,290	$48,910	$50,280
51-4035	Milling and Planing Machine Setters, Operators, and Tenders	2	1.1%	N/A	N/A	$47,930	N/A	N/A

Source: Bureau of Labor Statistics, O*NET and Author's Calculations

Figure 2.5 - Fabricated Metal Product Manufacturing Occupations by Share of Industry Employment – Top 30 Occupations (2017)

SOC	Occupation Title	Job Zone	Percent of Industry Employment	Madison MSA LQ	Janesville-Beloit MSA LQ	U.S. Annual Average Wage	Madison MSA Annual Avg. Wage	Janesville-Beloit MSA Annual Avg. Wage
51-4041	Machinists	3	9.40%	0.69	1.95	$42,660	$42,870	$44,060
51-4121	Welders, Cutters, Solderers, and Brazers	3	7.19%	1.01	2.71	$40,260	$42,880	$42,110
51-2098	Assemblers and Fabricators, All Other, Including Team Assemblers		6.61%	1.13	1.68	$33,090	$32,260	$30,850
51-1011	First-Line Supervisors of Production and Operating Workers	2	4.38%	1.22	1.70	$62,680	$58,670	$61,580
51-4031	Cutting, Punching, and Press Machine Setters, Operators, etc.	2	4.14%	1.03	3.55	$35,240	$35,340	$37,350
51-4011	Computer-Controlled Machine Tool Operators, Metal and Plastic	3	3.70%	0.93	3.53	$40,170	$41,500	$44,060
51-9061	Inspectors, Testers, Sorters, Samplers, and Weighers	2	3.19%	0.99	1.63	$41,830	$38,020	$32,170
51-2041	Structural Metal Fabricators and Fitters	3	2.62%	1.80	N/A	$39,150	$40,290	$47,690
11-1021	General and Operations Managers	4	2.37%	0.82	0.66	$128,550	$125,630	$110,390
51-9198	Helpers--Production Workers	2	2.30%	0.35	0.67	$28,570	$33,300	$30,560
53-7062	Laborers and Freight, Stock, and Material Movers, Hand	2	2.30%	0.74	1.33	$31,080	$32,460	$29,150
41-4012	Sales Reps, Wholesale & Mfg., Except Tech/Scientific Products	4	2.10%	1.17	1.86	$68,370	$67,600	$63,350
51-9121	Coating, Painting, and Spraying Machine Setters, Operators, etc.	2	2.10%	1.22	2.36	$33,810	$36,760	$38,180
43-5071	Shipping, Receiving, and Traffic Clerks	2	2.03%	0.79	1.51	$35,440	$35,100	$37,120
51-4033	Grinding, Lapping, Polishing, and Buffing Machine Tool Setters, etc.	2	1.86%	1.03	2.07	$35,410	$35,980	$34,680
43-9061	Office Clerks, General	2	1.79%	1.25	1.15	$36,280	$36,430	$34,060
51-4081	Multiple Machine Tool Setters, Operators, and Tenders	2	1.70%	2.41	0.91	$35,810	$35,560	$38,840
51-4193	Plating and Coating Machine Setters, Operators, and Tenders	2	1.68%	N/A	N/A	$33,150	N/A	N/A
47-2211	Sheet Metal Workers	2	1.52%	1.47	N/A	$44,070	$43,800	$33,340
49-9071	Maintenance and Repair Workers, General	3	1.33%	1.16	1.12	$43,590	$41,330	$35,500
11-3051	Industrial Production Managers	4	1.24%	1.24	1.32	$103,280	$108,840	$125,810
43-6014	Secretaries and Administrative Assistants	3	1.18%	0.50	0.43	$36,260	$38,880	$34,970
17-2141	Mechanical Engineers	4	1.16%	1.53	1.50	$78,970	$78,870	$74,880
17-2112	Industrial Engineers	4	1.06%	0.97	1.15	$76,570	$76,900	$77,180
51-4034	Lathe and Turning Machine Tool Setters, Operators, and Tenders	2	1.06%	N/A	N/A	$39,320	N/A	N/A
43-3031	Bookkeeping, Accounting, and Auditing Clerks	3	1.05%	1.06	1.38	$41,840	$39,610	$34,460
49-9041	Industrial Machinery Mechanics	3	1.04%	0.64	1.38	$48,540	$51,420	$54,850
51-4111	Tool and Die Makers	3	1.00%	0.99	2.87	$51,570	$48,700	$45,340
43-4051	Customer Service Representatives	2	0.95%	1.40	1.55	$42,150	$37,680	$36,640
51-9199	Production Workers, All Other	2	0.88%	0.24	N/A	$35,530	$31,210	$28,820

Source: Bureau of Labor Statistics, O*NET and Author's Calculations

Figure 2.6 - Machinery Manufacturing by Share of Industry Employment – Top 30 Occupations (2017)

SOC	Occupation Title	Job Zone	Percent of Industry Employment	Madison MSA LQ	Janesville-Beloit MSA LQ	U.S. Annual Average Wage	Madison MSA Annual Avg. Wage	Janesville-Beloit MSA Annual Avg. Wage
51-2098	Assemblers and Fabricators, All Other, Including Team Assemblers	2	12.18%	1.13	1.68	$35,110	$32,260	$30,850
51-4041	Machinists	3	7.22%	0.69	1.95	$44,710	$42,870	$44,060
51-4121	Welders, Cutters, Solderers, and Brazers	3	5.55%	1.01	2.71	$41,180	$42,880	$42,110
17-2141	Mechanical Engineers	4	3.61%	1.53	1.50	$81,580	$78,870	$74,880
51-1011	First-Line Supervisors of Production and Operating Workers	2	3.51%	1.22	1.70	$65,020	$58,670	$61,580
51-4011	Computer-Controlled Machine Tool Operators, Metal and Plastic	3	3.02%	0.93	3.53	$42,940	$41,500	$44,060
41-4012	Sales Reps, Wholesale & Mfg., Except Tech/Scientific Products	4	2.60%	1.17	1.86	$72,210	$67,600	$63,350
51-9061	Inspectors, Testers, Sorters, Samplers, and Weighers	2	2.35%	0.99	1.63	$43,780	$38,020	$32,170
51-2028	Electrical, Electronic, and Electromechanical Assemblers	3	2.15%	1.69	3.60	$37,610	$37,340	$25,740
17-2112	Industrial Engineers	4	2.04%	0.97	1.15	$80,600	$76,900	$77,180
11-1021	General and Operations Managers	4	1.94%	0.82	0.66	$143,900	$125,630	$110,390
51-4111	Tool and Die Makers	3	1.86%	0.99	2.87	$49,250	$48,700	$45,340
53-7062	Laborers and Freight, Stock, and Material Movers, Hand	2	1.82%	0.74	1.33	$33,650	$32,460	$29,150
43-5071	Shipping, Receiving, and Traffic Clerks	2	1.69%	0.79	1.51	$36,510	$35,100	$37,120
51-4031	Cutting, Punching, and Press Machine Setters, Operators, etc.	2	1.58%	1.03	3.55	$35,960	$35,340	$37,350
49-9041	Industrial Machinery Mechanics	3	1.44%	0.64	1.38	$52,740	$51,420	$54,850
51-2031	Engine and Other Machine Assemblers	2	1.35%	0.61	N/A	$40,610	$38,680	N/A
43-9061	Office Clerks, General	2	1.34%	1.25	1.15	$38,180	$36,430	$34,060
13-1020	Buyers and Purchasing Agents	3	1.27%	1.07	1.31	$62,320	$56,460	$53,980
49-9071	Maintenance and Repair Workers, General	3	1.23%	1.16	1.12	$45,160	$41,330	$35,500
51-4081	Multiple Machine Tool Setters, Operators, and Tenders	2	1.23%	2.41	0.91	$38,650	$35,560	$38,840
11-3051	Industrial Production Managers	4	1.22%	1.24	1.32	$108,590	$108,840	$125,810
51-4072	Molding, Coremaking, and Casting Machine Setters, Operators, etc.	2	1.14%	1.59	N/A	$36,490	$38,240	$42,590
43-4051	Customer Service Representatives	2	1.12%	1.40	1.55	$43,460	$37,680	$36,640
43-5061	Production, Planning, and Expediting Clerks	3	1.08%	0.68	0.73	$49,450	$48,290	$45,430
51-9198	Helpers--Production Workers	2	1.05%	0.35	0.67	$30,580	$33,300	$30,560
43-3031	Bookkeeping, Accounting, and Auditing Clerks	3	0.99%	1.06	1.38	$41,710	$39,610	$34,460
51-4033	Grinding, Lapping, Polishing, and Buffing Machine Tool Setters, etc.	2	0.99%	1.03	2.07	$37,470	$35,980	$34,680
51-9121	Coating, Painting, and Spraying Machine Setters, Operators, etc.	2	0.98%	1.22	2.36	$37,180	$36,760	$38,180
13-2011	Accountants and Auditors	4	0.93%	1.23	0.73	$75,250	$68,030	$67,340

Source: Bureau of Labor Statistics, O*NET and Author's Calculations

Figure 2.7 - Computer and Electronic Product Manufacturing Occupations by Share of Industry Employment – Top 30 Occupations (2017)

SOC	Occupation Title	Job Zone	Percent of Industry Employment	Madison MSA LQ	Janesville-Beloit MSA LQ	U.S. Annual Average Wage	Madison MSA Annual Avg. Wage	Janesville-Beloit MSA Annual Avg. Wage
51-2028	Electrical, Electronic, and Electromechanical Assemblers	3	10.80%	1.69	3.60	$34,390	$37,340	$25,740
15-1133	Software Developers, Systems Software	4	4.63%	1.13	N/A	$119,270	$82,390	N/A
51-2098	Assemblers and Fabricators, All Other, Including Team Assemblers	2	4.05%	1.13	1.68	$33,180	$32,260	$30,850
15-1132	Software Developers, Applications	4	3.63%	N/A	0.45	$117,950	$85,070	$80,470
17-2112	Industrial Engineers	4	3.24%	0.97	1.15	$97,900	$76,900	$77,180
17-2072	Electronics Engineers, Except Computer	4	3.14%	0.13	N/A	$111,460	$88,980	N/A
17-3023	Electrical and Electronics Engineering Technicians	3	3.06%	0.62	N/A	$60,490	$64,260	N/A
51-9061	Inspectors, Testers, Sorters, Samplers, and Weighers	2	2.89%	0.99	1.63	$42,270	$38,020	$32,170
17-2071	Electrical Engineers	4	2.75%	0.96	N/A	$102,310	$94,820	N/A
51-9141	Semiconductor Processors	2	2.08%	N/A	N/A	$38,920	N/A	N/A
11-9041	Architectural and Engineering Managers	5	2.01%	0.95	0.53	$163,030	$127,110	$111,160
17-2141	Mechanical Engineers	4	2.01%	1.53	1.50	$96,570	$78,870	$74,880
51-1011	First-Line Supervisors of Production and Operating Workers	2	1.98%	1.22	1.70	$67,830	$58,670	$61,580
17-2061	Computer Hardware Engineers	4	1.91%	1.88	N/A	$126,140	$79,530	N/A
11-1021	General and Operations Managers	4	1.90%	0.82	0.66	$165,480	$125,630	$110,390
41-4011	Sales Reps, Wholesale & Mfg., Technical and Scientific Products	4	1.70%	0.83	N/A	$88,690	$72,770	$108,340
13-1020	Buyers and Purchasing Agents	3	1.43%	1.07	1.31	$70,910	$56,460	$53,980
15-1151	Computer User Support Specialists	3	1.30%	1.60	0.78	$66,020	$54,840	$45,480
43-4051	Customer Service Representatives	2	1.29%	1.40	1.55	$44,800	$37,680	$36,640
51-4041	Machinists	3	1.28%	0.69	1.95	$46,200	$42,870	$44,060
13-1161	Market Research Analysts and Marketing Specialists	4	1.27%	1.57	0.82	$89,750	$59,310	$53,660
15-1121	Computer Systems Analysts	4	1.24%	2.52	0.63	$102,640	$88,000	$65,020
11-3021	Computer and Information Systems Managers	4	1.23%	1.47	0.47	$163,760	$120,180	$104,540
43-5071	Shipping, Receiving, and Traffic Clerks	2	1.21%	0.79	1.51	$35,570	$35,100	$37,120
13-2011	Accountants and Auditors	4	1.20%	1.23	0.73	$80,270	$68,030	$67,340
43-5061	Production, Planning, and Expediting Clerks	3	1.15%	0.68	0.73	$53,990	$48,290	$45,430
11-3051	Industrial Production Managers	4	1.10%	1.24	1.32	$125,220	$108,840	$125,810
13-1199	Business Operations Specialists, All Other	3	1.02%	1.27	0.25	$98,420	$64,370	$63,200
17-3026	Industrial Engineering Technicians	3	1.02%	0.55	N/A	$60,890	$48,570	N/A
41-4012	Sales Reps, Wholesale & Mfg., Except Tech/Scientific Products	4	0.97%	1.17	1.86	$77,110	$67,600	$63,350

Source: Bureau of Labor Statistics, O*NET and Author's Calculations

Figure 2.8 -Electrical Equipment, Appliance, and Component Manufacturing Occupations by Share of Industry Employment – Top 30 Occupations (2017)

SOC	Occupation Title	Job Zone	Percent of Industry Employment	Madison MSA LQ	Janesville-Beloit MSA LQ	U.S. Annual Average Wage	Madison MSA Annual Avg. Wage	Janesville-Beloit MSA Annual Avg. Wage
51-2028	Electrical, Electronic, and Electromechanical Assemblers	3	14.3%	1.69	3.60	$34,770	$37,340	$25,740
51-2098	Assemblers and Fabricators, All Other, Including Team Assemblers	2	12.6%	1.13	1.68	$33,510	$32,260	$30,850
51-1011	First-Line Supervisors of Production and Operating Workers	2	3.4%	1.22	1.70	$62,600	$58,670	$61,580
51-9061	Inspectors, Testers, Sorters, Samplers, and Weighers	2	2.7%	0.99	1.63	$41,390	$38,020	$32,170
17-2071	Electrical Engineers	4	2.4%	0.96	N/A	$89,170	$94,820	N/A
17-2141	Mechanical Engineers	4	2.4%	1.53	1.50	$85,220	$78,870	$74,880
53-7062	Laborers and Freight, Stock, and Material Movers, Hand	2	2.4%	0.74	1.33	$33,950	$32,460	$29,150
41-4012	Sales Reps, Wholesale & Mfg., Except Tech/Scientific Products	4	2.1%	1.17	1.86	$74,750	$67,600	$63,350
17-2112	Industrial Engineers	4	1.9%	0.97	1.15	$80,220	$76,900	$77,180
43-4051	Customer Service Representatives	2	1.8%	1.40	1.55	$41,670	$37,680	$36,640
51-4041	Machinists	3	1.8%	0.69	1.95	$43,930	$42,870	$44,060
11-1021	General and Operations Managers	4	1.8%	0.82	0.66	$146,340	$125,630	$110,390
51-9198	Helpers--Production Workers	2	1.7%	0.35	0.67	$32,660	$33,300	$30,560
51-2021	Coil Winders, Tapers, and Finishers	2	1.7%	N/A	N/A	$36,440	N/A	N/A
51-4031	Cutting, Punching, and Press Machine Setters, Operators, etc.	2	1.5%	1.03	3.55	$36,490	$35,340	$37,350
43-5071	Shipping, Receiving, and Traffic Clerks	2	1.4%	0.79	1.51	$35,740	$35,100	$37,120
49-9071	Maintenance and Repair Workers, General	3	1.4%	1.16	1.12	$45,820	$41,330	$35,500
51-4121	Welders, Cutters, Solderers, and Brazers	3	1.3%	1.01	2.71	$40,450	$42,880	$42,110
51-4021	Extruding and Drawing Machine Setters, Operators, and Tenders	2	1.3%	0.80	5.87	$38,070	$33,720	$29,600
51-4081	Multiple Machine Tool Setters, Operators, and Tenders	2	1.3%	2.41	0.91	$38,240	$35,560	$38,840
13-1020	Buyers and Purchasing Agents	3	1.2%	1.07	1.31	$63,570	$56,460	$53,980
17-3023	Electrical and Electronics Engineering Technicians	3	1.2%	0.62	N/A	$56,430	$64,260	N/A
53-7051	Industrial Truck and Tractor Operators	2	1.1%	0.68	1.79	$38,540	$34,950	$34,750
51-9199	Production Workers, All Other	2	1.1%	0.24	N/A	$39,530	$31,210	$28,820
43-9061	Office Clerks, General	2	1.0%	1.25	1.15	$37,980	$36,430	$34,060
51-4011	Computer-Controlled Machine Tool Operators, Metal and Plastic	3	1.0%	0.93	3.53	$41,220	$41,500	$44,060
11-3051	Industrial Production Managers	4	1.0%	1.24	1.32	$108,250	$108,840	$125,810
43-5061	Production, Planning, and Expediting Clerks	3	1.0%	0.68	0.73	$49,730	$48,290	$45,430
11-9041	Architectural and Engineering Managers	5	0.9%	0.95	0.53	$134,330	$127,110	$111,160
13-2011	Accountants and Auditors	4	0.8%	1.23	0.73	$74,330	$68,030	$67,340

Source: Bureau of Labor Statistics, O*NET and Author's Calculations

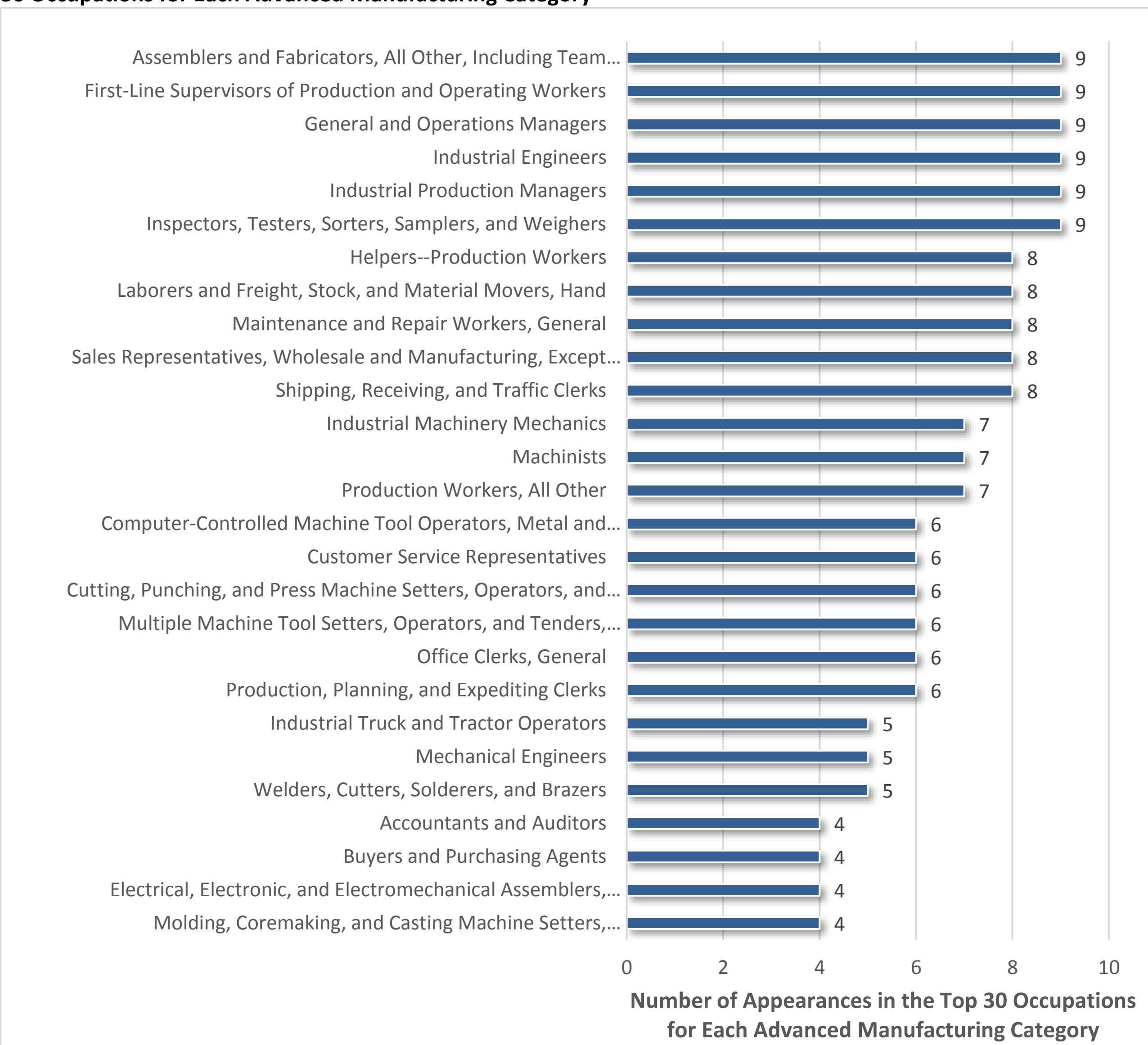
Figure 2.9 – Transportation Equipment Manufacturing Occupations by Share of Industry Employment – Top 30 Occupations (2017)

SOC	Occupation Title	Job Zone	Percent of Industry Employment	Madison MSA LQ	Janesville-Beloit MSA LQ	U.S. Annual Average Wage	Madison MSA Annual Avg. Wage	Janesville-Beloit MSA Annual Avg. Wage
51-2098	Assemblers and Fabricators, All Other, Including Team Assemblers	2	21.3%	1.13	1.68	$39,070	$32,260	$30,850
51-1011	First-Line Supervisors of Production and Operating Workers	2	3.4%	1.22	1.70	$67,200	$58,670	$61,580
51-4121	Welders, Cutters, Solderers, and Brazers	3	3.4%	1.01	2.71	$41,990	$42,880	$42,110
51-9061	Inspectors, Testers, Sorters, Samplers, and Weighers	2	3.3%	0.99	1.63	$47,980	$38,020	$32,170
17-2112	Industrial Engineers	4	3.0%	0.97	1.15	$92,680	$76,900	$77,180
51-4041	Machinists	3	2.8%	0.69	1.95	$46,990	$42,870	$44,060
51-2011	Aircraft Structure, Surfaces, Rigging, and Systems Assemblers	2	2.3%	N/A	N/A	$56,260	N/A	N/A
17-2141	Mechanical Engineers	4	2.0%	1.53	1.50	$91,020	$78,870	$74,880
53-7062	Laborers and Freight, Stock, and Material Movers, Hand	2	1.9%	0.74	1.33	$36,390	$32,460	$29,150
51-4031	Cutting, Punching, and Press Machine Setters, Operators, etc.	2	1.8%	1.03	3.55	$37,660	$35,340	$37,350
51-4081	Multiple Machine Tool Setters, Operators, and Tenders	2	1.6%	2.41	0.91	$41,340	$35,560	$38,840
17-2011	Aerospace Engineers	4	1.6%	N/A	N/A	$113,930	N/A	N/A
51-4011	Computer-Controlled Machine Tool Operators, Metal and Plastic	3	1.5%	0.93	3.53	$42,760	$41,500	$44,060
51-2028	Electrical, Electronic, and Electromechanical Assemblers	3	1.4%	1.69	3.60	$34,990	$37,340	$25,740
49-9041	Industrial Machinery Mechanics	3	1.3%	0.64	1.38	$55,840	$51,420	$54,850
51-4111	Tool and Die Makers	3	1.3%	0.99	2.87	$61,460	$48,700	$45,340
43-5061	Production, Planning, and Expediting Clerks	3	1.3%	0.68	0.73	$54,060	$48,290	$45,430
13-1020	Buyers and Purchasing Agents	3	1.3%	1.07	1.31	$73,960	$56,460	$53,980
49-3011	Aircraft Mechanics and Service Technicians	3	1.2%	0.37	N/A	$63,510	$49,740	N/A
49-9071	Maintenance and Repair Workers, General	3	1.2%	1.16	1.12	$47,960	$41,330	$35,500
11-3051	Industrial Production Managers	4	1.2%	1.24	1.32	$110,910	$108,840	$125,810
51-2031	Engine and Other Machine Assemblers	2	1.1%	0.61	N/A	$48,870	$38,680	N/A
51-9199	Production Workers, All Other	2	1.0%	0.24	N/A	$43,260	$31,210	$28,820
15-1133	Software Developers, Systems Software	4	1.0%	1.13	N/A	$121,670	$82,390	N/A
47-2111	Electricians	3	1.0%	0.85	1.13	$62,640	$54,930	$53,880
43-5071	Shipping, Receiving, and Traffic Clerks	2	1.0%	0.79	1.51	$36,740	$35,100	$37,120
51-4072	Molding, Coremaking & Casting Machine Setters, Operators, etc.	2	0.9%	1.59	N/A	$34,480	$38,240	$42,590
11-1021	General and Operations Managers	4	0.9%	0.82	0.66	$143,040	$125,630	$110,390
51-9198	Helpers--Production Workers	2	0.9%	0.35	0.67	$30,580	$33,300	$30,560
11-9041	Architectural and Engineering Managers	5	0.8%	0.95	0.53	$146,150	$127,110	$111,160

Source: Bureau of Labor Statistics, O*NET and Author's Calculations

While each advanced manufacturing category relies on a diversity of occupations, the overall advanced manufacturing industry has several occupations that are common across multiple subsectors. The frequency of an individual occupation appearing in the top 30 occupations for each subsector of advanced manufacturing shows that several occupational categories are found in the top 30 for all nine subsectors (Figure 2.10). These occupations include assemblers and fabricators; first-line supervisors; general and operations managers; industrial engineers, industrial production managers; and inspectors, testers, sorters, samplers, and weighers. Other commonly found occupations across the advanced manufacturing industry include specific production-related activities or the operation of machinery including: computer-controlled machine tool operators; cutting, punching, and press machine setters, operators, and tenders; multiple machine tool setters, operators, and tenders; welders; machinists and mechanics. Engineers are also common across multiple subsectors. Occupations that span multiple advanced manufacturing subsectors could provide opportunities for joint talent development initiatives such as regional recruitment, DACUM efforts, and internships.

Figure 2.10 – Advanced Manufacturing Occupational Frequency – Number of Times an Occupation Appears in the Top 30 Occupations for Each Advanced Manufacturing Category



Source: Bureau of Labor Statistics and Author's Calculations

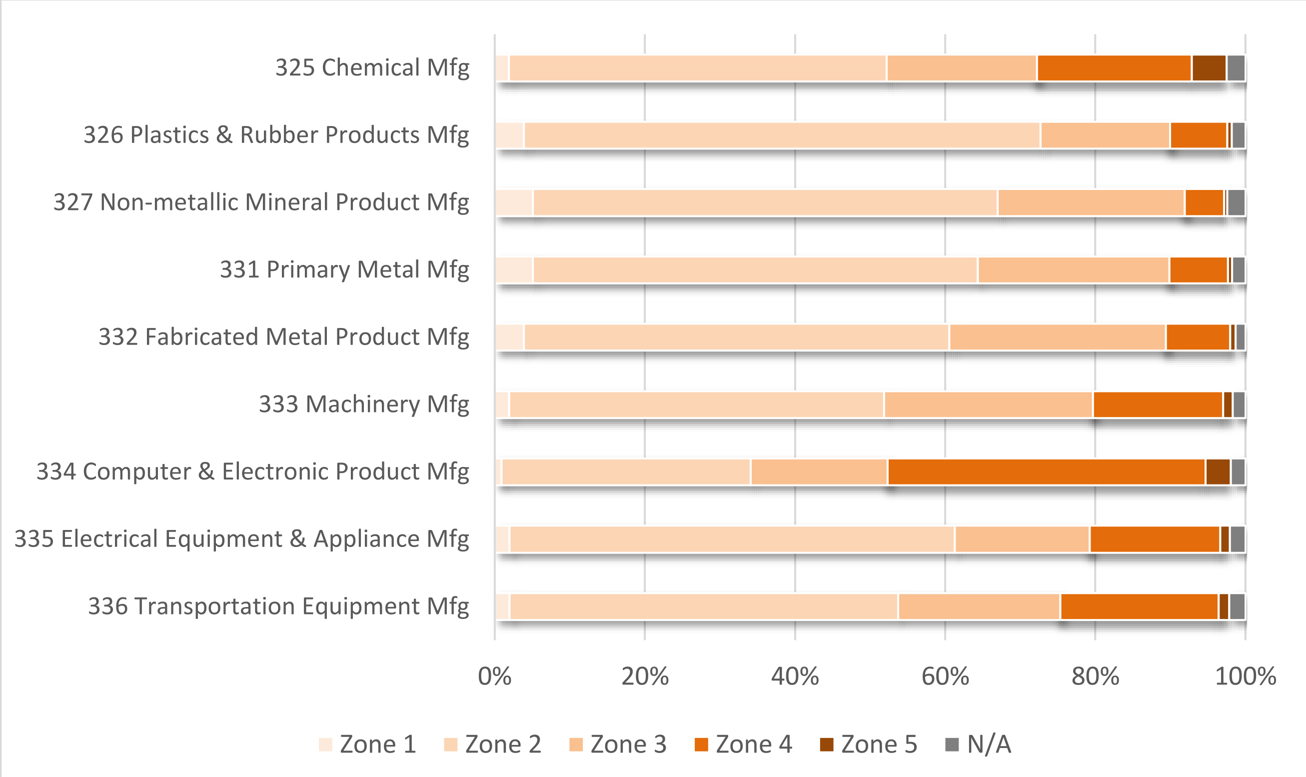
Sales and customer service occupations are also common across advanced manufacturing subsectors. Customer sales are driven through various forms including in-house sales representatives, traveling sales representatives, or independent dealers. Due to the highly technical nature of many products produced by firms in advanced manufacturing, salespeople in the industry often require extensive engineering and product knowledge. The complexity of some advanced manufacturing products (such as machinery) also requires the sales of service packages and spare parts as a means of retaining customers and generating additional revenue. Many manufacturers meet these needs through distribution networks comprised of regional or local service centers.

Advanced manufacturing subsectors also have occupational concentrations engaged in activities such as packaging, material moving and unclassified production work. Additionally, many advanced manufacturing firms rely on occupations that may not be directly involved with the production of final products, but instead provide support as mechanics, truck drivers, or administrative support. In all, it should be clear that advanced manufacturing involves a breadth and depth of occupations that require many different skills. Readers who are interested in learning about the typical tasks and skills associated with each occupation can access this information through the Occupational Information Network (O*NET) website at: http://www.onetonline.org/.

As mentioned earlier, each occupation in advanced manufacturing also can be associated with a so-called *Job Zone*. Job zones provide information on the usual types of preparation needed for given occupations within an industry. Job zones also suggest the typical length of time workers need to acquire information, learn techniques, and develop the capacity needed for average performance in these occupations. Note that training may be acquired in a variety of environments (vocational education, apprenticeship training, on-the-job, etc.) and does not include the orientation time required to become a fully-qualified worker or accustomed to special conditions of a job. Again, occupations in Job Zone 1 have lower preparation requirements and occupations in Job Zone 5 require the largest amount of preparation (see Appendix 2A for more on Job Zones).

The broad distribution of advanced manufacturing industry employment is summarized by Job Zone in Figure 2.11. When comparing Job Zone distributions within advanced manufacturing, four subsectors have at least 40% of their employment in occupations classified in Job Zone 3, Job Zone 4 and Job Zone 5. These subsectors include transportation equipment manufacturing (44.1%); chemical manufacturing (45.3%); machinery manufacturing (46.5%); and computer and electronic product manufacturing (64.0%). As these industries tend to have the highest education and training requirements, it should not be surprising that these advanced manufacturing subsectors often have the highest average wages as well.

Figure 2.11 – Share of Advanced Manufacturing Employment by Job Zone



Source: BLS, (O*NET) and Authors' Calculations

With the exception of computer and electronic product manufacturing, every category of advanced manufacturing has at least 50% of employment concentrated in occupations with Job Zone 2. These concentrations of workers in Job Zone 2 should not necessarily suggest that the advanced manufacturing industry is reliant on unskilled workers. Many of these occupations require specific skills and involve detailed training. As a result, these occupations also tend to pay greater wages than occupations with Job Zone 2 found in many other industries. Accordingly, the advanced manufacturing provides a diversity of employment opportunities for people across the skill and education continuums. However, many of these lower skilled occupations also face a growing susceptibility to replacement by automation (see discussion below).

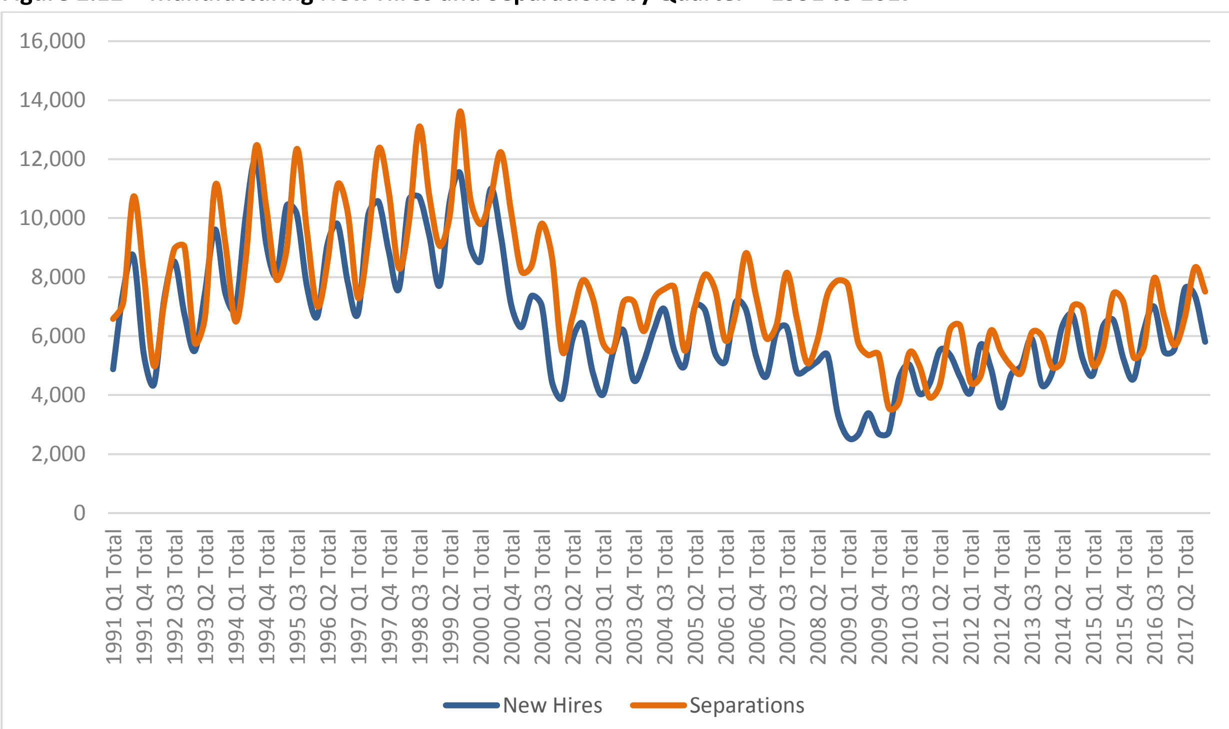
Location quotients and wages for the advanced manufacturing occupations listed in Figures 2.1 to 2.9 show the diversity of wages and specializations found in the Region. While it is difficult to draw many broad conclusions from these data, it is clear that the Janesville-Beloit MSA tends to have higher location quotients for many occupations when compared to the Madison MSA. These higher LQs show the greater reliance that Rock County has on advanced manufacturing. Nonetheless, many occupational location quotients for the Madison MSA are above 1.0 and show the importance of advanced manufacturing to the greater Region.

Employment Churn and Age Structure

The advanced manufacturing employment trends in Section 1 show the mixed and irregular nature of job growth and decline present in the industry. While overall employment in most subsectors remain below year 2000 levels, advanced manufacturing employment continues to ebb and flow due to macroeconomic, competitive and structural conditions. Furthermore, employment trends should not be viewed as the only means of measuring advanced manufacturing's demand for labor. Job separations occur regularly as workers leave firms for other employment opportunities. Workers also may retire or exit the labor force for various reasons. Consequently, hires can occur in establishments that are expanding, contracting, or staying the same size simply for purposes of worker replacement. In fact, most hiring and separations reflect *churn* within an industry, rather than the overall expansion or contraction of the industry. More specifically, churn is defined as the simultaneous hiring and separation within an industry (Hyatt and Spletzer 2013).

Data on employment churn specific to the advanced manufacturing industry is unavailable for the Madison Region. However, data on the entire manufacturing sector is available and serves as a proxy for advanced manufacturing subsectors. As the manufacturing industry grew between 1991 and 2000, both new hires and separations also increased.[6] With the onset of the new century, new hires and separations first declined notably and then remained largely consistent between 2002 and 2007. New hires and separations again declined with the beginning of the Great Recession, but have resumed their growth since 2010.

Figure 2.12 – Manufacturing New Hires and Separations by Quarter – 1991 to 2017



Source: U.S. Census Bureau LEHD and Authors' Calculations

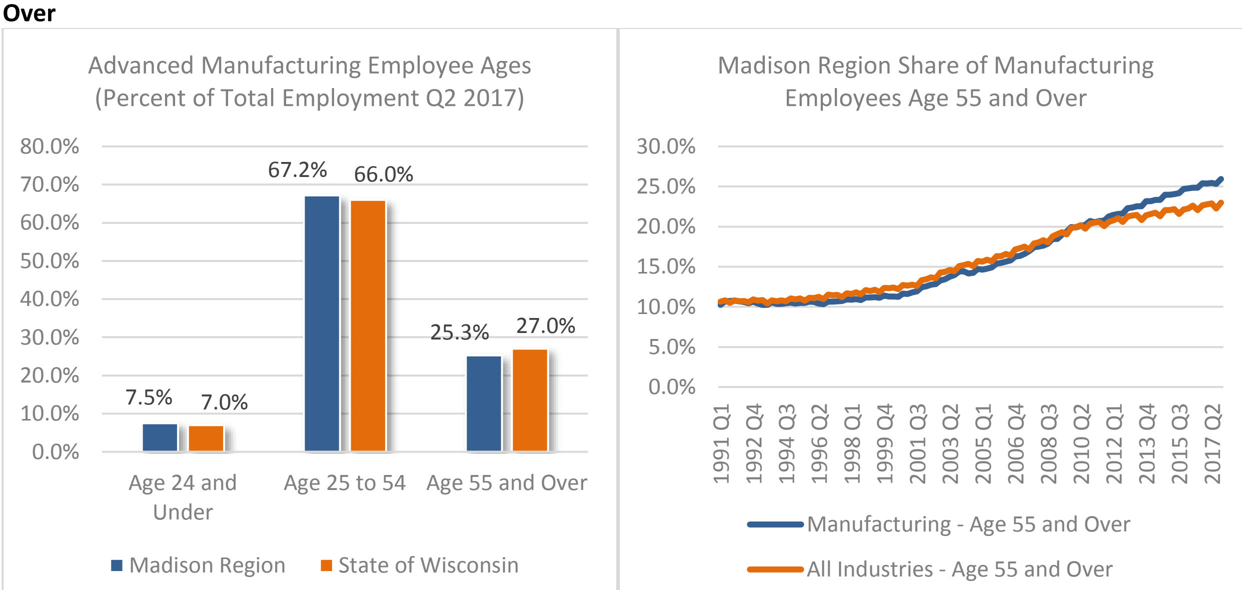
[6] New hires are workers who started a new job with an employer and were not employed by that employer in any of the previous four quarters. These figures do not include workers who returned to the same employer where they had worked within the previous year (such as those who may have been recalled from a layoff or work stoppage).

While the movements in new hires and separations reflect the region's overall trend in manufacturing employment, employers were still hiring more than 2,500 *new workers per quarter* at the lowest period between Q1 2009 and Q1 2010. More recently, the Madison Region reported between 6,000 and 8,000 new hires and separations per quarter. In particular, the current levels of new hires are the highest level in more than a decade.

The growth in new hires and separations shows the current strength of the industry in the Region, but also suggests that employees may have more confidence in their employment prospects. That is, employees are often more willing to change jobs when the economy offers greater opportunities to advance careers or increase wages. While job hopping is not ideal to employers, many companies understand that talent coming from other employers also bring new knowledge and ideas from their prior employer that may benefit a company. Higher levels of employment churn also offer opportunities for firms to examine their internal working environment and wages. If employers are in fact experiencing higher levels of employee turnover, they may want to consider whether their wages, benefits and work environment are competitive relative to other firms in the region. Furthermore, employers may want to also consider the costs of employee turnover relative to wage increases.

Employees leave their workplace for many reasons such as layoffs, new employment opportunities, schooling, and child care needs. One looming issue facing employers in the Madison Region is the share of the labor force that may leave the labor force as they reach retirement age. Over 25 percent of advanced manufacturing employees in the Madison Region and the State of Wisconsin were age 55 older in 2017 (Figure 2.13). Furthermore, the share of the overall manufacturing workforce age 55 and over has almost doubled over the past two decades.

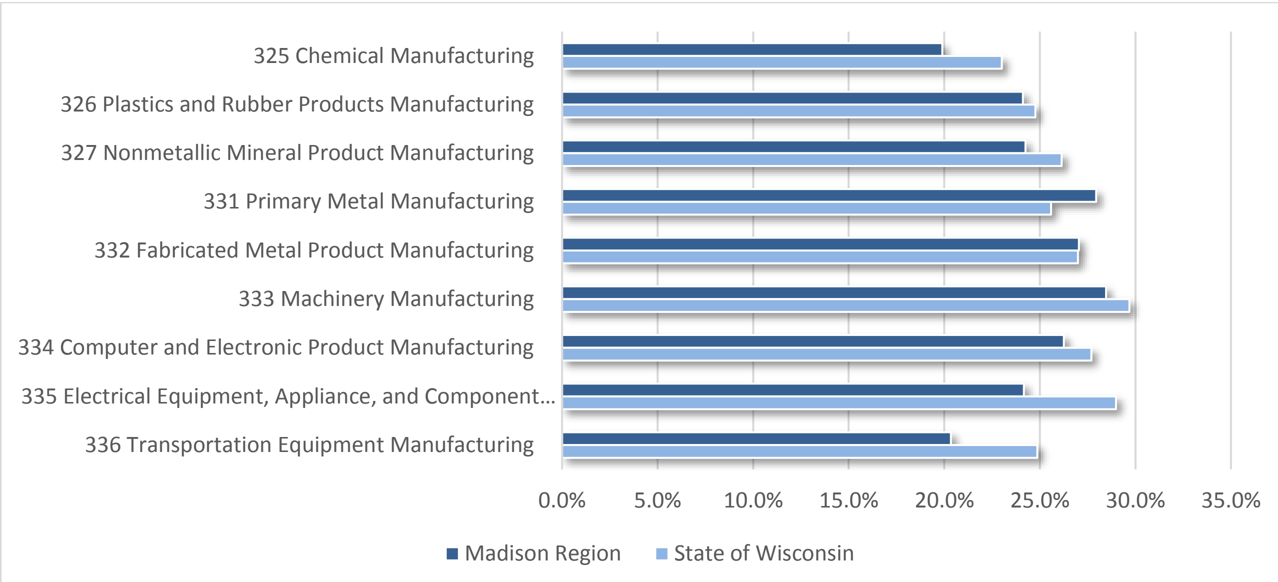
Figure 2.13 – Advanced Manufacturing Employee Age Structure and Share of All Manufacturing Employees Age 55 and Over



Source: U.S. Census Bureau LEHD and Authors' Calculations

When compared to the State of Wisconsin, the Madison Region has a somewhat smaller share of employees age 55 and over. Nonetheless, almost every advanced manufacturing subsector has 20 percent or more of its labor force comprised by workers age 55 and over (Figure 2.14). The highest levels are found in machinery manufacturing with almost 30 percent of workers in the subsector having an age 55 or over. Accordingly, the Region's advanced manufacturing industry will need to consider how to replace these workers over the next decade or more.

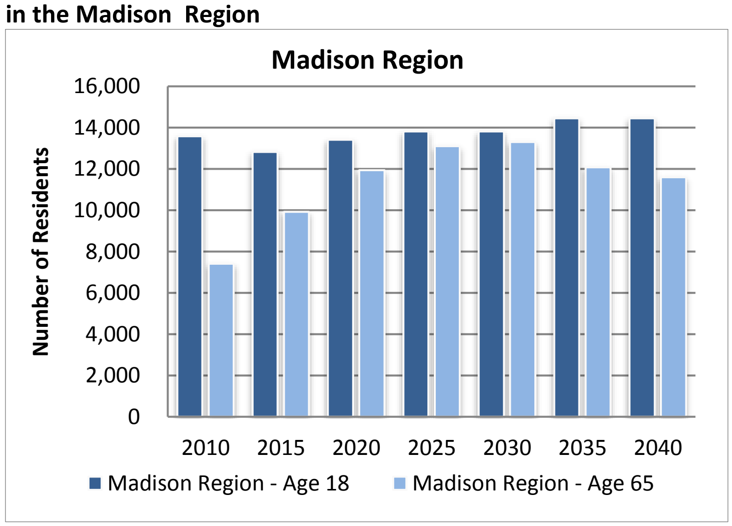
Figure 2.14 – Share of Employees Age 55 or Over by Advanced Manufacturing Subsector (Madison Region Q2 2017)



Source: U.S. Census Bureau LEHD and Authors' Calculations

The growing share of manufacturing workers age 55 and over reflects an overall aging of the labor force in the Region. To illustrate potential changes in labor force age structure, Figure 2.15 provides estimates on the number of residents turning age 18 and age 65 in the Madison Region over a 30-year period. Age 18 and age 65 provide proxies for when individuals may respectively enter and exit the labor force. Certainly workers may start a job before age 18 and continue to work past age 65, but these ages provide a beginning point for comparing worker availability. In 2010, there were almost twice as many residents turning age 18 as those turning age 65 in the Madison Region. By 2025, there are approximately as many people turning age 65 as those turning age 18. Specific trends will vary by individual county, but even Dane County faces an aging workforce despite the large number of young residents contributed annually to the area by UW-Madison.

Figure 2.15 – Convergence of the Population Age 18 and Age 65 in the Madison Region



Source: Wisconsin Deparment of Administration Demographic Services Center and Authors' Calculations

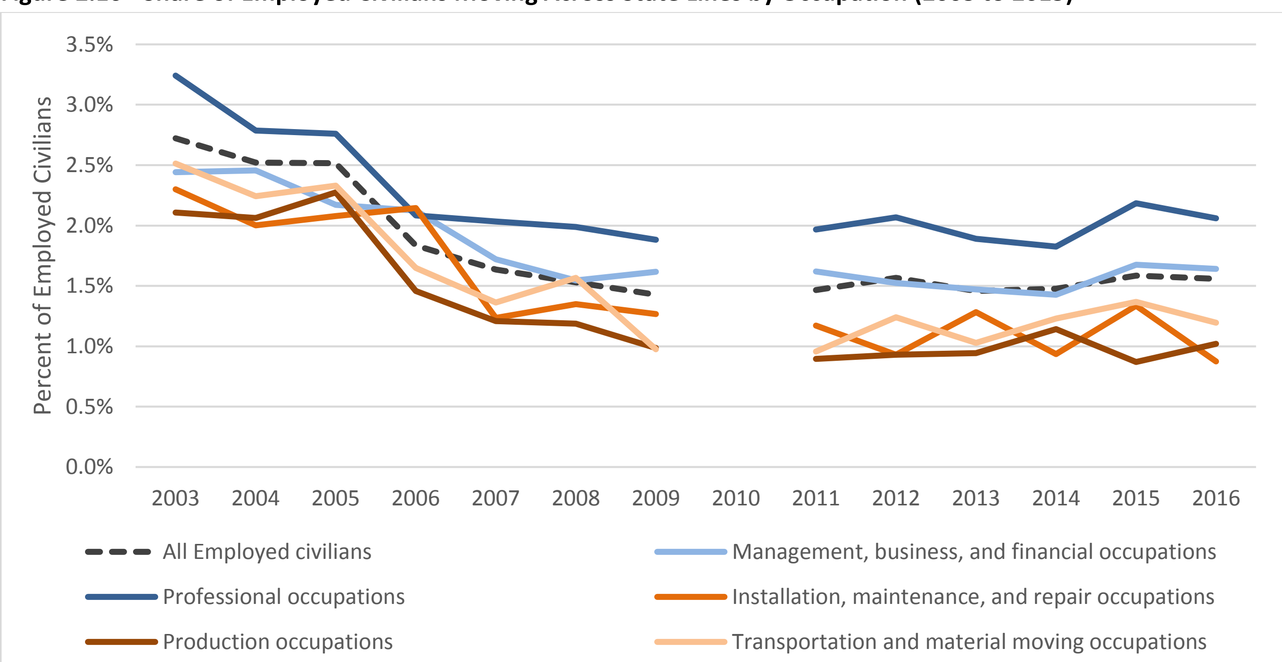
Labor Mobility

As the Madison Region's advanced manufacturing industry considers how to meet its future labor force demands, it will likely need to consider how to attract talent from outside the region while also growing its internal pipeline within the Region. More specifically, there is a distinct difference in the mobility of professional occupations (such as engineers) and production occupations that dominate employment in many advanced manufacturing categories. Indeed, people working in production occupations are among the least mobile in terms of their movement from one state to another (Figure 2.16). Individuals working in installation, repair and maintenance occupations, another occupational category commonly found in advanced manufacturing, are also relatively immobile.

In contrast, people working professional occupations are among the most mobile, with professional occupations moving across state lines at twice the rate of production occupations. The mobility trends in Figure 2.16 also show how mobility rates have declined across all occupational categories. These declining mobility rates are part of larger societal trend in the United States where moves of all types have dropped over the last several decades.

Overall, the broad mobility characteristics of people working in different occupations have two important characteristics: First, talent attraction efforts may help to fill professional or technical occupations, but it is less likely that production workers will be attracted to the Madison Region from outside the state. Green County and Rock County may be the exception to this observation given their location on the Illinois state line. Consequently, talent development initiatives for production occupations will likely need to emphasize a "grow your own" approach. Second, broad declines in mobility suggest that fewer people are moving overall and efforts to attract people from outside of Wisconsin will need to recognize the factors that motivate those people that do move.

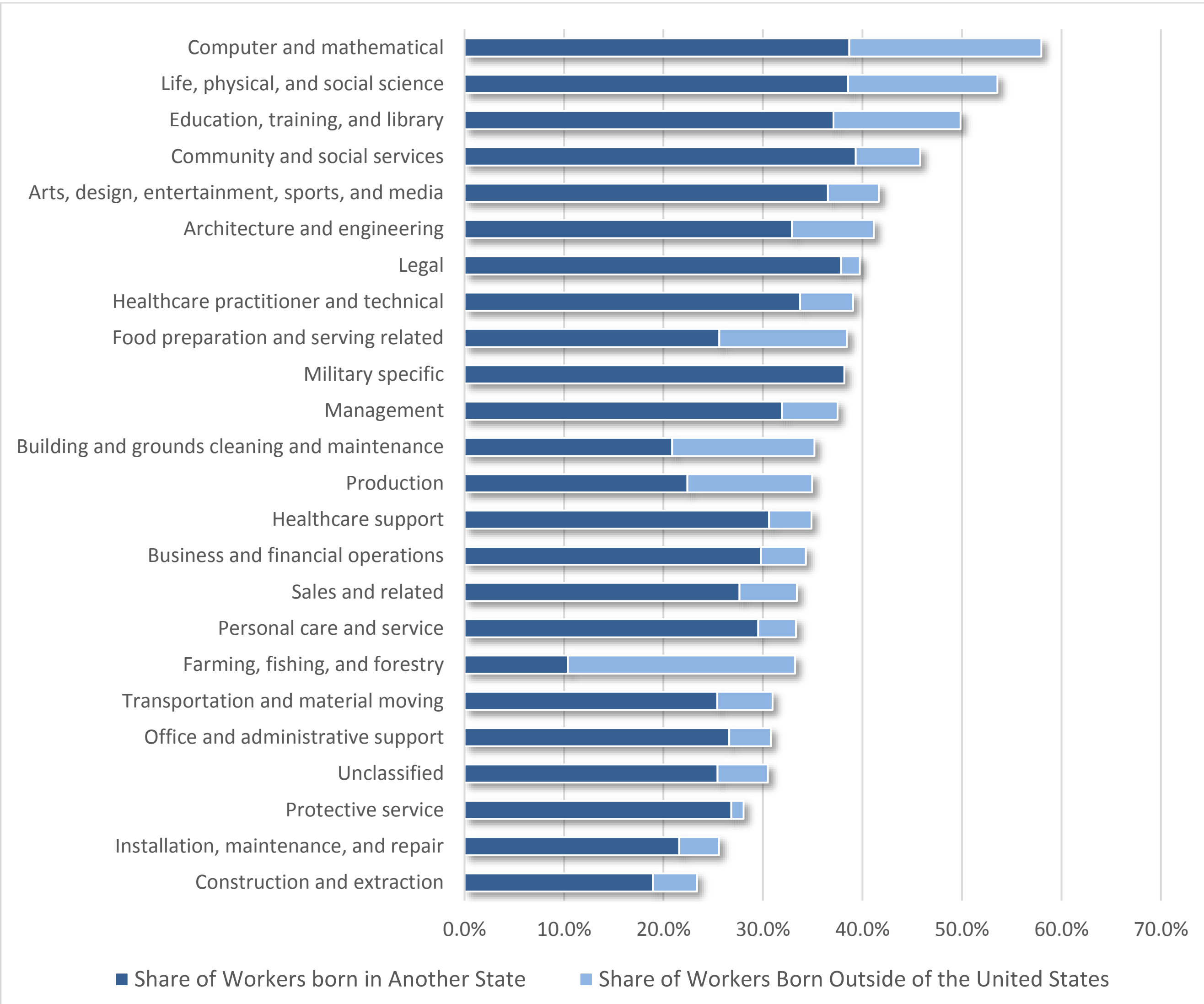
Figure 2.16 - Share of Employed Civilians Moving Across State Lines by Occupation (2003 to 2015)



Source: BLS/Census Bureau Current Population Survey and Authors' Calculations

While the figures depicted in Figure 2.16 are national trends, the origins of individuals working in different occupations can also be considered for the Madison Region. Specifically, individuals in various occupations can be identified by their place of birth. When compared to other occupations in the Madison Region, architecture and engineering occupations have among the highest share of individuals who were either born in another state or born outside of the United States (Figure 2.17). In contrast, production occupations and installation, maintenance and repair occupations have a much lower share of residents born in another state or another country.   If only those people born in another state are considered, production occupations and installation, maintenance and repair occupations have among the lowest shares.

Figure 2.17 – Place of Birth by Occupation for the Madison Region – Share of Workers born in Another State or Outside of the United States



Source: American Community Survey data extracted from IPUMS-USA, University of Minnesota, www.ipums.org and Authors' Calculations

Why are statistics on places of birth important? First, they suggest that individuals are less likely to have been born in Wisconsin and moved to the Region at some point in their lives. While some of these individuals may have moved to the Region when they were very young or resided in the Region for some time, the measure suggests that that the national mobility characteristics in Figure 2.16 are somewhat present in the Madison Region. Consequently, talent attraction and retention efforts are more likely to be effective for professional occupations and internal efforts have a greater priority for production occupations.

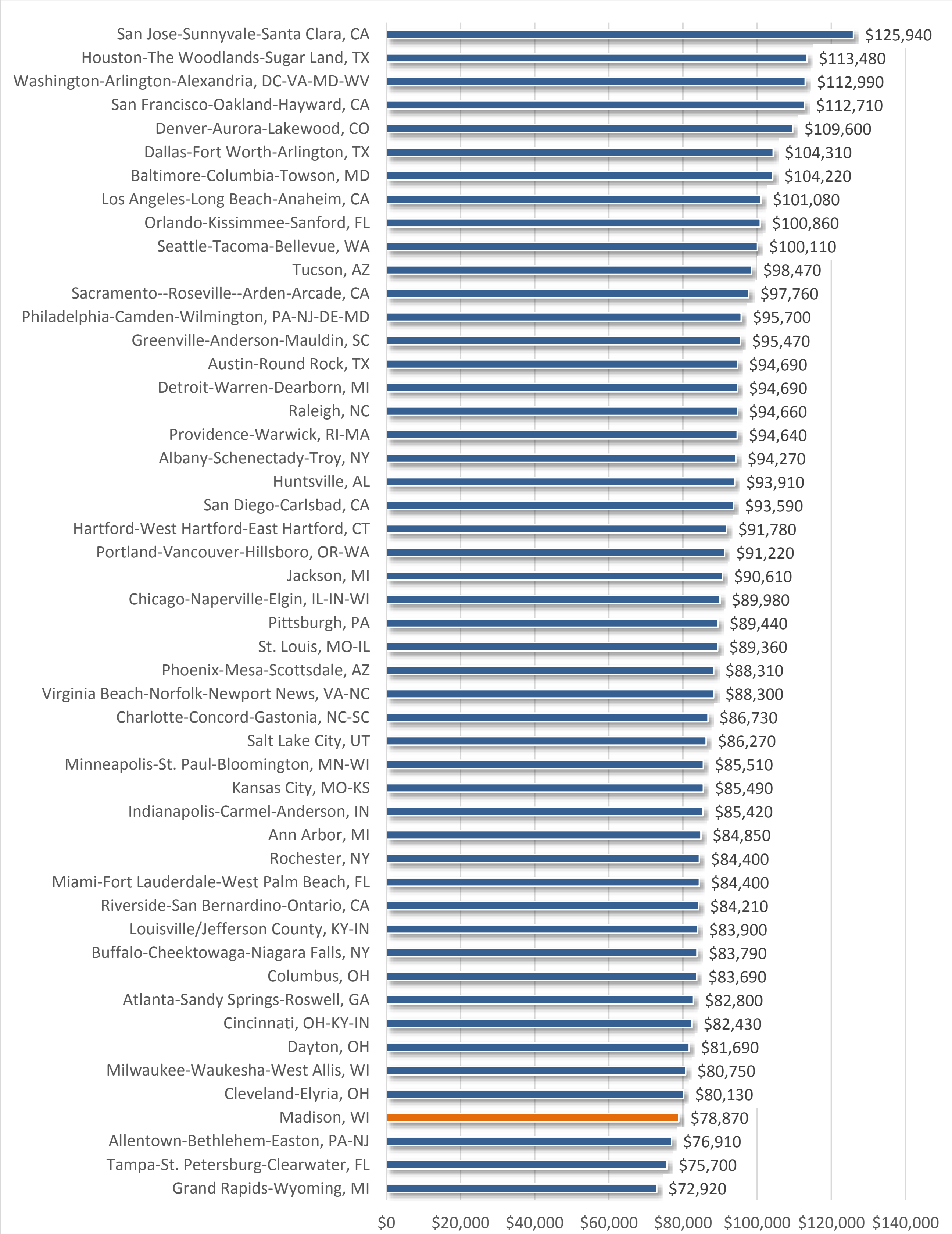
Second, the State of Wisconsin has one of the highest share of residents who were born in their state of residence. *Specifically, over 70% of the people who live in Wisconsin were also born here*. This high share of native residents also extends to many portions of the Madison Region. This raises the question of how the Region considers newcomers. That is, do we embrace residents who may not be native Wisconsinites or do we have an in-group preference for people who may be long term residents? As part of the survey process for this report, several of individuals interviewed who had relocated to the Region indicated they experienced problems breaking into established friend groups. Therefore, the inclusivity of the Region should be considered with regards to talent retention.

Despite the overall downward mobility rates across all occupational categories, the young, educated demographic remains one of the most mobile among all age groups and levels of educational attainment. The Madison Region has been successful in attracting this demographic more so than any other place in Wisconsin. However, this demographic is also increasingly targeted by talent attraction and retention initiatives by states and regions across the United States. While many of these efforts are misguided, the competition for talent will continue. For the Madison Region to continue its success in attracting and retaining talent, it needs to continue to build on those assets and qualities.

In terms of talent attraction and retention efforts that focus on individuals living outside of Wisconsin, efforts that focus on engineers may be the most relevant to the advanced manufacturing sector. Both mechanical and industrial engineers are prevalent across advanced manufacturing subsectors and are highly sought after. In the Region, both UW-Madison and UW-Platteville have world-class engineering programs. However, it is likely that local manufacturing firms will also need to look beyond the Region to meeting their engineering needs.

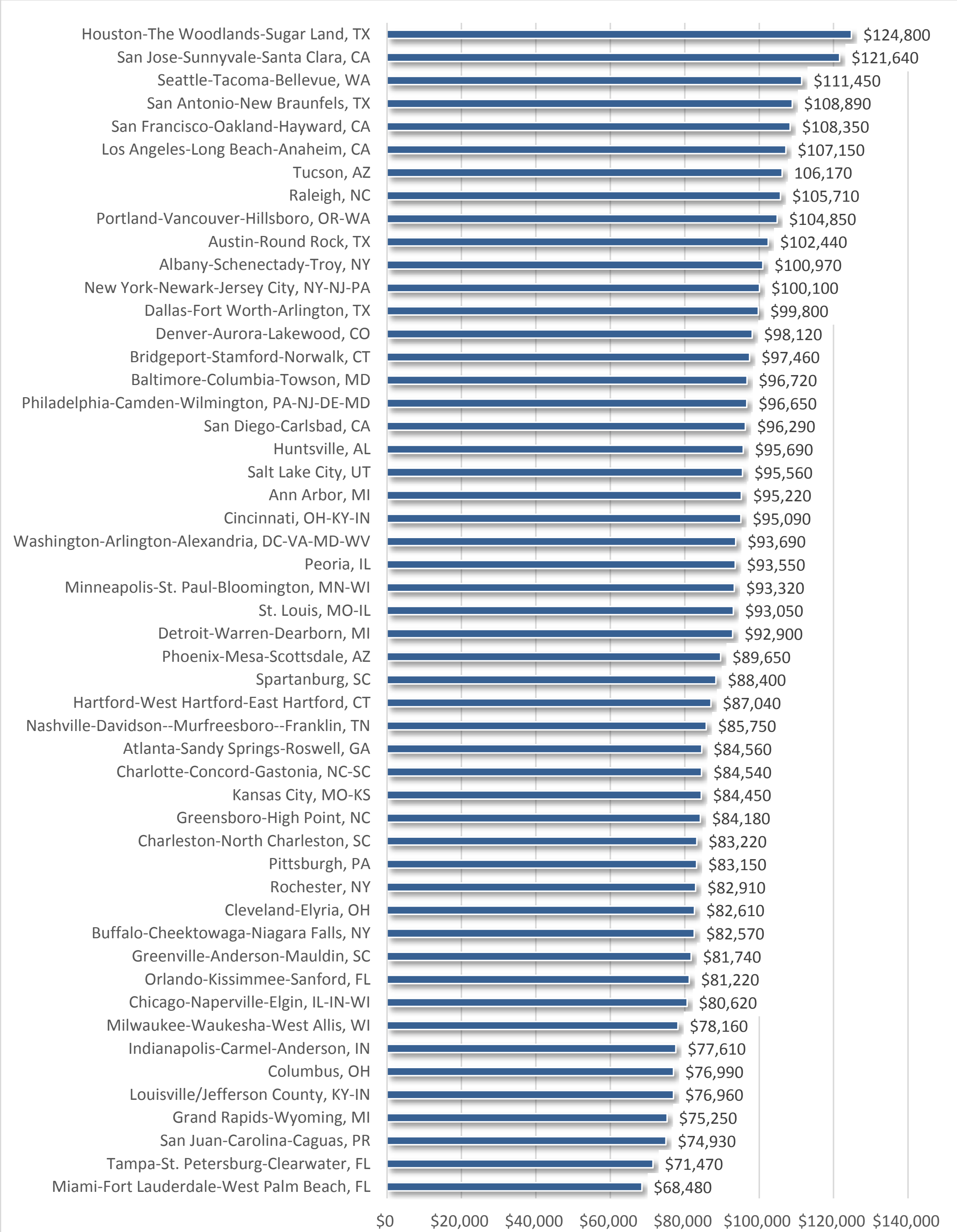
While an engineer may have many individual considerations when choosing a place to work, wages and labor market thickness are two important factors. In considering labor market thickness (i.e. the number of engineering jobs present in a region) and wages, Figure 2.18 and Figure 2.19 list annual average wages in the metropolitan areas with the 50 largest numbers of mechanical engineers and industrial engineers. Wages are also listed by metro areas with the 50 largest location quotients for these occupations in Appendix 2B. Note that the Janesville-Beloit MSA is not among the 50 largest labor markets for either engineering category and the Madison-MSA is only found in the top 50 for mechanical engineering. When comparing wages among these large labor markets, both Madison and the Janesville-Beloit metro areas are near the bottom for annual average wages. While these wage differentials do not consider costs of living and may be viewed as beneficial to employers, they could potentially place the Region at a disadvantage when trying to recruit engineers from elsewhere. The Region should also consider other assets it has to offer potential employees.

Figure 2.18 – Annual Avg. Wages for Mechanical Engineers (Metro Areas with the 50 Most Mechanical Engineers)*



Source: Bureau of Labor Statistics and Authors' Calculations * Janesville-Beloit Average Wage is $74,880

Figure 2.19 – Annual Average Wages for Industrial Engineers (Metro Areas with the 50 Most Industrial Engineers)*

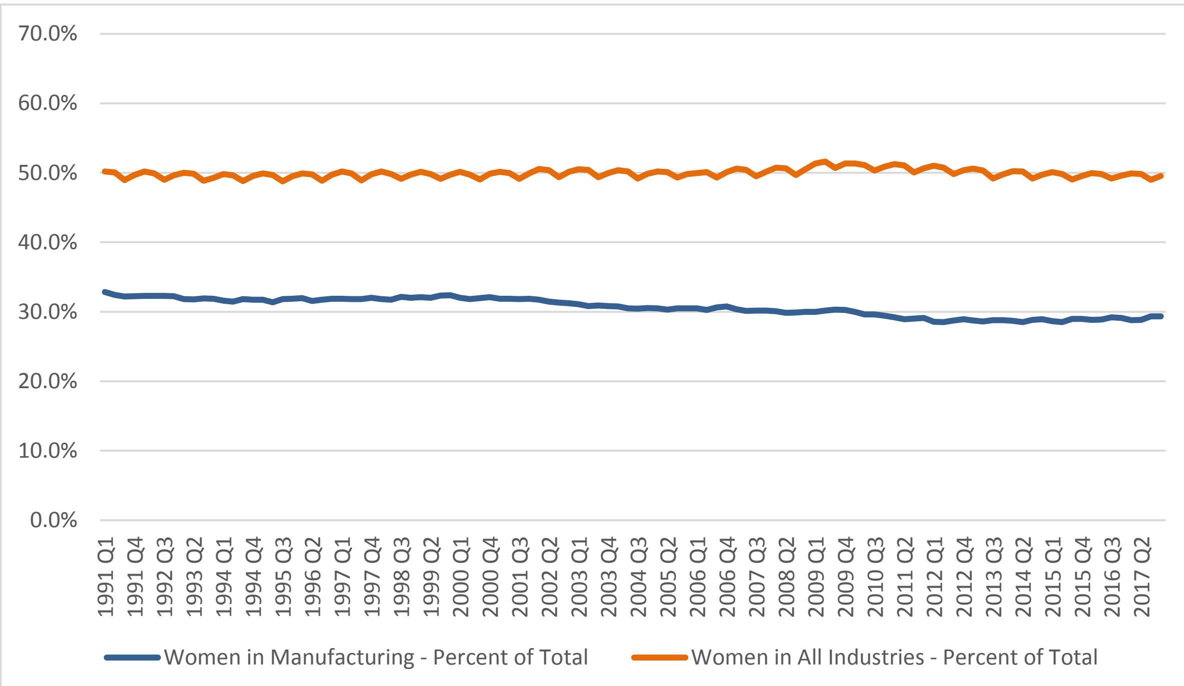


Source: Bureau of Labor Statistics and Author's Calculations *Janesville-Beloit Average Wage is $77,180; Madison MSA Average Wage is $76,900.

Talent Diversity

As advanced manufacturing firms seek solutions to their labor needs, engaging women in talent recruitment and development strategies provides one significant opportunity. At the end of 2017, women comprised just under half (49.5%) of all employment in the Madison Region. The share of employment by women has stayed largely consistent since the early 1990s, with a slight increase during the recession/post-recession recovery period when many males lost their jobs at a disproportionately high rate. In contrast, women employees comprise just 29.4% of all employment in manufacturing (Figure 2.20). The current rate is also three percentage points below its peak in the early 1990s.

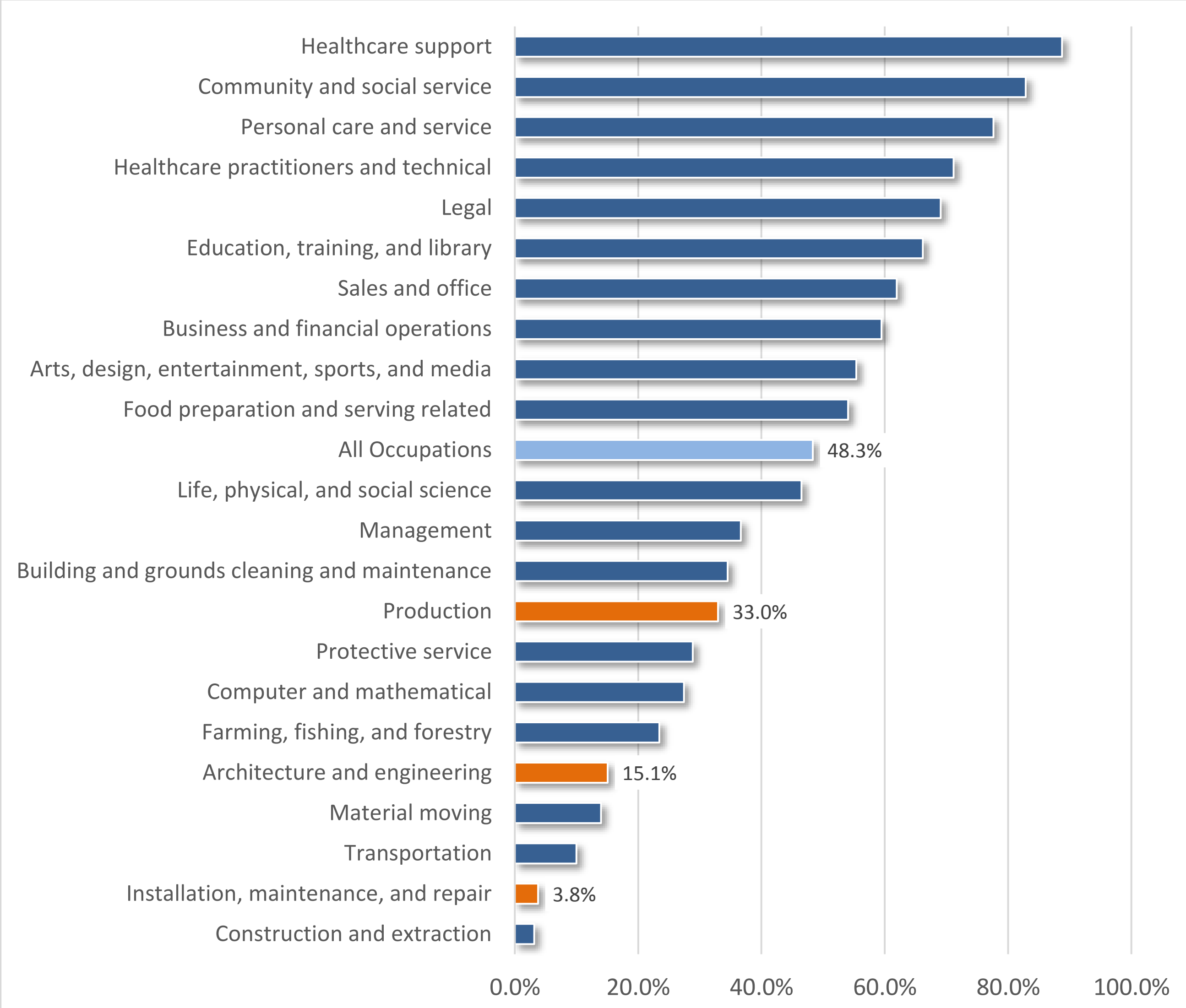
Figure 2.20 - Women as a Share of Manufacturing Employees



Source: U.S. Census Bureau LEHD and Authors' Calculations

Given the share of manufacturing employment comprised by women, it is not surprising that few women in the Madison metro area are found in occupations that are common to advanced manufacturing. Specifically, just 33% of production occupations and only 3.8% of installation, maintenance and repair occupations are occupied by women (Figure 2.21). Similar disparities are found in science, technology, engineering and mathematics (STEM) related fields often found in advanced manufacturing. For instance, women comprise just 15.1% of engineering and architecture occupations and 27.4% of computer and mathematical occupations (Figure 2.21). Certainly there are opportunities to increase the share of women across all advanced manufacturing occupations.

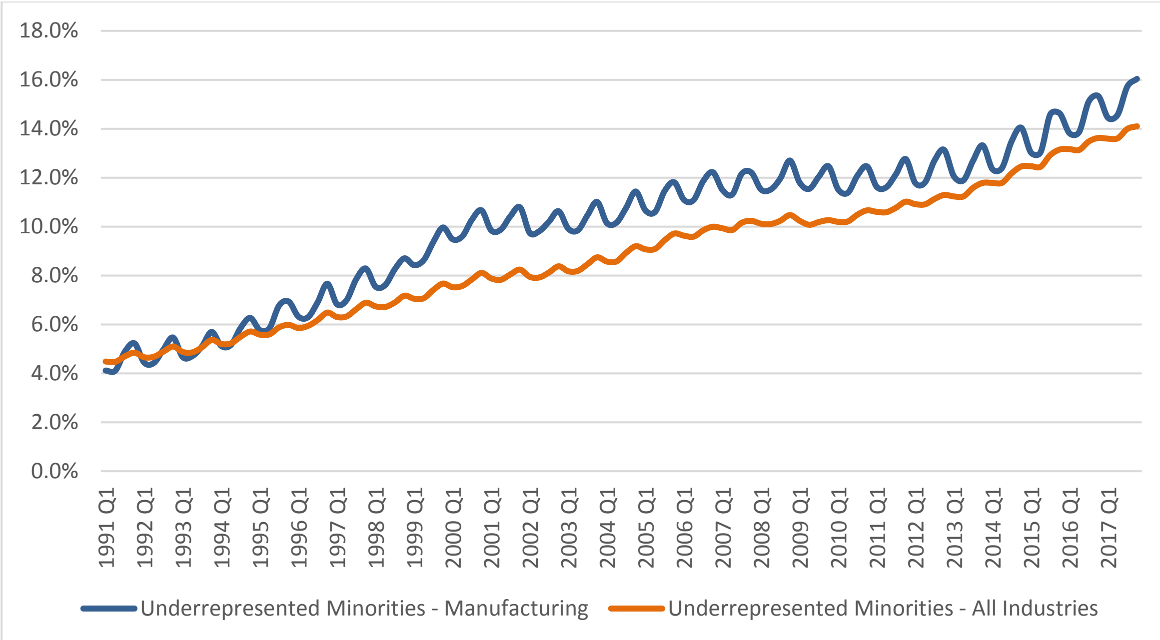
Figure 2.21 – Women as a Share of Total Employment by Occupation - Madison MSA in 2016



Source: U.S. Census Bureau American Community Survey and Authors' Calculations

Underrepresented minorities (URMs) also provide greater opportunities for talent development in advanced manufacturing. While official definitions of underrepresented minorities may vary, for purposes of this analysis we consider URMs to include those who identify as African Americans, American Indians/Alaska Natives, Latinos, and Asian or Pacific Islanders. In contrast to employment trends among women, manufacturing employment attributed to underrepresented minorities comprises a growing and disproportionately large share of employment. Underrepresented minorities comprised just 4.1% of manufacturing employment and 4.5% of all employment in 1991. By the end of 2017, the share of manufacturing employment attributed to underrepresented minorities increased to 16.0% (Figure 2.22). The share of all employment comprised by underrepresented minorities also increased, but to a smaller level (14.1%) than manufacturing.

Figure 2.22 – Underrepresented Minorities as a Share of Manufacturing Employment

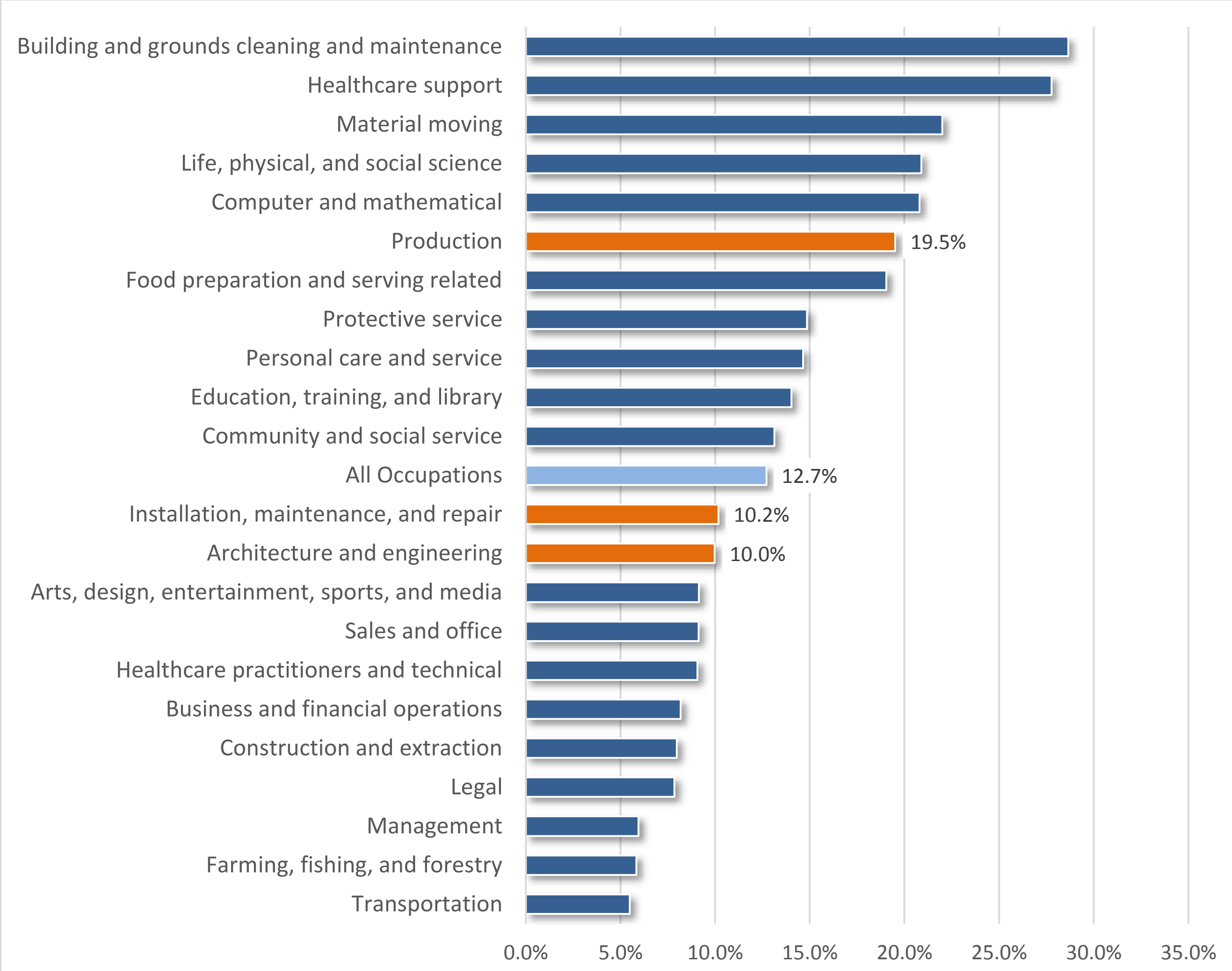


Source: U.S. Census Bureau LEHD and Authors' Calculations

As a share of all occupations, underrepresented minorities comprise 12.7% of all employment in the Madison MSA, but account for 19.5% of all production occupations. In contrast, URMs hold only 10.0% of engineering and architecture occupations (Figure 2.23). Underrepresented minorities also account for a lower share of installation, maintenance and repair occupations (10.2%).

The relatively higher share of manufacturing employment found among URMs does not necessarily mean that the Madison MSA is diverse. In comparison to many other metropolitan areas with large concentrations of advanced manufacturing, the Madison MSA has a low share of employment attributed to underrepresented minorities. This share is partly driven by the relatively low levels of overall diversity in the Madison MSA. That is, more diverse metro areas are more likely to have a higher share of manufacturing-related occupations found among underrepresented minorities. Accordingly, efforts to increase diversity in the Region's advanced manufacturing industry should continue to grow.

Figure 2.23 – Underrepresented Minorities as a Share Total Employment by Occupation - Madison MSA 2016



Source: U.S. Census Bureau 2016 American Community Survey and Authors' Calculations

Automation

Perhaps one of the biggest questions facing the advanced manufacturing industry is the influence of automation and computerization on future employment changes.[7] As manufacturing firms face labor constraints or seek ways to increase productivity and competitiveness, they may turn to the automation or computerizations of tasks. Unfortunately, it is difficult to predict the exact levels of automation as the automation of occupations will depend on many factors, including labor availability, capital and labor costs, technological advances, regulatory issues, and the desires of ownership (Kures, 2018). Nonetheless, numerous studies have examined how automation could potentially affect labor markets by estimating the share of occupations with the greatest susceptibility to automation (Aaronson and Phelan, 2017; Acemoglu and Restrepo, 2017; Devaraj, Hicks, Wornell and Faulk, 2017; Autor, Dorn and Hanson, 2015; Autor, Levy and Murnane, 2003).

A detailed analysis by Frey and Osborne (2017) estimates the computerization or automation probabilities for more than 700 occupation categories. Their estimates are based on a model that considers information contained in the aforementioned O*NET database; recent or anticipated advancements in machine learning, artificial intelligence, and mobile robotics; and current automation bottlenecks.[8] In general, occupations with a high probability of computerization and automation are more likely to involve routine tasks and less likely to require creative or social intelligence functions. Many of these occupations are also less likely to require higher levels of education (Frey and Osborne, 2017) and are found in Job Zone 2.

Using Frey and Osborne's automation probabilities, the following analysis estimates the share of occupations in each advanced manufacturing category with the greatest and least probabilities of automation (Figure 2.24). Note that these probabilities are based on the occupation distribution in these industries for the State of Wisconsin and not necessarily the Madison Region. Consequently, there may some variations in these distributions. *Based on these estimates, at least 35% of occupations face a 90% probability of being automated in every category of advanced manufacturing except chemical manufacturing and primary metal manufacturing.*

While many occupations face a high probability for automation, there are barriers to high rates of automation. Frey and Osborne note that their methodology relies on anticipated advances in automation that will likely occur, but still face hurdles. Many employees cannot be easily separated, or unbundled, from the equipment or technology that allows full automation to occur (Autor, 2015). Furthermore, many firms (especially smaller firms) may not have the capital necessary to incorporate automation at a high rate.

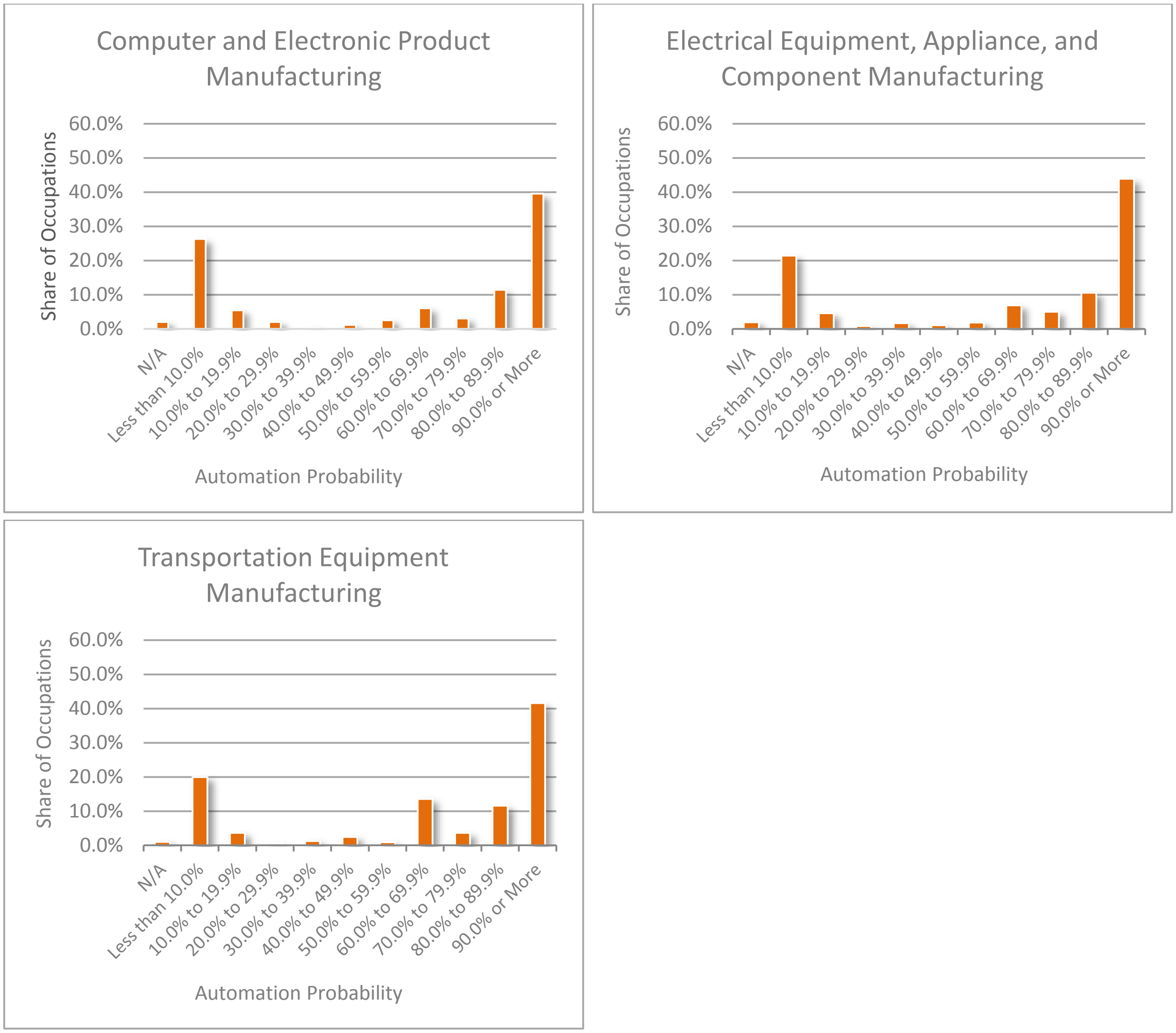
Despite the uncertainty with automation, a large number of jobs will likely be automated in the coming decade. The Region and State of Wisconsin will need to consider and plan for both the positive and negative effects of automation. Automation has the potential to address a tight labor market, increase productivity and increase the skills needed by many employees. These changes also could, but not necessarily, lead to higher wages. However, automation will also displace workers, create new competitive challenges for smaller firms, place pressure on the workforce development system, and reduce contributions to programs paid for by payroll taxes.

[7] The following discussion of automation is partially drawn from Kures, Deller and Conroy (2019).

[8] These bottlenecks are related to perception and manipulation tasks, creative intelligence tasks, and social intelligence tasks.

Figure 2.24 – Advanced Manufacturing Occupation Automation Probability/Susceptibility

Figure 2.24 – Advanced Manufacturing Occupation Automation Probability/Susceptibility (Continued)



Source: Bureau of Labor Statistics Occupational Employment Statistics, Frey and Osborne (2017) and Author's Calculations

Conclusions and Summary

- Advanced manufacturing involves a breadth and depth of occupations that require many different skills. Based on Job Zone distributions within advanced manufacturing, four subsectors require high levels of skill as they have at least 40% of their employment in occupations classified in Job Zone 3, Job Zone 4 and Job Zone 5. These subsectors include transportation equipment manufacturing (44.1%); chemical manufacturing (45.3%); machinery manufacturing (46.5%); and computer and electronic product manufacturing (64.0%). However, almost every category of advanced manufacturing has at least 50% of employment concentrated in occupations within Job Zone 2. These concentrations of workers in Job Zone 2 should not necessarily suggest that the advanced manufacturing industry is reliant on unskilled workers as many of these occupations require specific skills and involve detailed training. As a result, these occupations also tend to pay greater wages than occupations with Job Zone 2 found in many other industries. As a result, the industry provides opportunities to individuals with a diversity of skills and levels of educational attainment.

- Numerous occupations are common across multiple advanced manufacturing subsectors. These occupations include assemblers and fabricators; first-line supervisors; general and operations managers; industrial engineers, industrial production managers; and inspectors, testers, sorters, samplers, and weighers. Other commonly found occupations across the advanced manufacturing industry include specific production-related activities or the operation of machinery including: computer-controlled machine tool operators; cutting, punching, and press machine setters, operators, and tenders; multiple machine tool setters, operators, and tenders; welders; machinists and mechanics. Mechanical engineers are also common across multiple subsectors. Occupations that span multiple advanced manufacturing subsectors could provide opportunities for joint talent development initiatives such as regional recruitment, DACUM efforts, and internships.

- In the Madison Region, the share of manufacturing employees age 55 and over has increased from approximately 10% in 1991 to over 25% in 2017. In fact, all subsectors of advanced manufacturing face a notable share of employees that could potentially retire in the next decade or less. Importantly, the age structure of Region continues to shift toward older residents and will likely place additional pressure on the labor force due to retirements or reduced employee capacities. When considering the labor force pressures created by the Region's aging population, the demand for labor is more appropriately described as a "bodies gap" rather than a "skills gap. "

- As the Madison Region identifies opportunities to develop its advanced manufacturing labor force, initiatives should recognize differences in occupational mobility. Specifically, individuals working in professional and technical occupations, such as engineers, are more likely to move across state lines. In contrast, production occupations are among the least mobile occupational category. Accordingly, the Region will need to consider both internal and external talent development initiatives that recognize these types of differences.

- While employment in the Region’s manufacturing sector is increasingly diverse, women continue to account for a disproportionately low share of manufacturing employees. This disparity is true across both production-related occupations and STEM-related occupations such as engineering. As the Region’s labor market continues to tighten, both women and underrepresented minorities provide important opportunities for engagement.

- Based on estimated occupation automation probabilities, at least 35% of occupations face a 90% probability of being automated in every category of advanced manufacturing except chemical manufacturing and primary metal manufacturing. In anticipating these changes, the Region and State of Wisconsin will need to plan for both the positive and negative effects of automation. Indeed, automation has the potential to address a tight labor market, increase productivity and increase the skills needed by many employees. These changes also could, but not necessarily, lead to higher wages. However, automation will also displace workers, create new competitive challenges for smaller firms, place pressure on the workforce development system, and reduce contributions to programs paid for by payroll taxes.

Appendix 2A – Understanding Job Zones

Job Zone One: Little or No Preparation Needed

- *Education* - Some of these occupations may require a high school diploma or GED certificate.
- *Related Experience* - Little or no previous work-related skill, knowledge, or experience is needed for these occupations. For example, a person can become a waiter or waitress even if he/she has never worked before.
- *Job Training* - Employees in these occupations need anywhere from a few days to a few months of training. Usually, an experienced worker could show you how to do the job.
- *Specific Vocational Preparation Time* – Short demonstration, up to one month or one to 3 months.

Job Zone Two: Some Preparation Needed

- *Education* - These occupations usually require a high school diploma.
- *Related Experience* - Some previous work-related skill, knowledge, or experience is usually needed. For example, a teller would benefit from experience working directly with the public.
- *Job Training* - Employees in these occupations need anywhere from a few months to one year of working with experienced employees. A recognized apprenticeship program may be associated with these occupations.
- *Specific Vocational Preparation Time* – 3 to 6 months, 6 months to 1 year

Job Zone Three: Medium Preparation Needed

- *Education* - Most occupations in this zone require training in vocational schools, related on-the-job experience, or an associate's degree.
- *Related Experience* - Previous work-related skill, knowledge, or experience is required for these occupations. For example, an electrician must have completed three or four years of apprenticeship or several years of vocational training, and often must have passed a licensing exam, in order to perform the job.
- *Job Training* - Employees in these occupations usually need one or two years of training involving both on-the-job experience and informal training with experienced workers. A recognized apprenticeship program may be associated with these occupations.
- *Specific Vocational Preparation Time* – 1 to 2 years

Job Zone Four: Considerable Preparation Needed

- *Education* - Most of these occupations require a four-year bachelor's degree, but some do not.
- *Related Experience* - A considerable amount of work-related skill, knowledge, or experience is needed for these occupations. For example, an accountant must complete four years of college and work for several years in accounting to be considered qualified.
- *Job Training* - Employees in these occupations usually need several years of work-related experience, on-the-job training, and/or vocational training.
- *Specific Vocational Preparation Time* – 2 to 4 years

Job Zone Five: Extensive Preparation Needed

- *Education* - Most of these occupations require graduate school. For example, they may require a master's degree, and some require a Ph.D., M.D., or J.D. (law degree).
- *Related Experience* - Extensive skill, knowledge, and experience are needed for these occupations. Many require more than five years of experience. For example, surgeons must complete four years of college and an additional five to seven years of specialized medical training to be able to do their job.
- *Job Training* - Employees may need some on-the-job training, but most of these occupations assume that the person will already have the required skills, knowledge, work-related experience, and/or training.
- *Specific Vocational Preparation Time* – 4 to 10 years, or over 10 years

Source: O*NET

Appendix 2B – Engineering Occupations by MSA

Top 50 MSAs for Total Mechanical Engineers (2017)

Rank	Metropolitan Statistical Area	Total Mechanical Engineers in 2017	Location Quotient in 2017	Annual Average Wage in 2017
1	Detroit-Warren-Dearborn, MI	33,100	8.24	$94,690
2	Chicago-Naperville-Elgin, IL-IN-WI	10,540	1.12	$89,980
3	Los Angeles-Long Beach-Anaheim, CA	8,920	0.72	$101,080
4	Houston-The Woodlands-Sugar Land, TX	7,530	1.26	$113,480
5	Philadelphia-Camden-Wilmington, PA-NJ-DE-MD	5,610	0.98	$95,700
6	Washington-Arlington-Alexandria, DC-VA-MD-WV	5,440	0.86	$112,990
7	Dallas-Fort Worth-Arlington, TX	5,380	0.76	$104,310
8	Minneapolis-St. Paul-Bloomington, MN-WI	5,360	1.36	$85,510
9	Seattle-Tacoma-Bellevue, WA	5,050	1.27	$100,110
10	Columbus, OH	4,870	2.3	$83,690
11	San Jose-Sunnyvale-Santa Clara, CA	4,210	1.89	$125,940
12	Milwaukee-Waukesha-West Allis, WI	4,160	2.42	$80,750
13	Grand Rapids-Wyoming, MI	3,750	3.32	$72,920
14	San Diego-Carlsbad, CA	3,640	1.24	$93,590
15	Pittsburgh, PA	3,580	1.55	$89,440
16	Portland-Vancouver-Hillsboro, OR-WA	3,560	1.51	$91,220
17	Denver-Aurora-Lakewood, CO	3,070	1.04	$109,600
18	San Francisco-Oakland-Hayward, CA	3,050	0.63	$112,710
19	Baltimore-Columbia-Towson, MD	3,010	1.08	$104,220
20	Atlanta-Sandy Springs-Roswell, GA	2,780	0.52	$82,800
21	Indianapolis-Carmel-Anderson, IN	2,610	1.24	$85,420
22	Cleveland-Elyria, OH	2,440	1.16	$80,130
23	Charlotte-Concord-Gastonia, NC-SC	2,410	0.99	$86,730
24	Phoenix-Mesa-Scottsdale, AZ	2,340	0.58	$88,310
25	Cincinnati, OH-KY-IN	2,240	1.04	$82,430
26	Miami-Fort Lauderdale-West Palm Beach, FL	2,190	0.42	$84,400
27	Kansas City, MO-KS	2,160	1	$85,490
28	Louisville/Jefferson County, KY-IN	2,110	1.6	$83,900
29	Virginia Beach-Norfolk-Newport News, VA-NC	1,820	1.2	$88,300
30	St. Louis, MO-IL	1,770	0.64	$89,360
31	Greenville-Anderson-Mauldin, SC	1,770	2.16	$95,470
32	Albany-Schenectady-Troy, NY	1,700	1.85	$94,270
33	Hartford-West Hartford-East Hartford, CT	1,660	1.39	$91,780
34	Rochester, NY	1,650	1.59	$84,400
35	Austin-Round Rock, TX	1,400	0.69	$94,690
36	Providence-Warwick, RI-MA	1,390	1.2	$94,640
37	Raleigh, NC	1,360	1.09	$94,660
38	Allentown-Bethlehem-Easton, PA-NJ	1,330	1.82	$76,910
39	Buffalo-Cheektowaga-Niagara Falls, NY	1,230	1.09	$83,790
40	Tucson, AZ	1,220	1.63	$98,470
41	Madison, WI	1,210	1.53	$78,870
42	Orlando-Kissimmee-Sanford, FL	1,180	0.48	$100,860
43	Sacramento--Roseville--Arden-Arcade, CA	1,170	0.6	$97,760
44	Riverside-San Bernardino-Ontario, CA	1,160	0.4	$84,210
45	Huntsville, AL	1,140	2.51	$93,910
46	Tampa-St. Petersburg-Clearwater, FL	1,080	0.41	$75,700
47	Dayton, OH	1,080	1.42	$81,690
48	Jackson, MI	1,070	8.83	$90,610
49	Ann Arbor, MI	1,060	2.43	$84,850
50	Salt Lake City, UT	1,030	0.73	$86,270

Source: Bureau of Labor Statistics Occupational Employment Statistics (OES) and Authors' Calculations

Top 50 MSAs for Mechanical Engineers by Location Quotient (2017)

Rank	Metropolitan Statistical Area	Total Mechanical Engineers in 2017	Location Quotient in 2017	Annual Average Wage in 2017
1	Jackson, MI	1,070	8.83	$90,610
2	Detroit-Warren-Dearborn, MI	33,100	8.24	$94,690
3	Niles-Benton Harbor, MI	890	6.95	$94,400
4	California-Lexington Park, MD	510	5.49	$94,110
5	Columbus, IN	480	4.84	$69,280
6	Sheboygan, WI	530	4.49	$88,410
7	Decatur, IL	350	3.46	$97,490
8	Kokomo, IN	270	3.37	$83,380
9	Grand Rapids-Wyoming, MI	3,750	3.32	$72,920
10	Monroe, MI	240	3.08	$80,850
11	Bremerton-Silverdale, WA	540	3.07	$88,280
12	Battle Creek, MI	330	2.88	$101,040
13	Mount Vernon-Anacortes, WA	270	2.84	$85,980
14	New Bern, NC	250	2.80	$73,080
15	York-Hanover, PA	1,010	2.74	$78,470
16	Kalamazoo-Portage, MI	780	2.73	$75,900
17	Decatur, AL	290	2.67	$94,490
18	Rocky Mount, NC	300	2.61	$79,510
19	Huntsville, AL	1,140	2.51	$93,910
20	Ann Arbor, MI	1,060	2.43	$84,850
21	Milwaukee-Waukesha-West Allis, WI	4,160	2.42	$80,750
22	Panama City, FL	390	2.39	$92,930
23	Columbus, OH	4,870	2.30	$83,690
24	Portsmouth, NH-ME	430	2.29	$88,300
25	Appleton, WI	580	2.28	$80,730
26	Boulder, CO	820	2.24	$99,010
27	Rockford, IL	650	2.23	$79,210
28	Kingsport-Bristol-Bristol, TN-VA	520	2.20	$102,580
29	Muskegon, MI	280	2.20	$74,990
30	Greenville-Anderson-Mauldin, SC	1,770	2.16	$95,470
31	Palm Bay-Melbourne-Titusville, FL	910	2.15	$98,250
32	Racine, WI	330	2.15	$72,540
33	Davenport-Moline-Rock Island, IA-IL	760	2.05	$90,940
34	Fond du Lac, WI	190	2.04	$72,290
35	Ogden-Clearfield, UT	980	1.93	$84,540
36	San Jose-Sunnyvale-Santa Clara, CA	4,210	1.89	$125,940
37	Albany-Schenectady-Troy, NY	1,700	1.85	$94,270
38	Oshkosh-Neenah, WI	360	1.84	$73,630
39	Norwich-New London-Westerly, CT-RI	480	1.82	$80,090
40	Allentown-Bethlehem-Easton, PA-NJ	1,330	1.82	$76,910
41	Idaho Falls, ID	240	1.80	$98,760
42	Warner Robins, GA	250	1.78	$89,370
43	Lansing-East Lansing, MI	780	1.78	$78,120
44	Provo-Orem, UT	820	1.76	$88,080
45	Chambersburg-Waynesboro, PA	200	1.68	$80,680
46	Augusta-Richmond County, GA-SC	730	1.63	$113,020
47	Tucson, AZ	1,220	1.63	$98,470
48	Fort Wayne, IN	710	1.63	$76,720
49	Walla Walla, WA	80	1.60	$86,280
50	Louisville/Jefferson County, KY-IN	2,110	1.60	$83,900

Source: Bureau of Labor Statistics Occupational Employment Statistics (OES) and Authors' Calculations

Top 50 MSAs for Total Industrial Engineers (2017)

Rank	Metropolitan Statistical Area	Total Industrial Engineers in 2017	Location Quotient in 2017	Annual Average Wage in 2017
1	Detroit-Warren-Dearborn, MI	17,500	4.78	$92,900
2	Los Angeles-Long Beach-Anaheim, CA	9,790	0.87	$107,150
3	Chicago-Naperville-Elgin, IL-IN-WI	8,410	0.98	$80,620
4	New York-Newark-Jersey City, NY-NJ-PA	7,210	0.42	$100,100
5	Minneapolis-St. Paul-Bloomington, MN-WI	6,930	1.93	$93,320
6	Dallas-Fort Worth-Arlington, TX	6,370	0.98	$99,800
7	Seattle-Tacoma-Bellevue, WA	5,470	1.51	$111,450
8	Houston-The Woodlands-Sugar Land, TX	4,820	0.88	$124,800
9	Philadelphia-Camden-Wilmington, PA-NJ-DE-MD	4,450	0.85	$96,650
10	San Jose-Sunnyvale-Santa Clara, CA	4,250	2.1	$121,640
11	Cincinnati, OH-KY-IN	4,220	2.14	$95,090
12	Atlanta-Sandy Springs-Roswell, GA	3,660	0.75	$84,560
13	Portland-Vancouver-Hillsboro, OR-WA	3,520	1.63	$104,850
14	Grand Rapids-Wyoming, MI	3,380	3.29	$75,250
15	St. Louis, MO-IL	3,120	1.23	$93,050
16	San Diego-Carlsbad, CA	2,870	1.08	$96,290
17	Phoenix-Mesa-Scottsdale, AZ	2,810	0.76	$89,650
18	San Francisco-Oakland-Hayward, CA	2,670	0.6	$108,350
19	Cleveland-Elyria, OH	2,660	1.39	$82,610
20	Milwaukee-Waukesha-West Allis, WI	2,570	1.64	$78,160
21	Charlotte-Concord-Gastonia, NC-SC	2,260	1.02	$84,540
22	Washington-Arlington-Alexandria, DC-VA-MD-WV	2,240	0.39	$93,690
23	Miami-Fort Lauderdale-West Palm Beach, FL	2,180	0.46	$68,480
24	Columbus, OH	2,120	1.09	$76,990
25	San Juan-Carolina-Caguas, PR	2,080	1.68	$74,930
26	Denver-Aurora-Lakewood, CO	2,040	0.76	$98,120
27	Indianapolis-Carmel-Anderson, IN	2,000	1.04	$77,610
28	Tampa-St. Petersburg-Clearwater, FL	1,990	0.83	$71,470
29	Pittsburgh, PA	1,870	0.89	$83,150
30	Ann Arbor, MI	1,860	4.68	$95,220
31	Hartford-West Hartford-East Hartford, CT	1,750	1.61	$87,040
32	Nashville-Davidson--Murfreesboro--Franklin, TN	1,690	0.96	$85,750
33	Raleigh, NC	1,540	1.36	$105,710
34	Kansas City, MO-KS	1,540	0.78	$84,450
35	Bridgeport-Stamford-Norwalk, CT	1,520	1.96	$97,460
36	Orlando-Kissimmee-Sanford, FL	1,510	0.67	$81,220
37	Rochester, NY	1,500	1.58	$82,910
38	Spartanburg, SC	1,480	5.32	$88,400
39	Austin-Round Rock, TX	1,470	0.79	$102,440
40	Huntsville, AL	1,430	3.47	$95,690
41	Greenville-Anderson-Mauldin, SC	1,400	1.87	$81,740
42	Buffalo-Cheektowaga-Niagara Falls, NY	1,380	1.35	$82,570
43	Louisville/Jefferson County, KY-IN	1,360	1.13	$76,960
44	Salt Lake City, UT	1,290	0.99	$95,560
45	Peoria, IL	1,240	3.9	$93,550
46	Albany-Schenectady-Troy, NY	1,210	1.45	$100,970
47	Greensboro-High Point, NC	1,200	1.77	$84,180
48	Baltimore-Columbia-Towson, MD	1,140	0.45	$96,720
49	San Antonio-New Braunfels, TX	1,050	0.56	$108,890
50	Charleston-North Charleston, SC	1,040	1.65	$83,220

Source: Bureau of Labor Statistics Occupational Employment Statistics (OES) and Authors' Calculations

Top 50 MSAs for Industrial Engineers by Location Quotient (2017)

Rank	Metropolitan Statistical Area	Total Industrial Engineers in 2017	Location Quotient in 2017	Annual Average Wage in 2017
1	Spartanburg, SC	1,480	5.32	$88,400
2	Sheboygan, WI	550	5.10	$82,290
3	Detroit-Warren-Dearborn, MI	17,500	4.78	$92,900
4	Ann Arbor, MI	1,860	4.68	$95,220
5	Peoria, IL	1,240	3.90	$93,550
6	Bowling Green, KY	510	3.71	$79,090
7	Muskegon, MI	410	3.57	$73,710
8	Huntsville, AL	1,430	3.47	$95,690
9	Bloomington, IN	440	3.47	$72,570
10	Grand Rapids-Wyoming, MI	3,380	3.29	$75,250
11	Tuscaloosa, AL	600	3.21	$103,320
12	Mansfield, OH	290	3.12	$59,370
13	Jackson, MI	340	3.06	$78,130
14	Saginaw, MI	450	2.85	$78,080
15	California-Lexington Park, MD	210	2.49	$107,610
16	Niles-Benton Harbor, MI	290	2.45	$86,290
17	Oshkosh-Neenah, WI	420	2.36	$79,730
18	Lafayette-West Lafayette, IN	390	2.28	$87,080
19	Elkhart-Goshen, IN	530	2.26	$66,300
20	Appleton, WI	510	2.24	$87,740
21	Auburn-Opelika, AL	240	2.24	$71,850
22	Palm Bay-Melbourne-Titusville, FL	840	2.18	$87,380
23	Midland, MI	140	2.17	$98,250
24	Cincinnati, OH-KY-IN	4,220	2.14	$95,090
25	Decatur, AL	210	2.14	$104,630
26	Norwich-New London-Westerly, CT-RI	500	2.12	$85,180
27	Ocala, FL	390	2.11	$66,590
28	San Jose-Sunnyvale-Santa Clara, CA	4,250	20.1	$121,640
29	Battle Creek, MI	210	2.06	$87,030
30	Boulder, CO	670	2.03	$100,610
31	Danbury, CT	300	2.03	$89,520
32	York-Hanover, PA	670	2.01	$84,530
33	Lynchburg, VA	370	2.01	$78,740
34	Bridgeport-Stamford-Norwalk, CT	1,520	1.96	$97,460
35	Elmira, NY	130	1.94	$81,010
36	Minneapolis-St. Paul-Bloomington, MN-WI	6,930	1.93	$93,320
37	Davenport-Moline-Rock Island, IA-IL	650	1.92	$90,480
38	Youngstown-Warren-Boardman, OH-PA	750	1.88	$86,570
39	Greenville-Anderson-Mauldin, SC	1,400	1.87	$81,740
40	Kalamazoo-Portage, MI	480	1.87	$80,410
41	Florence, SC	280	1.79	$84,990
42	Greensboro-High Point, NC	1,200	1.77	$84,180
43	Savannah, GA	560	1.75	$90,130
44	Dalton, GA	210	1.72	$65,230
45	Fort Wayne, IN	670	1.69	$76,740
46	New Bern, NC	140	1.66	$76,150
47	Charleston-North Charleston, SC	1,040	1.65	$83,220
48	Milwaukee-Waukesha-West Allis, WI	2,570	1.64	$78,160
49	Portland-Vancouver-Hillsboro, OR-WA	3,520	1.63	$104,850
50	Hartford-West Hartford-East Hartford, CT	1,750	1.61	$87,040

Source: Bureau of Labor Statistics Occupational Employment Statistics (OES) and Authors' Calculations

This page is intentionally blank

Section 3 – Advanced Manufacturing Cluster Support and Development Ecosystem

As noted in the introduction, industry clusters are not comprised solely of for-profit, private-sector firms. Instead, industry clusters involve companies that are interconnected through supply chains, common infrastructure, a shared labor pool, connective and networking assets, and quality of place/quality of life considerations. Industry clusters also recognize the potential assistance and knowledge transfers that universities, trade associations, government agencies and similar organizations can provide. Accounting for all of these cluster elements together provides a clearer understanding of the advance manufacturing support and development ecosystem. Accordingly, the following analysis builds upon the prior analyses of advanced manufacturing talent, industries and niches by considering:

- Broadband availability and distribution;
- Workforce housing;
- International markets for advanced manufacturing products;
- Purchasing patterns
- Business parks, certified and gold shovel sites, and speculative buildings;
- Educational institutions;
- Support organizations that foster innovation and connect firms to resources. These organizations may provide technical assistance, mentoring, access to capital or other forms of assistance.

Broadband Infrastructure

While all industries increasingly rely on broadband availability, inexpensive and reliable high-speed Internet access is becoming very important to the advance manufacturing industry cluster. Companies will increasing require connectivity to drive their Internet of Things (IoT) or Industry 4.0 technologies, including on demand manufacturing systems (wherein machines manufacture highly specialized products based upon custom orders and specifications), on-site 3-D printing, predictive machine maintenance systems, inventory control and logistics systems, and virtual and augmented reality production and worker training systems. To provide some perspectives on broadband infrastructure in the Madison Region, several measures of access and speed are mapped below using Fixed Broadband Deployment Data from the Federal Communications Commission Form 477. As noted by the FCC, all facilities-based broadband providers are required to file data twice a year on the census blocks where Internet access service is offered at speeds exceeding 200 kilobits per second (Kbps) in at least one direction.[9]

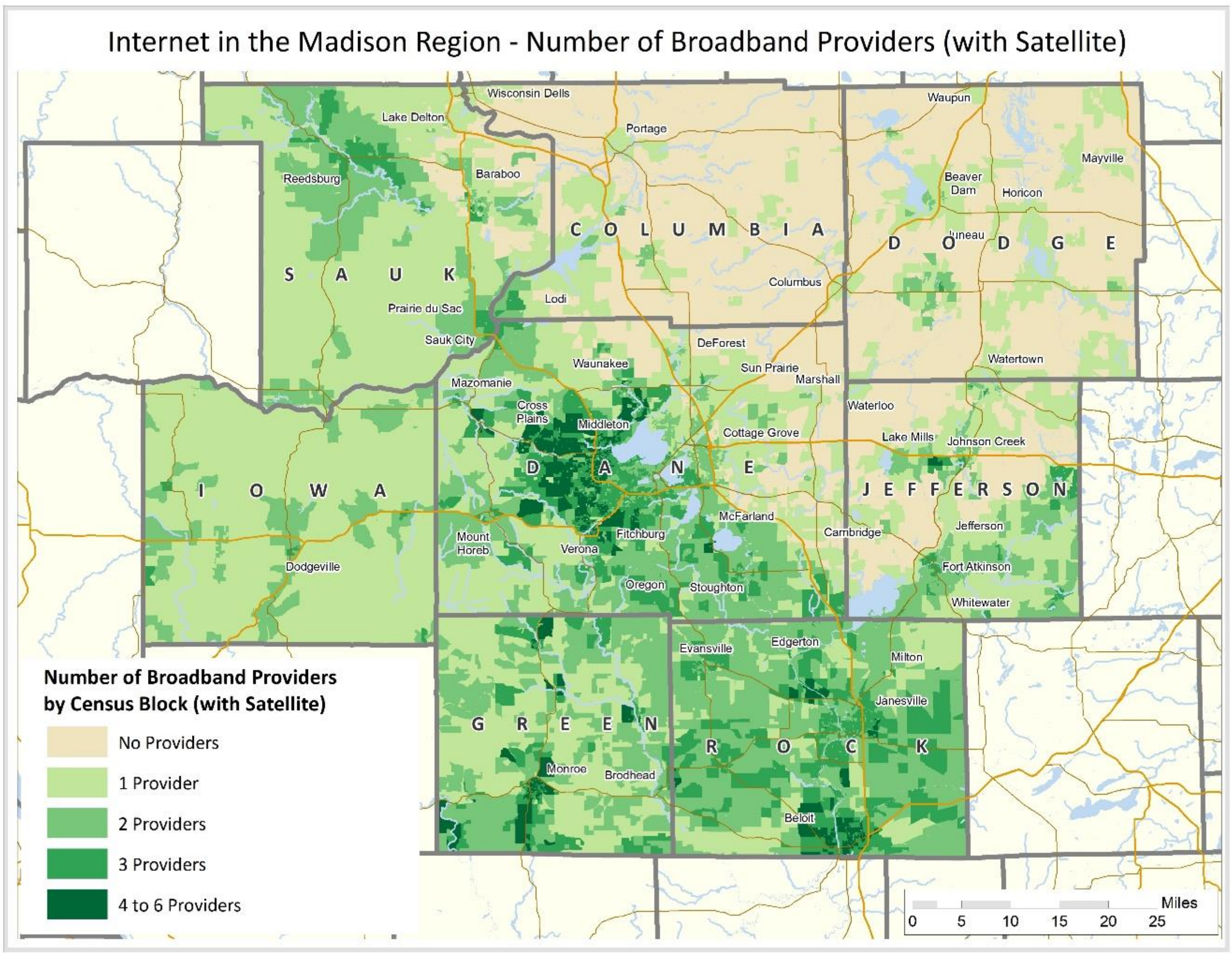
While the Form 477 data provide some perspectives on general Internet availability, it has several inherent challenges that prohibit users from effectively mapping or identifying comprehensive broadband access. First, providers file lists of census blocks in which they either can or do offer service to at least one location.

[9] For more information see: https://www.fcc.gov/general/broadband-deployment-data-fcc-form-477

However, there may be other addresses or locations within a given census block that do not have access to any broadband providers. Second, the most recent data are from December 2016; therefore, improvements in either speed or access made through provider investments over the last 2 years will not be reflected on these maps. Finally, the data provide no information on cost to the user.

The following maps consider 1) the maximum reported upload speed, 2) the maximum download speed and 3) the number of broadband providers in each census block. This analysis relies on the federal definition of broadband which is 25 megabits per second (Mbps) for download speeds and 3 Mbps for upload speeds. As the 25/3 definition is increasingly inadequate for some users, the maps showing maximum download and upload speeds provide additional detail on transfer rates. Note that these maps include "fixed" broadband connections such as cable, DSL and terrestrial fixed wireless. Accordingly, these maps do not include mobile or cellular data. Furthermore, the maps do no depict the locations of "dark fiber" or fiber optic infrastructure that is in place, but unused. Depending on where this dark fiber is located, it could provide opportunities to both expand and improve access in some parts of the Madison Region. Finally, the maps below also include satellite access, but a separate series of maps excluding satellite access are included in Appendix 3A.

Figure 3.1 – Number of Broadband Providers by Census Block (including Satellite)

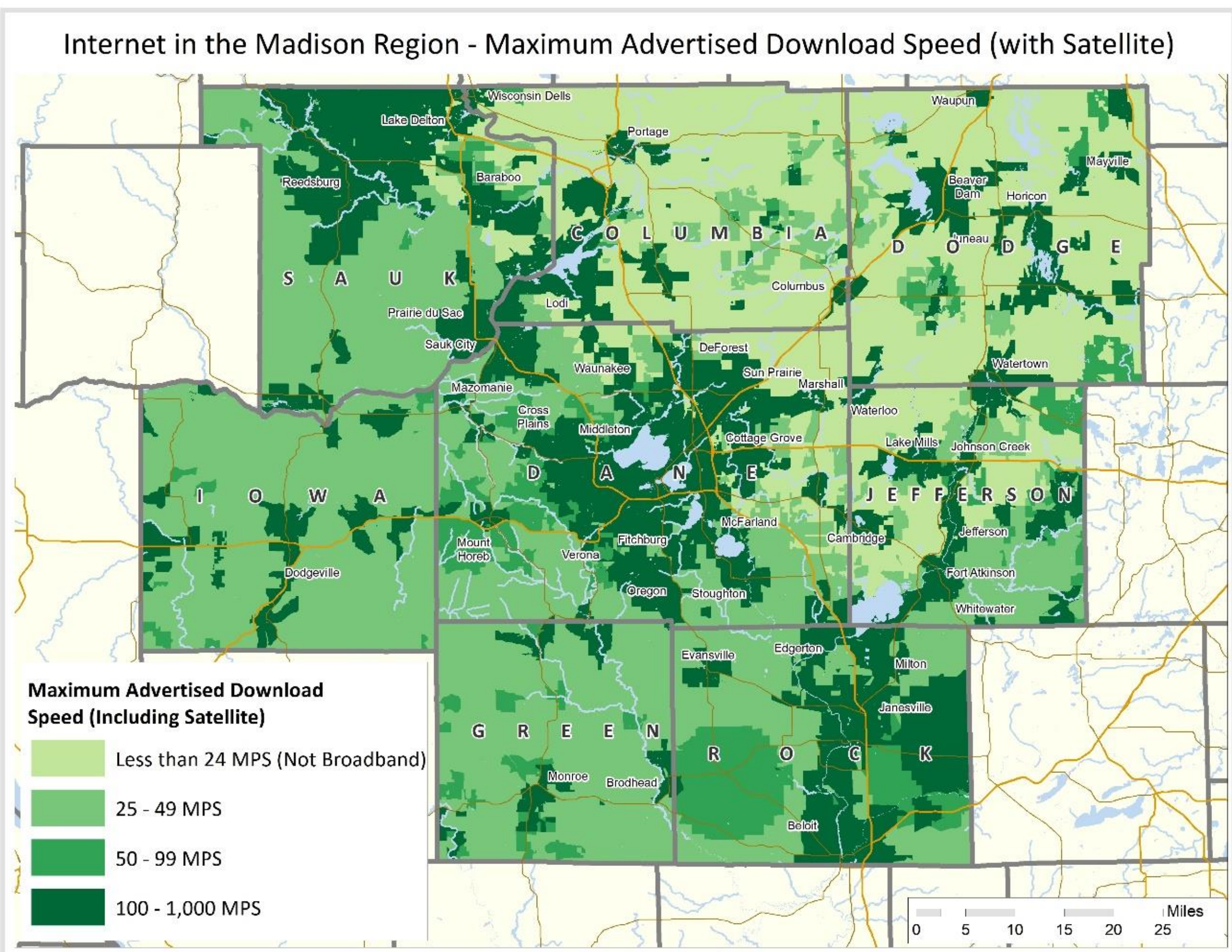


Source: Fixed Broadband Deployment Data - Federal Communications Commission Form 477 and Author's Calculations

The numbers of broadband providers available in each census block vary dramatically across the Region (Figure 3.1). The urban-rural divide in the number of providers is particularly apparent. A relatively large number of providers are found across the western portion of Madison and its surrounding communities. More than one broadband provider is also found in many smaller communities across the Region such as Monroe, Beloit and Reedsburg. In contrast, extensive rural areas throughout Dodge, Columbia, and Jefferson counties are without a reported broadband provider. Some rural areas in Dane and Sauk counties also lack broadband access. Again, these areas have some level of internet availability, but they do not have a provider that meets the 25/3 broadband definition. *If access to satellite providers is removed from consideration, a significant portion of all counties in the Madison Region are without a broadband provider (see Appendix 3A).*

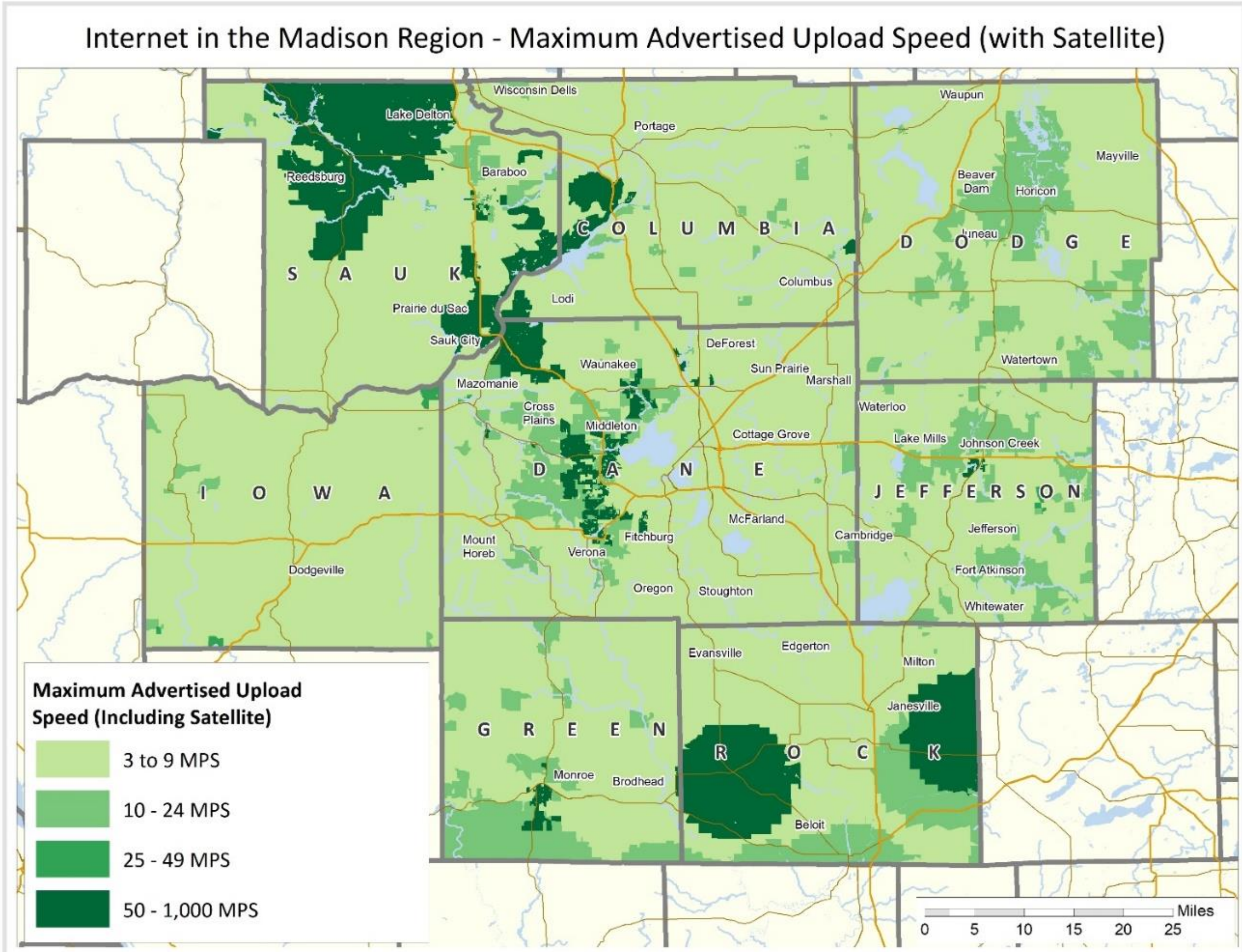
Download speeds also vary considerably across the Madison Region. Most of Madison and its surrounding communities have access to speeds of at least 100 Mbps, with some communities (such as Sun Prairie) having access to 1 gigabits per second (Gbps or 1,000 Mbps) download speeds (Figure 3.2). Most communities outside of Dane County also have at least partial access to download speeds of 100 Mbps or more. However, it is important to reiterate that the Form 477 data used to produce these maps cannot guarantee the availability of any specific download (or upload) speeds. Areas with high upload speeds are more concentrated in the Region. Notable areas with upload speeds between 50 to 1,000 Mbps include Reedsburg, Sauk City/Prairie du Sac, Middleton, Verona, Monroe, Orfordville and eastern Rock County (Figure 3.3).

Figure 3.2 – Maximum Advertised Download and Upload Speeds by Census Block (including Satellite)



Source: Fixed Broadband Deployment Data - Federal Communications Commission Form 477 and Author's Calculations

Figure 3.3 – Maximum Advertised Upload Speeds by Census Block (including Satellite)



Source: Fixed Broadband Deployment Data - Federal Communications Commission Form 477 and Author's Calculations

An important MadREP key strategic initiative (KSI) is to promote the increased availability and reliability of broadband in the ring counties, and particularly in rural communities, wherein many of the Region's advance manufacturing businesses are located. Wireless technologies beyond satellite, including the 5G wireless systems discussed in the next section, could be a huge potential mechanism used to assist in meeting this objective in these hard to serve areas.

5G Wireless

While the previous discussion of broadband infrastructure did not consider wireless technologies, fifth-generation (5G) broadband technology can be used to replace or supplement cable and fiber technologies and can potentially be used to deliver wireless broadband to remote areas previously unreachable. Furthermore, the near-term development and installation of 5G is essential to the successful implementation of artificial intelligence and machine learning applications, as well as the edge processing software applications that are anticipated as part of future IoT installations. 5G has the ability to deliver operating speeds of more than 100 Mbps and allows wireless communication to occur in high-frequency bands (particularly important will be the 28, 37-40 and 64-71 GHz ranges).

5G systems will require mini-cell towers (or "small cell" antenna arrays) placed in a dense network to ensure high frequency signal transmission through thick walls and in bad weather. Units will be located on common structures, such as buildings, telephone poles and street lights, throughout a customer service area. Indeed, a proof of concept 20 Gbps 5G network made its debut during the 2018 Winter Olympics in PyeongChang, South Korea. Particularly impressive was the drone synchronization demonstration made possible by the technology, in which anywhere from 300 to a record 1,218 drones were used to create 3-D patterns against the night sky during the opening and closing ceremonies (Barrett, 2018).

Distinguishing Features of 5G

As noted by West (2016), four factors distinguish 5G from 4G Long Term Evolution (LTE) networks:

1. *Connected devices* - By 2020, the 5G network is expected to support 50B connected devices and 212B connected sensors that will essentially be machines talking to each other through IoT protocols and middleware technologies. These connected devices will allow people to enjoy more personalized, more immersive and more enhanced experiences anywhere in the world that deploys the network, as well as allow advance manufacturing businesses to increase operating efficiencies through deployment of their connected factory technologies;

2. *Fast and intelligent networks* - The end goal is to develop a fully software driven and virtualized network where human decision making is removed from the computational process. The network will rely upon machine-to-machine communication, remote sensors and automated decision making (including data traffic prioritization) to speed execution and make more efficient use of computational power. The network speed will enable applications such as social multiplayer gaming, interactive television, high definition and 3-D video, virtual reality, augmented reality, robotics, driverless cars, and all the advanced manufacturing Industry 4.0 systems (Figure 3.4);

3. *Extremely low latency* - The goal of 5G will be to lower the time between when a command is requested to when it is executed from the current 50 to 80 milliseconds to a few milliseconds;

4. *Back-end services* - The emerging network will enlist back-end data centers, cloud services and remote file servers to provide users a responsive experience using "computing at the edge" technology, meaning computations are performed either at the source or at a nearby cloud based processing center. This combination of edge technology, faster operating speeds and low latency will allow machines to talk and

react in real time, improving their efficiency and increasing system safety (such as the quick braking of an autonomous vehicle to avoid a collision or the shutting down of a machine when a worker is perceived to be in danger). The marketplace is currently developing new chipsets and end point devices to utilize 5G networks. Intel plans to release the first 5G enabled laptops by 2019.

Figure 3.4 - Manufacturing and Industry 4.0

While "Industry 4.0" has become a somewhat generic term applied to the integration of digital technologies to the production process, the concept was first developed by Germany Trade and Invest (GTAI). GTAI notes that Industry 4.0 "…connects innovative embedded system production technologies and smart production processes to pave the way to a new industrial age which will radically transform industry and production value chains and business models in tomorrow's smart factories." Specifically, the simultaneous integration of technologies such as robotics, additive manufacturing, the Internet of Things (IoT), artificial intelligence, and augmented reality provides new opportunities for manufacturing firms to improve their operations and grow their businesses.

Several examples of Industry 4.0 technology integration include:

- Adding sensors, network connections, machine learning and data analytics to the production process that allow robotics and other manufacturing equipment to provide instantaneous feedback to employees. This feedback can improve product quality, monitor machine performance and mechanical issues that can lead to downtime, create higher levels of product quality assurance, and increase employee safety and productivity;

- Incorporating new additive manufacturing and augmented reality technologies that allow products to be quickly prototyped and/or customized which in turn reduces time-to-market and allows for customer needs to be rapidly met;

- Connecting the production facility to final products being used by customers through cloud computing. These connections allow products to communicate their performance and maintenance needs back to product designers and developers. Doing so provides opportunities for constant analysis of product performance that can be rapidly incorporated into quality improvement and design processes. Connecting final products to the production facility also allows manufacturers to develop algorithms that predict demand for their goods and foresee the maintenance needs of the products they produce;

Ultimately, the incorporation of Industry 4.0 concepts to the manufacturing industry can help firms improve their production processes, anticipate consumer demand, create new supply chain efficiencies, improve worker satisfaction and increase revenues. However, Industry 4.0 will also require investment in equipment, research, information technology and cybersecurity. Industry 4.0 will also require the development and training of a workforce that is further skilled in engineering, data science and security, robotics, computer programming and database development. The educational system and government agencies both have opportunities to foster these necessary investments in technology and labor.

Source: Conroy, Kures and Deller (2018). Used with permission.

5G System Rollout

AT&T, Verizon and Sprint have targeted late 2018 and 2019 launch dates for U.S. rollouts. Providers located in China and Japan will roll out their networks in 2020. As noted earlier, in South Korea the provider Korean Telecom already began implementation of a nationwide 5G network in advance of the Olympics.

In the Madison region, a representative from AT&T indicated during a Wisconsin Innovation Network luncheon that planning has begun for the rollout of a local 5G network. The exact dates of the implementation effort have yet to be made public. Several important legislative bills and actions are currently pending, which will assist with the rollout of this network across all regions of the state (Still, 2018):

- Assembly Bill 348: Provides for administrative and regulatory changes that will speed up the deployment of a network of "small cell" antennas for 5G use.

- Assembly Joint Resolution 100/Senate JR 96: Encourages the use of television white space technology to increase access to the Internet.

5G Technology Headwinds

The marketplace is still attempting to settle on the final protocols for edge devices and middleware systems that will connect to the 5G network. Other technologies which will be helpful to implementation, such as Web3 design and blockchain, are also in their infancy and need to develop accepted standards before 5G networks can operate at top efficiencies. Unlike 4G, which was developed for a smartphone product that was already available and commercialized in the market, all the use cases for 5G are in development and not currently well commercialized. These include: connected factories, autonomous vehicles, smart city platforms and virtual reality. Until these use cases become commercially viable, it will be hard for providers to justify large scale investments and wide-ranging rollouts of 5G networks, particularly in remote and under-served areas. Thus, it is anticipated that the earliest implementations of the technology will occur in the larger, more technology dense, metropolitan areas of the country. MadREP needs to ensure that its eight-county Region is high on the list of target areas to be served and the network gets built out as quickly as possible.

5G and Business Retention and Attraction Issues

5G will help usher in the IoT era which will result in the commodification of information and data intelligence (West, 2016). Advance manufacturing businesses that are currently investing in IoT technologies, including Spectrum Brands, Sub-Zero Group, Gilson, Faith Technologies, GE Healthcare, Trek, and oneEvent Technologies, will benefit from this transition to 5G. The Region cannot afford to lag the nation on the network rollout or staff believes we risk compromising our competitiveness in retaining and attracting these types of advance manufacturing businesses.

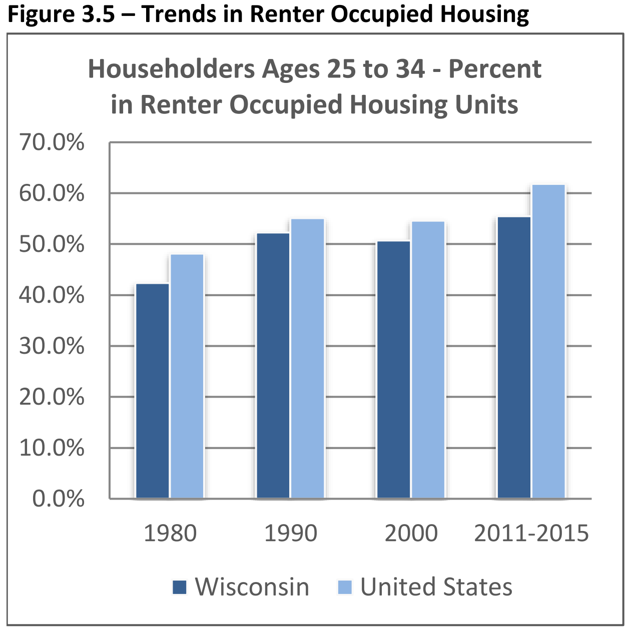
Workforce Housing

The Region's housing market should also be considered as a factor in talent attraction and retention, not only for the advance manufacturing sector, but all industries in the Region. Conversations with the Region's economic development professionals, employers and workforce development organizations suggest that housing cost and availability, particularly for first-time buyers, is emerging as a challenge for many communities. This issue has been particularly acute for advance manufacturing businesses that are struggling to hire a sufficient number of employees to expand and increase profitability. The availability of affordable workforce housing has become a limiting factor in this recruitment process, as employees struggle to live in the community they work and have difficultly absorbing the high transportation costs associate with a large commute.

As a result, workforce housing has become a top issue that many communities are required to address if they are going to successfully retain and attract these types of businesses that are, in many cases, key local economic drivers. This issue has become so important that several government programs, mainly involving the provision of tax credits to private developers, have been created at both the state and federal levels to incent this type of housing development.

Rental unit availability and cost are important considerations to attracting and retaining talent. While younger residents may be driving recent increases in home sales, the rates of young adults living in rental housing have increased over the past several decades. In 1980, when a cohort of Baby Boomers were young, only 48 percent of U.S. residents between the ages of 25 and 34 lived in rental units. Wisconsin's rate that year was even smaller at just 42 percent. By 2015, when this age category consisted of Millennials, the proportion of renters had grown to 62 percent of U.S. residents between the ages of 25 and 34 (Figure 3.5). The Joint Center for Housing Studies of Harvard University notes that factors such as higher levels of student debt, lower incomes and a limited inventory of new starter homes contribute to these higher renter rates. Delayed marriage and household formation rates are also factors.

Figure 3.5 – Trends in Renter Occupied Housing

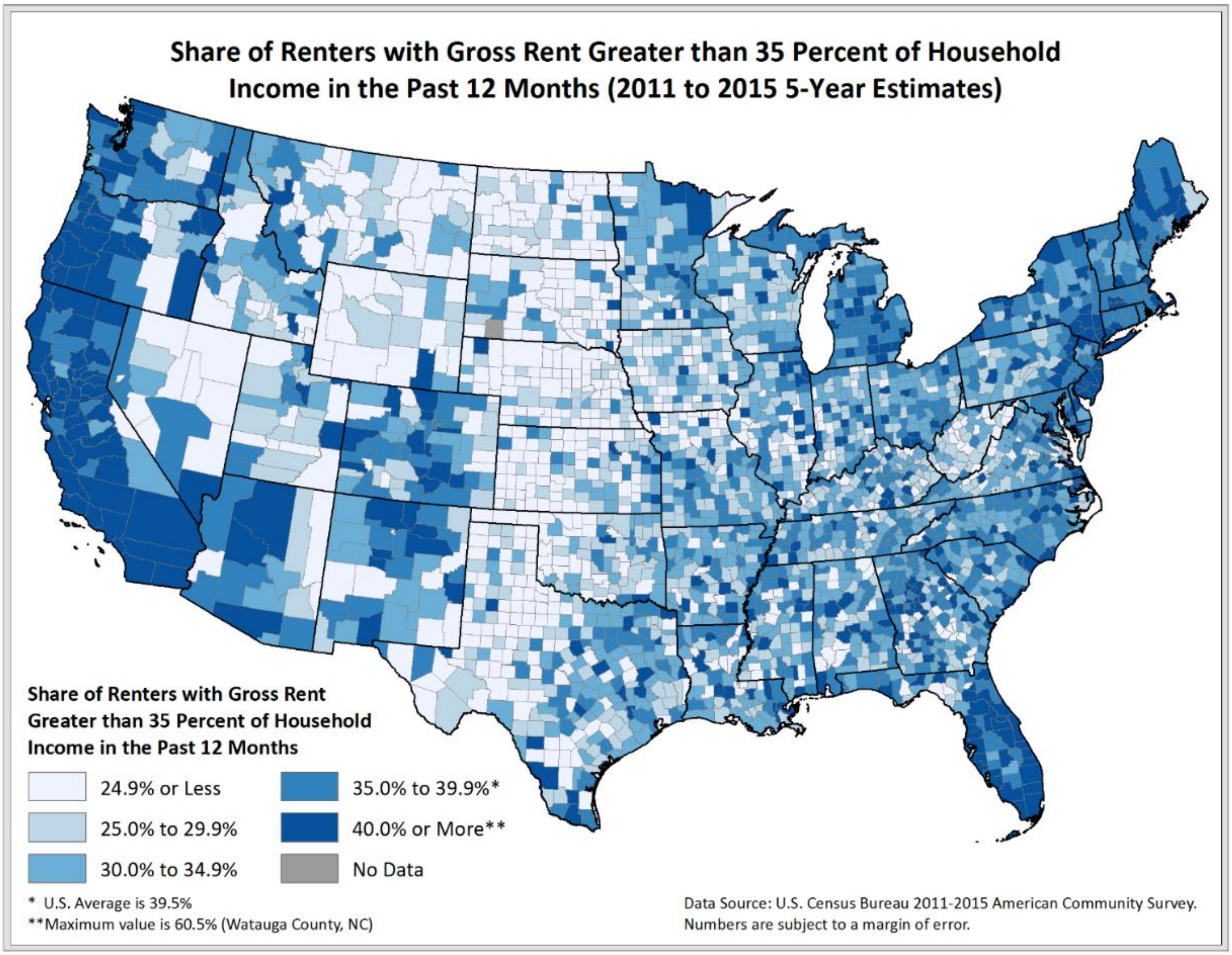


Source: U.S. Census Bureau and Author's Calculations

Using rental housing costs that exceed 35% of household income as a measure of cost burden, rental costs in the Madison Region can be viewed from several perspectives. First, lower shares of renter household in the Madison Region are considered to be cost-burdened relative many areas in the United States. When compared to many other areas along the West Coast, the Mountainous West, the Northeast, the Madison Region has a lower share of households that would be considered as rent burdened, or above the 35% threshold. The Madison Region also has an advantage to neighboring large metro areas such as Minneapolis and Chicago

(Figure 3.6). Second, rates of cost-burdened renter households vary throughout counties and communities within the Madison Region. Dane County and Rock County tend to have a higher share of renter households considered to be cost-burdened while Green and Iowa counties have lower shares. Finally, renter costs do not necessarily describe housing quality. That is, lower costs (and higher costs in some instances) could also be associated with low quality housing stock. Accordingly, the Madison Region will likely need to consider its rental market from both local and regional perspectives. More detailed assessments of housing supply and demand are needed than can be provided in this overview.

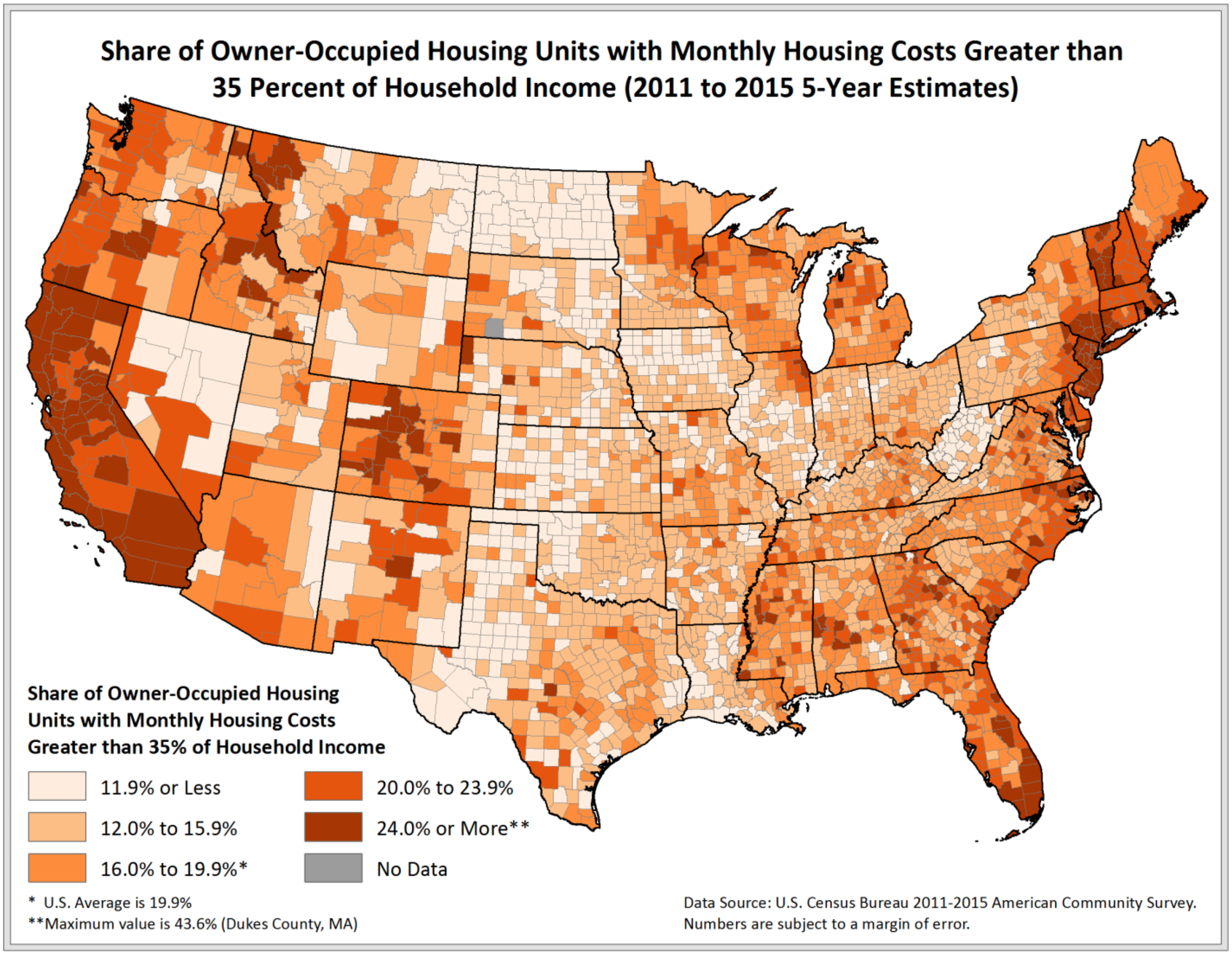
Figure 3.6 – Renter Occupied Housing Units with Monthly Housing Costs Greater than 35% of Income



Similar to rates of renter burdened household, owner occupied housing costs in the Madison Region have lower levels of stress relative to many other areas in the United States. Again, using 35% of income as a threshold for housing stress shows that all counties in the Madison Region have less than 20 percent of their owner-occupied households that exceed this threshold (Figure 3.7). As with cost burdens for renters, many areas on the coasts and in the high amenity mountainous west have more shares of households that may be under housing cost stress. However, the Madison Region does have higher shares of owner-occupied households that are cost burdened than other manufacturing centers in the Fox Valley, Green Bay and Central

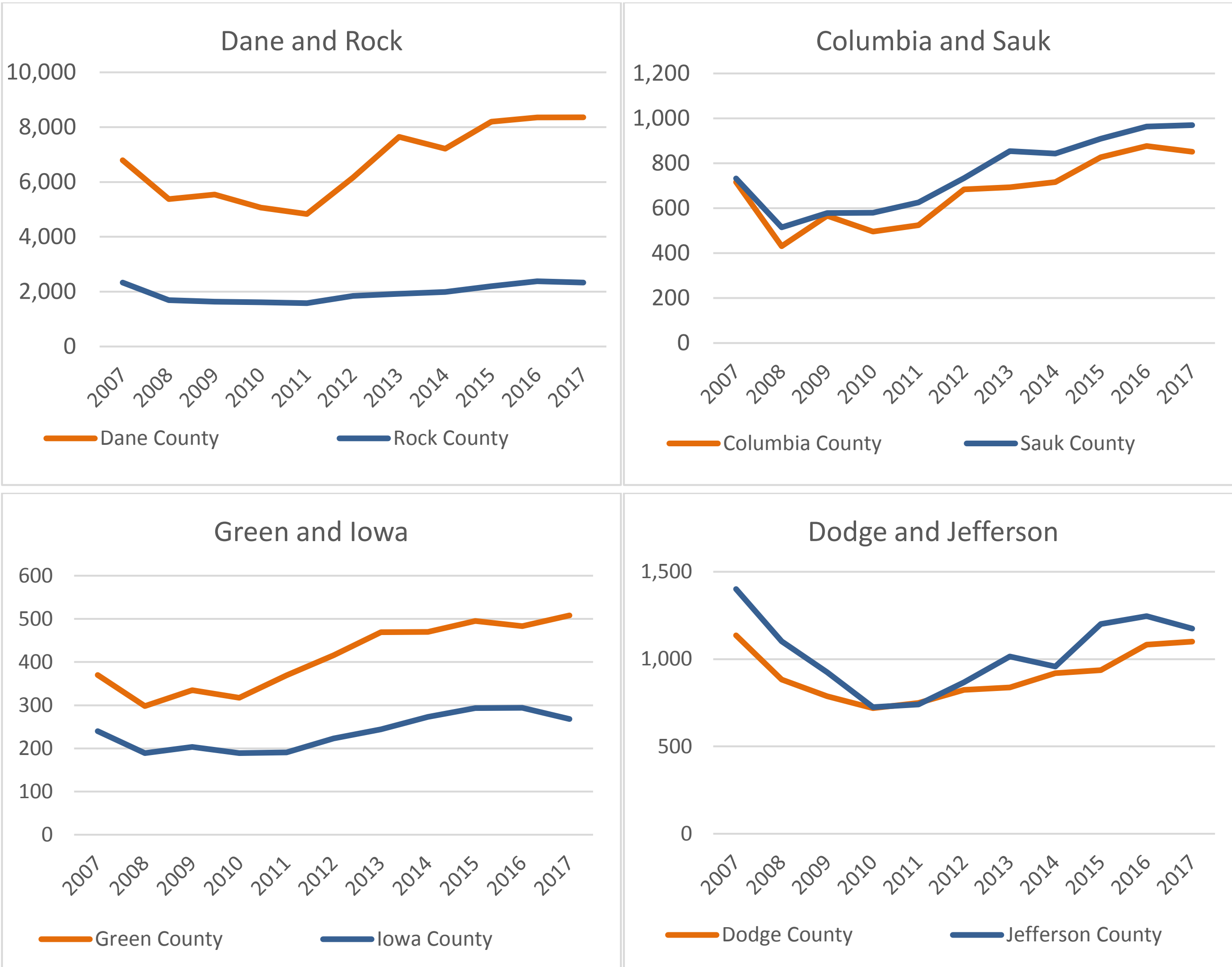
Wisconsin. Higher shares are also found in the Madison Region relative to other regions in the manufacturing belt such as Indiana, Ohio, Pennsylvania and Central Illinois.

Figure 3.7 – Owner Occupied Housing Units with Monthly Housing Costs Greater than 35% of Income



When considering current and future housing costs and availability in the Madison Region, it is important to note that the cost and supply of housing in the Region has experienced a number of changes since the Great Recession. In particular, the number of home sales in most Madison Region counties are above or well above sales volumes at the start of the Great Recession. Dane, Columbia, Sauk and Green counties have seen significant growth in sales over the past six years. Only Jefferson and Rock counties have lagged somewhat in sales activity (Figure 3.8). The recent growth in home sales is partially driven by Millennials who are increasingly entering the housing market.

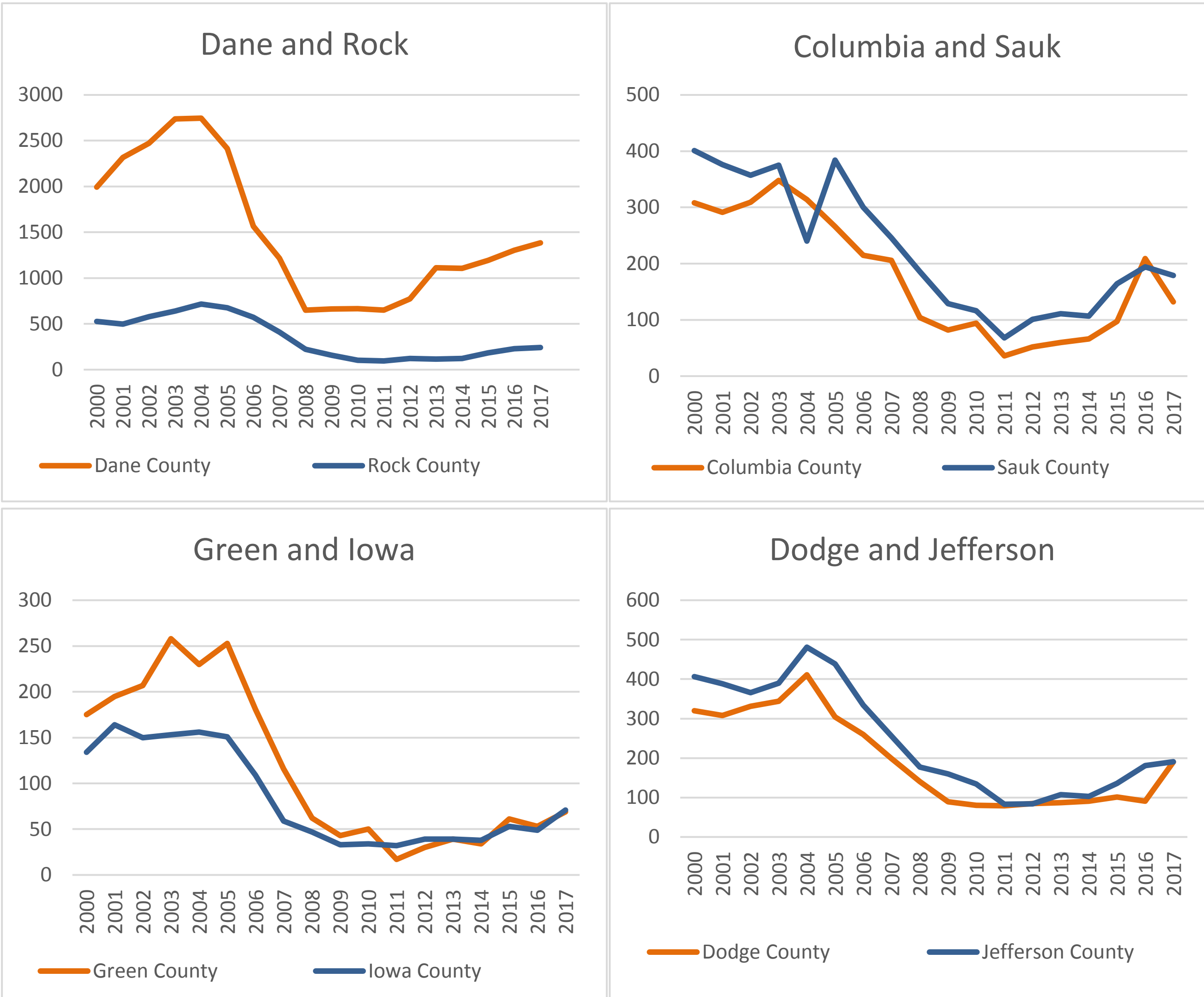
Figure 3.8 – Annual Home Sales by County in the Madison Region



Source: Wisconsin Realtors Association

While sales have rebounded somewhat in the last five years, single family housing permits for new construction continue to remain below their 2007 levels in all counties in the Madison Region with the exception of Dane. From a longer term perspective, single family home permits continue to be well below the levels found in the early 2000s (Figure 3.9). These changes to single family housing market are certainly attributed to lingering effects of the recessionary period, but are due to other factors such as changes to the construction sector. For instance, 82% of builders nationally report labor shortages compared with just 11% in 2011. These shortages drive up builder costs, lengthen building cycle times and hamper construction activity. Labor force conditions in the Region make it unlikely these shortages will change in the near future.

Figure 3.9 – Single Family Home Permits by County in the Madison Region



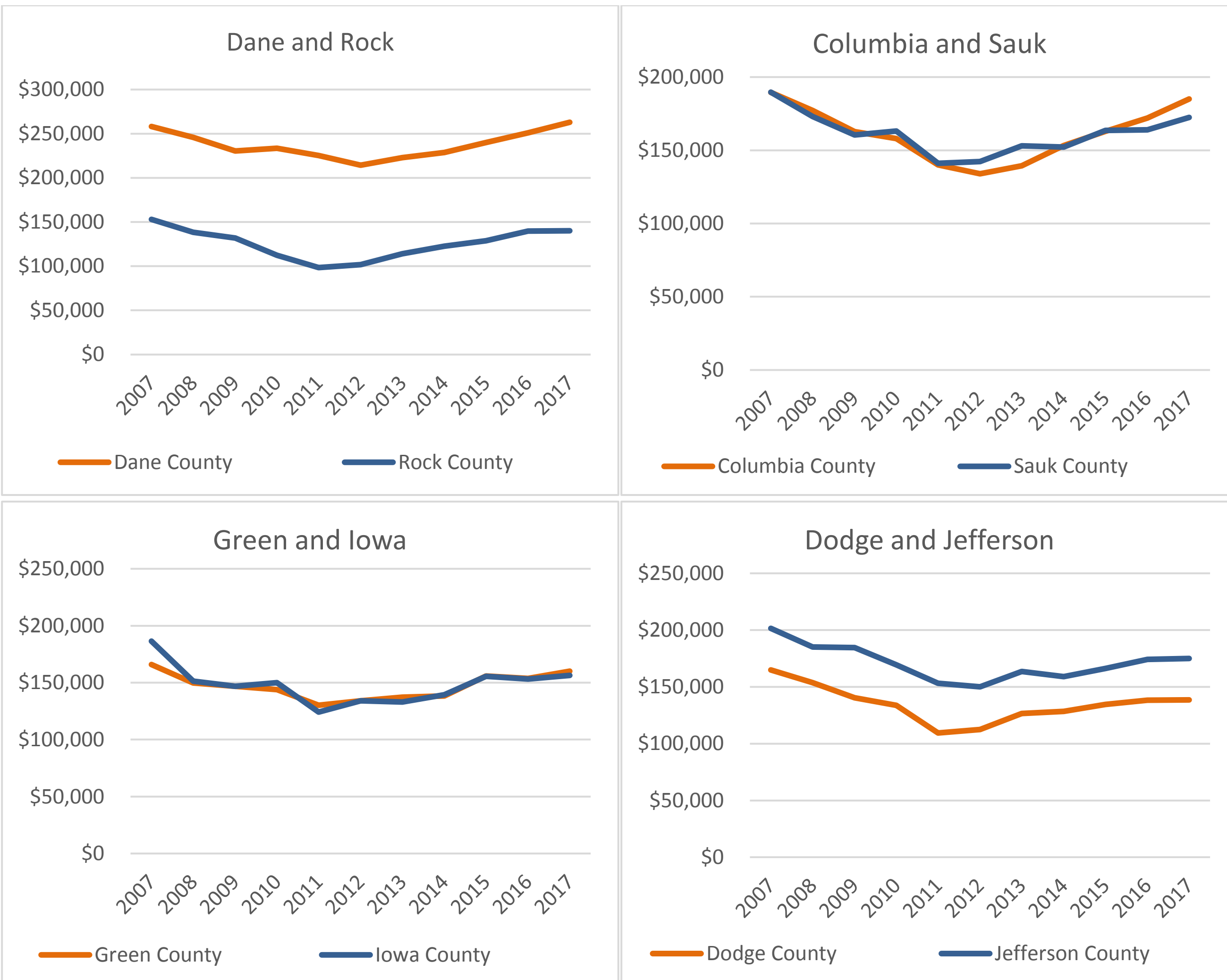
Source: U.S. Census Bureau Business Permits Survey

While not included in this analysis, it is important to note that Dane County has continued to add a significant number of multi-family units, averaging almost 2,500 units per year over the past five years. In 2016 and 2017, Dane County added approximately 3,000 units each year, which were the highest levels in the last two decades. In contrast, other counties have struggled to add multi-family units. Combined, the other seven counties in the Madison Region have only added 250 to 300 total units per year since 2013. If these areas are to attract younger residents, the development of multi-family rental units should be considered as one strategy. Otherwise, outlying counties may not have the housing stock desired by many younger households.

The question with rates of new home construction is whether they will increase in a manner that will keep regional home prices affordable and competitive, particularly for first-time buyers. After adjusting for inflation, the median sales prices for single family homes in most Madison Region counties have rebounded over the last five years and are now approaching 2007 values (Figure 3.10). Dane County is one exception to this trend, where the median sales price now exceeds its 2007 value. In contrast, median sales prices in Dodge and Jefferson counties have not experienced the same levels of increases found in other counties.

While median sales prices have rebounded, they have done so during a period of historically low interest rates. However, average 30 year mortgage rates have increased from 3.96% to 4.52% in the past year. As the Federal Reserve is expected to continue increasing interest rates, mortgage rates will continue to rise as well. As interest rates rise, they will continue to impact the number of households that can afford home mortgages as well as the value of homes that can be purchased.

Figure 3.10 – Median Sales Price by County in the Madison Region



Source: Wisconsin Realtors Association

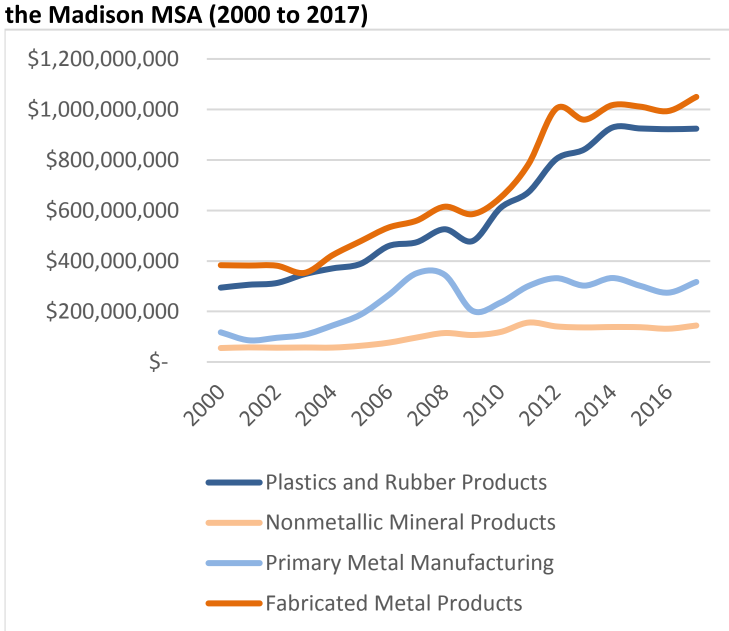
In addition to the government incentive programs which provide developer's tax credits as an incentive to develop more workforce housing, communities can also increase housing supply by implementing zoning and other regulatory changes that encourage development. Key among these are: allowing accessory dwelling units on single family lots, allowing more density within existing residential zoning classifications, and creating incentives and opportunities for more in-fill development.

International Trade

While there are many current unknowns related to federal trade policies, international markets have traditionally been important sources of revenue for local manufacturing firms. Accordingly, helping local manufacturing firms to navigate trade policies and providing export assistance are opportunities for MadREP to assist the advanced manufacturing cluster. These opportunities could be in partnership with WEDC's Global Business Development Program. While international trade figures are not available for the entire Madison Region (and for all categories of advanced manufacturing), figures for the Madison MSA show significant growth in international exports for both plastic products and fabricated metal products (Figure 3.11). While export growth within primary metal products and nonmetallic mineral products has occurred at lesser rates, overall export levels are notable nonetheless. Given the statewide patterns in exports examined below, it is likely the overall Madison Region has experienced similar trends.

Given the lack of detailed export data for the Madison Region, export characteristics for advanced manufacturing in the overall State of Wisconsin are considered. Again, there are likely some differences in the export characteristics of the Madison Region, but the trends in Wisconsin provide important insights into trade developments and key international markets for advanced manufacturing products. In 2017, machinery manufacturing accounted for the largest amount of advanced manufacturing international exports ($4.4 billion) followed by computer and electronic products ($2.74 billion), transportation equipment ($2.73 billion), and chemical manufacturing ($2.03 billion) (Figure 3.12).

Figure 3.11 – Advanced Manufacturing International Exports from the Madison MSA (2000 to 2017)

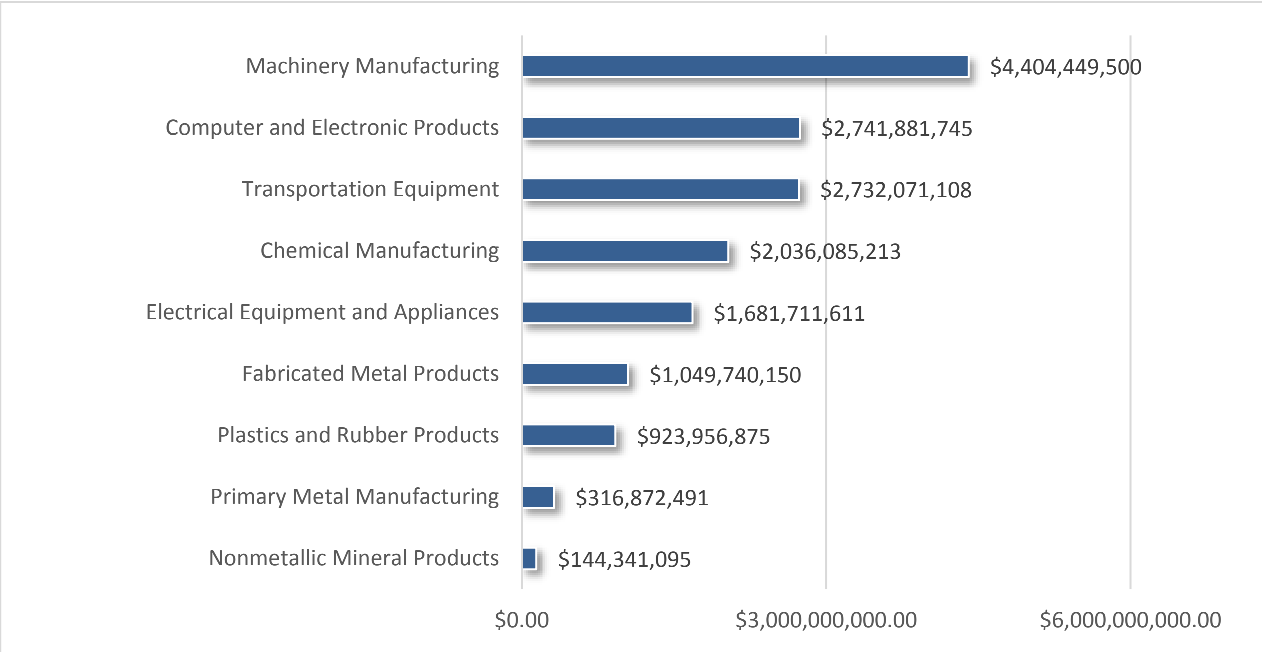


Source: International Trade International Trade Administration and Authors' Calculations

Advanced manufacturing international exports have varied over the last several decades. While the Great Recession had negative impacts on international trade for all categories of advanced manufacturing, many categories of exports have again trended upwards in the post-recessionary period. Machinery manufacturing is the primary exception to this trend as the industry experienced significant declines since 2012. The declines are partially attributed to changes in the mining equipment manufacturing industry during this time period. Furthermore, exports in computer and electronic products, primary metal products and nonmetallic mineral products have remained largely flat since 2006.

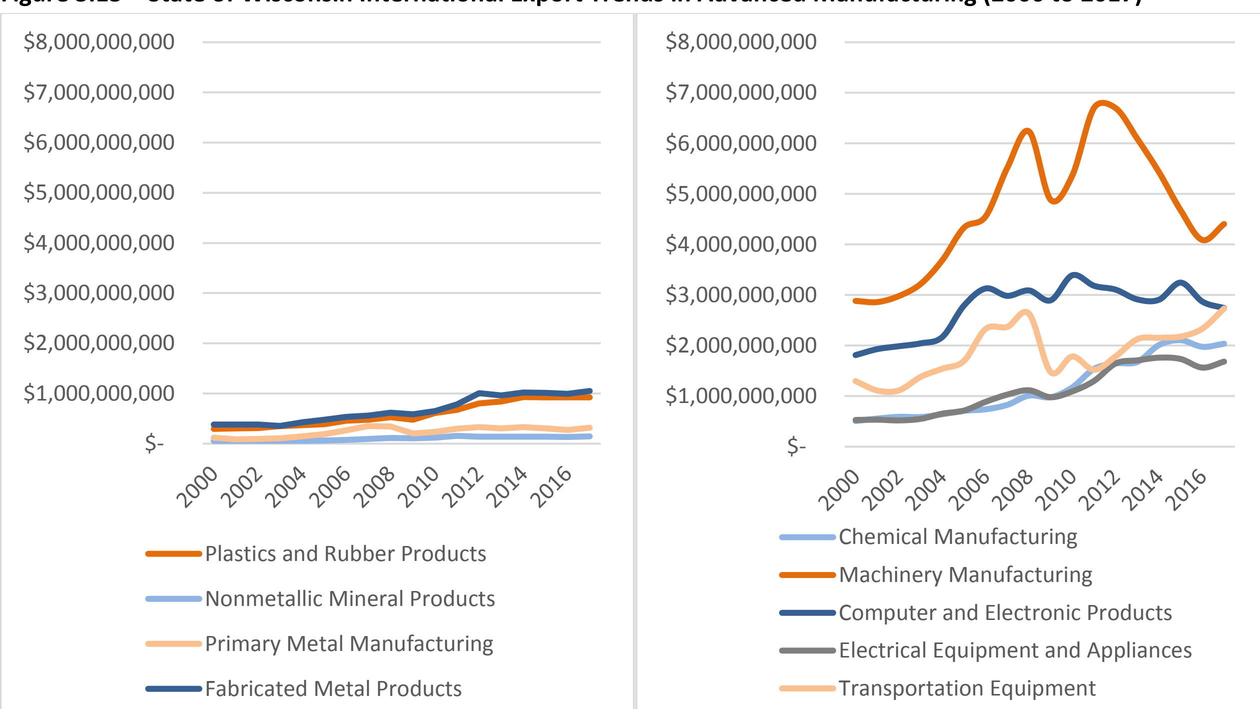
With the exception of computer and electronic components, Canada and Mexico are the top destinations for Wisconsin's advanced manufacturing exports. Accordingly, changes to North American Free Trade Agreement (NAFTA) are particularly important to Wisconsin and Madison Region advanced manufacturing firms. However, China, Japan, U.K. Germany and France are also common destinations that have already been impacted by changes to U.S. trade policies. While these policies have been made at the federal level, the impacts are felt locally and regionally. Accordingly, strategic initiatives developed by MadREP could help local firms adapt to changes while also identifying additional opportunities for export growth.

Figure 3.12 – State of Wisconsin International Exports in Advanced Manufacturing (2017)



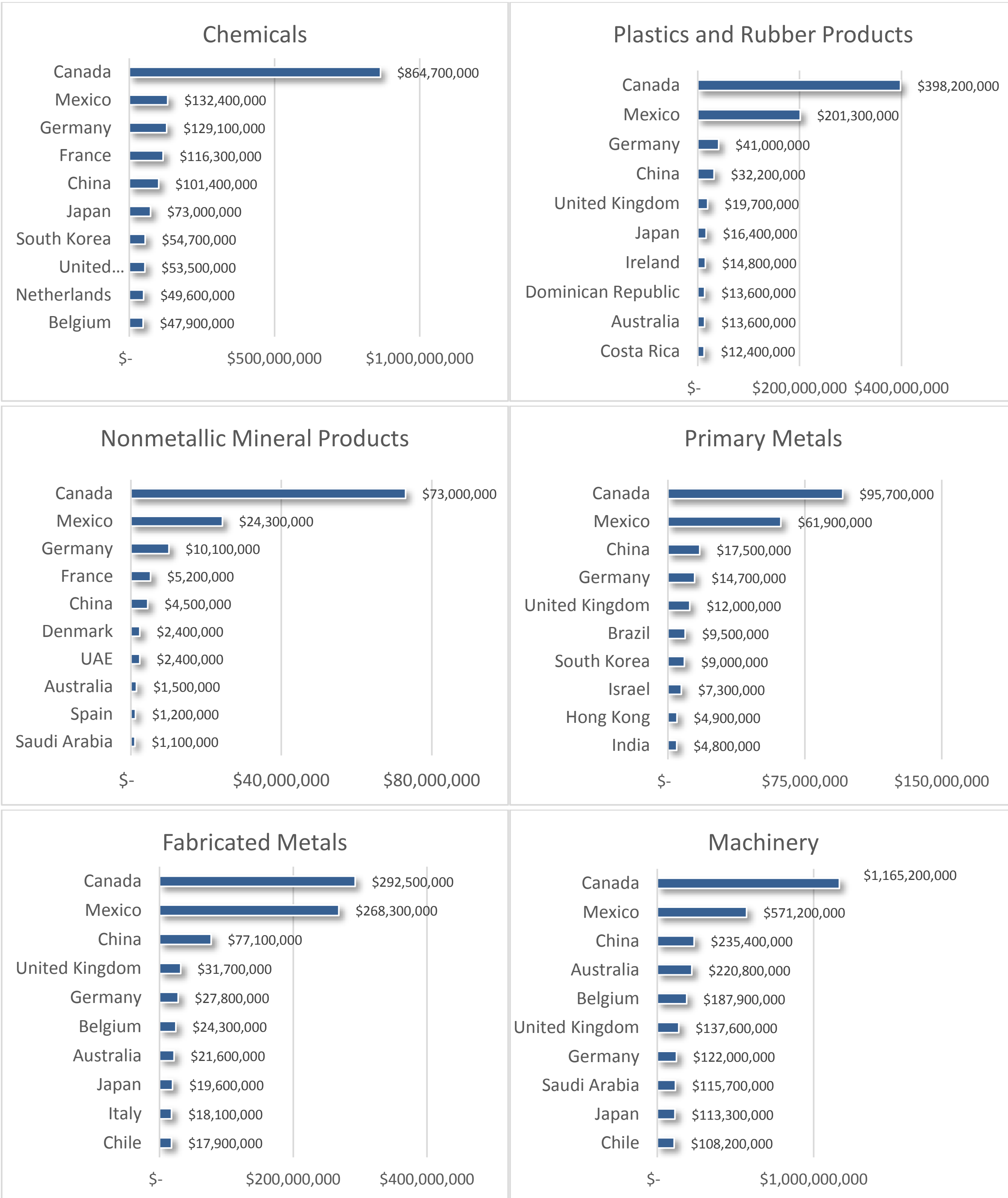
Source: International Trade International Trade Administration and Authors' Calculations

Figure 3.13 – State of Wisconsin International Export Trends in Advanced Manufacturing (2000 to 2017)



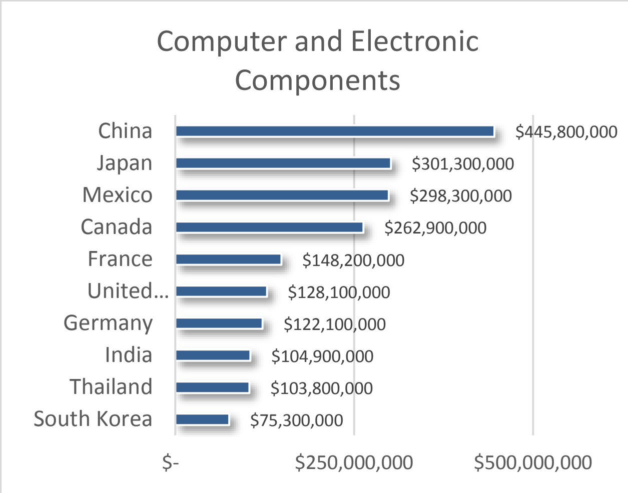
Source: International Trade International Trade Administration and Authors' Calculations

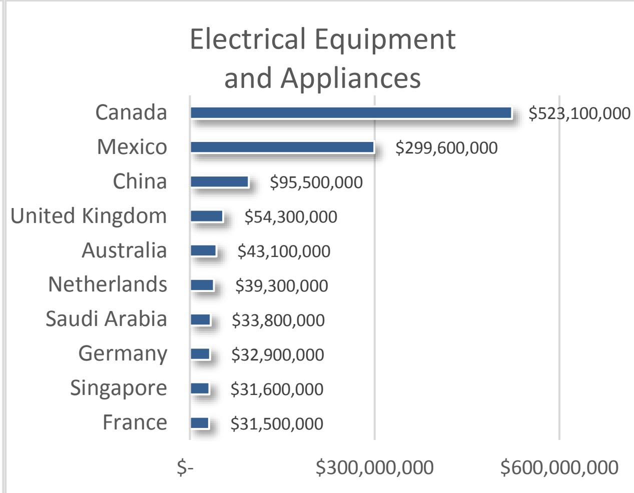
Figure 3.14 – Top 10 Destinations for Wisconsin Exports in Advanced Manufacturing (2015 to 2017 Average)

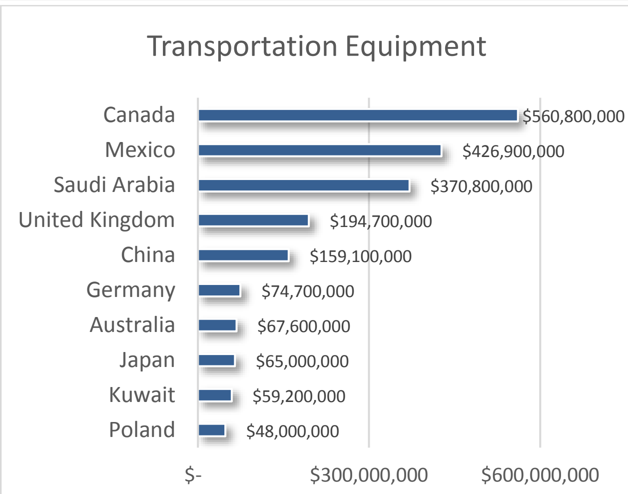


Source: International Trade International Trade Administration and Authors' Calculations

Figure 3.14 (Continued) – Top 10 Destinations for Wisconsin Exports in Advanced Manufacturing (2015 to 2017 Average)







Source: International Trade International Trade Administration and Authors' Calculations

Advanced Manufacturing Purchasing Patterns

Every firm in advanced manufacturing relies on relationships with individual suppliers and service providers. However, the overall advanced manufacturing cluster also depends broadly on specific industry categories for inputs in their supply chains and operations. Some of these dependencies involve commodities or products that are consumed or used directly in production processes. For instance, advanced manufacturers require a variety of metals, plastics, electronics, glasses and other components as parts of their supply chains. However, advanced manufacturing firms also have other dependencies that include specialized support services or products that are indirectly needed by manufacturing establishments, but do not become a part of the final product produced. Specifically, advanced manufacturing establishments may require secondary support from transportation and distribution services; packaging materials; professional and technical services; and machinery manufacturing and repair.

Detailed purchasing information can only be obtained by talking directly with manufacturing firms. However, input-output (I-O) models can also provide some perspective on industry interactions within the advanced cluster. Using a number of assumptions, an I-O model can estimate the magnitude of purchases among industries and approximate what share of these purchases are made within the region.[10] When using purchasing estimates derived from input-output models, it is important recognize that these figures are partially rooted in national purchasing patterns among industry sectors. *Consequently, the purchasing estimates presented below should be used only to guide and inform more targeted research efforts. That is, business and investment decisions should not be based on this information.*

In addition to mapping industry dependencies within the advanced manufacturing cluster, input-output modeling can also be used to explore potential *gaps* and *disconnects* in the region. As noted by Deller (2012), gaps and disconnects occur in the regional economy where there are products and services with high levels of imports. Specifically, a gap occurs when certain goods and services are not sufficiently available within a region and must be purchased elsewhere. There are many reasons for gaps and certain gaps may actually be desirable in those industry categories that could have a negative impact on the local economy and quality of life. In contrast, a disconnect arises when a good or service is available locally, but a cluster establishment chooses to purchase that service outside of the region. Reasons for a disconnect include a lack of information within the business community; long standing partnerships between firms; unfavorable pricing policies; mistrust; or specialization or expertise of firms in a specific industry (Deller, 2012).

When goods and services are purchased outside of the region, these imports can be viewed as a *leakage* of economic activity. Consequently, evaluating gaps and disconnects may suggest opportunities for reducing this leakage through the local provision of these goods and services. That is, there may be opportunities to replace some level of imports with goods and services produced by regional companies. These import replacement opportunities could ultimately suggest prospects for strengthening current businesses in the area or spurring new business development.

[10] For a detailed discussion of input-output models, including their limitations, see Shaffer, Deller and Marcouiller (2004).

To better identify industry interactions in the advanced manufacturing cluster, an input-output model is created using IMPLAN for the eight county Madison Region. The estimated 80 largest categories of goods and services purchased by advanced manufacturers are depicted in Figure 3.15. Each product category in Figure 3.15 includes three figures:

1. The total amount of the product or service purchased by advanced manufacturers in the study area;

2. The estimated amount (output) and percentage of the product purchased locally within the Madison Region;

3. The total dollar value (output) of the product produced by companies currently located within the Madison Region;

Comparing the dollar amount of products purchased to the amount of a product produced in the study area provides some perspective on potential gaps or disconnects. If manufacturers purchase a large amount of a given product, and there is insufficient production of the product in the region, then the product category is a potential gap. In contrast, a disconnect may exist if a product is produced in the region, but manufacturing firms still purchase a large percentage of the product outside the study area.[11] As previously mentioned, any potential gap or disconnect suggested by the data will need to be confirmed with additional primary research. However, the purchasing patterns in Figure 3.15 reveal a number of insights to the advanced manufacturing cluster:

- Not surprisingly, purchasing patterns among advanced manufacturing industries reinforce the strong synergies and potential connections among firms within the cluster. That is, the advanced manufacturing cluster purchases a significant amount of products from within the cluster. Specifically, firms buy a significant amount of metal products, plastic products, electronics, machinery, glass, chemical and other products that are produced by advanced manufacturers. Again, there may be opportunities to further these connections and relationships within the Madison Region given the low estimated shares of local purchases in several categories of plastics, metals and chemicals.

- Wholesale establishments are large providers of goods to advanced manufacturing firms. Wholesalers provide a wide variety of products ranging from production equipment to direct inputs to packaging goods. Unfortunately, the input-output model used in this analysis combines all wholesale categories into a single industry sector, precluding the analysis of specific wholesale gaps or disconnects.

- Several goods and services categories with high levels of importation are not necessarily gaps or disconnects, despite their seemingly large values. For instance, many petrochemicals and refined petroleum products purchased by advanced manufacturing firms are produced by petroleum refineries and related operations that are found in very few, specialized locations throughout the United States.

[11] Note that only so-called *intermediate purchases* are included in these estimates. Intermediate purchases are goods or services purchased by private industries, rather than those bought by households or institutions (e.g. schools). While goods and services purchased by public institutions or private households are important, purchases among industries are of the greatest concern for understanding the region's supply chains.

Figure 3.15 – Goods and Services Used by Advanced Manufacturing Firms in the Madison Region

Good or Service Purchased	Estimated Amount Purchased	Amount Purchased in the Study Area	Study Area Purchase Percentage	Total Existing Regional Output
Wholesale trade distribution services	$1,253,700,000	$1,042,300,000	83.1%	$5,966,400,000
Management of companies and enterprises	$821,100,000	$763,200,000	92.9%	$3,409,800,000
Iron and steel and ferroalloy products	$729,600,000	$2,900,000	0.4%	$63,200,000
Plastics materials and resins	$466,800,000	$1,000,000	0.2%	$92,100,000
Petrochemicals	$412,500,000	$100,000	0.0%	$23,900,000
Other basic organic chemicals	$338,300,000	$1,800,000	0.5%	$877,500,000
Aluminum sheets, plates, and foils	$316,700,000	$1,500,000	0.5%	$35,300,000
Biological products (except diagnostic)	$214,900,000	$23,900,000	11.1%	$546,400,000
Other engine equipment	$211,100,000	$1,600,000	0.8%	$405,700,000
Truck transportation services	$209,800,000	$179,800,000	85.7%	$1,240,000,000
Other motor vehicle parts	$205,100,000	$2,300,000	1.1%	$89,500,000
Aluminum products	$189,400,000	$200,000	0.1%	$6,800,000
Semiconductors and related devices	$186,100,000	$200,000	0.1%	$7,200,000
Electricity transmission and distribution	$172,400,000	$158,200,000	91.8%	$1,418,400,000
Plastics packaging materials and unlaminated films/sheets	$164,000,000	$7,500,000	4.6%	$364,700,000
Motors and generators	$155,400,000	$11,700,000	7.5%	$327,600,000
Paperboard containers	$145,500,000	$11,800,000	8.1%	$173,200,000
Other plastics products	$134,700,000	$12,100,000	9.0%	$1,212,900,000
Machined products	$130,200,000	$6,100,000	4.7%	$160,400,000
Printed circuit assemblies (electronic assemblies)	$127,700,000	$700,000	0.5%	$53,800,000
Crowned and stamped metals	$123,000,000	$10,400,000	8.5%	$148,900,000
Paints and coatings	$118,700,000	$3,000,000	2.5%	$78,100,000
Advertising, public relations, and related services	$118,200,000	$72,700,000	61.5%	$1,132,900,000
Turned products and screws, nuts, and bolts	$117,200,000	$4,400,000	3.8%	$81,500,000
Refined petroleum products	$114,100,000	$0	0.0%	$200,000
Motorcycles, bicycles, and parts	$111,400,000	$10,700,000	9.6%	$706,600,000
Leasing of nonfinancial intangible assets	$107,500,000	$103,300,000	96.1%	$898,400,000
Rolled, drawn, extruded, and alloyed copper	$101,200,000	$100,000	0.1%	$40,700,000
Motor vehicle gasoline engines and engine parts	$83,600,000	$100,000	0.1%	$72,400,000
Ferrous metals	$83,000,000	$7,500,000	9.0%	$320,400,000
Securities and commodity contracts intermediation	$78,800,000	$40,500,000	51.4%	$298,600,000
Valve and fittings, other than plumbing	$78,700,000	$1,100,000	1.4%	$57,700,000
Maintained and repaired nonresidential structures	$78,000,000	$77,500,000	99.4%	$773,100,000
Architectural, engineering, and related services	$77,100,000	$66,700,000	86.5%	$886,500,000
Medicines and botanicals	$76,600,000	$15,300,000	20.0%	$85,900,000
Heavy duty trucks	$76,200,000	$1,900,000	2.5%	$137,900,000
Marketing research	$75,900,000	$40,200,000	53.0%	$237,900,000
Fluid power pumps and motors	$72,800,000	$500,000	0.7%	$73,300,000
Natural gas distribution	$72,100,000	$6,300,000	8.7%	$26,200,000
Other basic inorganic chemicals	$68,800,000	$5,900,000	8.6%	$191,200,000

Figure 3.15 – Goods and Services Used by Advanced Manufacturing Firms in the Madison Region (Continued)

Good or Service Purchased	Estimated Amount Purchased	Amount Purchased in the Study Area	Study Area Purchase Percentage	Total Existing Regional Output
Rail transportation services	$68,800,000	$32,600,000	47.4%	$130,400,000
Aircraft engines and engine parts	$67,000,000	$700,000	1.0%	$104,400,000
Noncomparable imports	$65,300,000	$0	0.0%	$0
Relay and industrial controls	$65,300,000	$700,000	1.1%	$92,700,000
Motor vehicle seating and interior trim	$64,400,000	$1,600,000	2.5%	$321,100,000
Monetary authorities and depository credit intermediation	$64,300,000	$43,900,000	68.3%	$1,339,400,000
Scrap	$62,800,000	$32,400,000	51.6%	$84,100,000
Air conditioning, refrigeration, and warm air heating equip.	$61,500,000	$2,700,000	4.4%	$248,000,000
Other rubber products	$61,100,000	$4,800,000	7.9%	$91,000,000
Nonferrous metals	$60,000,000	$4,700,000	7.8%	$172,700,000
Tires	$57,300,000	$0	0.0%	$500,000
Waste management and remediation services	$57,100,000	$42,000,000	73.6%	$366,700,000
Nonferrous metal (exc aluminum) smelting and refining	$56,000,000	$0	0.0%	$4,200,000
Motor vehicle electrical and electronic equipment	$55,300,000	$100,000	0.2%	$3,500,000
Metal barrels, drums and pails	$54,200,000	$1,200,000	2.2%	$11,700,000
Metal cans	$53,800,000	$16,700,000	31.0%	$582,300,000
Other electronic components	$53,500,000	$800,000	1.5%	$54,700,000
Sheet metal work (except stampings)	$52,300,000	$2,700,000	5.2%	$103,100,000
Data processing, hosting, and related services	$51,500,000	$46,600,000	90.5%	$699,200,000
Pharmaceuticals	$49,900,000	$4,900,000	9.8%	$939,700,000
Balls and roller bearings	$46,900,000	$0	0.0%	$1,800,000
Air transportation services	$45,700,000	$1,200,000	2.6%	$24,600,000
Iron and steel forgings	$45,200,000	$4,100,000	9.1%	$102,100,000
Other fabricated metals	$44,000,000	$4,400,000	10.0%	$443,900,000
Motor vehicle steering, suspension components/brakes	$43,400,000	$0	0.0%	$4,700,000
Wired telecommunications	$42,900,000	$40,700,000	94.9%	$1,352,300,000
Other miscellaneous chemical products	$42,100,000	$1,700,000	4.0%	$57,200,000
Management consulting services	$40,100,000	$20,000,000	49.9%	$504,300,000
Coated and engraved products	$39,800,000	$3,300,000	8.3%	$111,400,000
Fabricated structural metal products	$39,600,000	$2,300,000	5.8%	$80,200,000
Insurance agencies, brokerages, and related services	$39,500,000	$31,400,000	79.5%	$1,531,900,000
Rolled, drawn, and extruded aluminum	$38,800,000	$300,000	0.8%	$12,900,000
Accounting, tax preparation, bookkeeping & payroll svcs.	$37,000,000	$18,000,000	48.6%	$312,000,000
Secondary processing of other nonferrous metals	$36,200,000	$0	0.0%	$2,900,000
Rubber and plastics hoses and belts	$35,700,000	$6,300,000	17.6%	$78,800,000
Legal services	$35,600,000	$18,000,000	50.6%	$636,500,000
Broadcast and wireless communications equipment	$35,500,000	$0	0.0%	$5,600,000
Nonferrous metal, except copper and aluminum, shaping	$35,200,000	$0	0.0%	$2,500,000
Employment services	$35,100,000	$26,200,000	74.6%	$848,500,000
Computer storage devices	$34,100,000	$0	0.0%	$5,800,000

Sources: IMPLAN and Author's Calculations

- Advanced manufacturing is highly dependent on truck transportation, with a large estimated share of these services purchased locally. Rail transportation and air transportation also constitute important components of the advanced manufacturing distribution system. Transportation characteristics of advanced manufacturing products are explored later in Section 3.

- Advanced manufacturers are large users of metal, plastic, and paper packaging goods. Purchasing patterns for plastics packaging materials and paperboard containers suggest two potential disconnects in the Region. However, these disconnects may not be surprising given that the State of Wisconsin is a national leader in production for many of these packaging materials. It may be that these products do not need to be purchased locally as advanced manufacturing establishments have access to large concentrations of packaging material manufacturers in other parts of the state.

- Several categories of purchases suggest that local demand potentially outpaces local supply. For instance, the advanced manufacturing industry purchases $186 million in semiconductors and other related devices while only $7.2 million of these products are produced in the region. Similar gaps are found within plastic resins, aluminum products, metal barrels and drums, printed circuit assemblies, paints and coatings, valves and fittings, turned metal products, copper products, balls and roller bearings and many types of motor vehicle components.

- Other categories where advanced manufacturing demand accounts for almost all of the supply in the region include machined products, crowned and stamped metals, medicines and botancials, fluid pumps and motors, other electronic components and other miscellaneous chemical products.

- For those products where demand exceeds supply (i.e. gaps) or demand matches supply, there are several products that are unlikely to be met with a new or expanded local supplier. For instance, plastic resins and many metal products are produced in few places in the United States. Some of these products may also be cheaper on the international market. Other categories, such as those related to machined products or crowned and stamped metals, could provide local opportunities for import substitution. Again, the data provided here is a starting point for further conversations and ground-truthing with local advanced manufacturing firms.

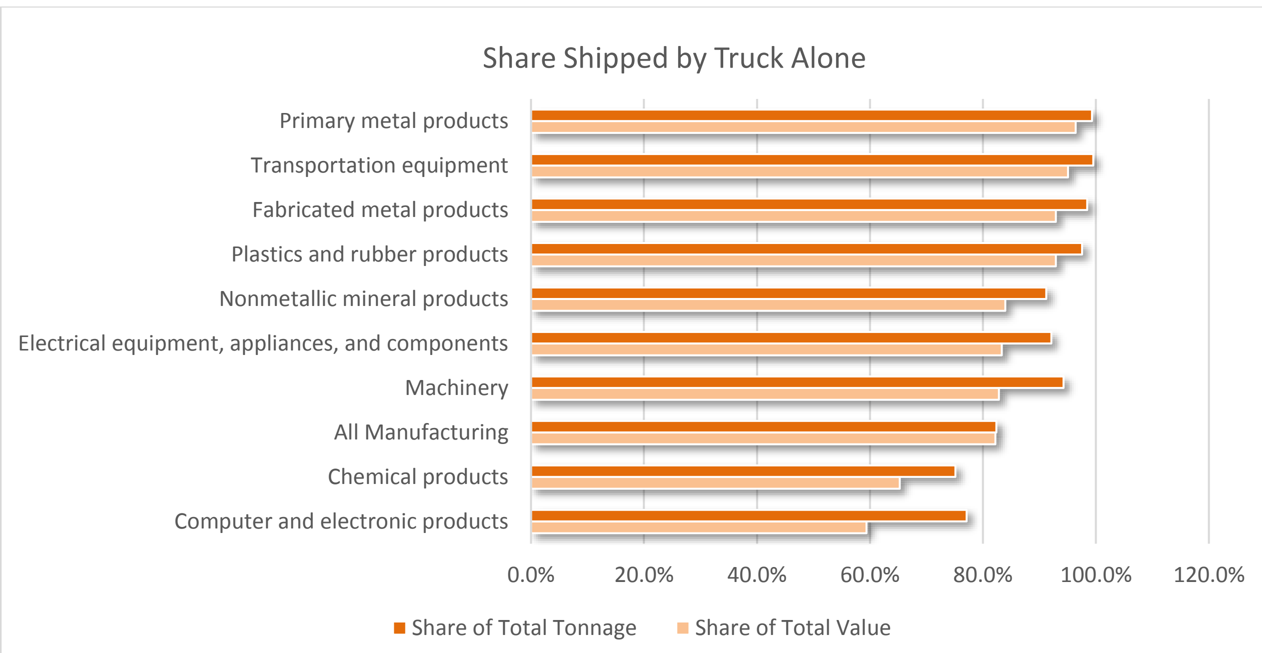
- Advanced manufacturing firms are large purchasers of professional, technical and administrative services such as management consulting services, accounting, legal services, employment services, engineering services and insurance services. MadREP could consider creating a directory of providers of these services who have expertise or specializations in working with advanced manufacturing firms.

Transporation Modes and Market Access

Advanced manufacturers rely on a variety of transportation modes to distribute and receive products. Unfortunately, product transportation characteristics specific to the Madison Region are unavailable. However, Wisconsin specific characteristics of advanced manufacturing products provide perspectives on how the cluster typically moves goods from producers to customers. Specific modes of transportation for each category of advanced manufacturing are listed in Appendix 3B.

In terms of total value of shipments, the advanced manufacturing industry relies heavily on single-mode truck transportation. Plastic and rubber products, primary metal products, fabricated metal products and transportation equipment manufacturers ship over 90% of their product value and tonnage by truck alone (Figure 3.16). Other advanced manufacturing categories also are highly dependent on truck transportation. Unfortunately, road funding remains a challenging issue in the State of Wisconsin. As noted by Conroy, Kures and Deller (2018), creating a sustainable approach to road funding is necessary to truly support manufacturing statewide. While funding must consider the potential improvement of freeways, funding for last mile and local roads is also important to many manufacturing firms in urban and rural areas.

Figure 3.16 – Share of Advance Manufacturing Products Shipped by Truck Alone



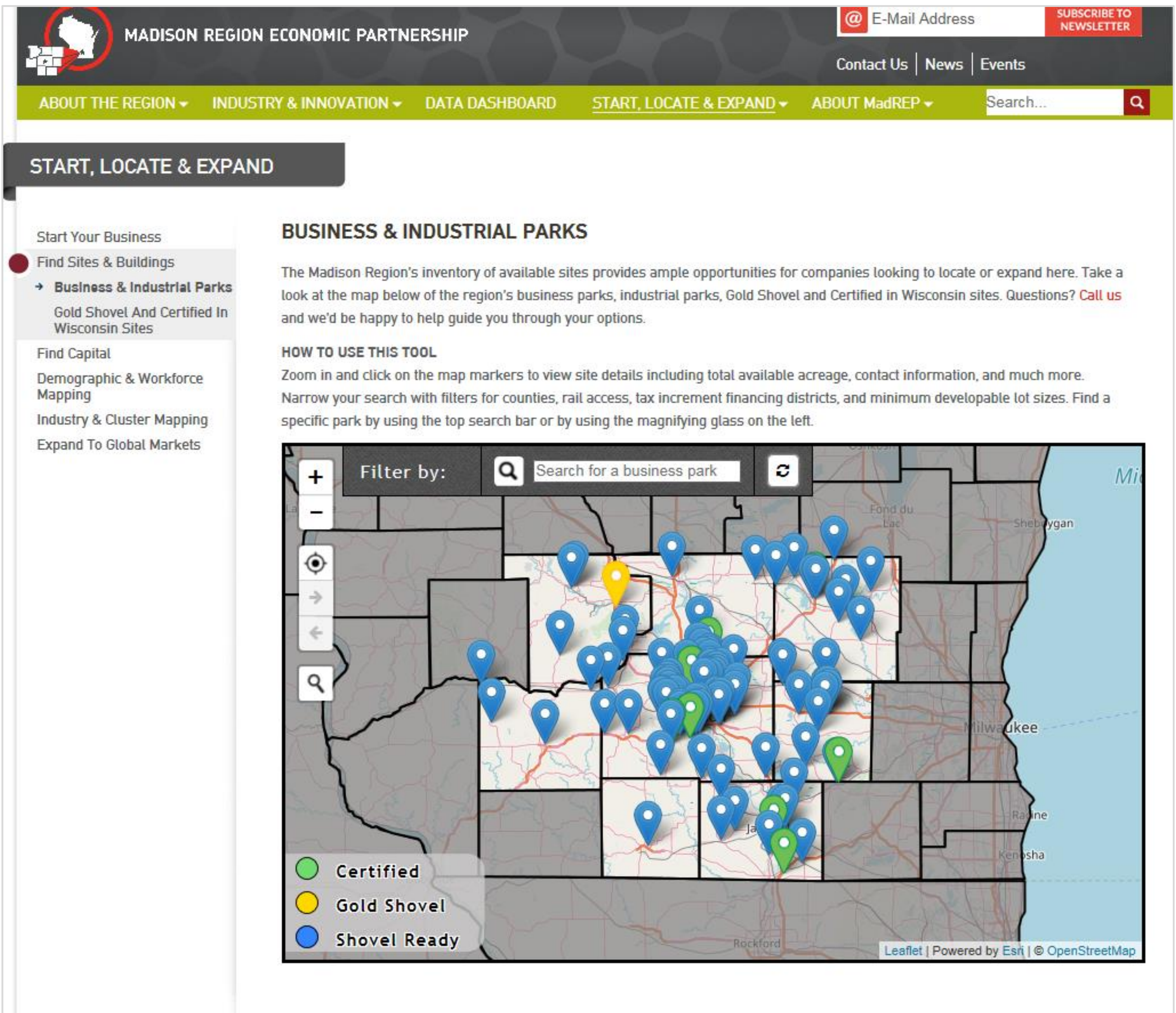
In addition to truck transportation, both rail services and air transportation are important to several categories of advanced manufacturing. Chemical manufacturing relies on rail transportation to ship 10.8% of products by value and 15.5% of products by tonnage. Chemical manufacturing also uses air transportation for a small, but important amount of products, often in the form of pharmaceuticals. Nonmetallic mineral products also has a notable reliance on rail transportation, while computer and electronic components has a somewhat larger dependence on air transportation.

Business and Industrial Parks, Certified and Gold Shovel Sites, and Speculative Buildings

There are many real estate based assets that are available to assist targeted industries, including advance manufacturing businesses, find suitable locations to start or expand their operations in the Region. A summary of three of these assets are provided below.

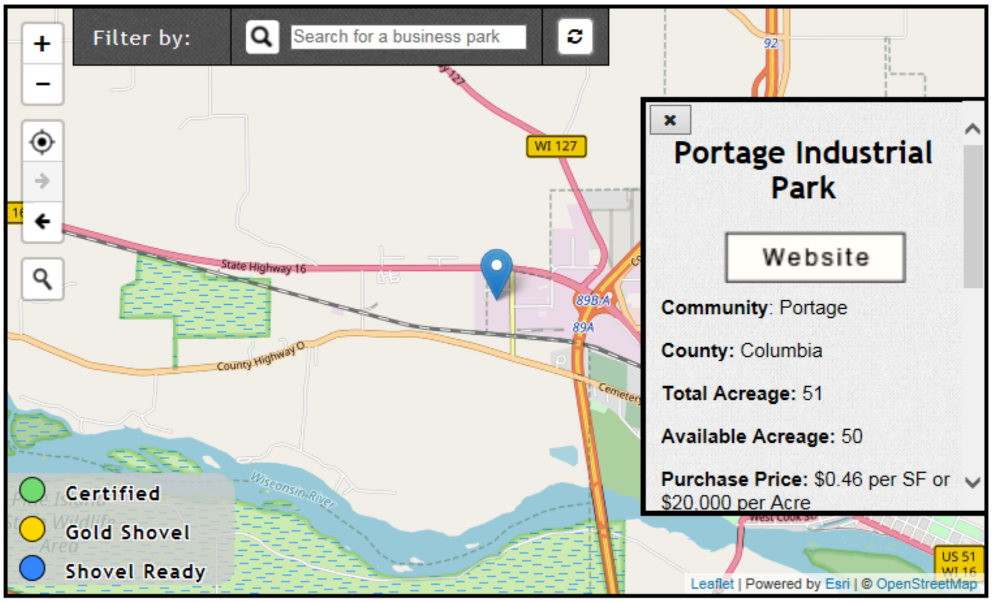
- *Business and Industrial Parks* - MadREP maintains an interactive map of all 103 business and industrial parks located in the Region. In 2017, these parks totaled a combined 11,000 acres (115 acres average) of which 4,200 acres were available for development (48 acres average). See http://madisonregion.org/start-locate-expand/find-sites-and-buildings/business-industrial-parks/ for a link to the map. A screen shot of the mapping tool is provided below along with a pop-out dialogue box for the Portage Industrial Park showing the information included when a user clicks on the mapping icons.

Figure 3.17 – Screen Shot of MadREP Interactive Business and Industrial Park Mapping Tool



Source: MadREP

Figure 3.18 – Screen Shot of Dialogue Box for Portage Enterprise Center



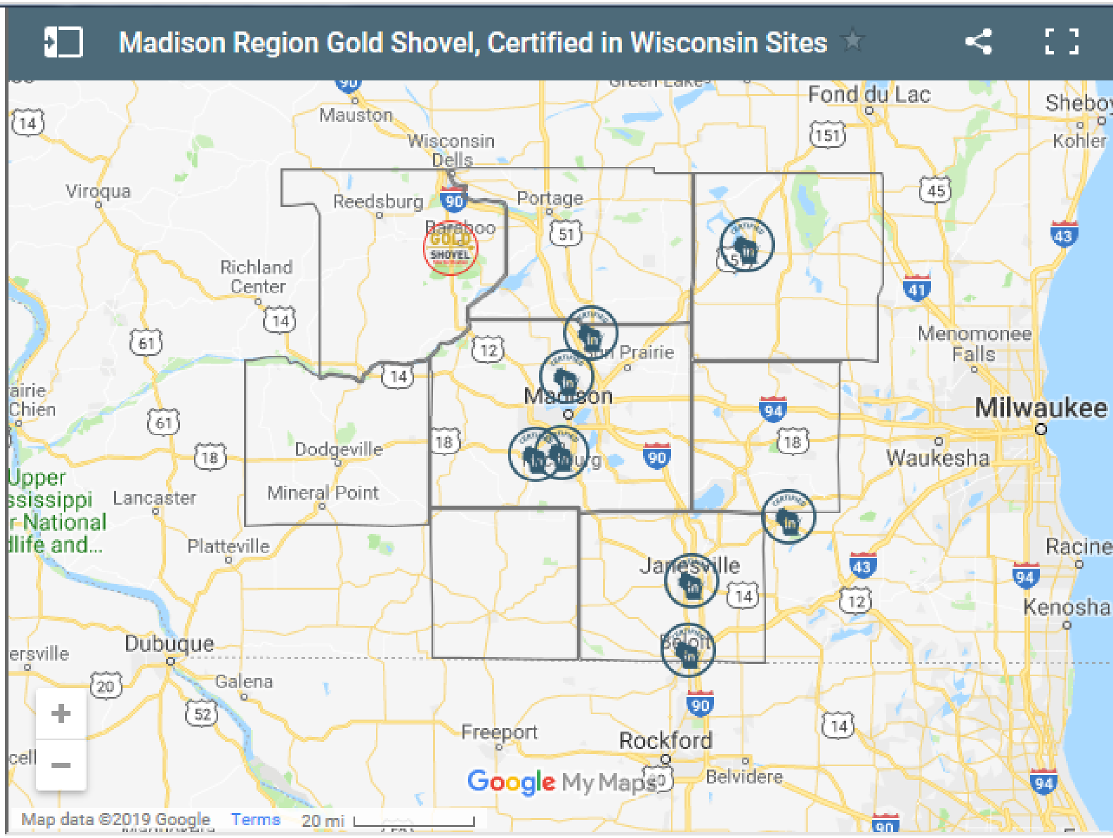
Source: MadREP

- *Certified and Gold Shovel Sites* – The WEDC developed the Certified In Wisconsin® program to set consistent standards for the certification of industrial sites, putting in place all the key reviews, documents and assessments most commonly required for industrial use. Certified sites mean faster turnaround times, quicker approvals and lower risk for businesses seeking developable land for a start-up or expansion project. There are currently eight certified sites located in the Region (or 38.1% of the 21 total sites located in the state) representing a combined 950 developable acres of land.

  Similar to the Certified program, the Gold Shovel Site Verification Program assists communities, counties, and private land owners in packaging and marketing development ready land to site selectors and business owners looking to locate or expand in the Region. However, in this case, the approval process is available to the site's developer at lower cost, making it a more attractive option particularly for smaller sites. Under the Gold Shovel program, administered by MadREP, a site is not held to the same level of review, documentation, and assessment as the Certified site program, but the designation does provide some assurance to a business that a site is ready for development shortly following a close. The program currently has one approved 26.66 acre site located in Baraboo. Four additional sites are currently going through the approval process in Evansville, Whitewater, Horicon and Madison.

  See http://madisonregion.org/start-locate-expand/find-sites-and-buildings/gold-shovel-sites/ for an up to date listing and map showing the location of all the Certified in Wisconsin and Gold Shovel sites in the Region (a screen shot of the most recent landing page is provided below).

Figure 3.19 – Screen Shot of Madison Region Gold Shovel and Certified in Wisconsin Sites Landing Page



GATEWAY BUSINESS PARK Baraboo, Wisconsin Ideally located off the newly completed Highway 12 (slated to open in 2017) at the entrance to the City of Baraboo. Read more.	**BEAVER DAM 151 BUSINESS PARK** Beaver Dam, Wisconsin A brand new, 200-plus-acre corporate park development bordered on the east by Highway 151. Read more.
DEFOREST BUSINESS PARK DeForest, Wisconsin DeForest's Business Park is located on 115 acres on US 51 adjacent to existing industrial uses. Read more.	**GATEWAY BUSINESS PARK** Beloit, Wisconsin The new Gateway Business Park is easily accessible on the east side of the Interstate. Read more.
HIGHWAY 11 BUSINESS PARK Janesville, Wisconsin A 224-acre business park located on the southern side of the city, along Hwy 11, east of I-90/39. Read more.	**LIBERTY BUSINESS PARK** Verona, Wisconsin This 130-acre site fronts US Hwy 151, which connects to US Hwys 12/18, then to I-90/39/94. Read more.
NORTH MENDOTA ENERGY AND TECHNOLOGY PARK Westport, Wisconsin 33 acres of contiguous buildable land 5 miles away from I-94 and I-90/39. Read more.	**RDC FITCHBURG TECHNOLOGY CAMPUS PHASE II** Fitchburg, Wisconsin Easily accessible and located within minutes of commercial activity and area amenities. Read more.
WHITEWATER UNIVERSITY TECHNOLOGY PARK Whitewater, Wisconsin A 35-acre park on the east side of the city with convenient access to I-90. Read more.	

Source: MadREP

- *Speculative Buildings* – A robust inventory of speculative buildings is an important economic development asset to the Region, in that it represents property that can be quickly occupied by either expanding or new businesses starting or relocating to the area. This is an important tool used retain and attract businesses to the Region without requiring the extensive lead time necessary to obtain approvals and construct new space. It is particularly important for businesses that would like to try operating in the Region prior to making a sizable capital investment in real estate.

  In analyzing the site selection activity engaged by MadREP over the most recent three year period, it is clear that many of the projects are looking for either an existing manufacturing or office building space as part of their search parameters (see Figure 3.20). In 2017, the median square footage being sought was 90,000 sf for manufacturing and 75,000 sf for office space. In this same year, there were only two spaces available in the entire Region that could even marginally meet these specifications, which made it difficult for MadREP and the Region to compete with larger metropolitan areas on these searches.

Figure 3.20 - MadREP Site Selection Summary by Year

Criteria	2016	2017	2018
Foreign Direct Investment Projects	7	8	4
National Projects	15	17	20
Regional Projects	6	9	3
Total Projects	**28**	**34**	**37**
Seeking Existing Manufacturing Building	11	17	11
- Total Square Footage	1,500,000 sf	3,400,000 sf	325,000 sf
- Median Square Footage	75,000 sf	90,000 sf	10,000 sf
Seeking Existing Office Building	2	6	9
- Total Square Footage	210,000 sf	501,500 sf	265,000 sf
- Median Square Footage		75,000 sf	35,000 sf
Seeking Greenfield Site	9	13	9
- Total Acreage	1,145 acres	1,470 acres	926 acres
- Median Acreage	15 acres	25 acres	30 acres
Seeking Incentives Only	2	11	
Job Creation (Total)	659 FTE	4,700 FTE	1,799 FTE
Job Creation (Median)	25 FTE	40 FTE	82 FTE

Source: MadREP

As a result of this activity, MadREP staff sought to inform local communities and developers of the difficulties the organization was experiencing competing without a larger inventory of speculative buildings. MadREP developed a KSI for increasing the inventory of available space, including a particular focus on buildings greater than 100,000 sf with 30’ to 32’ side walls. In 2018, these efforts paid off with the development of two new speculative buildings, both located in Dane County, representing a combined 270,000 sf of space. In addition, two new projects are currently being planned for development in the City of Janesville (Rock County) representing a combined 402,000 sf of space. These projects are being planned by Zilber, Ltd. (302,000 sf on the City’s south side) and Badger Property Investments (100,000 sf on the City’s east side). Finally, the former Oscar Mayer site on Madison’s north side, representing 1,700,000 sf and 70 acres (of which 1,283,000 sf is available for sale or lease), was purchased by Reich Brothers Holdings and Rabin Worldwide and is being reposition as potential speculative space in the local market. Details regarding the two newest buildings and the Oscar Mayer site, rebranded as OM Station, are detailed below.

- Interstate Partners, LLC – Commerce I at Park 151, 2840 Innovation Way, Sun Prairie
  Website: http://www.interstatepartners.com/property/64

Picture credit: Interstate Partners, LLC

Figure 3.21 - Building Specifications: Commerce I at Park 151

Size	130,000 sf
Dimensions	650’ x 200’
Bay Size	50’ x 50’
Construction	Precast concrete panels
Divisibility	Approximately 20,000 sf
Clear Height	28’
Lighting	LED interior and exterior
Docks	11 exterior with levelers and seats (expandable)
Drive-in Doors	4 (expandable)
Truck Court	130’ concrete pads
Parking	233 spaces
Fire Protection	Fully sprinklered with ESFR
Power	3,000 amps, 480/277 volt, 3-phase, 4-wire service
Heat	Gas-fired unit heaters and anti-stratification fans
Zoning	Suburban Industrial

Source: Interstate Partners, LLC

- Greywolf Partners, Inc. and Rizzo Development Group, LLC – 3319 John Wall Drive, Madison
  Website: https://www.greywp.com/Properties/Details/dfe69e08-f6da-4751-8257-5b7e344da333

Picture Credit: Greywolf Partners and Rizzo Development

Figure 3.22 - Building Specifications: CIC Industrial Spec Space

Size	138,802 sf
Divisibility	32,000 sf
Bay Size	50' x 50' with a 60' speed bay
Construction	Precast concrete panels
Clear Height	32'
Lighting	LED throughout project
Docks	22 exterior loading dock doors (expandable)
Drive-in Doors	4 (12' x 14')
Fire Protection	Fully sprinklered with ESFR
Zoning	Industrial Limited

Source: Greywolf Partners and Rizzzo Development

- OM Station (formerly Oscar Mayer) – 910 Mayer Avenue, Madison
  Website: https://reichbros.com/property/oscar-mayer-madison-wisconsin/

Source: Reich Brothers Holdings

Figure 3.23 - Building Specifications: OM Station

Size	1,700,000 sf on 70 acres
Multiple buildings for sale or lease	
Manufacturing	800,000 sf
Corporate Office	273,000 sf
Cold Storage	150,000 sf
General Warehouse	60,000 sf
Total Available	**1,283,000 sf**

Source: Reich Brothers Holdings

An important MadREP KSI is to assist the property owners through site searches and other business start-up and expansion activity in filling these spaces.

Educational Institutions

The National Association of Manufacturers (NAM) suggests that "A long-term manufacturing strategy for America will further investment in the research, ideas and people who produce innovation. R&D is, as the Commerce Department's Manufacturing Council phrased it, "the single most important source of technological advancement leading to higher productivity."

Similarly, Conroy, Kures and Deller (2018, pg. 28) suggest that "recent spending on R&D has slowed in the United States. In contrast, R&D efforts are increasing in competing nations such as China. Helping Wisconsin firms strategically move from ordinary competition to quality competition through innovation, will not only help to increase wages and productivity, but also better insulate Wisconsin firms from competing against nations with a low cost of production. State and local investments in nurturing early stage research; developing new technology platforms; and supporting later stage commercialization can help firms innovate. These investments may be particularly important for the significant number of small-to-medium sized manufacturing firms in Wisconsin that may not have the resources to heavily invest in R&D."

While individual manufacturing firms invest internally in research and development, educational institutions are also important partners in providing R&D to advanced manufacturing firms. The role of educational institutions is particularly relevant to early-stage basic research that may could be beneficial to both the advanced manufacturing cluster and broader society, but is also often too costly, risky and uncertain for a single firm to undertake (Deller and Conroy, 2017). Accordingly, the region's educational institutions have important roles in producing research and talent.

In terms of talent, many positions require some sort of post-secondary educational attainment (such as the occupations in Job Zone 3, Job Zone 4 and Job Zone 5 noted in Section 2. Consequently, the connections between firms and higher educational institutions are often an important component of advance manufacturing sector development initiatives. The development of advance manufacturing talent also starts in the region's K-12 system to provide a pipeline of students to higher educational institutions.

The Madison Region's vast network of higher education institutions serves as a launch pad for professionals ready to fill positions with new and expanding advance manufacturing companies. In 2016-2017, higher education institutions in and adjacent to the Madison Region conferred 5,830 degrees and certificates applicable to advanced manufacturing positions (Figure 3.24).

Figure 3.24 - 2016-17 Degrees Conferred: Advanced Manufacturing

Institution	Certificate	Associate	Bachelor	Master	Doctor	Total
UW-Madison			1,299	527	215	**2,041**
UW-Milwaukee			548	222	50	**820**
UW-Platteville			576	59		**635**
UW-Whitewater			127			**127**
Beloit College			6			**6**
Blackhawk Technical College	89	34				**123**
Edgewood College			17			**17**
Herzing University – Madison		16	32			**48**
Madison College	388	238				**626**
Marquette University			318	74	7	**399**
Milwaukee School of Engineering			439	44		**483**
Moraine Park Technical College	299	101				**400**
Southwest Wisconsin Technical	74	31				**105**
Total	**850**	**420**	**3,362**	**926**	**272**	**5,830**

Source: National Center for Education Statistics. Note: Includes programs and award levels that are offered as a distance education program. Degree programs in advanced manufacturing include computer and information sciences and support services; construction trades; engineering; engineering technology and engineering-related fields; mathematics and statistics; mechanic and repair technologies/technicians; and precision production.

- *University of Wisconsin-Madison* - Granting Bachelor's, Master's and Doctorate degrees, UW-Madison's computer science program consistently ranks in the top ten computer science departments in the United States. UW-Madison also provides significant course and degree offerings in chemical, electrical, industrial and mechanical engineering, as well as mathematics and statistics.

- *University of Wisconsin System* - Wisconsin's three UW System engineering schools are in or immediately adjacent to the Madison Region—UW-Madison, UW-Milwaukee, and UW-Platteville. Independently and collectively, all three universities have nationally recognized mechanical, electrical, material science, nanotechnology, industrial, chemical, industrial engineering technology, and sales engineering programs.

- *Beloit College* – This private liberal arts college offers Bachelor's degrees in computer sciences, engineering and mathematics.

- *Blackhawk Technical College (Janesville and Milton)* **–** Blackhawk Technical College's new advanced manufacturing facilities provide training in machining, electricity and hydraulics, with supporting disciplines in blueprint reading, welding, rigging, refrigeration fundamentals, and drives and linkages.

- *Edgewood College (Madison)* - This private four-year institution offers Bachelor's degrees in computer information systems and mathematics, and boasts 100% field placement upon graduation.

- *Herzing University (Madison)* **–** Associate's degree programs include computer networking and security technology, and software development. Bachelor's degrees offered include information technology, software development, and modeling virtual environments and simulation.

- *Madison College (Madison)* - The new Ingenuity Center at Madison College features state-of-the-art facilities and tools to train students in the field of advanced manufacturing. The center boasts prototype and material testing machines, along with classrooms, faculty spaces, and high bay workspace for manufacturing labs.

- *Marquette University* – This Milwaukee based university grants Bachelor's, Master's and Doctorate degrees in computer sciences, mathematics, and civil, biomedical, computer, construction, electrical, environmental and mechanical engineering.

- *Milwaukee School of Engineering* – Confers Bachelor's and Master's degrees in architectural, biomedical, chemical, civil, computer, computer software, electrical, environmental, industrial, mechanical and structural engineering. The school's two largest graduating cohorts in 2016-17 were electrical (80 or 19%) and mechanical engineers (136 or 32% of all conferred engineering degrees).

- *Moraine Park Technical College (Beaver Dam)* **-** Several specializations are available within Associate's degree and certificate programs including: web designer/developer, information security, computer programming, construction trades and technology, engineering technicians, industrial mechanics, computer numerically controlled (CNC) machinist, metal fabrication, tool and die technology, and welding.

- *Southwest Wisconsin Technical College (Fennimore)* **-** Southwest Tech provides Associate's degrees in electromechanical engineering technology, construction trades, digital multimedia design, computer networking and telecommunications, and computer support specialist.

Feedback from primary surveys and interviews conducted as part of this analysis indicate that local educational institutions are largely aligning their degree programs to reflect current demand in the job market that help to meet internal placement metrics. While this practice is not necessarily bad, and in most cases is successful in producing graduates that local businesses want to employ, it fails to acknowledge the fundamental shift discussed earlier, wherein jobs follow talent. As a result, the Region's local educational institutions have not necessarily on-boarded new curriculum around AI, VR/AR, cybersecurity, IoT and blockchain as employers are not currently employing a large number of individuals with these degrees, specializations, or job titles. MadREP believes it is important for educators to be at the forefront of these trends and be more proactive rather than reactive when defining degree programs that will be attractive to advance manufacturing employers. Again, a deep pool of talent with diverse skill sets increases the Region's ability to start, grow and attract these employers.

Likewise, educational institutions have an important role to play in increasing the diversity of the STEM talent pool. As discussed in Section 2, the regional advanced manufacturing industry has struggled with diversity issues, particularly among women. This challenge however, is a national versus simply a local trend. In 2015, women filled 47% of all U.S. jobs, but only held 24% of STEM jobs. Similarly, women constitute slightly more than half of college educated workers, but only make-up 25% of college educated STEM workers (U.S. Department of Commerce, 2017). The persistent lack of underrepresented minorities among students completing STEM degrees is also acknowledged by experts as a societal problem that is resistant to quick solutions (Syed and Chemers, 2011). Possible longer-term solutions that can be drawn from research on the issue include:

- Begin promoting science and mathematics to underrepresented groups during the student's middle school and high school years. In the Region, three activities that are being used to begin this STEM career exploration and promotion process at earlier ages are Inspire-Madison Region, high school fabrication laboratories, and the youth apprenticeship program (Shapiro and Sax, 2011).

- Develop curriculum and pedagogies that stress real-world applications of science and seek to create learning environments focused upon collaboration and group dynamics versus competition and individual achievement.

- Introduce faculty and professional role models into classrooms settings who look like the underrepresented students. This has the effect of bolstering the student's confidence and seeing themselves as successful in STEM majors and careers, allows them to overcome some of the negative stereotypes about having a career in STEM, and encourages discussion of their own experiences and strategies for working through barriers in STEM fields.

- Use community and technical colleges to introduce underrepresented groups to the STEM fields. Due to open admission, affordable tuition, flexible scheduling, small class sizes, and child care, two-year public institutions have long been the school of choice for underrepresented and non-traditional students. In addition, currently 50% of college students start their postsecondary education at a two-year institution (Jackson, Starobin and Laanan, 2013). As a result, community and technical colleges represent an important pathway to introducing students to STEM fields. In the Madison Region, efforts are already underway to begin this process with the announcement of a partnership between the Madison Metropolitan School District (MMSD) and Madison College to create a STEM academy for high school students at the new south Madison campus.

As suggested, educational institutions provide new research that can hopefully be used by new or existing firms. In the Madison Region, UW-Madison is the primary producer of new research related to the advance manufacturing cluster. Indeed, the Wisconsin Alumni Research Foundation (WARF) currently lists almost 250 inventions and patents in advance manufacturing. These technologies include sensors, lasers, power control systems, engines, engineering and nanotech. Many of these innovations are important due to their impact on productivity and safety. In many cases, they also allow advanced manufacturing firms to move beyond being commodity based enterprises seeking to constantly lower costs in order to compete in an international marketplace.

While new advanced manufacturing related research is constantly being generated, the bigger challenge may be transferring this technology to the private sector. While the technology transfer process is often criticized as being inefficient, Shane (2010) suggests many factors that can affect university technology transfer. The most important issue may be the willingness of faculty to disclose inventions, or inform the university's technology licensing office (TLO) about their discovery. If a TLO is not aware of an invention, then it cannot be licensed for commercial use. Shane suggests that the number of inventions licensed through a TLO is not tied to inefficiencies in the process, but that license numbers are highly correlated with the number of invention disclosures received by a TLO from faculty.

As suggested by Shane, a faculty member's unwillingness to disclose an invention may be tied to traditional university compensation and culture. Faculty members are often rewarded and promoted by the number and quality of papers published, not by technology licensing. Faculty may work in fields where commercialization is uncommon. They may be in a department where colleagues do not want to participate in technology transfer. A faculty member may have personal reasons for not wanting to pursue commercialization or wanting to disclose an invention. Furthermore, faculty simply may not be familiar or comfortable with the commercialization process.

Importantly, the rate of commercialization also is propelled by the private sector's level of interest in university technology. Shane also notes that a lack of private sector interest can be driven by inventions not yet ready for practical or commercial use (e.g. they are too basic or have insufficient applications). Uncertainly about inventions also creates financial risks that may be deemed as too high to justify private sector investment. Consequently, Shane cites that "industry is uninterested in them for the very reason that the government funds basic research at universities in the first place – the difficulty of appropriating the returns to investment in their development."

Re-thinking university compensation and culture may be worth exploring as one approach to fostering additional technology transfer and commercialization. However, there are many appropriate reasons that current systems exist and it is unlikely that changes will occur in the short term. Another opportunity for transferring university research and ultimately creating technology spin-offs is to better connect university faculty and staff with a network of non-academic contacts such as investors, researchers from private sector firms and entrepreneurial advisors (Hayter, 2015). In fact, university spin-off success may be dependent on the types of sizes of contacts in an academic entrepreneur's social network. Access to these individuals outside of the university allows for a broader base of knowledge and resources than those available in a university setting (Hayter, 2015). As noted below, there are many advance manufacturing support organizations that could provide a means of establishing these types of connections.

Advanced Manufacturing Support Organizations

In addition to MadREP, many local agencies and institutions operate in the Region with the purpose of helping advance manufacturing companies start, expand and/or relocate in order to grow the local economy. Some provide direct technical assistance, several conduct research and promote product innovation, and others provide financing to commercialize new technologies and help pay for innovation and modernization efforts. These agencies and institutions, along with their primary means of assistance, are identified below.

Physical Spaces

A total of forty physical spaces are located in the Region that provide space and other start-up resources to advance manufacturing businesses. These spaces include incubators, co-working spaces, hacker/makerspaces, prototyping centers and accelerators. They are identified and geo-coded on a dynamic map available through the MadREP website, with the most up-to-date version found at http://madisonregion.org/start-locate-expand/start-your-business-2/. These spaces are particularly important to supporting the number of small firms who may be trying to achieve scale noted in Section 1.

Fabrication Laboratories

An important subset of the physical spaces are the fabrication laboratories which have been developed at five of the Region's high schools over the last five years. These schools include: Beaver Dam, Edgerton, Stoughton, Waunakee and Waupun High School. All are open to the public and have computer and equipment resources that could potentially cater to advance manufacturing start-up businesses. The state created a grant program in 2015, implemented by the WEDC, which has funded all of the facilities located in the Region and a majority of the 43 total facilities operating statewide. This represents 24.7% of the labs operating nationally and 3.4% operating globally (174 and 1,267 respectively as reported by the Fab Foundation).

In most cases, the laboratories are used as part of the school's technology education and science curriculum, to introduce students to potential Science, Technology, Engineering, Arts and Mathematics (STEAM) careers. Many programs have developed metrics around attracting female and disadvantaged students to use and take classes at the labs in order to expose a diverse mix of students to the "cool" technology. Quite a few schools make their labs available to middle school students and coordinate with counseling and career exploration resources such as Inspire Madison-Region (a career coaching and experiential learning program) to encourage young students to consider majoring in STEAM fields. This is a critically important first step in developing the local advance manufacturing workforce pipeline.

Mentor Programs and Technical Assistance

- *Doyenne Group* – A Madison-based organization with the mission of building entrepreneurial ecosystems that invest in the power and potential of women entrepreneurs through mechanisms including networking, collaboration and mentorship. They offer 2.5-day strategic planning retreats, sponsor a local pitch session, and offer one-on-one coaching with the Doyenne Founders and Ambassadors.

- *MERLIN Mentors* -The Madison Entrepreneur Resource, Learning and Innovation Network (MERLIN) is a program which seeks to align the skills and experience of volunteer mentors from the local business community with the needs and preferences of a young company's founder team. The goal is to create a larger pool of viable entrepreneurs and increase the survivability of local start-up businesses. MERLIN was developed with the support of WARF, the University Research Park (URP), the Wisconsin School of Business and the UW-Madison Office of Business Engagement.

- *Service Corp of Retired Executives* - A program of the United States Small Business Administration (SBA) designed to use retired volunteers to offer business counseling and mentoring services to businesses. There are two SCORE chapters that provide service to businesses in the Region.

- *UW-Madison Law & Entrepreneurship Clinic* - A program of the UW-Madison law school, the clinic provides free legal services to help entrepreneurs and small business owners with legal questions regarding starting or expanding a business. Third year law students and faculty provide counsel on issues involving corporate structure, finance, tax, intellectual property and insurance.

- *UW-Madison, Discovery to Product (D2P) Program* - A program designed to help commercialize and license new product innovation at UW-Madison. Staff provide mentorship and idea/market validation to early stage projects conceived by faculty, staff or students. The program is also focused on expanding access to key technology commercialization resources, including investment capital and proven entrepreneurial talent.

- *UW-System, Center for Technology Commercialization* – The Center works with innovators, entrepreneurs and researchers to bring new technologies to market by guiding the commercialization process. Staff help clients develop the business case for a new technology and provide assistance in developing applications to competitive funding sources including the federal government's Small Business Innovation Research and Small Business Technology Transfer (SBIR/STTR) programs.

- *WARF Accelerator Program* – A program designed to speed up the commercialization of UW-Madison discoveries that have been patented by WARF, by providing founders access to targeted funding and expert advice from seasoned business mentors known as Catalysts.

- *Wisconsin Small Business Development Centers* – The Centers provide business counseling and educational programs designed to support small business creation and growth. Four SBDC's primarily serve the Region, with locations at UW-Madison, UW-Whitewater, UW-Platteville and UW-LaCrosse.

- *Wisconsin Manufacturing Extension Partnership* – WMEP employs a team of industry leading experts that work with manufacturing businesses to find and develop talent, identify and develop new markets for products, innovate new products, and improve a manufacturing plant's operational efficiencies in order to reduce waste and increase profitability. Sample services offered include: ISO 9001 Certification, Lean Sigma Six Green and Black Belt Training, ExporTech™, Profit Risk Assessment (PRA™) evaluations, and various supply chain and cybersecurity evaluation programs.

Networking Programming

- *Doyenne Group* – Offers monthly connect events that can be used by entrepreneurs to build and mobilize networks within the regional I&E ecosystem.

- *Forward Fest* – A weeklong festival started in 2010 and modeled after South by Southwest (SXSW), which offers entrepreneurs access to over 40 events designed to bring the technology and start-up communities together to learn, share and network. The festival attracts over 5,000 attendees and is held at a variety of locations in and around Madison.

- *Capital Entrepreneurs* – A grassroots community group founded in 2009 with the goal of offering networking and social events that allow local entrepreneurs to connect and grow the start-up community. The group's marquee networking event is Forward Fest. They also hold monthly meetings, run the Madison Start-up Fair, host the Spring Tech Kickoff, and provide peer support resources.

- *Greater Madison Chamber of Commerce* – A business member organization founded over 140 years ago that provides networking opportunities in the form of over 50 local events each year. Many of these events cater to the Region's growing technology community including: the Annual Dinner, Ice Breaker, neXXpo, Pressure Chamber (a pitch competition that occurs during Forward Fest) and Big Night Out. The Chamber also sponsors a trip each summer for early stage companies to pitch Silicon Valley investors, and markets the Region at technology focused events like SXSW.

- *High Tech Happy Hour* – A networking event started in 2001 to offer a monthly gathering spot for the growing high technology community in Madison to meet and collaborate.

- *1 Million Cups* – A program developed by the Ewing Marion Kauffman Foundation in 2012 which is designed to offer an entrepreneur a safe environment in which to network and pitch a business idea to an audience instructed to listen and offer constructive suggestions for how to evolve the idea into a viable business. The Madison based chapter of the group hosts weekly pitch and peer networking sessions at StartingBlock Madison.

- *WARF Inventor and Entrepreneur Programming* – Several networking related programs are hosted by WARF on the UW-Madison campus which are all designed to bring inventors, entrepreneurs and researchers together and inspire collaboration. These include:

    1. <u>Innovation Roadmap: The Speaker Series</u> - Speakers from across the country who have used an entrepreneurial approach to push boundaries and spur innovation share their stories;

    2. <u>Innovation Roadmap: The Workshop Series</u> - Local leaders and changemakers help UW–Madison faculty, students and staff gain the skills they need to create a company or drive change inside an existing organization;

    3. <u>Noon @ the Niche</u> - Faculty, staff, students and the community are invited to bring their lunch to hear an in-depth talk and discussion about the research currently featured at the Wisconsin Institute of Discovery;

    4. <u>UpStart</u> – A program designed to equip entrepreneurially minded women and people of color in the Madison area with the tools needed to launch or expand any business venture;

    5. <u>WARF Ambassadors</u> - A program which engages students to serve as WARF Ambassadors in order to increase WARF's visibility and presence among researchers on campus, and enhance the vital connection between research and technology transfer.

- *Wisconsin Technology Council/Wisconsin Innovation Network* – The Council was created in 2001 as the science and technology advisor to the Governor and Legislature. It also serves an important in-state networking role through the Innovation Network, a membership arm that is dedicated to fostering innovation and entrepreneurship. It sponsors the Wisconsin Entrepreneurs' Conference, the Governor's Business Plan Contest, the Wisconsin Early Stage Symposium and the Wisconsin Tech Summit. All offer opportunities for existing businesses, entrepreneurs and investors to network and collaborate on technology related projects and issues.

Capital

- *Doyenne Evergreen Fund* – A fund developed by the Doyenne Group that provides grants, equity and/or loans to support businesses led by women and people of color. The Fund is paired with the Doyenne Accelerator, which provides coaching assistance to all entrepreneurs who receive funding.

- *Forward Community Investments (FCI)* - Provides financing, one-on-one advising and group training programs to nonprofit, cooperative and for profit businesses that are reducing racial, social and economic disparities.

- *Madison Development Corporation (MDC)* - Manages a business loan fund created using Community Development Block Grant (CDBG) funding to help start and expand small businesses in the Region.

- *WARF Start-up Portfolio (Internal Seed and Venture Fund)* – WARF currently holds equity in over 30 companies and is seeking to create a $60M start-up fund ($10M seed and $50M venture fund activity) that would increase its investment activity in businesses that commercialize UW-Madison research. Markets that WARF invests in include: advance manufacturing, biotechnology, clean technology, medical devices, medical imaging, stem cells, research tools and therapeutics.

- *Wisconsin Economic Development Corp (WEDC)* - The state's economic development entity that provides business development incentives, including loans, tax credits and training grants to advance manufacturing businesses looking to start or expand in the Region. The WEDC also administers the important Qualified New Business Venture (QNBV) Program. This program, which began in 2005, provides tax credits to eligible angel and venture fund investors who make cash investments in qualified early-stage technology based businesses. The credit is equal to 25 percent of the value of the investment made in companies certified by the WEDC. The program had 211 certified companies in 2016 (the most recent year for which statistics are publicly available), including 34 or 16% that were classified as advance manufacturing businesses.[12] Of the 211 total certified companies statewide, 114 or 54% where located in the Region. The total amount of funding received by QNBV companies reached $281.7M in 2016, up 60% from $177M in 2015. Of this funding activity, $40.0M or 14% was invested in advance manufacturing businesses across the state.

- *Wisconsin Women's Business Initiative Corp (WWBIC)* – Provides access to business and financial education services and financial products through a regional office located in Madison. The organization has provided over $39M in lending to 3,500 businesses statewide since 1987.

- *Angel and Venture Capital Funds* - The Wisconsin Technology Council maintains a listing and generates a map of all the equity based funds operating in the state. The current version of the map, which geo-codes 47 active funds appears in Figure 3.25. Twenty-two of these funds, or 47%, are located in the Region.

[12] "2016 QNBV Report," Wisconsin Economic Development Corporation, September 2017.

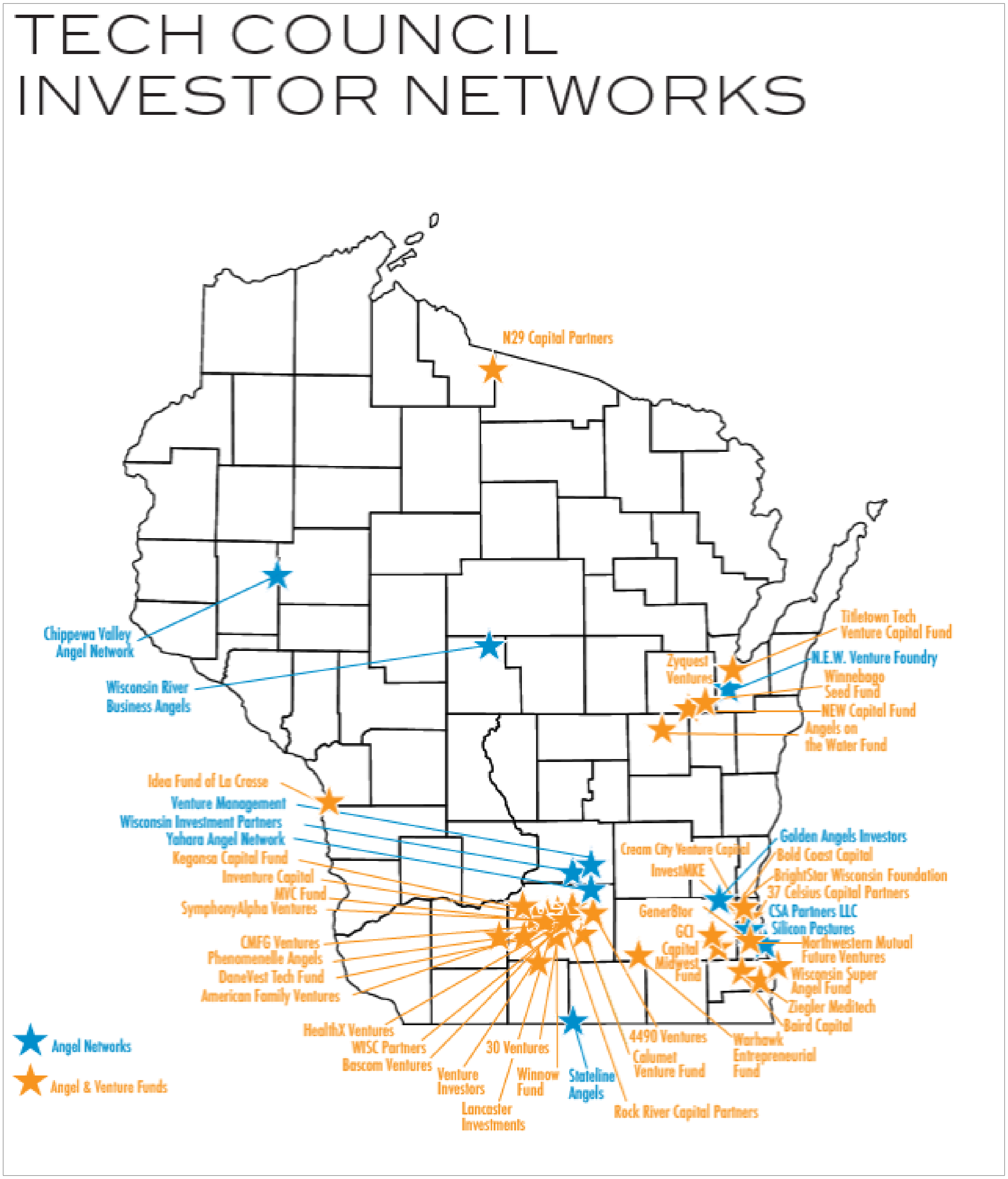
Some of the most active funds that have made investments in the Region's advance manufacturing businesses include:

1. Badger Fund of Funds Program – The Fund of Funds is a limited partnership formed in 2014 to invest up to $25M in capital provided by the state and the State of Wisconsin Investment Board (SWIB) and $10M in private capital ($35M total) into six to eight angel funds around the state. The mission of the newly created funds is to make early and middle stage investments in Wisconsin based start-up companies. The Program has made investments in three funds to date; namely, the Idea Fund, LaCrosse, the Winnebago Seed Fund, Neenah, and Rock River Capital Partners, Madison. These funds have raised a combined $40M and have invested in one advance manufacturing firm; namely, American Provenance based in Mount Horeb. Two additional funds, Bold Coast Capital, Milwaukee and the Winnow Fund, Madison, are planned to be created in either late 2018 or early 2019;

2. Wisconsin Investment Partners (WIP) – WIP is currently one of the most active angel funds in the state, having invested over $30M in start-up companies since its formation in 2000. Fund managers invite companies to pitch before up to 50 accredited investors who each make their own individual investment decisions. The fund primarily targets investments in early stage life science companies, but several investments have also been placed in advance manufacturing companies including: Carson Life, Performance Polymer Solutions, Inc, Phoenix Nuclear Labs, Silatronix, and Virent;

3. Venture Investors (VI) – Since its formation in 1982, VI has raised seven funds totaling $280M, which it has used to make equity investments in 71 total companies. These investments have mainly been placed in life science companies originating from research conducted at UW-Madison. More recently however, VI has begun making investments in advance manufacturing companies including: Alfalight, Intralase, LenSx, Silatronix, and Virent;

Figure 3.25 – Investor Networks



Source: Wisconsin Technology Council, 2018 Wisconsin Portfolio.

Advance Manufacturing Investments in Wisconsin

One key resource for tracking equity investment activity in Wisconsin based businesses is the Wisconsin Portfolio, published annually since 2008 by the Wisconsin Technology Council (WTC). Statistics from this report, representing total statewide investment in the advance manufacturing Industry from 2015 to 2017, are presented in Figure 3.26. Key findings include:

- Advance manufacturing represents approximately 5% of all equity investment activity across the state over the last three years.
- Investments in the industry have been declining from 14 (10.9% of all deals) in 2015 to 5 (3.9% of all deals) in 2017.
- Many of the companies that received investment are located in the Region, including Ab E Discovery, C-Motive Technologies, Phoenix Nuclear Labs, SimpleMachines, Rowheels, and Ebullient.

Figure 3.26 - Wisconsin Angel and Venture Capital Investment - Advance Manufacturing Industry, 2015 to 2017

Category	Year					
	2015	Deals (%)	2016	Deals (%)	2017	Deals (%)
Adv Mfg	$18,164,571	14 (10.9%)	$12,496,026	11 (8.0%)	$7,479,000	5 (3.9%)
All Industries	$209,479,099	128	$276,191,739	138	$231,040,882	127
Percent ($)	8.7%		4.5%		3.2%	

Source: Wisconsin Technology Council, 2018 Wisconsin Portfolio.

In reviewing this support organization activity, it is important to recognize how many resources have been developed within the last 5 to 10 years. It is truly remarkable how far the regional I&E ecosystem has evolved in a relatively short period of time. MadREP's staff has very little reason to believe that it will slow down in the near future, but will most likely continue and may even accelerate.

Staff would recommend continuing to promote efforts to link the evolving I&E ecosystem to UW-Madison, UW-Whitewater and UW-Platteville in order to help accelerate the commercialization of both faculty and student research. It is important to note that UW-Madison and UW-System have been making tremendous strides at assisting these efforts through the enhanced resources represented by MERLIN Mentors, D2P, the Law & Entrepreneurship Clinic, the Center for Technology Commercialization, and the Small Business Development Center. These resources are available on campus centered on @1403 and Grainger Hall. Off campus resources are mainly located at the University Research Park, but also include 100State, Sector67 and StartingBlock Madison. All three of the latter facilities make themselves attractive to students. Finally, it is critically important to acknowledge and continue to support the growing role that WARF is playing in the Region and state's I&E ecosystem through its increasing investment activity in resources and capital programming.

Conclusions - Advance Manufacturing Cluster Support and Development Ecosystem

- Many areas in the Madison Region have robust broadband access beyond the FCC definition of 25/3. However, other areas in the Region completely lack access to a single broadband provider. The lack of broadband in many of these areas is well-known and discussed. However, for these areas and the entire Region to fully support the growing advance manufacturing cluster, broadband will need to become more widely available throughout the Madison Region.

- 5G will help usher in the IoT era which will result in the commodification of information and data intelligence. Furthermore, 5G could also provide opportunities for filling broadband availability gaps in rural areas. While it is anticipated that the earliest implementations of the technology will occur in the larger, more technology dense, metropolitan areas of the country, MadREP needs to ensure that its eight-county region is high on the list of target areas to be served and the network gets built out as quickly as possible.

- The Region's housing market provides both opportunities and challenges related to attracting and retaining talent. Compared to many other regions throughout the United States, overall housing costs in the Madison Region are somewhat favorable. However, this potential advantage depends greatly depending on an individual's wage and may be lessened when considering the Region's housing costs relative to other competing regions in the nation's traditional industrial belt. As housing costs rise in the Region and new housing construction continues to lag pre-recession levels, the ratio of median wages to median housing costs could continue to erode this source of comparative advantage.

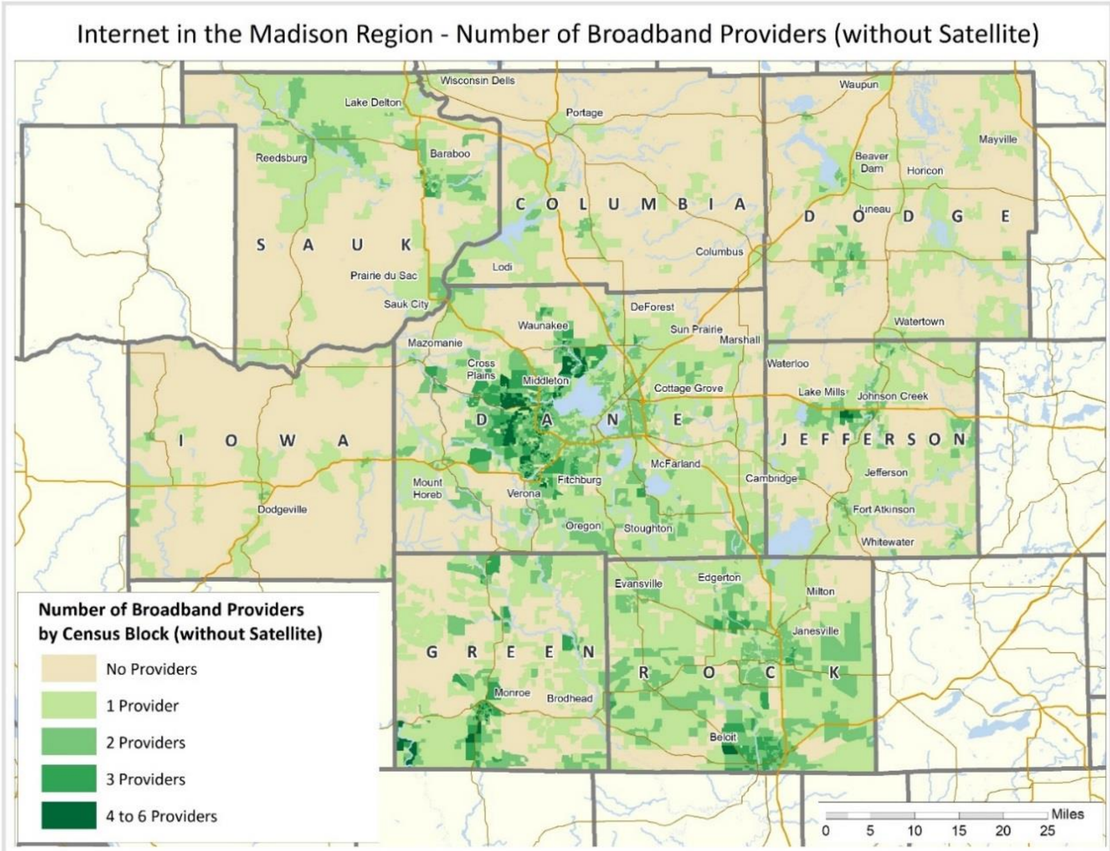
- The Region's advanced manufacturing cluster has many potential synergies related to supply chains. A number potential gaps and disconnects in the region, particularly those related to several plastics and metal products, should be explored as opportunities for business expansion and development. MadREP may also consider producing a directory of professional, technical and administrative service providers with expertise in serving advanced manufacturing clientele.

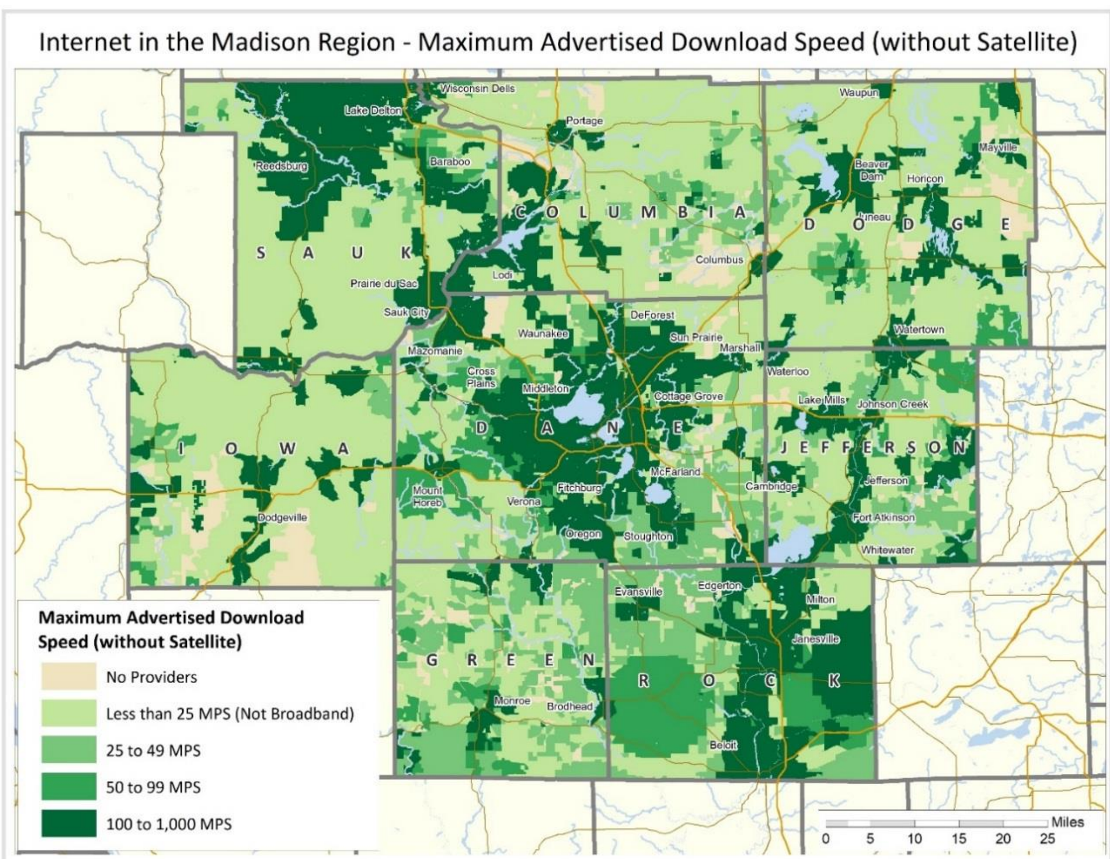
- Advanced manufacturers are highly dependent on truck transportation and rail and air transportation to a somewhat lesser extent. Creating solutions to transportation funding are vital to supporting the advanced manufacturing cluster in the Region and Statewide.

- The connections between firms and universities are often an important component of advanced manufacturing sector development initiatives. However, advance manufacturing support from educational institutions extends beyond 4-year universities to include colleges and technical schools that may provide Associate's degrees, certificates or continuing education. The development of advance manufacturing talent also starts in the region's K-12 system to provide a pipeline of students to higher educational institutions. Given the growing prominence of the Region's advanced manufacturing cluster, institutions at all levels should continue to pursue opportunities outlined above that foster a deep, diverse pool of talent.

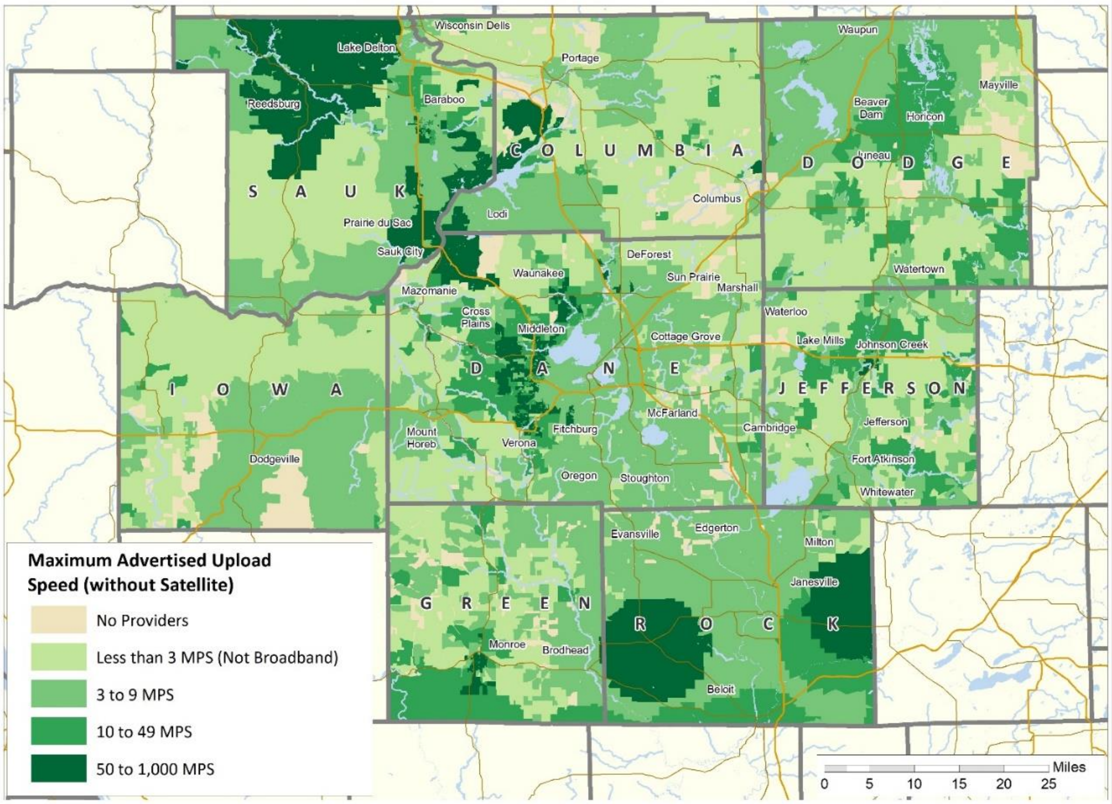
- In reviewing the Region's support organization activity, it is important to recognize the remarkable number of resources that have been developed within the last 5 to 10 years. It is likely that the support ecosystem will continue to grow and accelerate. However, given the large and growing number of resources to support the advance manufacturing ecosystem, it is unlikely that many potential stakeholders who could benefit are entirely aware of these organizations and resources in the Madison Region. MadREP should continue to foster and expand the connections among these numerous assets, advance manufacturing firms and advance manufacturing talent.

Appendix 3A – Internet Availability Characteristics without Satellite





Internet in the Madison Region - Maximum Advertised Upload Speed (without Satellite)



Appendix 3B – Transportation Characteristics for Advanced Manufacturing

Wisconsin Shipment Characteristics for Chemical Manufacturing

Mode	Value (million $)	Tons (thousands)	Ton-miles (millions)*	Average miles per shipment
All modes	11,079	6,367	2,710	847
Single modes	81.7%	92.8%	80.2%	784
Truck	65.3%	75.1%	56.5%	764
For-hire truck	61.4%	64.9%	54.3%	793
Private truck	3.9%	10.2%	2.3%	171
Rail	10.8%	15.5%	23.3%	1,006
Air (incl truck and air)	5.3%	0.1%	S	907
Pipeline	S	S	S	S
Multiple modes	18.3%	7.2%	19.8%	915
Parcel, U.S.P.S. or courier	7.8%	S	S	914
Truck and rail	S	5.9%	S	1,233
Truck and water	0.2%	0.1%	0.3%	2,596

S= suppressed * Ton-miles estimates are based on estimated distances traveled along a modeled transportation network.
Source: U.S. Department of Transportation, Bureau of Transportation Statistics and U.S. Census Bureau, 2012 Commodity Flow Survey.

Wisconsin Shipment Characteristics for Plastic and Rubber Product Manufacturing

Mode	Value (million $)	Tons (thousands)	Ton-miles (millions)*	Average miles per shipment
All modes	7,657	2,163	1,342	602
Single modes	93.7%	97.8%	94.1%	566
Truck	92.9%	97.5%	93.1%	557
For-hire truck	83.2%	84.5%	89.0%	662
Private truck	9.7%	13.0%	4.0%	S
Rail	S	S	S	S
Air (incl truck and air)	0.6%	0.1%	S	1,167
Multiple modes	6.4%	2.2%	5.8%	656
Parcel, U.S.P.S. or courier	3.7%	0.4%	0.5%	650
Truck and rail	S	1.4%	3.7%	1,387

S= suppressed * Ton-miles estimates are based on estimated distances traveled along a modeled transportation network.
Source: U.S. Department of Transportation, Bureau of Transportation Statistics and U.S. Census Bureau, 2012 Commodity Flow Survey.

Wisconsin Shipment Characteristics for Nonmetallic Mineral Product Manufacturing

Mode	Value (million $)	Tons (thousands)	Ton-miles (millions)*	Average miles per shipment
All modes	3,177	17,338	2,168	198
Single modes	95.1%	99.6%	95.7%	S
Truck	84.0%	91.2%	54.1%	S
For-hire truck	67.4%	26.6%	40.8%	252
Private truck	16.6%	64.6%	13.3%	19
Rail	10.4%	S	41.5%	S
Air (incl truck and air)	0.8%	S	S	1,311
Multiple modes	4.9%	S	S	1,064
Parcel, U.S.P.S. or courier	3.9%	0.0%	0.1%	1,062
Truck and rail	S	S	S	1,504

S= suppressed * Ton-miles estimates are based on estimated distances traveled along a modeled transportation network.
Source: U.S. Department of Transportation, Bureau of Transportation Statistics and U.S. Census Bureau, 2012 Commodity Flow Survey.

Wisconsin Shipment Characteristics for Primary Metal Manufacturing

Mode	Value (million $)	Tons (thousands)	Ton-miles (millions)*	Average miles per shipment
All modes	5,740	2,468	1,224	572
Single modes	96.9%	99.6%	98.9%	423
Truck	96.4%	99.3%	98.6%	420
For-hire truck	85.7%	95.1%	97.3%	527
Private truck	10.7%	4.3%	S	S
Rail	S	S	S	S
Air (incl truck and air)	S	S	S	1,122
Multiple modes	3.1%	0.4%	1.1%	1,029
Parcel, U.S.P.S. or courier	S	S	S	1,031
Truck and rail	S	0.3%	0.7%	S
Truck and water	S	S	S	S

S= suppressed * Ton-miles estimates are based on estimated distances traveled along a modeled transportation network.
Source: U.S. Department of Transportation, Bureau of Transportation Statistics and U.S. Census Bureau, 2012 Commodity Flow Survey.

Wisconsin Shipment Characteristics for Fabricated Metal Product Manufacturing

Mode	Value (million $)	Tons (thousands)	Ton-miles (millions)*	Average miles per shipment
All modes	14,993	3,357	1,390	490
Single modes	93.9%	99.2%	96.9%	343
Truck	92.9%	98.5%	94.0%	339
For-hire truck	76.3%	73.9%	90.1%	532
Private truck	16.6%	24.6%	3.8%	44
Rail	0.2%	0.6%	2.7%	S
Air (incl truck and air)	0.8%	S	S	858
Multiple modes	6.1%	0.8%	3.1%	772
Parcel, U.S.P.S. or courier	5.5%	0.4%	0.7%	768
Truck and rail	S	S	S	1,328
Truck and water	0.4%	0.1%	1.1%	3,429

S= suppressed * Ton-miles estimates are based on estimated distances traveled along a modeled transportation network.
Source: U.S. Department of Transportation, Bureau of Transportation Statistics and U.S. Census Bureau, 2012 Commodity Flow Survey.

Wisconsin Shipment Characteristics for Machinery Manufacturing

Mode	Value (million $)	Tons (thousands)	Ton-miles (millions)*	Average miles per shipment
All modes	22,673	2,232	1,531	825
Single modes	86.0%	96.4%	92.6%	703
Truck	82.8%	94.3%	88.7%	653
For-hire truck	75.1%	80.7%	86.0%	798
Private truck	7.7%	13.5%	S	45
Rail	S	S	S	1’101
Air (incl truck and air)	1.7%	0.7%	1.6%	1200
Multiple modes	14.0%	3.5%	7.4%	898
Parcel, U.S.P.S. or courier	12.1%	1.9%	2.5%	896
Truck and rail	1.4%	1.1%	2.4%	1’168
Truck and water	S	S	S	1’617

S= suppressed * Ton-miles estimates are based on estimated distances traveled along a modeled transportation network.
Source: U.S. Department of Transportation, Bureau of Transportation Statistics and U.S. Census Bureau, 2012 Commodity Flow Survey.

Wisconsin Shipment Characteristics for Computer and Electronic Component Manufacturing

Mode	Value (million $)	Tons (thousands)	Ton-miles (millions)*	Average miles per shipment
All modes	8,408	83	64	822
Single modes	77.4%	92.8%	92.2%	771
Truck	59.4%	77.1%	67.2%	670
For-hire truck	56.5%	74.7%	67.2%	815
Private truck	S	S	S	70
Rail	0.4%	6.0%	10.9%	1,300
Air (incl truck and air)	17.6%	9.6%	14.1%	1,087
Multiple modes	S	7.2%	7.8%	843
Parcel, U.S.P.S. or courier	S	7.2%	7.8%	843
Truck and rail	S	S	S	S

S= suppressed * Ton-miles estimates are based on estimated distances traveled along a modeled transportation network.
Source: U.S. Department of Transportation, Bureau of Transportation Statistics and U.S. Census Bureau, 2012 Commodity Flow Survey.

Wisconsin Shipment Characteristics for Electrical Equipment, Appliance and Component Manufacturing

Mode	Value (million $)	Tons (thousands)	Ton-miles (millions)*	Average miles per shipment
All modes	7,954	621	551	858
Single modes	87.0%	93.6%	93.3%	816
Truck	83.4%	92.1%	90.7%	803
For-hire truck	78.7%	85.3%	89.1%	853
Private truck	4.6%	6.8%	S	114
Rail	S	S	S	S
Air (incl truck and air)	2.9%	0.6%	0.7%	1,111
Multiple modes	13.0%	6.3%	6.7%	880
Parcel, U.S.P.S. or courier	11.4%	2.9%	3.1%	879
Truck and rail	1.4%	S	S	751
Truck and water	0.2%	S	S	S

S= suppressed * Ton-miles estimates are based on estimated distances traveled along a modeled transportation network.
Source: U.S. Department of Transportation, Bureau of Transportation Statistics and U.S. Census Bureau, 2012 Commodity Flow Survey.

Wisconsin Shipment Characteristics for Transportation Equipment Manufacturing

Mode	Value (million $)	Tons (thousands)	Ton-miles (millions)*	Average miles per shipment
All modes	11,889	2,000	1,134	635
Single modes	95.3%	99.7%	99.3%	509
Truck	95.1%	99.6%	99.2%	507
For-hire truck	66.4%	64.0%	80.9%	629
Private truck	S	S	S	157
Air (incl truck and air)	S	S	S	810
Multiple modes	4.7%	0.4%	0.7%	788
Parcel, U.S.P.S. or courier	4.7%	0.4%	0.4%	778
Truck and water	S	S	S	S
All modes	11,889	2,000	1,134	635
Single modes	95.3%	99.7%	99.3%	509

S= suppressed * Ton-miles estimates are based on estimated distances traveled along a modeled transportation network.
Source: U.S. Department of Transportation, Bureau of Transportation Statistics and U.S. Census Bureau, 2012 Commodity Flow Survey.

Appendix 3C – Office Market Snapshot

Office Market Forecast - 2018

- Robust new construction starting to hit the market (we have begun phase III)
- Vacancy has reached its low point; will trend upward
- Absorption will still be higher than average
- High TI costs continue to impact deals
- Sales market cools from 2016 all-time high and strong 2017

Year	2016	2017
Total Inventory (Sq. Ft.)	15.4 million	15.9 million
Average Asking Rate Overall	$20.57	$20.16
Vacancy Rate Overall	8.6%	7.3%
Class A Vacancy	5.3%	4.3%
Absorption (Sq. Ft.)	487,000	304,000
Number of Bldg Sales	56	44
Square Feet Sold	*2,676,100	909,400

*Vanta Portfolio Sale: 35 buildings, 2.29M SF

Statistics as of 4Q 2017

Dane County office submarkets (downtown, east, near and far west side, south/beltline) with information on average lease rates/absorption/vacancy rates per area.

Submarket	Number of Buildings	Inventory (sf)	Vacant (sf)	Vacancy Rate (%)	YTD Total Net Absorption (sf)	Under Construction (sf)
Near West A	7	443,795	744	0.2%	67,127	-
Far West A	27	2,700,785	111,017	4.1%	26,308	235,000
East A	12	771,454	33,117	4.3%	4,362	90,000
Downtown A	15	1,771,149	98,731	5.6%	36,763	200,000
South A	7	512,912	25,716	5.0%	-	110,000
Overall	**68**	**6,200,095**	**269,325**	**4.3%**	**134,560**	**635,000**

Vacancy Rate					
Submarkets	**4Q 2016**	**1Q 2017**	**2Q 2017**	**3Q 2017**	**4Q 2017**
Near West A	15.3%	5.2%	5.2%	1.8%	0.2%
Far West A	4.0%	3.9%	4.8%	4.0%	4.1%
East A	4.9%	5.4%	5.4%	4.3%	4.3%
Downtown A	5.1%	5.7%	8.4%	6.5%	5.6%
South A	5.0%	5.0%	5.0%	5.0%	5.0%

Weighted Average Asking Rent (FSG)					
Submarket	**4Q 2016**	**1Q 2017**	**2Q 2017**	**3Q 2017**	**4Q 2017**
Near West A	$25.25	$25.70	$25.70	$27.00	$27.00
Far West A	$25.58	$29.08	$26.38	$25.58	$25.52
East A	$22.51	$23.14	$22.81	$23.43	$23.43
Downtown A	$26.46	-	$38.00	$38.00	$38.00
South A	$19.74	$23.41	$23.41	$23.41	-

Absorption (sq. ft.)						
Submarket	**2013**	**2014**	**2015**	**2016**	**2017**	**Average**
Near West A	-	20,701	8,456	11,378	67,127	21,532
Far West A	237,876	-13,695	51,663	104,794	26,308	81,389
East A	24,583	21,232	33,016	8,131	4,362	18,265
Downtown A	29,730	16,195	23,176	13,758	36,763	23,924
South A	-13,388	17,099	15,199	31,359	-	10,054
Overall	**278,801**	**61,532**	**131,510**	**169,420**	**134,560**	**155,165**

Recent Key Office Leasing Transactions

TENANT	SUBMARKET	TYPE	SF
Exact Sciences	Near West	Lease/Purchase	150,000
Illumina	Near West	BTS/Lease	132,000
Navitus	Far West	Exp./Relocate	100,000
NSI/West Bend	Far West	Consolidation	80,000
Zendesk	Downtown	Relo./Expand	78,000
Spectrum Brands	Far West	Bldg. Addition	30,100
BMO Harris	Southeast	Relo. (from Hilldale)	28,000
Performance Gateway	East	Relo./Expand	25,600
Catalent	Far West	Expansion	25,500

Key Deals in the Market this year

TENANT	SUBMARKET	TYPE	Sq. Ft.
Hy-Cite	Far West	Land/New Bldg	90,000
Undisclosed	Suburban	Back-office space	45,000
Boardman & Clark	Downtown	Relocation	40,000
Dean Health Plan	Far West	Expansion	33,000
Tech Company	E. Wash	The Gebhardt	30,000
Cellular Dynamics	Near West	Expansion	27,000
Exact Sciences	Middleton	Short term	26,000
Nordic Consulting	Downtown	Expansion	+20,000

Addendum 1 - Key Advance Manufacturing Subsectors and Industry Trends

The following analysis uses research from public and private sources; interviews with local industry experts; and peer review to understand key trends impacting the five subsectors that have been previously identified as important advance manufacturing industry targets for the Madison Region. These subsectors include: 1) advance composite materials, 2) Internet of Things (IoT), 3) electrical equipment and appliances, 4) medical devices, and 5) bicycles. Again, these subsectors are those that currently show substantial business activity in the Region or are categories in which staff believes the Region has the appropriate assets in place to allow it to develop a comparative advantage.

Advance Composite Materials

<&>

Internet of Things (Industry 4.0)

The digital economy has affected and will continue to impact many aspects of our daily lives, from human health, to asset maintenance, to operating our cities and factories. Part of the future manifestation of the digital economy is what many term the *Internet of Things (IoT)* or a network of machines communicating and working together based upon system protocols that reduce the need for human intercession. In the manufacturing setting, experts refer to this as Industry 4.0 or the fourth major industrial revolution of the modernized word.[13] The McKinsey Global Institute (MGI) has forecasted that as IoT applications begin to take hold across all industry sectors, the impact to the U.S. economy will be $2.2T in additional actual GDP output annually by 2025.

IoT Settings

MGI breaks downs the major applications and annual economic impacts of IoT across nine settings (Figure 3.5). The top four settings in rank order are factories ($1.2T to $3.7T), cities ($930B to $1.7T), human wellness ($170B to $1.6T) and retail environments ($410B to $1.2T). Together, these top four represent approximately 70% of the total forecasted value. The impact across all nine settings increases from the $2.2T quoted above, to the $3.9T per year represented as the low estimate in the figure when you include consumer surplus in the analysis (the difference between what consumers would be willing to pay and what they actually pay for goods and services). The estimate goes up to the high estimate of $11.1T if you include opportunity costs (lost time savings) and externalities (environmental benefits) in the analysis.

Figure 3.5 - Potential Annual Economic Impact of IoT in 2025 ($ Billions, adjusted to 2015 dollars)

Settings	Low Impact	High Impact	Major Applications

[13] The first three revolutions where steam, electricity and automation.

Factories	$1,210	$3,700	Operations optimization, predictive maintenance, inventory optimization, health and safety.
Cities	$930	$1,660	Public safety and health, traffic control, resource management.
Human	$170	$1,590	Monitoring and managing illness, improving wellness.
Retail Environments	$410	$1,160	Automated checkout, layout optimization, smart CRM, in-store personalized promotions, inventory shrinkage prevention.
Worksites	$160	$930	Operations optimization, equipment maintenance, health and safety, IoT enabled R&D.
Outside	$560	$850	Logistics routing, autonomous cars and trucks, navigation.
Vehicles	$210	$740	Condition based maintenance, reduced insurance.
Home	$200	$350	Energy management, safety and security, chore automation, usage based design of appliances.
Offices	$70	$150	Organizational redesign and worker monitoring, augmented reality for training, energy monitoring, building security.
Totals	**$3,920**	**$11,130**	---

Source: McKinsey Global Institute, 2015

The exact impacts of IoT depend upon a number of factors including the level of acceptance by consumers and workers over time which will affect the demand for IoT products; whether opportunity costs and externalities are included in the estimate; and the potential to realize cost savings on IoT implementation over time as software and hardware costs are reduced through economies of scale. MGI measures both the direct financial impacts of IoT (such as potential savings from improved machine utilization) and non-financial factors converted to economic value (such as consumer time saved or improved health) in its production of the estimates (McKinsey Global Institute, 2015).

It is important to note that 40% of this value, on average, requires multiple IoT systems to work together often across different vendors, and sometimes across different industries. To operate efficiently, IoT systems will either require widely accepted interface standards, or the programming of translation and aggregation protocols into middleware systems (McKinsey Global Institute, 2015). It will take time to develop these standards, ideally on a global scale. Without this type of interoperability, the efficiencies of IoT systems will be reduced and the potential positive economic impacts of the technology will be harder to realize.

Rise of B2B and IoT

MGI estimates that business-to-business (B2B) uses can represent nearly 70% of the economic value generated by IoT systems (McKinsey Global Institute, 2015). In these applications of the technology, data from consumer IoT products (such as health care monitors, home sensing devices and wearables) are utilized and shared by businesses to improve their product and service offerings (such as personalized insurance priced based upon actual home or car usage data). In addition, data produced by the businesses themselves, through IoT implementations at worksites, factories and office spaces, would be used to generate, inform and incentivize new B2B as well as B2C (business-to-consumer) activity.

Big Data Analytics

Both the IoT and the Social Matrix will become the two main sources of data necessary to drive future advanced analytics and artificial intelligence applications. Firms will develop new business models to commodify these rich data sources over the next 5 to 10 years which will mark the real start of the big data analytics era (West, 2016).

IoT in the Madison Region

The major IoT applications in our Region center around our factories (operation optimization, predictive maintenance, inventory and supply chain optimization), our farms (agriculture yield improvement), our cities (adaptive traffic management, autonomous vehicles, resource infrastructure management, and public transit schedule management), our health (health care management) and our vehicles (condition based maintenance). As suggested by MGI (2015) 73% of IoT value is forecasted to occur in three things the MadREP Region does extremely well; namely:

- Operations optimization.
- Conditions based maintenance.
- Health management.

The City of Madison has already begun examining and beta testing smart city systems involving mass transit payment and scheduling systems as well as adaptive traffic signalization. An autonomous vehicle pilot project is also in the planning stages. The City also is one of 16 US municipalities participating in the Smart Cities Collaborative (Yao, 2017). MadREP should support and continue to encourage these efforts in both Madison, as well as other communities throughout the Region.

Industry analyst International Data Corporation (IDC) expects US firms to invest more than $357B in IoT hardware, software, services and connectivity by 2019 (West, 2016). Some industry experts believe the US and Wisconsin are a decade behind Germany and other early adopters at making these types of IoT investments.[14] It will be incumbent upon organizations like MadREP to make the use case to communities and businesses to speed up these investments, so the Region does not fall further behind and start to lose its ability to innovate and compete in the global marketplace.

Connection to Milwaukee

Political and business leaders in the MadREP Region need to recognize that firms in the Milwaukee region, such as Johnson Controls and Rockwell Automation, play an important role in developing hardware products for the IoT ecosystem. Staff believes it is important to link Madison's software with Milwaukee's hardware expertise to maximize the state's potential to excel in the IoT space. This type of connectivity is also important on the research side and could be enhanced by encouraging more activity and collaboration between the UWM IoT Center of Excellence and the UW-Madison IoT Lab. We have already begun to see the benefits of enhanced connectivity with the two region's innovation and entrepreneurship ecosystems. It is also exemplified by M-WERC aligning a portion of its activity with the UW-Madison College of Engineering. If the

[14] Interview with Peter Dettmer, Madison College, October 26, 2017.

two regions can continue to make progress on breaking down these long standing political barriers, the economic benefits (particularly in the IoT niche sector, but also across other target sectors) could be substantial.

Electrical Equipment and Appliances

<&>

Medical Devices

<&>

Bicycles

<&>

Addendum 2 – Opportunities and Key Strategic Initiatives to Support the Madison Region's Advance Manufacturing Industry Sector

The previous sections of this report detail how the Madison Region, the Madison MSA, and the City of Madison are exceptional leaders in the advance manufacturing industry sector.

To address these challenges and move the sector forward, Key Strategic Initiatives (KSIs) are highlighted in this chapter as priority items for MadREP's strategic plan.

Target Advance Manufacturing Companies by Employment Size and Revenue

Between 2000 and 2011, the Madison Region averaged 43 startup firms per year in the combined categories of computer systems design and software publishers. More recently, the Region has experienced significant growth in the number of new firms, with over 100 start-ups per year in 2012, 2015, and 2016. Start-ups that make it through the so-called valley of death become second stage companies that could become scalable "gazelles", or high growth companies, with major potential for the Region.

Non-employer companies are sole-proprietors who may have small enterprises located at home or elsewhere. Non-employer figures originate from IRS tax return information and provide some perspective on the so-called "gig" economy. In 2015, there were more than 1,000 sole proprietors classified in the computer systems design and related service industry within the Madison Region, a number that has grown substantially over the last decade.

- **KSI:** While many of these sole proprietors are in Dane County, a notable number are found in the balance of the Region, with every county in the Madison Region having more than 15 sole proprietors in computer systems design and related services. These non-employers may be an overlooked source of nascent entrepreneurs looking to grow their advance manufacturing businesses.

As firms grow to significant sizes, it may be that other regions or states will offer incentives for their relocations. However, a firm that is valued by its current community is less likely to move. Creating and maintaining relationships with fast-growing firms should be a clear economic development strategy, but community leaders are often unaware of the importance of these firms as they may still be small enough to be missed.

- **KSI:** Creating and maintaining relationships with fast-growing firms should be a clear economic development strategy. Staff should regularly communicate with local elected officials and other community leaders regarding the importance of these firms. Business Retention and Expansion (BRE) visits across the Region should target these advance manufacturing firms.

Second-stage establishments in any industry typically have 10-99 employees and $1 million to $50 million in revenue. Second-stage companies represented only 11.6% of U.S. establishments between 1995 and 2012 while generating nearly 34% of jobs and about 34.5% of sales over this period.

- **KSI:** There are over 100 advance manufacturing establishments in the Region that could potentially fit into this definition. While not all firms may want to grow, dedicated programs to support enterprises in this growth stage could provide a unique opportunity for the Region and fill a common gap in service provision. Most of the major second stage programs are focused on market research, capitalization, supply chain management, international trade, cybersecurity, social media, R&D, human resources, and succession planning. <reference to economic gardening from AN2.0>.

It is important to recognize how many organizational resources have been developed to support the advance manufacturing sector within the last 5 to 10 years. It is truly remarkable how far the Regional I&E ecosystem has evolved in a relatively short period of time. Forward Fest is a major example. MadREP's staff has every reason to believe that the I&E Ecosystem will continue to grow and even accelerate.

- **KSI:** Staff would recommend continuing to promote efforts to link the evolving I&E ecosystem to UW-Madison, UW-Whitewater and UW-Platteville to help accelerate the commercialization of both faculty and student research. It is important to note that UW-Madison and UW-System have been making tremendous strides at assisting these efforts through the enhanced resources represented by MERLIN Mentors, D2P, the Law & Entrepreneurship Clinic, the Center for Technology Commercialization, and the Small Business Development Center. These resources are available on campus centered on @1403 and Grainger Hall. Off campus resources are mainly located at the University Research Park, but also include 100State, Sector67 and StartingBlock Madison. All three of the latter facilities make themselves attractive to students. It is also critically important to acknowledge and continue to support the growing role that WARF is playing in the Region and state's I&E ecosystem through its increasing investment activity in resources and capital programming.

The Madison Region needs to foster more business development partnerships with other regions in the Midwest. The Madison-Milwaukee region opportunities are the most logical and are profiled later in this chapter surrounding sensors, IoT, and smart city technologies. A second, and equally important, opportunity exists with the Minneapolis/St Paul Metro. This region, just four hours away by car, has a much larger population base, a strong technology and manufacturing focus, and has large pools of organization and management expertise with strong track records in scaling companies.

For its size, the Madison Region has an excellent track record for innovation and developing start-ups. The Minneapolis-St. Paul metro area has a record of building mature companies, having successfully scaled thirty Fortune 500 companies in the last 40 years. There is an opportunity to keep the entrepreneurs and their innovations in the northern climates and share innovations, enterprise scaling expertise, physical spaces, and access to capital rather than sending them to the coasts. Similar partnerships should be explored with Ann Arbor, Columbus, Pittsburg, and Waterloo, Ontario; all northern metros with world-class engineering, math and science universities. Partnership discussions should start at the regional economic development level to first assess which regions: a) implement asset-based programming, monitor and maintain solid regional economic data, and b) have the capacity and interest to explore consortium best practices that cross state and country lines.

Advance Manufacturing Subsectors and Niches

When drilling down into the subsectors within the overall ICT sector, several areas or "niches" within the sector tend to stand out as strengths in the Madison Region. These niches are elevated due to the local "need and opportunity," the breadth of companies inside of them, the talent leading and innovating within them, and at times, the national and global market reach of their goods and services.

With respect to this report and the Key Strategic Initiatives (KSI) that drives MadREP's annual operational investment of time, capital and partnerships, the following five advance manufacturing niches stand out as the strongest opportunities for success: advance composite materials, Internet of Things (IoT), electrical equipment and appliances, medical devices, and bicycles.

Advance Material Composites

<&>

Internet of Things (IoT or Industry 4.0)

Ultimately, the incorporation of Industry 4.0 concepts in the manufacturing industry can help firms improve their production processes, anticipate consumer demand, create new supply chain efficiencies, improve worker satisfaction and increase revenues.

- **KSI:** MadREP and its partners will work together to educate companies that Industry 4.0 will also require investment in equipment, research, information technology and cybersecurity by the companies that deploy it.

- **KSI:** MadREP and its partners will work together to educate companies that Industry 4.0 will also require the development and training of a workforce that is further skilled in engineering, data science and security, robotics, computer programming and database development. The educational system, non-profit sector (Wisconsin Tech Council and MadREP Business Education Collaborative) and government agencies all have opportunities to foster these necessary investments in technology and labor.

Electrical Equipment and Appliances

Medical Devices

Bicycles

Other Issues Impacting Advance Manufacturing

Cybersecurity

With Industry 4.0 (i.e. Manufacturing Internet of Things), advance manufacturing businesses are highly susceptible to ransomware and cyberattacks. These hacks typically come from overseas and involve shutting down machinery, stealing intellectual property and getting access to sensitive government and defense related information. Over half of SMEs (small-to-medium enterprises) in Wisconsin have experienced a data breach or cyber-attack per Wisconsin Manufacturing Extension Partnership (WMEP). Per Wisconsin Center for Manufacturing and Productivity (WCMP), many Wisconsin manufacturers that supply the defense industry have been slow to fully comply with the Department of Defense's (DOD) and NIST's special publication 800-171 requirements that went into effect January 1, 2018. SMEs in the Region and state need to prioritize cybersecurity if the manufacturing sector is to stay relevant and grow.

Government, education, health care, retail and essentially all industry sectors, are also susceptible to cyberattacks that could significantly affect their operations and the customers they serve. While WMEP concentrates on the manufacturing sector and defense contractors, a new organization called the Wisconsin Cyber Threat Response Alliance (WICTRA) is concentrating on the culture of cyberattacks and trying to raise overall awareness, preparedness and communication through; a) creating an environment of trust in a non-attribution environment, b) building cyber-attack infrastructure where "live fire experiences" can be tested, and c) working with educational institutions on the creation of necessary workforce, they hope to move Wisconsin in a positive direction.

- **KSI:** Ultimately, we need to understand the threats and their potential severity to change the general apathy leaders at all levels seem to have regarding cybersecurity (i.e. it won't happen to us). MadREP and its partners, such as chambers of commerce and the Wisconsin Tech Council, will drive this awareness through training presentations and newsletters.

- **KSI:** Companies and government need to prioritize cybersecurity systems implementation. This means invest more in up front cyber security protection for operations and systems management while dealing with cyber-attacks once they occur.

- **KSI:** Manufacturers should establish cross-organizational teams to address NIST's special publication 800-171. WMEP has staff as well as NIST personnel at their disposal that can help companies implement the meaningful road map for cyber security protections. Upon completion of this assessment, companies must prioritize budget for cyber protection, hire staff or consultants and implement change.

- **KSI:** Promote organizations like the Midwest Cyber Security Alliance and the SVA/Settlers Bank Partnership that educate private industry and non-profits, respectively, on the new and ever-changing Duty of Care Risk Analysis (DoCRA) and data breach protection.

- **KSI:** Industry leaders need an effective communication conduit into higher education for sharing their desired skill sets and abilities with academics in the hopes of creating a better equipped cybersecurity professional. As an example, gener8tor's Insurtech OnRamp programming could drive academic curriculum and training development for cybersecurity serving the Madison Region.

- **KSI:** Promote StartingBlock Madison and 100State as physical spaces to start, fund and grow mobile application developers.

Blockchain

Although blockchain was invented to support crypto currencies coming out of the Great Recession (2010 Bitcoin value in was $0.003. 8/31/18 bitcoin value was $7,500 with an estimated 1600+ cryptocurrencies around the world), blockchain technology has evolved to essentially serve as a trusted, secure and distributed ledger that can be programmed to record and track anything of value. Different from the common ledger, blockchain data is stored in a shared memory and distributed in a decentralized public ledger that creates trust in the data. Blockchain is poised to revolutionize the way we access, verify and transact data. To summarize Dan Tapscott's TED Talk on the social equity potential behind blockchain, blockchain technologies "will ensure compensation for creators of value, protect rights through immutable records, create a true sharing environment, end remittance rip-offs and the middleman, and enable citizens to own and monetize their data (and its privacy)."

Within the industry sectors of significance in the Madison Region, blockchain has applications in all financial transactions—both public and private, E-Commerce, medical and real estate records, livestock tracking, food safety and traceability, manufacturing supply chain management, insurance and contracts, and agriculture and water resource management. Capacity will be the key to the applicability of where this technology takes root and grows as computing power, data storage, and ultimately, applications processed per second, are drivers.

100State has created 100Crypto, a mini-group of blockchain consultants (roughly 20) that have co-located together at 100State. These are very small groups of individuals that are more "consultants" than "entrepreneurs" developing scalable business. They consult globally, are connected nationally, and hold monthly meet ups that attract 50 attendees.

- **KSI:** Support the legitimization of a separate Center of Excellence (CoE) inside of 100State called 100Crypto focused on developing a blockchain community. The goal is to turn the community into an accelerator of ideas that work on projects and attract talent. The CoE, via its consultant tenants, their network, and related programming, will code blockchain solutions in support of the state's business and industries of significance. The asset for the CoE is intellectual human capital, not intellectual property.

- **KSI:** Create and support either a Capital Catalyst or TIP application for/to WEDC to underwrite the first three years of operation for this non-traditional CoE. WEDC resources will support technology (computing power and storage), educational sessions, blockchain meet-ups, marketing, student scholarships, web development, staffing, shared office space, and an annual blockchain hack-a-thon.

- **KSI:** Find local and national corporate sponsors to backstop the early years, form strategic partnerships, and build brand and networks.

Smart and Connected Cities

This application of IoT technology examines how to make the actual city, business and residential experience innovative and better. Smart city efforts mostly focus on outcomes that effect public safety, energy, infrastructure, operational savings, connectivity, education, inclusion and economic development.

Inside the Region, the City of Madison seems to be the only local government making critical steps towards prioritizing smart cities investments. The City has already begun examining and beta testing smart city systems involving mass transit payment and scheduling systems as well as adaptive traffic signalization. An autonomous vehicle pilot project is also in the planning stages. Traffic Engineering has been leading the Smart City effort in Madison. Madison is one of only 16 US municipalities participating in the Smart Cities Collaborative.

To support smart cities efforts, the City of Madison has budgeted $219,000 in 2019 for a City-wide fiber audit as well as improvement recommendations. CTC Technology and Energy is also under contract with the City to conduct a "fiber-to-the-premises" feasibility study and implementation plan. Original estimates for implementation are around $150 million for a City-wide buildout of core infrastructure with 1 gig symmetry. Special assessment for each household are estimated to be $250 per year for five years.

- **KSI:** MadREP hopes that Smart City initiatives continue to be important for the Madison Common Council and that staff are empowered to be drivers of ideas and applications.

- **KSI:** Political and business leaders in the MadREP Region need to recognize that firms in the Milwaukee region, such as Johnson Controls and Rockwell Automation, play an important role in developing hardware products for the IoT ecosystem. Staff believes it is important to link Madison's software with Milwaukee's hardware expertise to maximize the state's potential to really excel in the IoT space. This type of connectivity is also important on the research side and could be enhanced by encouraging more activity and collaboration between the UWM/Johnson Controls IoT Center of Excellence and the UW-Madison IoT Lab. We have already begun to see the benefits of enhanced connectivity with the two region's I&E ecosystems. It is also exemplified by M-WERC aligning a portion of its activity with the UW-Madison College of Engineering. If we can continue to make progress on breaking down these long standing political barriers, the economic benefits (particularly in the IoT niche sector, but also across other target sectors) could be substantial.

- **KSI:** UW-Madison has a small initiative called UniverCities that has a $250,000 budget state wide. This program needs to be paired with private sector partners to increase their budget and impact 10-fold.

- **KSI:** As the City of Madison's smart city initiatives gain momentum, we need to market and bring these technologies to other interested communities throughout the Region. A couple of examples with great potential are a) ground penetration software systems that are connected to VR where the headsets detect leaks inside of water systems, b) Paradrops 5G WIFI router technology from UW-Madison that is testing with the Madison Police department for accident reduction, and c) energy use in homes tied to energy management outcomes.

- **KSI:** Foxconn is sponsoring smart cities grants to students that could provide $5,000 to each student technology developed. Although these awards are limited in their amounts, this program could serve as a platform for identifying problems, sharing data, and devising technological solutions.

Advance Manufacturing Talent Concerns

Local educational institutions traditionally align their degree programs to meet internal placement metrics. While this practice is not necessarily bad, and in most cases is successful in producing graduates that local businesses want to employ, it fails to acknowledge the fundamental shift discussed earlier where jobs follow talent. As a result, the Region's local educational institutions have not necessarily on-boarded new curriculum around AI, VR/AR, cybersecurity, IoT and blockchain as employers are not currently employing a large number of individuals with these degrees, specializations, or job titles.

MadREP believes it is important for educational institutions to be at the forefront of these trends and be more proactive rather than reactive when defining degree programs that will be attractive to advance manufacturing employers. A deep pool of talent with diverse skill sets increases the Region's ability to start, grow and attract these employers.

- **KSI:** Promote science and mathematics to all students, particularly underrepresented groups during middle and high school years. Inspire Madison Region and high school fabrication laboratories (fab labs) are two of MadREP's programs that need to proliferate throughout the Region. Currently, Inspire only has seven advance manufacturing companies (<&>) volunteering to mentor students.

- **KSI:** The Madison Region needs to add three new high schools to the Fab Lab rolls in the State of Wisconsin each year for the next decade.

- **KSI:** Businesses in the advance manufacturing sector need to partner with Madison College on their new South Campus in Madison that will have 200 MMSD high school students embedded and taking STEM-focused classes.

Within two and four-year universities and colleges, there is a need for more computer and engineering research scientists to support this industry sector. UW needs to continue to change its image from "silos" of research to outward facing Centers of Excellence.

- **KSI:** MadREP encourages Chancellor Blank's Future of Computer Education, Impact and Contribution Advisory Committee to create more outward facing centers, consortiums and institutes serving the advance manufacturing sector. Faculty, alumni, and other innovators are on this committee. MadREP would welcome the opportunity to serve on this Committee.

- **KSI:** Staff believes that getting faculty and academic staff off campus, interacting with entrepreneurs, inventors and integrated to the physical spaces with private sector innovation will be beneficial to their research, entrepreneurs, and the overall I&E ecosystem. Rethinking university compensation and culture is worth exploring to better foster tech transfer and commercialization of ideas. Smart cities, cybersecurity, blockchain and IoT are specific current opportunities.

Specific Talent Opportunities of Significance in Advance Manufacturing Sector Niches

Above and beyond the cybersecurity talent needs discussed earlier, below are some specific talent needs and opportunities within the advance manufacturing niches:

- *Big Data Analytics and Storage:* The UW-Madison Information School (iSchool) has expanded from long standing degrees in Library Science (Librarianship) and Archiving (Archives in the digital age) to include Information Organization (metadata taxonomy, ontology, relational databases, content management, and systems analysis), Data Management and Analytics, and the User Experience (UX). Given the Madison Region's ICT, biosciences, non-profit, government, and overall research-oriented employment base, these Master's programs are highly responsive to the state and nation's need for data asset managers. This Master's program, like others related to ICT careers that are evolving at the UW but are lessor known, need more exposure to the Region's employers. This program will have evolved even further when students and faculty are collaborating with the nation's best cybersecurity experts and firms to protect the data they are collecting, organizing and putting to productive use;

- *Advanced Computing Technologies / Big Data / IoT / Smart Cities:* Advanced computing includes computer hardware, software, AR/VR/XR and the talent needed to utilize these technologies. Advanced computing enables government leaders to rethink and improve their infrastructure and programming tied to their economy. It also fortifies a company's ability in most industry sectors to implement emerging technologies related to smart manufacturing, IoT, AI, big data and innovative product design. UW CSM students trained in predictive algorithms and big data analytics are desirable.

Infrastructure: Building out Our Communities and Business Parks

For our businesses, citizens, communities and Region to stay competitive and globally connected, broadband infrastructure must be built out to *future* standards throughout the Region. 4G technologies is the base minimum for the entire Region as broadband is critical to IoT, smart cities, and data center investments and planning. 5G technologies should be the standard for the more technology dense metropolitan areas (such as the cities of Madison, Beloit, Whitewater and Janesville) where financial return on investment (ROI) may exist for providers.

All the use cases for 5G are in development and not currently well commercialized. These include connected factories, autonomous vehicles, smart city platforms and virtual reality. However, 5G will help usher in the IoT era which will result in the commodification of information and data intelligence (West, 2016).

- **KSI:** Other companies could be potentially drawn into the area, with a well-developed marketing effort focused on talent and quality of life, provided that the Region has begun installation of a 5G network. The Region cannot afford to lag the nation on the network rollout or staff believes we risk compromising our competitiveness in retaining and attracting these types of IoT dependent advance manufacturing businesses. MadREP needs to ensure that its eight-county Region is high on the list of target areas to be served and the network gets built out as quickly as possible.

Schools, hospitals, universities and libraries in most communities throughout the Region have access to high speed Internet at 25 Mbps (megabytes per second) or higher. In the Madison Region, the communities of Sun Prairie, Mt. Horeb and Reedsburg have/had their own Local Exchange Carriers, Internet Service Providers, and Wireless Carriers that provide broadband telecommunications to their residents and businesses. These three communities are a rarity in the Region.

In Dane County, the Metropolitan Unified Fiber Network (MUFN) is a collaborative metro fiber-optic network assisting education, healthcare, government, and non-profit organizations located inside major portions of the cities of Madison, Middleton, and Monona.[15] Outside of these communities, the rest of the Region historically has not met state broadband standards (10 Mbps download and 1 Mbps upload), let alone federal standards (25 Mbps download and 3 Mbps upload) throughout each community. Southwestern Sauk County, the western half of Rock County, south eastern Dane County, eastern Columbia County and major portions of Iowa, Dodge and Jefferson County have major dead zones for broadband using national standards.

In the collar counties around Dane, CenturyLink, Frontier and AT&T are the big players. In Madison proper, Charter (cable), AT&T and TDS are the largest providers. In Dane County, TDS has investments in business corridors in Madison and residential build-outs in Fitchburg, Verona and Middleton. MadisonWIFI serves residents, and 5NINES and SupraNet Communications are very company focused, providing networking, gear, equipment, IT solutions, LAN, Data Center along with ISP services.

Moving forward, the City of Sun Prairie has set the benchmark for broadband. In 2017, TDS acquired the Sun Prairie Telco infrastructure Prairie and built out the entire community in 16 months with 4,500 connections serving both residential and business users. Packages of up to 1 gig are available but 100 Mbps symmetry is

[15] MUFN Members include UW Health, UW Madison, DayNET (NGO that focuses on digital literacy working with underserved populations), Wisconsin Independent Network, SupraNet Communications, the Cities of Monona, Middleton, and Madison, Dane County, Madison College, the School Districts serving Madison, Middleton- Cross Pains and Monona Grove, South Central Library System, Unity Point Health-Meriter, UW Health, WiscNET, WDPI, Wisconsin Geological and Natural survey, and the Wisconsin State Hygiene Lab.

the base standard.[16] TDS is now under contract to do the same in Oregon, McFarland, Cottage Grove, and DeForest/Windsor. The Village of Deforest invested $150,000 towards their future build out to be both a partner in the effort and have a say over targeted areas they want to be wired.

- **KSI:** The State's Public Service Commission and the Wisconsin Broadband Office (WBO) have an annual state grant program. State funding for 2019 is $7 million and communities are encouraged to apply. Though not much funding, this program has been beneficial to grant recipients. We need to advocate for more and consistent funding.

- **KSI:** As communities plan and partner to build out their broadband infrastructure, they should talk to other communities that have already implemented and invested, reach out in state to the Wisconsin State Telecommunications Association (WSTA), and connect to Broadband USA, which works in a number of areas to remove barriers to broadband deployment and enhance connectivity throughout the United States. Though Broadband USA no longer is accepting grant applications to facilitate broadband improvements, they do have the following major programming efforts that are proving helpful across the country:

  - **Broadband Interagency Working Group**. National Telecommunications and Information Administration (NTIA) and USDA's Rural Utility Service co-lead BIWG's work to enhance broadband deployment by streamlining federal broadband permitting, enhancing broadband funding information and leveraging federal assets. Agency contacts are available here.

  - **State Broadband Leaders Network.** SBLN is a community of practitioners who work on state broadband initiatives.

  - **Smart City and Smart Ag and Rural**. NTIA works with NIST's Global City's Team Challenge to help lead the Public WIFI and Ag and Rural Superclusters.

  - **One-on-One and Group Technical Assistance.** Technical assistance is available at broadbandusa@ntia.doc.gov.

- **KSI:** At this time, the City of Madison is the only community in the Madison Region big enough to warrant interest from 5G providers. It is important that the City find ways to partner with 5G providers to keep the Madison Region connected at the type of speeds and symmetry required by advance manufacturing businesses to remain competitive. MadREP will work with Madison's neighbors to facilitate expansion of this system when appropriate.

- **KSI:** As technology is changing rapidly, MadREP will continue to find local and global technological solutions that will enhance 5G build out throughout the City and Region. Computing via home Wi-Fi routers can help build out the 5G infrastructure by leasing these systems to ISP firms. UW-Madison's Suman Banerjee has a prototype of a home WiFi router called Paradrop that is filled with a gigabit of

[16] *100 Mbps symmetry means 100 Mbps up and download speeds.*

capacity that could host many apps for the mobile phone. This technology integrates with the phone, cloud, Bluetooth, Zigbee, IoT and other related communication and storage technologies. Processing is done locally, not mandating the use of the cloud. There are cybersecurity benefits to this system since data is locally stored and analyzed. There are cost savings as well since broadband needs are less.

Housing

Conversations with the Region's economic development professionals, employers and workforce development organizations suggest that housing cost and availability, particularly for first-time buyers, is emerging as a challenge for many communities. It is estimated that over a dozen communities in the Madison Region have performed or budgeted to perform a housing market study with a focus on workforce housing.

- **KSI:** MadREP will work with communities throughout the Region to site, fund, and maintain the affordability of new workforce housing.

- **KSI:** The single-family new construction market is limited by workforce availability. In Dane County alone, there is an annual market for 1,200 new single-family homes to be built but only enough workforce to construct 600 homes per year. 70% of construction workers work in the state they were born. MadREP needs to work with the International Economic Development Council (IEDC) on workforce development research that helps define workforce issues and education, training and immigration solutions.