# Abstract of the Madison Region's Bioscience Industry Cluster

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*Prepared for*
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# 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 Bioscience Industry Cluster.[1] Specifically, the Region has a diversity of firms engaged in a variety of bioscience 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 bioscience 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 bioscience 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 bioscience cluster. However, Southern Wisconsin is by no means the only region attempting to build a cluster around similar assets. Cities, regions and states across the nation are aggressively pursuing cluster opportunities in bioscience industries such as drugs and pharmaceuticals; medical devices and equipment; research, development and testing; and agricultural feedstock and industrial biosciences. Regions are also considering how their bioscience industries are being influenced by modern production technologies associated with Industry 4.0. *The challenge for the Madison Region is to build its bioscience cluster around its comparative advantages in a manner that differentiates itself from other bioscience related initiatives.* Accordingly, a primary goal of this abstract is to begin understanding the Region's bioscience cluster in a way that identifies its potential comparative advantages.

[1] The *Advance Now* economic development strategy formally identifies bioscience 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 bioscience 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 bioscience 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 bioscience 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 bioscience 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 bioscience-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 bioscience cluster opportunities extend into nearby areas (such as Milwaukee, 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 bioscience 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 bioscience cluster initiative will require: 1) considering the breadth and depth of industries in the bioscience cluster; 2) understanding characteristics of the Region's labor force or human capital; 3) identifying potential niches or opportunities for differentiating the Region's bioscience 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 bioscience cluster abstract is organized as follows:

*Section 1 – Bioscience 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 bioscience cluster. Measures of bioscience industry scale and scope include employment, location quotients, establishments, and concentration. Definitions of bioscience industries are further detailed in Section 1.

*Section 2 – Human Capital in the Bioscience Industry Cluster*. Section 2 focuses on bioscience-related 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 bioscience human capital include occupational concentrations, talent diversity, mobility and wage rates.

*Section 3 – Bioscience Industry Cluster Support and Development Ecosystem*. Section 3 examines other factors that contribute to the support and development of the Region's bioscience industry including: broadband availability and distribution; regional assets that influence talent attraction and retention; 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 bioscience industry 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 bioscience cluster.

## Defining Bioscience

This analysis relies on bioscience industry classifications from the Biotechnology Industry Organization (BIO). These classifications are used for purposes of consistency as they have been utilized for many years and provide opportunities to benchmark the Madison Region's bioscience industry against national trends and other regions. These bioscience industry classifications include:

- **Drugs and pharmaceuticals** — Firms that develop and produce biological and medicinal products and manufacture pharmaceuticals and diagnostic substances.

- **Medical devices and equipment** — Firms that develop and manufacture surgical and medical instruments and supplies, laboratory equipment, electromedical apparatus including MRI and ultrasound equipment, dental equipment and supplies.

- **Research, testing and medical laboratories** — Firms engaged in research and development in biotechnology and other life sciences, life science testing laboratories and medical laboratories. Includes contract and clinical R&D organizations.

- **Agricultural feedstock and industrial biosciences** — Firms engaged in agricultural production and processing, organic chemical manufacturing and fertilizer manufacturing. The subsector includes industry activity in the production of ethanol and other biofuels.

- **Bioscience-related distribution** — Firms that coordinate the delivery of bioscience-related products spanning pharmaceuticals, medical devices and agricultural biotech. Distribution in the biosciences is unique in its deployment of specialized technologies including cold storage, highly regulated monitoring and tracking and automated drug distribution systems.

While this analysis focuses on specific bioscience industries, many other industries covered in MadREP's ICT, Advanced Manufacturing and Health Care industry cluster abstracts overlay or complement the bioscience industries considered here. Accordingly, these industry categories are not necessarily exclusive.

## Life Science Core Industries (NAICS)

**Drugs and pharmaceuticals**

- Medicinal and Botanical Manufacturing (325411)
- Pharmaceutical Preparation Manufacturing (325412)
- In-Vitro Diagnostic Substance Manufacturing (325413)
- Biological Product (Except Diagnostic) Mfg. (325414)

**Medical devices and equipment**

- Electromedical Apparatus Manufacturing (334510)
- Analytical Laboratory Instrument Mfg. (334516)
- Irradiation Apparatus Manufacturing (334517)
- Medical Equipment and Supplies Mfg. (3391)

**Research, testing, and medical laboratories**

- Research and Development in the Physical, Engineering and Life Sciences (54171)
- Testing Laboratories (54138)
- Medical and Diagnostic Laboratories (6215)

**Agricultural feedstock and chemicals**

- Wet Corn Milling (311221)
- Soybean and Other Oilseed Processing (311224)
- Ethyl Alcohol Manufacturing (325193)
- Pesticide, Fertilizer and Other Ag. Chemical Mfg. (3253)

**Bioscience-related distribution**

- Medical, Dental, and Hospital Equipment and Supplies Merchant Wholesalers (423450)
- Drugs and Druggists' Sundries Merchant Wholesalers (424210)
- Farm Supplies Merchant Wholesalers (424910)

## Life Science Talent

**Life Science Occupations**

- Medical Scientists
- Epidemiologists
- Chemists
- Biochemists and Biophysicists
- Biological Scientists, All Other
- Microbiologists
- Clinical Laboratory Technologists and Technicians
- Chemical Technicians
- Biological Technicians
- Dental Laboratory Technicians

**Engineers and Computer Occupations**

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

**Production, Transportation and Repair Occupations**

- Inspectors, Testers, Sorters, Samplers, and Weighers
- Assemblers and Fabricators
- Chemical Equipment Operators and Tenders
- Packaging and Filling Machine Operators and Tenders
- Mixing and Blending Machine Setters, Operators, and Tenders
- Industrial Machinery Mechanics
- Machinists
- Maintenance and Repair Workers, General
- Shipping, Receiving, and Traffic Clerks
- Laborers and Freight, Stock, and Material Movers, Hand
- Production, Planning, and Expediting Clerks

**Business, Management and Financial Occupations**

- General and Operations Managers
- Architectural and Engineering Managers
- Natural Sciences Managers
- Industrial Production Managers
- Compliance Officers
- Accountants and Auditors
- Bookkeeping, Accounting, and Auditing Clerks
- Market Research Analysts and Marketing Specialists
- Business Operations Specialists, All Other

**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 of Office and Administrative Support Workers
- Sales Representatives, Wholesale and Manufacturing

## Life Science Support and Development Components

- Specialized Financial, Legal and Advertising Services
- Air, Truck and Rail Transportation
- Educational Institutions/R&D Funding
- Entrepreneurial Support Organizations
- Specialized Commercial Space
- Government
- Regional Quality of Life

## Life Science Core Industry Supply Chains

**Drugs and pharmaceuticals**

- Basic organic and inorganic chemicals
- Pharmaceutical preparations and botanicals
- Biological products
- In-vitro diagnostic substances
- Refined petroleum products
- Petrochemical and other chemical products and preparations
- Scientific research and development services
- Management, scientific, and technical consulting services
- Commercial and industrial machinery and equipment repairs, maintenance, rental and leasing
- Electronic and precision equipment repairs and maintenance
- Plastics bottles and glass containers
- Other pressed and blown glass and glassware
- Processed animal and rendered byproducts
- Laminated/unlaminated paper and plastic materials, films and sheets
- Light gauge metal containers
- Glass containers
- Oilseeds
- Industrial gases

**Medical devices and equipment**

- 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

**Research, testing, and medical laboratories**

- Management, scientific, and technical consulting services
- Architectural, engineering, and related services
- Computer systems design services
- Other computer related services, including facilities management
- Scientific R&D services
- Accounting, tax preparation, bookkeeping, and payroll services
- Environmental and other technical consulting services
- Other plastics and rubber products
- Soaps and cleaning compounds
- Waste management and remediation services
- Other basic organic chemicals
- Commercial and industrial machinery and equipment repair, maintenance, sales and leasing
- Electronic and precision equipment repairs and maintenance
- Pharmaceutical preparations
- Other pressed and blown glass and glassware
- Printed materials
- Computer terminals and other computer peripheral equipment

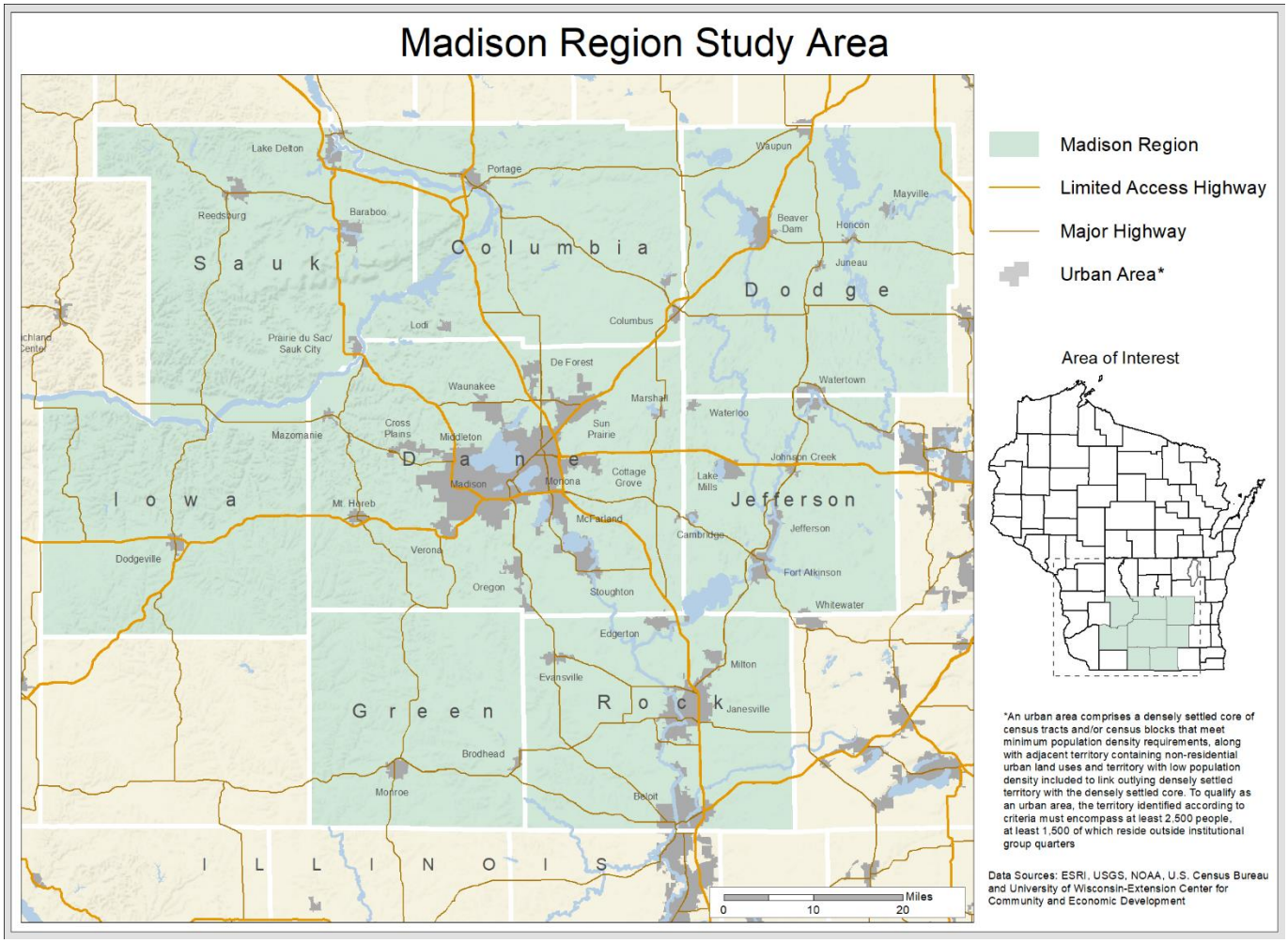
**Agricultural feedstock and chemicals**

- Basic organic and inorganic chemicals
- Scientific R&D services
- Refined petroleum products
- Soaps and cleaning compounds
- Semiconductor and related devices
- Other chemical products and preparations
- Industrial gases
- Synthetic dyes and pigments
- Alkalies and chlorine
- Adhesives
- Petroleum lubricating oils and greases
- Oilseeds and Forest products
- Printed circuit assemblies
- Bare printed circuit boards
- Plastics bottles
- Metal tanks (heavy gauge)
- Power boilers and heat exchangers
- Commercial and industrial machinery and equipment repair, maintenance, sales and leasing
- Coated, engraved, heat treated products, metals and plastics
- Paperboard containers
- Printed materials
- Valves and fittings
- Machined products, metals and plastics

## Study Area

The bioscience 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 bioscience 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 bioscience 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 bioscience 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.

# Section 1 – Bioscience Industries in the Madison Region

As noted in the Introduction to this analysis, the Madison Region's Bioscience Industry Cluster includes a diversity of industries that have individual strengths and characteristics, but also complement one another in terms of their needs for human, social, physical and financial capital. In other words, each category of bioscience is somewhat unique, but together are important contributors to the Region's labor market, innovation environment, entrepreneurial ecosystem and overall regional prosperity. To better understand the scale and scope of the Madison Region's bioscience industries, the following section considers the cluster from the perspectives of bioscience industry employment, concentration and diversity.

Again, this analysis relies on bioscience industry classifications from the Biotechnology Industry Organization (BIO). These classifications are used for purposes of consistency as they have been utilized for many years and provide opportunities to benchmark the Madison Region's bioscience industry against national trends and other regions. As noted by BIO, these bioscience industry classifications include:

- **Drugs and pharmaceuticals** — Firms that develop and produce biological and medicinal products and manufacture pharmaceuticals and diagnostic substances.
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- **Research, testing and medical laboratories** — Firms engaged in research and development in biotechnology and other life sciences, life science testing laboratories and medical laboratories. Includes contract and clinical R&D organizations.
- **Agricultural feedstock and industrial biosciences** — Firms engaged in agricultural production and processing, organic chemical manufacturing and fertilizer manufacturing. The subsector includes industry activity in the production of ethanol and other biofuels.
- **Bioscience-related distribution** — Firms that coordinate the delivery of bioscience-related products spanning pharmaceuticals, medical devices and agricultural biotech. Distribution in the biosciences is unique in its deployment of specialized technologies including cold storage, highly regulated monitoring and tracking and automated drug distribution systems.

Bioscience industries are examined in terms of employment, concentration, output and establishments. However, due to the detailed industry categories used to define the bioscience cluster, not every bioscience category can be examined in a precise manner. Furthermore, it may be some businesses in the bioscience cluster do not neatly fit into one bioscience category (such as Promega). Accordingly, it may be that some bioscience categories have measures of employment or establishments that may not meet preconceptions or assumptions about their size or scale. While not included as part of the analysis in Section 1, it is also important to note that the Madison Region also has several bioscience niches that are not explicitly delineated by these classifications. These niches will be further considered by MadREP in a future analysis.

## Drugs and Pharmaceuticals

The drugs and pharmaceuticals bioscience category is covered by the *Pharmaceutical and Medicine Manufacturing (NAICS 3254)* industry. As reported by the Census Bureau, this industry "comprises establishments primarily engaged in one or more of the following: (1) manufacturing biological and medicinal products; (2) processing (i.e., grading, grinding, and milling) botanical drugs and herbs; (3) isolating active medicinal principals from botanical drugs and herbs; and (4) manufacturing pharmaceutical products intended for internal and external consumption in such forms as ampoules, tablets, capsules, vials, ointments, powders, solutions, and suspensions." Subcategories of pharmaceuticals include:

- Medicinal and Botanical Manufacturing (NAICS 325411);
- Pharmaceutical Preparation Manufacturing (NAICS 325412);
- In-Vitro Diagnostic Substance Manufacturing (NAICS 325413); and
- Biological Product (Except Diagnostic) Manufacturing (NAICS 325414).

In 2017, the Madison Region's drug and pharmaceutical manufacturing industry accounted for over 2,200 employees, $1.66 billion in industrial output and $221.5 million in employee compensation ($100,000 per employee). The Region also accounts for more than 50% of Wisconsin's total output and employment in this category of bioscience (Figure 1.1).[3] While firms may actually produce products found in multiple categories, most firms are found in pharmaceutical preparation manufacturing and biological product manufacturing (Figure 1.2). Six firms in the region have at least 100 employees, with one firm having more than 500 employees. These larger firms include Promega, Invitrogen (Thermo Fisher), and Scientific Protein Laboratories (SPL).

**Figure 1.1 - Drugs and Pharmaceuticals Industry Employment, Output and Employee Compensation in the Madison Region**

| Industry Measure | Madison Region | Madison Region as a Percent of Wisconsin Total for Industry |
|---|---|---|
| Total Employment | 2,210 | 53.7% |
| Total Industrial Output | $1,663,300,000 | 51.2% |
| Total Employee Compensation | $221,500,000 | 54.1% |

Source: IMPLAN and Authors Calculations

**Figure 1.2 – Madison Region Establishments by Employment size in Drugs and Pharmaceuticals (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. |
| 325411 | Medicinal and botanical manufacturing | 4 | 0 | 2 | 2 | 0 |
| 325412 | Pharmaceutical preparation manufacturing | 12 | 4 | 6 | 2 | 0 |
| 325413 | In-vitro diagnostic substance manufacturing | 6 | 1 | 4 | 0 | 1 |
| 325414 | Biological product (except diagnostic) mfg. | 10 | 2 | 7 | 1 | 0 |
| | *Drugs and Pharmaceuticals Total* | *32* | *7* | *19* | *5* | *1* |

Source: U.S. Census Bureau County Business Patterns

[3] The Madison Region accounts for 18% of Wisconsin's total population

Most firms in this bioscience category are classified as Stage 2 firms, or so-called second-stage companies (Figure 1.3). Second-stage companies are often overlooked by economic and business development activities. Stage 2 firms 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. Consequently, more formal operational structures and strategies 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.

Importantly, research from the Edward Lowe Foundation suggests that second-stage companies provide an important source of employment growth. For instance, second-stage companies represented only 11.6% of U.S. establishments between 1995 and 2012, but generated nearly 34% of jobs and about 34.5% of sales over this period. Second-stage establishments typically have 10-99 employees and $1 million to $50 million in revenue. Accordingly, many of Madison Region's bioscience establishments potentially fit into this definition. While not all of these firms may want to grow, dedicated programs to support enterprises in this growth stage could provide a unique opportunity for the Region.

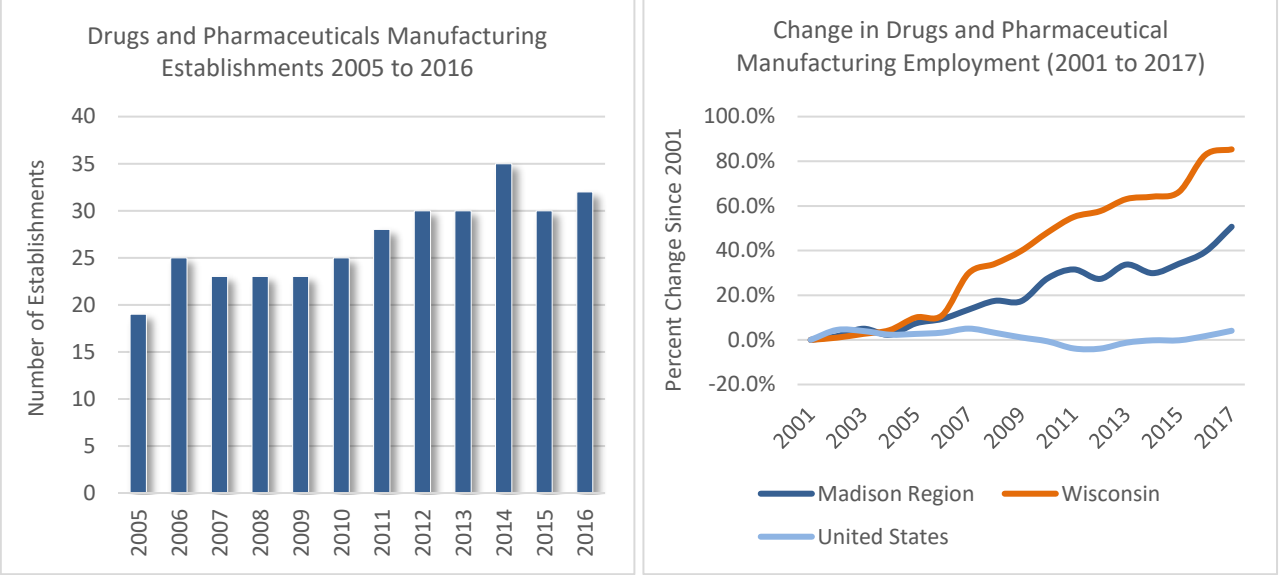
**Figure 1.3 – Business Stages**

- 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/YourEconomy.org

While data suppression issues preclude a detailed analysis of change within individual categories of the drugs and pharmaceuticals bioscience industry, broader trends in establishments and employment can be measured. While the number of individual establishments in the Region changes from year-to-year, the total number of firms has largely increased over the last decade. Indeed, the number of establishments grew from 19 in 2005 to the current level of 32 (Figure 1.3). Drug and pharmaceutical manufacturing employment in the Madison Region also increased notably by50% since 2001 (Figure 1.3). While the rate of employment growth in the Madison Region was somewhat slower than that of the State of Wisconsin, the Region's employment grew significantly faster than the national rate. Furthermore, the Region's drug and pharmaceutical manufacturing industry did not experience the downturn in employment the national industry faced during the Great Recession.

**Figure 1.3 – Madison Region Establishments by Employment size in Drugs and Pharmaceuticals (2016)**




Source: U.S. Census Bureau County Business Patterns, Bureau of Labor Statistics QCEW and Authors' Calculations

In terms of total pharmaceutical and medicine manufacturing establishments, the Madison MSA ranks 25th among all metro areas (Figure 1.4). *Note that the number of establishments and total employment in metro areas comparisons throughout this analysis will different somewhat from those in other tables due to differences in year, geography and data sources.* Large metropolitan areas that are long established centers of pharmaceutical manufacturing are found near the top of these rankings such as New York, Los Angeles, Philadelphia, San Diego, San Francisco, Boston and Chicago. In fact, the Madison MSA is among the smaller metro areas included in Figure 1.4. However, many of the smaller to mid-sized metro areas that are ranked among the top 50 are home to an R1 research university, which reinforces the role of UW-Madison and other educational institutions in driving the bioscience industry cluster.

**Figure 1.4 – Top 50 MSAs for Pharmaceutical and Medicine Manufacturing (NAICS 3254) Establishments (2017)**

| Rank | Metropolitan Statistical Area | Number of Establishments | Total Employment | Employment Location Quotient |
|---|---|---|---|---|
| 1 | New York-Newark-Jersey City, NY-NJ-PA MSA | 345 | 31,776 | 1.70 |
| 2 | Los Angeles-Long Beach-Anaheim, CA MSA | 185 | 11,990 | 0.99 |
| 3 | Philadelphia-Camden-Wilmington, PA-NJ-DE-MD MSA | 115 | 14,637 | 2.61 |
| 4 | Miami-Fort Lauderdale-West Palm Beach, FL MSA | 114 | 2,590 | 0.51 |
| 5 | San Diego-Carlsbad, CA MSA | 111 | 7,088 | 2.43 |
| 6 | San Francisco-Oakland-Hayward, CA MSA | 95 | S | S |
| 7 | Boston-Cambridge-Newton, MA-NH MSA | 85 | 9,465 | 1.77 |
| 8 | Chicago-Naperville-Elgin, IL-IN-WI MSA | 82 | 17,181 | 1.89 |
| 9 | Washington-Arlington-Alexandria, DC-VA-MD-WV MSA | 72 | 5,562 | 0.88 |
| 10 | Denver-Aurora-Lakewood, CO MSA | 69 | 1,404 | 0.48 |
| 11 | Seattle-Tacoma-Bellevue, WA MSA | 66 | S | S |
| 12 | Atlanta-Sandy Springs-Roswell, GA MSA | 53 | 1,542 | 0.30 |
| 13 | Dallas-Fort Worth-Arlington, TX MSA | 53 | 4,168 | 0.59 |
| 14 | Phoenix-Mesa-Scottsdale, AZ MSA | 52 | S | S |
| 15 | Houston-The Woodlands-Sugar Land, TX MSA | 49 | 2,468 | 0.42 |
| 16 | Tampa-St. Petersburg-Clearwater, FL MSA | 49 | 1,745 | 0.68 |
| 17 | St. Louis, MO-IL MSA | 42 | 4,095 | 1.53 |
| 18 | Minneapolis-St. Paul-Bloomington, MN-WI MSA | 41 | 3,253 | 0.85 |
| 19 | Salt Lake City, UT MSA | 41 | S | S |
| 20 | San Juan-Carolina-Caguas, PR MSA | 41 | 12,080 | 9.50 |
| 21 | Kansas City, MO-KS MSA | 39 | 1,626 | 0.78 |
| 22 | Portland-Vancouver-Hillsboro, OR-WA MSA | 35 | S | S |
| 23 | Detroit-Warren-Dearborn, MI MSA | 34 | S | S |
| 24 | Baltimore-Columbia-Towson, MD MSA | 33 | 2,554 | 0.95 |
| **25** | **Madison, WI MSA** | **33** | **2,025** | **2.62** |
| 26 | San Jose-Sunnyvale-Santa Clara, CA MSA | 30 | 2,754 | 1.25 |
| 27 | Austin-Round Rock, TX MSA | 28 | 2,023 | 1.01 |
| 28 | Durham-Chapel Hill, NC MSA | 26 | 6,264 | 10.47 |
| 29 | Riverside-San Bernardino-Ontario, CA MSA | 26 | 1,081 | 0.37 |
| 30 | Provo-Orem, UT MSA | 24 | S | S |
| 31 | Trenton, NJ MSA | 24 | 2,024 | 4.03 |
| 32 | Boulder, CO MSA | 23 | 1,142 | 3.13 |
| 33 | Cincinnati, OH-KY-IN MSA | 23 | 2,098 | 1.00 |
| 34 | Orlando-Kissimmee-Sanford, FL MSA | 23 | 909 | 0.37 |
| 35 | Charlotte-Concord-Gastonia, NC-SC MSA | 22 | 2,123 | 0.90 |
| 36 | Ogden-Clearfield, UT MSA | 22 | 1,455 | 2.84 |
| 37 | Milwaukee-Waukesha-West Allis, WI MSA | 21 | S | S |
| 38 | Indianapolis-Carmel-Anderson, IN MSA | 20 | S | S |
| 39 | Boise City, ID MSA | 19 | S | S |
| 40 | Raleigh, NC MSA | 19 | S | S |
| 41 | San Antonio-New Braunfels, TX MSA | 19 | 1,166 | 0.58 |
| 42 | Portland-South Portland, ME MSA | 18 | 1,814 | 3.31 |
| 43 | Buffalo-Cheektowaga-Niagara Falls, NY MSA | 17 | S | S |
| 44 | Las Vegas-Henderson-Paradise, NV MSA | 16 | 524 | 0.27 |
| 45 | Richmond, VA MSA | 16 | 719 | 0.56 |
| 46 | Sacramento--Roseville--Arden-Arcade, CA MSA | 16 | 743 | 0.38 |
| 47 | Albuquerque, NM MSA | 15 | 551 | 0.73 |
| 48 | Allentown-Bethlehem-Easton, PA-NJ MSA | 15 | S | S |
| 49 | Charleston-North Charleston, SC MSA | 15 | 136 | 0.20 |
| 50 | Oklahoma City, OK MSA | 15 | 562 | 0.46 |

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

The establishment rankings also provide location quotients for the pharmaceutical and medicine manufacturing industry in these metro areas. A location quotient (LQ) is calculated by comparing an industry's share of local employment to the industry's share of overall national employment.

$$\textit{Location Quotient (LQ) for a bioscience industry} = \frac{\dfrac{\text{Bioscience industry employment in the Region}}{\text{Total employment in the Region (all industries)}}}{\dfrac{\text{Bioscience industry national employment}}{\text{Total national employment (all industries)}}}$$

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.

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.

The Madison Region's location quotient for pharmaceutical and medicine manufacturing is 2.62. This LQ value reflects that the Region has a notable specialization in this industry. While many LQs in Figure 1.5 are suppressed, the Madison Region is among the highest of those reported. The Region's LQ and employment levels are also larger than those of many metro areas with populations of one million or more.

## Medical Devices and Equipment

The medical devices and equipment component of the bioscience industry includes several specific categories of manufacturing. As described by the U.S. Census Bureau, these categories include:

- *Electromedical and Electrotherapeutic Apparatus Manufacturing (NAICS 334510)* - This U.S. industry comprises establishments primarily engaged in manufacturing electromedical and electrotherapeutic apparatus, such as magnetic resonance imaging equipment, medical ultrasound equipment, pacemakers, hearing aids, electrocardiographs, and electromedical endoscopic equipment.

- *Analytical Laboratory Instrument Manufacturing (NAICS 334516)* - This U.S. industry comprises establishments primarily engaged in manufacturing instruments and instrumentation systems for laboratory analysis of the chemical or physical composition or concentration of samples of solid, fluid, gaseous, or composite material.

- *Irradiation Apparatus Manufacturing (NAICS 334517)* - This U.S. industry comprises establishments primarily engaged in manufacturing irradiation apparatus and tubes for applications, such as medical diagnostic, medical therapeutic, industrial, research and scientific evaluation. Irradiation can take the form of beta-rays, gamma-rays, X-rays, or other ionizing radiation.

- *Medical Equipment and Supplies Manufacturing (NAICS 3391)* - This industry comprises establishments primarily engaged in manufacturing medical equipment and supplies. Examples of products made by these establishments are surgical and medical instruments, surgical appliances and supplies, dental equipment and supplies, orthodontic goods, ophthalmic goods, dentures, and orthodontic appliances.

In 2017, the Region's medical devices and equipment manufacturing industry accounted for almost 1,900 employees, $821.3 million in industrial output and $190.8 million in employee compensation (Figure 1.6). The Region is home to approximately 17% Wisconsin's total medical devices and equipment industry in terms of employment, output and compensation, with a large share of the state's employment also located in the nearby Milwaukee metro area. In terms of total establishments, the medical equipment and supplies manufacturing category is the largest with 47 establishments located in the Madison Region (Figure 1.7)

Eight firms in the region have at least 100 employees, with one firm having more than 500 employees. These larger firms include some of the Region's prominent bioscience firms including Thermo Fisher, Bruker AXS, GE Healthcare and Accuray. Again, many firms in this bioscience category are classified as Stage 2 firms, or so-called second-stage companies. However, the industry also has 42 establishments with less than 10 employees.

**Figure 1.6 – Medical Devices and Equipment Industry Employment, Output and Compensation in the Madison Region**

| Industry Measure | Madison Region | Madison Region as a Percent of Wisconsin Total for Industry |
|---|---|---|
| Total Employment | 1,897 | 16.5% |
| Total Industrial Output | $821,300,000 | 16.7% |
| Total Employee Compensation | $190,800,000 | 17.0% |

Source: BLS QCEW (employment), IMPLAN and Authors Calculations

**Figure 1.7 – Madison Region Establishments by Employment size in Medical Devices and Equipment (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. |
| 334510 | Electromedical and electrotherapeutic apparatus manufacturing | 8 | 3 | 3 | 2 | 0 |
| 334516 | Analytical laboratory instrument manufacturing | 8 | 3 | 2 | 3 | 0 |
| 334517 | Irradiation apparatus manufacturing | 4 | 1 | 1 | 2 | 0 |
| 3391 | Medical equipment and supplies manufacturing | 47 | 35 | 11 | 0 | 1 |
| | *Medical Devices and Equipment Total* | *67* | *42* | *17* | *7* | *1* |

Source: U.S. Census Bureau County Business Patterns and Authors' Estimates

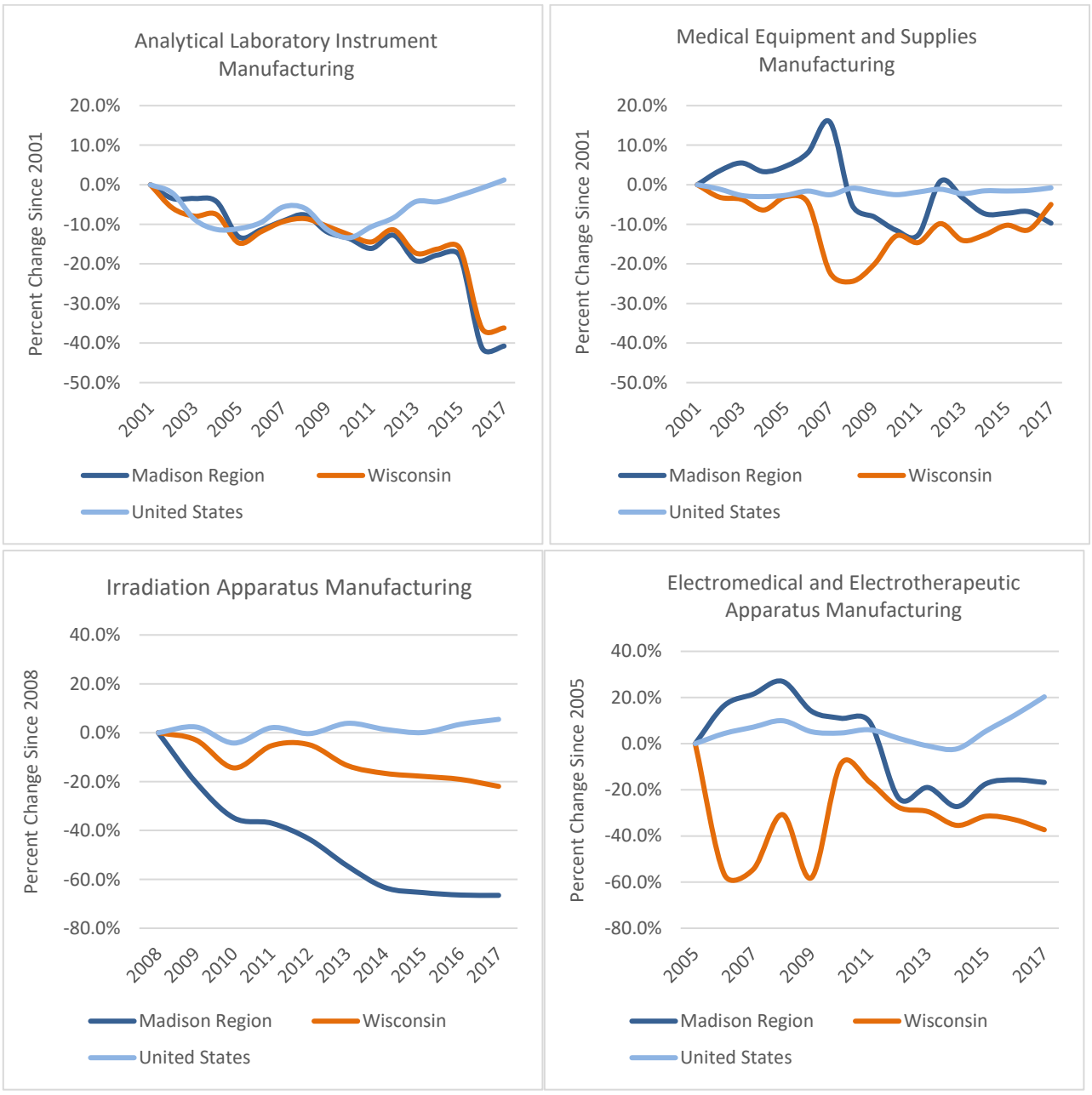
Employment within the medical device and equipment manufacturing component of the bioscience cluster has largely declined over the past decade (Figure 1.8). In 2017, employment in analytical laboratory instrument manufacturing in the Madison Region was 41% below 2001 employment levels. Similarly, 2017 employment in medical equipment and supplies manufacturing was 10% below 2001 employment levels in the industry. Employment data suppression precludes an analysis of employment change over the same period since 2001, but 2017 employment in electromedical and electrotherapeutic apparatus manufacturing was 17% below 2005 levels. Furthermore, 2017 employment in irradiation apparatus manufacturing was 66% below 2008 employment values.

The employment changes in medical device and equipment manufacturing may surprise some readers, but are not necessarily unexpected for several reasons. First, total employment within each of these categories is relatively small, making the industries much more sensitive to percentage changes relative to state and national changes in employment. Second, while national employment changes have not been as intense as those found in the Madison Region, employment in these industries has indeed dropped nationwide over the last several decades. These industries in the State of Wisconsin also have not been immune to employment declines. Finally, the Madison Region has experienced a number of well-documented closures or employment reductions in these industries.

Despite these employment changes, the Madison Region remains an important location for the manufacturing of medical devices and equipment. Specifically, the Madison MSA ranks 29$^{th}$ among all MSAs for electromedical and electrotherapeutic apparatus establishments, 20$^{th}$ in analytical laboratory instrument manufacturing establishments and 12$^{th}$ for irradiation apparatus manufacturing establishments. The Madison MSA also has location quotients either above 1.25 or well above 1.25 in these three manufacturing categories (Figures 1.9 to 1.11). Accordingly, the 20 or so firms in this category comprise an important niche in the Madison Region's bioscience industry.

The Madison MSA is not ranked in the top 50 metro areas for medical equipment and supplies manufacturing. Instead the Madison, WI MSA is ranked 78th in total establishments and has a location quotient of 1.09. The top 10 metro areas for medical equipment manufacturing establishments include the large MSAs of New York, Los Angeles, Chicago, Miami, Minneapolis-St. Paul, Philadelphia, Dallas, Atlanta, San Francisco and Boston. Again, many of these areas are also highly ranked for pharmaceutical and drug manufacturing.

**Figure 1.8 - Medical Device and Equipment Manufacturing Employment Trends**




Source: BLS QCEW and Authors' Calculations

**Figure 1.9 – Top 50 MSAs for Electromedical & Electrotherapeutic Apparatus Manufacturing Establishments (2017)**

| Rank | Metropolitan Statistical Area | Number of Establishments | Total Employment | Employment Location Quotient |
|---|---|---|---|---|
| 1 | Los Angeles-Long Beach-Anaheim, CA MSA | 79 | 8,652 | 3.06 |
| 2 | Minneapolis-St. Paul-Bloomington, MN-WI MSA | 65 | 13,909 | 15.56 |
| 3 | San Francisco-Oakland-Hayward, CA MSA | 54 | S | S |
| 4 | Seattle-Tacoma-Bellevue, WA MSA | 50 | S | S |
| 5 | New York-Newark-Jersey City, NY-NJ-PA MSA | 48 | 2,186 | 0.50 |
| 6 | San Jose-Sunnyvale-Santa Clara, CA MSA | 48 | 2,869 | 5.59 |
| 7 | Chicago-Naperville-Elgin, IL-IN-WI MSA | 42 | 1,028 | 0.49 |
| 8 | San Diego-Carlsbad, CA MSA | 35 | 3,320 | 4.91 |
| 9 | Boston-Cambridge-Newton, MA-NH MSA | 32 | 3,784 | 3.04 |
| 10 | Salt Lake City, UT MSA | 28 | S | S |
| 11 | Miami-Fort Lauderdale-West Palm Beach, FL MSA | 25 | 1,508 | 1.27 |
| 12 | Houston-The Woodlands-Sugar Land, TX MSA | 19 | 624 | 0.46 |
| 13 | Atlanta-Sandy Springs-Roswell, GA MSA | 15 | 270 | 0.22 |
| 14 | Philadelphia-Camden-Wilmington, PA-NJ-DE-MD MSA | 15 | S | S |
| 15 | Portland-Vancouver-Hillsboro, OR-WA MSA | 15 | 566 | 1.04 |
| 16 | Cleveland-Elyria, OH MSA | 13 | 1,363 | 2.87 |
| 17 | Dallas-Fort Worth-Arlington, TX MSA | 13 | 1,015 | 0.62 |
| 18 | Denver-Aurora-Lakewood, CO MSA | 13 | 104 | 0.15 |
| 19 | Pittsburgh, PA MSA | 13 | 2,168 | 4.15 |
| 20 | Baltimore-Columbia-Towson, MD MSA | 12 | S | S |
| 21 | Boulder, CO MSA | 12 | 2,244 | 26.47 |
| 22 | Washington-Arlington-Alexandria, DC-VA-MD-WV MSA | 12 | S | S |
| 23 | Detroit-Warren-Dearborn, MI MSA | 11 | 81 | 0.09 |
| 24 | San Juan-Carolina-Caguas, PR MSA | 11 | 3,354 | 11.36 |
| 25 | Milwaukee-Waukesha-West Allis, WI MSA | 10 | S | S |
| 26 | Phoenix-Mesa-Scottsdale, AZ MSA | 10 | 500 | 0.53 |
| 27 | Providence-Warwick, RI-MA MSA | 10 | S | S |
| 28 | Gainesville, FL MSA | 9 | 335 | 5.35 |
| **29** | **Madison, WI MSA** | **9** | **302** | **1.68** |
| 30 | Worcester, MA-CT MSA | 9 | S | S |
| 31 | Orlando-Kissimmee-Sanford, FL MSA | 8 | 292 | 0.52 |
| 32 | Oklahoma City, OK MSA | 7 | S | S |
| 33 | Tampa-St. Petersburg-Clearwater, FL MSA | 7 | 446 | 0.75 |
| 34 | Akron, OH MSA | 6 | S | S |
| 35 | Durham-Chapel Hill, NC MSA | 6 | 199 | 1.43 |
| 36 | Raleigh, NC MSA | 6 | 18 | 0.06 |
| 37 | Santa Maria-Santa Barbara, CA MSA | 6 | 189 | 2.03 |
| 38 | Tulsa, OK MSA | 6 | S | S |
| 39 | Bridgeport-Stamford-Norwalk, CT MSA | 5 | 69 | 0.35 |
| 40 | Iowa City, IA MSA | 5 | S | S |
| 41 | Nashville-Davidson--Murfreesboro--Franklin, TN MSA | 5 | 16 | 0.04 |
| 42 | Riverside-San Bernardino-Ontario, CA MSA | 5 | S | S |
| 43 | Jacksonville, FL MSA | 4 | S | S |
| 44 | Knoxville, TN MSA | 4 | S | S |
| 45 | Louisville-Jefferson County, KY-IN MSA | 4 | 15 | 0.05 |
| 46 | New Haven-Milford, CT MSA | 4 | 119 | 0.69 |
| 47 | Richmond, VA MSA | 4 | 28 | 0.09 |
| 48 | State College, PA MSA | 4 | 266 | 8.13 |
| 49 | Albuquerque, NM MSA | 3 | S | S |
| 50 | Boise City, ID MSA | 3 | S | S |

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

**Figure 1.10 – Top 50 MSAs for Analytical Laboratory Instrument Manufacturing Establishments (2017)**

| Rank | Metropolitan Statistical Area | Number of Establishments | Total Employment | Employment Location Quotient |
|---|---|---|---|---|
| 1 | Boston-Cambridge-Newton, MA-NH MSA | 75 | S | S |
| 2 | San Francisco-Oakland-Hayward, CA MSA | 41 | 3,015 | 5.13 |
| 3 | Philadelphia-Camden-Wilmington, PA-NJ-DE-MD MSA | 38 | 1,457 | 2.13 |
| 4 | New York-Newark-Jersey City, NY-NJ-PA MSA | 36 | 880 | 0.39 |
| 5 | San Diego-Carlsbad, CA MSA | 25 | 779 | 2.19 |
| 6 | Houston-The Woodlands-Sugar Land, TX MSA | 24 | 658 | 0.92 |
| 7 | San Jose-Sunnyvale-Santa Clara, CA MSA | 23 | S | S |
| 8 | Washington-Arlington-Alexandria, DC-VA-MD-WV MSA | 21 | 685 | 0.89 |
| 9 | Los Angeles-Long Beach-Anaheim, CA MSA | 19 | S | S |
| 10 | Chicago-Naperville-Elgin, IL-IN-WI MSA | 18 | S | S |
| 11 | Pittsburgh, PA MSA | 14 | 317 | 1.16 |
| 12 | Seattle-Tacoma-Bellevue, WA MSA | 14 | S | S |
| 13 | Boulder, CO MSA | 12 | 386 | 8.67 |
| 14 | Cincinnati, OH-KY-IN MSA | 11 | 333 | 1.30 |
| 15 | Minneapolis-St. Paul-Bloomington, MN-WI MSA | 11 | 302 | 0.64 |
| 16 | Baltimore-Columbia-Towson, MD MSA | 10 | S | S |
| 17 | New Haven-Milford, CT MSA | 10 | 125 | 1.39 |
| 18 | Salt Lake City, UT MSA | 9 | 79 | 0.46 |
| 19 | Austin-Round Rock, TX MSA | 8 | 47 | 0.19 |
| **20** | **Madison, WI MSA** | **8** | **427** | **4.53** |
| 21 | Santa Maria-Santa Barbara, CA MSA | 8 | 495 | 10.11 |
| 22 | Dallas-Fort Worth-Arlington, TX MSA | 7 | S | S |
| 23 | Miami-Fort Lauderdale-West Palm Beach, FL MSA | 7 | 184 | 0.30 |
| 24 | Portland-Vancouver-Hillsboro, OR-WA MSA | 7 | 765 | 2.67 |
| 25 | Raleigh, NC MSA | 7 | S | S |
| 26 | Worcester, MA-CT MSA | 7 | 1,658 | 17.38 |
| 27 | Albany-Schenectady-Troy, NY MSA | 6 | S | S |
| 28 | Bridgeport-Stamford-Norwalk, CT MSA | 6 | S | S |
| 29 | Hartford-West Hartford-East Hartford, CT MSA | 6 | S | S |
| 30 | Riverside-San Bernardino-Ontario, CA MSA | 6 | 294 | 0.82 |
| 31 | State College, PA MSA | 6 | 630 | 36.65 |
| 32 | Tucson, AZ MSA | 6 | 61 | 0.68 |
| 33 | Atlanta-Sandy Springs-Roswell, GA MSA | 5 | S | S |
| 34 | Denver-Aurora-Lakewood, CO MSA | 5 | S | S |
| 35 | Indianapolis-Carmel-Anderson, IN MSA | 5 | 30 | 0.12 |
| 36 | Manchester-Nashua, NH MSA | 5 | 146 | 2.92 |
| 37 | Omaha-Council Bluffs, NE-IA MSA | 5 | S | S |
| 38 | Orlando-Kissimmee-Sanford, FL MSA | 5 | S | S |
| 39 | Providence-Warwick, RI-MA MSA | 5 | S | S |
| 40 | Sacramento--Roseville--Arden-Arcade, CA MSA | 5 | 198 | 0.83 |
| 41 | St. Louis, MO-IL MSA | 5 | 851 | 2.61 |
| 42 | Trenton, NJ MSA | 5 | S | S |
| 43 | Virginia Beach-Norfolk-Newport News, VA-NC MSA | 5 | S | S |
| 44 | Albuquerque, NM MSA | 4 | 32 | 0.35 |
| 45 | Baton Rouge, LA MSA | 4 | S | S |
| 46 | Cleveland-Elyria, OH MSA | 4 | S | S |
| 47 | Columbia, SC MSA | 4 | 29 | 0.31 |
| 48 | Columbus, OH MSA | 4 | 43 | 0.17 |
| 49 | Detroit-Warren-Dearborn, MI MSA | 4 | S | S |
| 50 | Durham-Chapel Hill, NC MSA | 4 | 146 | 2.00 |

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

**Figure 1.11 – Top 50 MSAs for Irradiation Apparatus Manufacturing Establishments (2017)**

| Rank | Metropolitan Statistical Area | Number of Establishments | Total Employment | Employment Location Quotient |
|---|---|---|---|---|
| 1 | Milwaukee-Waukesha-West Allis, WI MSA | 25 | S | S |
| 2 | Chicago-Naperville-Elgin, IL-IN-WI MSA | 17 | S | S |
| 3 | Los Angeles-Long Beach-Anaheim, CA MSA | 13 | S | S |
| 4 | New York-Newark-Jersey City, NY-NJ-PA MSA | 11 | S | S |
| 5 | Boston-Cambridge-Newton, MA-NH MSA | 10 | S | S |
| 6 | San Francisco-Oakland-Hayward, CA MSA | 10 | 581 | 2.63 |
| 7 | Atlanta-Sandy Springs-Roswell, GA MSA | 6 | 32 | 0.13 |
| 8 | Houston-The Woodlands-Sugar Land, TX MSA | 5 | 150 | 0.55 |
| 9 | Salt Lake City, UT MSA | 5 | S | S |
| 10 | Bridgeport-Stamford-Norwalk, CT MSA | 4 | S | S |
| 11 | Dallas-Fort Worth-Arlington, TX MSA | 4 | 5 | 0.02 |
| **12** | **Madison, WI MSA** | **4** | **264** | **7.43** |
| 13 | Miami-Fort Lauderdale-West Palm Beach, FL MSA | 4 | S | S |
| 14 | New Orleans-Metairie, LA MSA | 4 | 32 | 0.63 |
| 15 | Raleigh, NC MSA | 4 | S | S |
| 16 | Rochester, NY MSA | 4 | S | S |
| 17 | San Diego-Carlsbad, CA MSA | 4 | S | S |
| 18 | San Jose-Sunnyvale-Santa Clara, CA MSA | 4 | S | S |
| 19 | Cleveland-Elyria, OH MSA | 3 | 158 | 1.68 |
| 20 | Denver-Aurora-Lakewood, CO MSA | 3 | 15 | 0.11 |
| 21 | New Haven-Milford, CT MSA | 3 | S | S |
| 22 | Orlando-Kissimmee-Sanford, FL MSA | 3 | 65 | 0.58 |
| 23 | Provo-Orem, UT MSA | 3 | S | S |
| 24 | Richmond, VA MSA | 3 | S | S |
| 25 | Tampa-St. Petersburg-Clearwater, FL MSA | 3 | S | S |
| 26 | Washington-Arlington-Alexandria, DC-VA-MD-WV MSA | 3 | S | S |
| 27 | Albany-Schenectady-Troy, NY MSA | 2 | S | S |
| 28 | Anchorage, AK MSA | 2 | S | S |
| 29 | Baltimore-Columbia-Towson, MD MSA | 2 | S | S |
| 30 | Charleston-North Charleston, SC MSA | 2 | S | S |
| 31 | Cincinnati, OH-KY-IN MSA | 2 | S | S |
| 32 | Jacksonville, FL MSA | 2 | S | S |
| 33 | Knoxville, TN MSA | 2 | S | S |
| 34 | Memphis, TN-MS-AR MSA | 2 | S | S |
| 35 | Nashville-Davidson--Murfreesboro--Franklin, TN MSA | 2 | S | S |
| 36 | Philadelphia-Camden-Wilmington, PA-NJ-DE-MD MSA | 2 | S | S |
| 37 | Pittsburgh, PA MSA | 2 | S | S |
| 38 | Providence-Warwick, RI-MA MSA | 2 | S | S |
| 39 | Santa Cruz-Watsonville, CA MSA | 2 | S | S |
| 40 | Santa Maria-Santa Barbara, CA MSA | 2 | S | S |
| 41 | Akron, OH MSA | 1 | S | S |
| 42 | Albuquerque, NM MSA | 1 | S | S |
| 43 | Ann Arbor, MI MSA | 1 | S | S |
| 44 | Augusta-Richmond County, GA-SC MSA | 1 | S | S |
| 45 | Austin-Round Rock, TX MSA | 1 | S | S |
| 46 | Birmingham-Hoover, AL MSA | 1 | S | S |
| 47 | Boulder, CO MSA | 1 | S | S |
| 48 | Buffalo-Cheektowaga-Niagara Falls, NY MSA | 1 | S | S |
| 49 | Charlotte-Concord-Gastonia, NC-SC MSA | 1 | S | S |
| 50 | Charlottesville, VA MSA | 1 | S | S |

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

**Figure 1.12 – Top 50 MSAs for Medical Equipment and Supplies Manufacturing Establishments (2017)**

| Rank | Metropolitan Statistical Area | Number of Establishments | Total Employment | Employment Location Quotient |
|---|---|---|---|---|
| 1 | New York-Newark-Jersey City, NY-NJ-PA MSA | 727 | S | S |
| 2 | Los Angeles-Long Beach-Anaheim, CA MSA | 669 | 25,721 | 2.00 |
| 3 | Chicago-Naperville-Elgin, IL-IN-WI MSA | 444 | 11,962 | 1.24 |
| 4 | Miami-Fort Lauderdale-West Palm Beach, FL MSA | 363 | 4,749 | 0.88 |
| 5 | Minneapolis-St. Paul-Bloomington, MN-WI MSA | 269 | 14,995 | 3.69 |
| 6 | Philadelphia-Camden-Wilmington, PA-NJ-DE-MD MSA | 231 | S | S |
| 7 | Dallas-Fort Worth-Arlington, TX MSA | 225 | S | S |
| 8 | Atlanta-Sandy Springs-Roswell, GA MSA | 223 | 4,124 | 0.75 |
| 9 | San Francisco-Oakland-Hayward, CA MSA | 220 | 5,570 | 1.09 |
| 10 | Boston-Cambridge-Newton, MA-NH MSA | 209 | S | S |
| 11 | Seattle-Tacoma-Bellevue, WA MSA | 195 | 2,538 | 0.61 |
| 12 | Tampa-St. Petersburg-Clearwater, FL MSA | 185 | 4,897 | 1.82 |
| 13 | Washington-Arlington-Alexandria, DC-VA-MD-WV MSA | 171 | 1,374 | 0.21 |
| 14 | Denver-Aurora-Lakewood, CO MSA | 166 | S | S |
| 15 | San Diego-Carlsbad, CA MSA | 158 | 6,196 | 2.01 |
| 16 | Salt Lake City, UT MSA | 152 | 8,282 | 5.51 |
| 17 | San Jose-Sunnyvale-Santa Clara, CA MSA | 151 | S | S |
| 18 | Detroit-Warren-Dearborn, MI MSA | 150 | 2,378 | 0.58 |
| 19 | Phoenix-Mesa-Scottsdale, AZ MSA | 149 | S | S |
| 20 | Houston-The Woodlands-Sugar Land, TX MSA | 143 | S | S |
| 21 | Portland-Vancouver-Hillsboro, OR-WA MSA | 142 | 3,513 | 1.41 |
| 22 | St. Louis, MO-IL MSA | 129 | 2,262 | 0.80 |
| 23 | Orlando-Kissimmee-Sanford, FL MSA | 119 | 1,080 | 0.42 |
| 24 | Riverside-San Bernardino-Ontario, CA MSA | 113 | 2,847 | 0.92 |
| 25 | Cleveland-Elyria, OH MSA | 99 | S | S |
| 26 | Kansas City, MO-KS MSA | 89 | 1,861 | 0.84 |
| 27 | Providence-Warwick, RI-MA MSA | 78 | S | S |
| 28 | Indianapolis-Carmel-Anderson, IN MSA | 77 | 2,284 | 1.07 |
| 29 | Milwaukee-Waukesha-West Allis, WI MSA | 77 | 1,515 | 0.86 |
| 30 | Pittsburgh, PA MSA | 77 | 3,209 | 1.35 |
| 31 | San Antonio-New Braunfels, TX MSA | 74 | 1,375 | 0.64 |
| 32 | Sacramento--Roseville--Arden-Arcade, CA MSA | 73 | S | S |
| 33 | Baltimore-Columbia-Towson, MD MSA | 71 | S | S |
| 34 | Las Vegas-Henderson-Paradise, NV MSA | 70 | 471 | 0.23 |
| 35 | Austin-Round Rock, TX MSA | 69 | S | S |
| 36 | Memphis, TN-MS-AR MSA | 64 | 6,471 | 4.95 |
| 37 | Charlotte-Concord-Gastonia, NC-SC MSA | 63 | S | S |
| 38 | Virginia Beach-Norfolk-Newport News, VA-NC MSA | 63 | 425 | 0.27 |
| 39 | Cincinnati, OH-KY-IN MSA | 59 | 943 | 0.42 |
| 40 | Buffalo-Cheektowaga-Niagara Falls, NY MSA | 58 | 1,552 | 1.34 |
| 41 | New Orleans-Metairie, LA MSA | 57 | S | S |
| 42 | Jacksonville, FL MSA | 56 | S | S |
| 43 | Richmond, VA MSA | 54 | S | S |
| 44 | Columbus, OH MSA | 53 | 1,395 | 0.64 |
| 45 | Nashville-Davidson--Murfreesboro--Franklin, TN MSA | 53 | 950 | 0.47 |
| 46 | Albuquerque, NM MSA | 50 | S | S |
| 47 | North Port-Sarasota-Bradenton, FL MSA | 49 | 904 | 1.46 |
| 48 | Oxnard-Thousand Oaks-Ventura, CA MSA | 49 | 775 | 1.12 |
| 49 | Oklahoma City, OK MSA | 48 | 528 | 0.41 |
| 50 | Hartford-West Hartford-East Hartford, CT MSA | 47 | 1,074 | 0.81 |

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

The Madison, WI MSA is ranked 78th in total establishments (27) and has 890 employees with a location quotient of 1.09.

## Research, Testing and Medical Laboratories

The research, testing and medical laboratories component of the bioscience industry cluster includes several specific categories of health care and professional, scientific and technical services. As described by the U.S. Census Bureau, these categories include:

- *Research and Development in the Physical, Engineering, and Life Sciences (NAICS 54171)* - This industry comprises establishments primarily engaged in conducting research and experimental development in the physical, engineering, and life sciences, such as agriculture, electronics, environmental, biology, botany, biotechnology, computers, chemistry, food, fisheries, forests, geology, health, mathematics, medicine, nanotechnology, oceanography, pharmacy, physics, veterinary, and other allied subjects.

- *Testing Laboratories (NAICS 541380)* - This industry comprises establishments primarily engaged in performing physical, chemical, and other analytical testing services, such as acoustics or vibration testing, assaying, biological testing (except medical and veterinary), calibration testing, electrical and electronic testing, geotechnical testing, mechanical testing, nondestructive testing, or thermal testing. The testing may occur in a laboratory or on-site.

- *Medical and Diagnostic Laboratories (NAICS 6215)* - This industry comprises establishments known as medical and diagnostic laboratories primarily engaged in providing analytic or diagnostic services, including body fluid analysis and diagnostic imaging, generally to the medical profession or to the patient on referral from a health practitioner.

In 2017, the research, testing and medical laboratories industry accounted for over 5,600 employees in the Madison Region (Figure 1.13). *Importantly, the Region is home to approximately 71.2% of Wisconsin's total employment in the research and development in the physical, engineering, and life sciences industry.* The Madison Region also accounts for 30% of the state's employment in medical and diagnostic laboratories. Of the 140 total establishments in the research, testing and medical laboratories category, five have between 100 and 499 employees while four have 500 employees or more (Figure 1.14).

The research, testing and medical laboratories industry includes several highly visible and growing companies in the Madison Region such as Exact Sciences, PPD and Covance. While these firms have achieved significant growth, many more firms have less than 100 employees, with the greatest number of firms having 1 to 9 employees. Helping these firms, and others in the bioscience sector, achieve scale requires a

**Figure 1.13 – Employment in Research, Testing and Medical Laboratories**

| Industry | Madison Region | Madison Region as a Percent of Wisconsin Total for Industry |
|---|---|---|
| Research and Development in the Physical, Engineering, and Life Sciences | 4,360 | 71.2% |
| Testing Laboratories | 276 | 13.0% |
| Medical and Diagnostic Laboratories | 1,021 | 30.1% |

Source: BLS QCEW and Authors' Calculations

robust, supportive entrepreneurial ecosystem. Important components of this ecosystem are examined later in this Section as well as in Section 3 of this analysis.

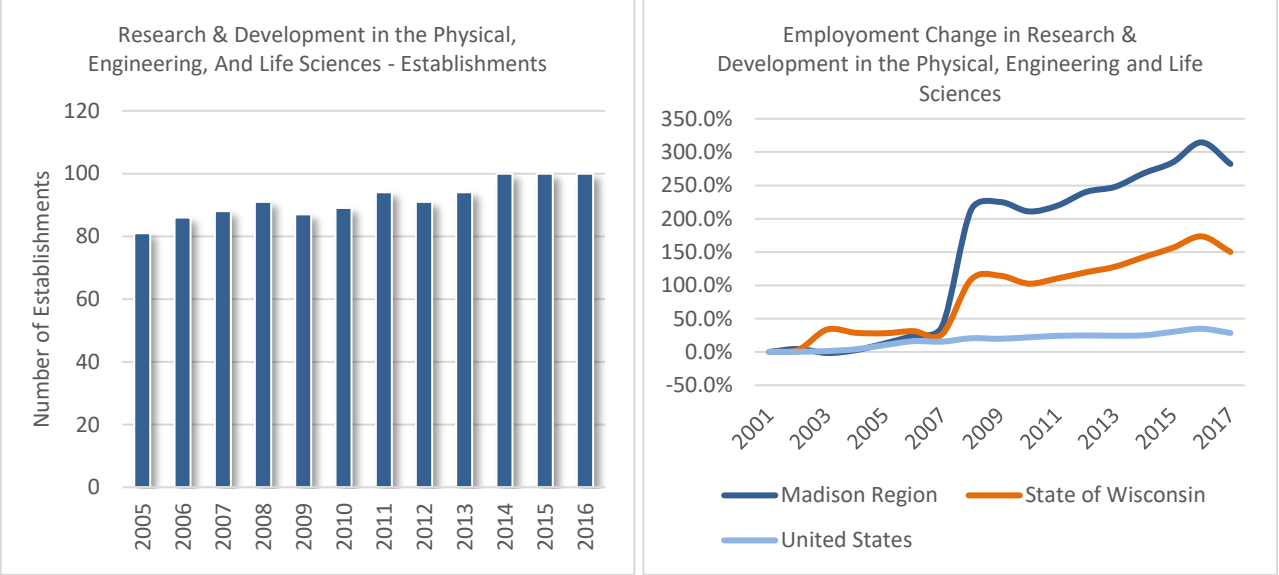
**Figure 1.14 – Madison Region Establishments by Employment Size: Research, Testing & Medical Laboratories (2016)**

| 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. |
| **54171** | Research and development in the physical, engineering, and life sciences | 100 | 63 | 30 | 3 | 4 |
| **54138** | Testing laboratories | 22 | 16 | 6 | 0 | 0 |
| **6215** | Medical and diagnostic laboratories | 18 | 12 | 4 | 2 | 0 |
| | *Research, Testing & Medical Laboratories Total* | *140* | *91* | *40* | *5* | *4* |

Source: U.S. Census Bureau County Business Patterns

The research and development in the physical, engineering, and life sciences industry is by far the largest component of the Madison Region's bioscience cluster. The scale and scope of this industry reflects the large amount of capital, human and otherwise, devoted to bioscience research in the Madison Region. The research and development in the physical, engineering, and life sciences is also one of the categories of the Region's bioscience cluster that has recently grown in terms of establishments and employment. Between 2005 and 2016, this category added almost 20 establishments. Furthermore employment in the industry grew significantly. Note that the large spike in employment growth between 2007 and 2008 is partially attributed to a re-classification of Covance from the testing laboratories industry to research and development in the physical, engineering, and life sciences. A corresponding decline in testing laboratories employment is depicted in Figure 1.16. Nonetheless employment in the industry still increased by 22% since 2008, despite the impacts of the Great Recession.

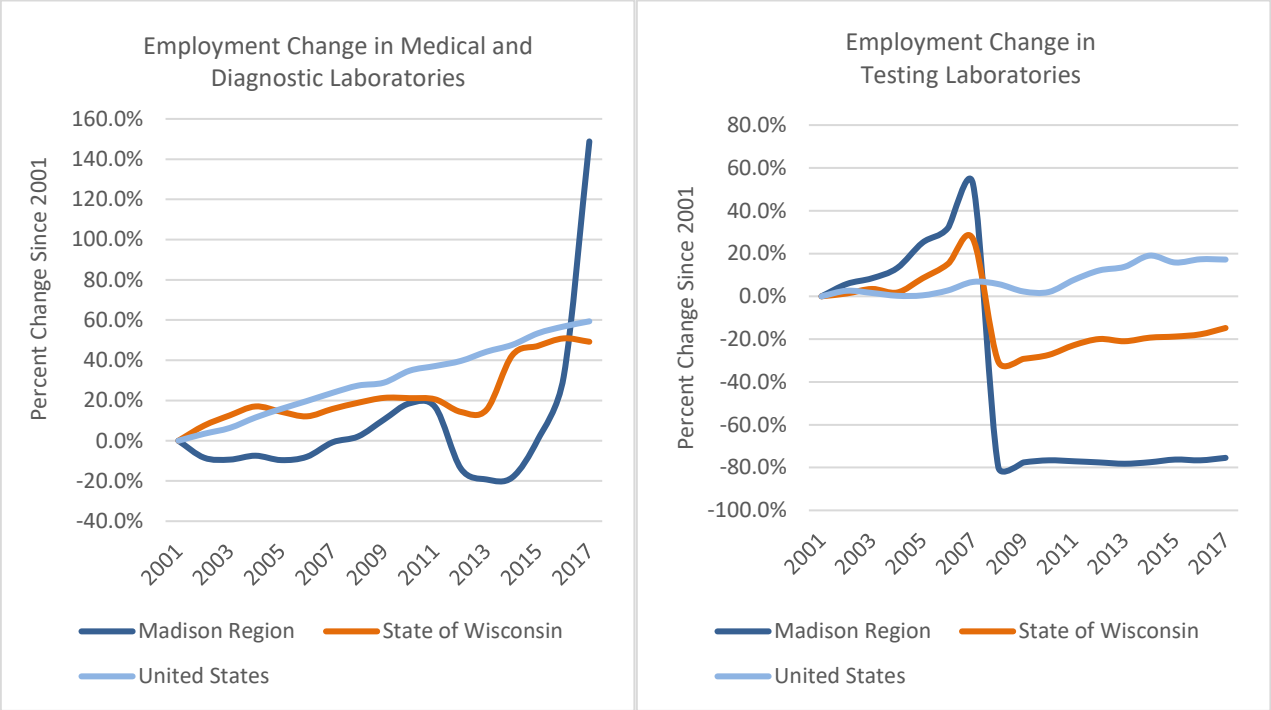
**Figure 1.15 – Madison Region Establishments by Employment size in Research and Development in the Physical, Engineering, and Life Sciences**




Source: U.S. Census Bureau County Business Patterns, Bureau of Labor Statistics QCEW and Authors' Calculations

Employment growth in medical and diagnostic laboratories and testing laboratories has been somewhat muted (Figure 1.16). Again, these are somewhat smaller industries in the bioscience cluster and are sensitive to minor employment changes. As previously mentioned, employment changes in the testing laboratories category are partially attributed to the industrial re-classification of Covance. Despite these overall trends, employment in the medical and diagnostic laboratories category experienced notable growth between 2016 and 2017 when employment almost doubled.

**Figure 1.16 – Madison Region Employment Trends in Medical and Diagnostic Laboratories and Testing Laboratories**




Source: BLS QCEW and Authors' Calculations

When compared to other metro areas, the Madison MSA ranks 42nd in terms of establishments in research and development in the physical, engineering, and life sciences (Figure 1.17). While the Madison MSA employment location quotient is suppressed, Dane County's LQ in the industry is 3.11. As most firms in this category are located in Dane County, this LQ is notable. As mentioned with other bioscience categories in this analysis, many metro areas with significant establishments and employment in the life sciences R&D industry are well established bioscience industry centers. Again, bioscience industries in many of these metro areas are anchored by R1 research universities. As in other categories of bioscience, the presence of UW-Madison helps the Madison Region's high ranking in establishments relative to much larger metro areas.

Medical and diagnostic laboratories and testing laboratories are not ranked in the top 50 MSAs for establishments, ranking 159th and 81st respectively. Nonetheless, they are important components in the Madison Region's bioscience cluster.

**Figure 1.17 – Top 50 MSAs for Research and Development in the Physical, Engineering, and Life Sciences Establishments (2017)**

| Rank | Metropolitan Statistical Area | Number of Establishments | Total Employment | Employment Location Quotient |
|---|---|---|---|---|
| 1 | Boston-Cambridge-Newton, MA-NH MSA | 1,489 | S | S |
| 2 | Washington-Arlington-Alexandria, DC-VA-MD-WV MSA | 964 | 28,442 | 2.22 |
| 3 | New York-Newark-Jersey City, NY-NJ-PA MSA | 826 | 40,761 | 1.07 |
| 4 | San Francisco-Oakland-Hayward, CA MSA | 809 | S | S |
| 5 | San Diego-Carlsbad, CA MSA | 731 | 30,533 | 5.17 |
| 6 | Los Angeles-Long Beach-Anaheim, CA MSA | 603 | 21,718 | 0.88 |
| 7 | Philadelphia-Camden-Wilmington, PA-NJ-DE-MD MSA | 519 | S | S |
| 8 | San Jose-Sunnyvale-Santa Clara, CA MSA | 426 | S | S |
| 9 | Seattle-Tacoma-Bellevue, WA MSA | 415 | 11,418 | 1.43 |
| 10 | Houston-The Woodlands-Sugar Land, TX MSA | 358 | 6,918 | 0.58 |
| 11 | Miami-Fort Lauderdale-West Palm Beach, FL MSA | 351 | 3,404 | 0.33 |
| 12 | Baltimore-Columbia-Towson, MD MSA | 307 | S | S |
| 13 | Chicago-Naperville-Elgin, IL-IN-WI MSA | 281 | 14,522 | 0.79 |
| 14 | Durham-Chapel Hill, NC MSA | 253 | S | S |
| 15 | Dallas-Fort Worth-Arlington, TX MSA | 251 | 3,802 | 0.27 |
| 16 | Portland-Vancouver-Hillsboro, OR-WA MSA | 230 | 2,672 | 0.56 |
| 17 | Raleigh, NC MSA | 223 | 3,854 | 1.55 |
| 18 | Atlanta-Sandy Springs-Roswell, GA MSA | 211 | 3,504 | 0.33 |
| 19 | Denver-Aurora-Lakewood, CO MSA | 199 | 4,125 | 0.69 |
| 20 | Phoenix-Mesa-Scottsdale, AZ MSA | 191 | S | S |
| 21 | Salt Lake City, UT MSA | 186 | S | S |
| 22 | Austin-Round Rock, TX MSA | 181 | 2,338 | 0.58 |
| 23 | Minneapolis-St. Paul-Bloomington, MN-WI MSA | 177 | 5,885 | 0.75 |
| 24 | St. Louis, MO-IL MSA | 167 | 4,607 | 0.85 |
| 25 | Boulder, CO MSA | 157 | 5,231 | 7.06 |
| 26 | Tampa-St. Petersburg-Clearwater, FL MSA | 148 | S | S |
| 27 | Providence-Warwick, RI-MA MSA | 143 | 1,742 | 0.61 |
| 28 | Kansas City, MO-KS MSA | 134 | S | S |
| 29 | San Antonio-New Braunfels, TX MSA | 134 | 4,506 | 1.1 |
| 30 | Cleveland-Elyria, OH MSA | 124 | 1,537 | 0.37 |
| 31 | Detroit-Warren-Dearborn, MI MSA | 120 | 14,092 | 1.8 |
| 32 | Pittsburgh, PA MSA | 120 | 7,590 | 1.66 |
| 33 | Albuquerque, NM MSA | 113 | 12,365 | 8.03 |
| 34 | Orlando-Kissimmee-Sanford, FL MSA | 113 | S | S |
| 35 | Huntsville, AL MSA | 108 | S | S |
| 36 | Cincinnati, OH-KY-IN MSA | 106 | 2,649 | 0.62 |
| 37 | Worcester, MA-CT MSA | 104 | S | S |
| 38 | New Haven-Milford, CT MSA | 100 | 1,740 | 1.16 |
| 39 | Columbus, OH MSA | 96 | 6,534 | 1.56 |
| 40 | Ann Arbor, MI MSA | 93 | 2,620 | 3.03 |
| 41 | Charlotte-Concord-Gastonia, NC-SC MSA | 90 | 815 | 0.17 |
| **42** | **Madison, WI MSA** | **90** | **S** | **S** |
| 43 | Indianapolis-Carmel-Anderson, IN MSA | 88 | 2,446 | 0.59 |
| 44 | Las Vegas-Henderson-Paradise, NV MSA | 79 | 1,468 | 0.37 |
| 45 | Sacramento--Roseville--Arden-Arcade, CA MSA | 78 | 5,259 | 1.32 |
| 46 | Nashville-Davidson--Murfreesboro--Franklin, TN MSA | 77 | 559 | 0.15 |
| 47 | Buffalo-Cheektowaga-Niagara Falls, NY MSA | 75 | S | S |
| 48 | Tucson, AZ MSA | 73 | 2,375 | 1.58 |
| 49 | Urban Honolulu, HI MSA | 73 | 597 | 0.31 |
| 50 | Bridgeport-Stamford-Norwalk, CT MSA | 69 | 2,513 | 1.45 |

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

**Figure 1.18 – Top 50 MSAs for Testing Laboratory Establishments (2017)**

| Rank | Metropolitan Statistical Area | Number of Establishments | Total Employment | Employment Location Quotient |
|---|---|---|---|---|
| 1 | New York-Newark-Jersey City, NY-NJ-PA MSA | 373 | 10,568 | 1.00 |
| 2 | Los Angeles-Long Beach-Anaheim, CA MSA | 331 | 6,218 | 0.90 |
| 3 | Houston-The Woodlands-Sugar Land, TX MSA | 321 | 8,301 | 2.49 |
| 4 | Chicago-Naperville-Elgin, IL-IN-WI MSA | 232 | 5,104 | 0.99 |
| 5 | Dallas-Fort Worth-Arlington, TX MSA | 175 | 2,372 | 0.60 |
| 6 | Boston-Cambridge-Newton, MA-NH MSA | 163 | S | S |
| 7 | Philadelphia-Camden-Wilmington, PA-NJ-DE-MD MSA | 149 | S | S |
| 8 | Detroit-Warren-Dearborn, MI MSA | 142 | S | S |
| 9 | Miami-Fort Lauderdale-West Palm Beach, FL MSA | 141 | 1,402 | 0.48 |
| 10 | Phoenix-Mesa-Scottsdale, AZ MSA | 131 | S | S |
| 11 | San Francisco-Oakland-Hayward, CA MSA | 126 | 2,945 | 1.08 |
| **12** | Seattle-Tacoma-Bellevue, WA MSA | 126 | 1,213 | 0.54 |
| 13 | Denver-Aurora-Lakewood, CO MSA | 119 | 1,247 | 0.75 |
| 14 | Atlanta-Sandy Springs-Roswell, GA MSA | 116 | 1,533 | 0.52 |
| 15 | San Diego-Carlsbad, CA MSA | 105 | 2,205 | 1.33 |
| 16 | Washington-Arlington-Alexandria, DC-VA-MD-WV MSA | 100 | 1,551 | 0.43 |
| 17 | Pittsburgh, PA MSA | 91 | S | S |
| 18 | Portland-Vancouver-Hillsboro, OR-WA MSA | 90 | 1,197 | 0.90 |
| 19 | Minneapolis-St. Paul-Bloomington, MN-WI MSA | 89 | 2,521 | 1.15 |
| 20 | Tampa-St. Petersburg-Clearwater, FL MSA | 89 | S | S |
| 21 | San Jose-Sunnyvale-Santa Clara, CA MSA | 81 | S | S |
| 22 | Salt Lake City, UT MSA | 79 | S | S |
| 23 | Baltimore-Columbia-Towson, MD MSA | 76 | S | S |
| 24 | Las Vegas-Henderson-Paradise, NV MSA | 76 | 811 | 0.73 |
| 25 | Charlotte-Concord-Gastonia, NC-SC MSA | 74 | 558 | 0.42 |
| 26 | Cincinnati, OH-KY-IN MSA | 67 | 1,558 | 1.30 |
| 27 | Cleveland-Elyria, OH MSA | 67 | 1,365 | 1.18 |
| 28 | St. Louis, MO-IL MSA | 67 | 1,221 | 0.80 |
| 29 | Columbus, OH MSA | 66 | 1,056 | 0.90 |
| 30 | Raleigh, NC MSA | 63 | S | S |
| 31 | Indianapolis-Carmel-Anderson, IN MSA | 60 | 994 | 0.87 |
| 32 | Kansas City, MO-KS MSA | 59 | 676 | 0.57 |
| 33 | New Orleans-Metairie, LA MSA | 59 | 1,186 | 1.90 |
| 34 | Austin-Round Rock, TX MSA | 58 | 711 | 0.63 |
| 35 | Riverside-San Bernardino-Ontario, CA MSA | 58 | 700 | 0.42 |
| 36 | Hartford-West Hartford-East Hartford, CT MSA | 55 | 683 | 0.96 |
| 37 | Sacramento--Roseville--Arden-Arcade, CA MSA | 53 | 734 | 0.66 |
| 38 | Milwaukee-Waukesha-West Allis, WI MSA | 49 | 486 | 0.51 |
| 39 | Providence-Warwick, RI-MA MSA | 49 | 478 | 0.60 |
| 40 | Orlando-Kissimmee-Sanford, FL MSA | 48 | 798 | 0.58 |
| 41 | Baton Rouge, LA MSA | 46 | 1,182 | 2.67 |
| 42 | Lafayette, LA MSA | 46 | 737 | 3.29 |
| 43 | Louisville-Jefferson County, KY-IN MSA | 42 | 386 | 0.53 |
| 44 | Tulsa, OK MSA | 42 | 489 | 1.00 |
| 45 | Nashville-Davidson--Murfreesboro--Franklin, TN MSA | 41 | 715 | 0.67 |
| 46 | Oxnard-Thousand Oaks-Ventura, CA MSA | 41 | 410 | 1.11 |
| 47 | San Antonio-New Braunfels, TX MSA | 40 | 847 | 0.74 |
| 48 | Richmond, VA MSA | 39 | 498 | 0.68 |
| 49 | Birmingham-Hoover, AL MSA | 38 | 415 | 0.74 |
| 50 | Buffalo-Cheektowaga-Niagara Falls, NY MSA | 37 | S | S |

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

The Madison, WI MSA is ranked 81st in total establishments with 21 establishments, 276 employees and an LQ of 0.63

**Figure 1.19 – Top 50 MSAs for Medical and Diagnostic Laboratory Establishments (2017)**

| Rank | Metropolitan Statistical Area | Number of Establishments | Total Employment | Employment Location Quotient |
|---|---|---|---|---|
| 1 | New York-Newark-Jersey City, NY-NJ-PA MSA | 1,282 | 22,590 | 1.31 |
| 2 | Los Angeles-Long Beach-Anaheim, CA MSA | 843 | 14,987 | 1.34 |
| 3 | Miami-Fort Lauderdale-West Palm Beach, FL MSA | 625 | 8,324 | 1.77 |
| 4 | Washington-Arlington-Alexandria, DC-VA-MD-WV MSA | 530 | 6,610 | 1.13 |
| 5 | Dallas-Fort Worth-Arlington, TX MSA | 506 | 8,461 | 1.31 |
| 6 | Atlanta-Sandy Springs-Roswell, GA MSA | 486 | 4,807 | 1.00 |
| 7 | San Juan-Carolina-Caguas, PR MSA | 473 | 4,122 | 3.52 |
| 8 | Philadelphia-Camden-Wilmington, PA-NJ-DE-MD MSA | 430 | 5,815 | 1.13 |
| 9 | Houston-The Woodlands-Sugar Land, TX MSA | 383 | 6,088 | 1.12 |
| 10 | Chicago-Naperville-Elgin, IL-IN-WI MSA | 368 | 7,775 | 0.93 |
| 11 | Charlotte-Concord-Gastonia, NC-SC MSA | 310 | 1,209 | 0.56 |
| 12 | San Francisco-Oakland-Hayward, CA MSA | 275 | S | S |
| 13 | Denver-Aurora-Lakewood, CO MSA | 251 | 3,440 | 1.27 |
| 14 | Tampa-St. Petersburg-Clearwater, FL MSA | 248 | 4,798 | 2.04 |
| 15 | Boston-Cambridge-Newton, MA-NH MSA | 236 | 4,629 | 0.94 |
| 16 | Las Vegas-Henderson-Paradise, NV MSA | 212 | 3,273 | 1.81 |
| 17 | Raleigh, NC MSA | 204 | S | S |
| 18 | Riverside-San Bernardino-Ontario, CA MSA | 201 | 1,841 | 0.68 |
| 19 | Orlando-Kissimmee-Sanford, FL MSA | 200 | 2,462 | 1.10 |
| 20 | Phoenix-Mesa-Scottsdale, AZ MSA | 183 | S | S |
| 21 | San Diego-Carlsbad, CA MSA | 182 | 5,074 | 1.89 |
| 22 | Baltimore-Columbia-Towson, MD MSA | 179 | S | S |
| 23 | Kansas City, MO-KS MSA | 176 | 3,977 | 2.06 |
| 24 | Richmond, VA MSA | 165 | 2,144 | 1.81 |
| 25 | Virginia Beach-Norfolk-Newport News, VA-NC MSA | 162 | 1,080 | 0.78 |
| 26 | Columbus, OH MSA | 159 | 1,176 | 0.62 |
| 27 | Cincinnati, OH-KY-IN MSA | 158 | 1,932 | 1.00 |
| 28 | Oklahoma City, OK MSA | 156 | S | S |
| 29 | San Antonio-New Braunfels, TX MSA | 152 | S | S |
| 30 | New Orleans-Metairie, LA MSA | 145 | 1,115 | 1.10 |
| 31 | Pittsburgh, PA MSA | 144 | S | S |
| 32 | Seattle-Tacoma-Bellevue, WA MSA | 143 | 2,647 | 0.73 |
| 33 | Birmingham-Hoover, AL MSA | 132 | S | S |
| 34 | Detroit-Warren-Dearborn, MI MSA | 127 | 1,960 | 0.55 |
| 35 | St. Louis, MO-IL MSA | 124 | 1,710 | 0.69 |
| 36 | Portland-Vancouver-Hillsboro, OR-WA MSA | 120 | 2,148 | 0.99 |
| 37 | Nashville-Davidson--Murfreesboro--Franklin, TN MSA | 118 | 3,991 | 2.29 |
| 38 | Salt Lake City, UT MSA | 111 | S | S |
| 39 | San Jose-Sunnyvale-Santa Clara, CA MSA | 111 | S | S |
| 40 | Austin-Round Rock, TX MSA | 107 | 2,486 | 1.35 |
| 41 | Providence-Warwick, RI-MA MSA | 104 | S | S |
| 42 | Indianapolis-Carmel-Anderson, IN MSA | 97 | 2,997 | 1.60 |
| 43 | Sacramento--Roseville--Arden-Arcade, CA MSA | 97 | 1,060 | 0.59 |
| 44 | Greensboro-High Point, NC MSA | 94 | 2,446 | 3.74 |
| 45 | Jacksonville, FL MSA | 93 | 841 | 0.69 |
| 46 | Hartford-West Hartford-East Hartford, CT MSA | 91 | 831 | 0.72 |
| 47 | Cleveland-Elyria, OH MSA | 87 | S | S |
| 48 | Aguadilla-Isabela, PR MSA | 86 | S | S |
| 49 | Greenville-Anderson-Mauldin, SC MSA | 84 | 446 | 0.61 |
| 50 | Albuquerque, NM MSA | 82 | S | S |

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

The Madison, WI MSA is ranked 159th in total establishments with 19 estalishments. Employment and LQ values are supressed.

## Agricultural Feedstock and Industrial Biosciences & Bioscience-Related Distribution

Unfortunately, the data needed to fully assess the agricultural feedstock and bioscience-related distribution components of the Region's bioscience cluster are largely suppressed. Nonetheless, descriptions of these industries and establishment counts are included below:

- *Wet Corn Milling (NAICS 311221)* - This U.S. industry comprises establishments primarily engaged in wet milling corn and other vegetables (except to make ethyl alcohol). Examples of products made in these establishments are corn sweeteners, such as glucose, dextrose, and fructose; corn oil; and starches (except laundry).

- *Soybean and Other Oilseed Processing (NAICS 311224)* - This U.S. industry comprises establishments primarily engaged in crushing oilseeds and tree nuts, such as soybeans, cottonseeds, linseeds, peanuts, and sunflower seeds. Examples of products produced in these establishments are oilseed oils, cakes, meals, and protein isolates and concentrates.

- *Ethyl Alcohol Manufacturing (NAICS 325193)* - This U.S. industry comprises establishments primarily engaged in manufacturing nonpotable ethyl alcohol.

- *Pesticide, Fertilizer, and Other Agricultural Chemical Manufacturing (NAICS 3253)* - This industry group comprises establishments primarily engaged in one or more of the following: (1) manufacturing nitrogenous or phosphatic fertilizer materials; (2) manufacturing fertilizers from sewage or animal waste; (3) manufacturing nitrogenous or phosphatic materials and mixing with other ingredients into fertilizers; (4) mixing ingredients made elsewhere into fertilizers; and (5) formulating and preparing pesticides and other agricultural chemicals.

- *Medical, Dental, and Hospital Equipment and Supplies Merchant Wholesalers (NAICS 423450)* - This industry comprises establishments primarily engaged in the merchant wholesale distribution of professional medical equipment, instruments, and supplies (except ophthalmic equipment and instruments and goods used by ophthalmologists, optometrists, and opticians).

- *Drugs and Druggists' Sundries Merchant Wholesalers (NAICS 424210)* - This industry comprises establishments primarily engaged in the merchant wholesale distribution of biological and medical products; botanical drugs and herbs; and pharmaceutical products intended for internal and/or external consumption in such forms as ampoules, tablets, capsules, vials, ointments, powders, solutions, and suspensions.

- *Farm Supplies Merchant Wholesalers (NAICS 424910)* - This industry comprises establishments primarily engaged in the merchant wholesale distribution of farm supplies, such as animal feeds, fertilizers, agricultural chemicals, pesticides, plant seeds, and plant bulbs.

**Figure 1.20 – Madison Region Estabs. by Employment Size: Agricultural Feedstock and Industrial Biosciences (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. |
| **311221** | Wet corn milling | 1 | 0 | 1 | 0 | 0 |
| **311224** | Soybean and Other Oilseed Processing | 0 | 0 | 0 | 0 | 0 |
| **325193** | Ethyl alcohol manufacturing | 5 | 0 | 5 | 0 | 0 |
| **3253** | Pesticide, fertilizer, and other agricultural chemical manufacturing | 6 | 3 | 1 | 2 | 0 |
| | *Total Agricultural Feedstock and Industrial Biosciences* | *12* | *3* | *7* | *2* | *0* |

Source: U.S. Census Bureau County Business Patterns

**Figure 1.21 – Madison Region Establishments by Employment Size: Bioscience-Related Distribution (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. |
| 423450 | Medical, Dental, and Hospital Equipment and Supplies Merchant Wholesalers | 33 | 21 | 9 | 3 | 0 |
| 424210 | Drugs and Druggists' Sundries Merchant Wholesalers | 14 | 12 | 2 | 0 | 0 |
| 424910 | Farm Supplies Merchant Wholesalers | 71 | 44 | 26 | 1 | 0 |
| | *Total Bioscience-Related Distribution* | *118* | *77* | *37* | *4* | *0* |

Source: U.S. Census Bureau County Business Patterns

## Bioscience Industries and the Madison Region's Entrepreneurial Ecosystem

As noted throughout Section 1, the Region's bioscience industries have a number of prominent, large employers that are key components of the cluster. While these large firms provide an important foundation for the bioscience cluster, it is also critical to consider that most firms have fewer than 100 employees, with many establishments having under 10 employees. These smaller firms are often neglected by economic development policies and incentives that target larger establishments for business recruitment and workforce development activities. In contrast, the needs of smaller firms may vary and often require greater support in the form of access to capital and technical assistance.

Many of these small firms are recent start-ups. The importance of new business start-ups to economic growth has been well established (see Conroy, Chen, Chriestenson, Kures and Deller, 2018 for one summary of this research). High levels of business start-up activity signal a dynamic economy supportive of entrepreneurs. Start-ups of all sizes provide employment opportunities, but also have the opportunity to grow and scale to significant employment and revenue levels. Furthermore, even if a start-up does not succeed, an entrepreneur may have learned lessons from this experience that will help her or him in future ventures.

Compared to many other areas in the United States, the Madison Region has made significant gains in supporting entrepreneurs. Nonetheless, there are many opportunities to develop and grow the Region's entrepreneurial ecosystem. These opportunities partially arise from further recognizing that supporting entrepreneurs should have its foundation in human capital development. Entrepreneurs are "*people* (emphasis added) who design, produce and generate value through the creation or expansion of economic activity" (Ahmad and Hoffman, 2008). That is, the focus of an entrepreneurial ecosystem should be on developing people as they are the drivers of new ventures and are a source of human capital to be leveraged. Importantly, this definition of entrepreneurs includes those involved in many types of economic activities and are not restricted to the creation or expansion of businesses. As noted by Drucker (1985), entrepreneurial ventures are not limited to businesses, but can include non-profits, universities and government institutions.[4]

Furthermore, an entrepreneurial ecosystem should recognize that each entrepreneur may face unique needs related to technical assistance, access to capital or workforce development. Consequently, broad assumptions should not be made about how to best serve entrepreneurs. Instead, community leaders and economic developers should continue listening to the needs of existing and nascent firms in the bioscience cluster through one-on-one conversations or other learning opportunities.

Economic development professionals and elected officials should be particularly mindful of start-ups and second-stage firms that are going to scale. 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

[4] This discussion of entrepreneurship and entrepreneurial culture is partially drawn from prior work by the author. See Kures, 2013 and Kures, 2014.

economic development strategy, but elected officials and other community leaders are often unaware of the importance of these firms as they may still be small enough to be missed (Zipper, 2016). Importantly, many of these conversations are already occurring in the Madison Region.

While the exact needs of individual entrepreneurs will vary, communities and EDOs can also broadly support entrepreneurship by creating an ecosystem where latent, new and existing entrepreneurs can succeed. In other words, the Region needs to continually enhance its entrepreneurial culture. While a detailed discussion of the Region's entrepreneurial culture is beyond the scope of this study, an entrepreneurial culture can be broadly described as one in which a community is aware of the importance of entrepreneurs to the local economy. It is open to new and different ideas and it accepts failure. It is willing to experiment. Ultimately, it encourages and supports a breadth of entrepreneurs.

More specifically, Hustedde (2007) and Macke et al (2014) maintain that an entrepreneurial culture and support system are fostered by:

- *Welcoming fresh voices and embracing diversity* – Communities often have preconceptions about entrepreneurs. In reality, not all entrepreneurs have the same vision or goals for starting a firm. Some entrepreneurs are interested in generating high-growth companies. Other individuals may desire a limited enterprise that supports a specific lifestyle. A nascent entrepreneur may have never started a company before, while another may be a serial entrepreneur who has started many companies. As previously noted, creating an entrepreneurial culture and support system for the bioscience cluster requires understanding the needs and motivations of many entrepreneurial types;

- *Creating opportunities to learn, question and think differently about entrepreneurship* - Too often in communities, entrepreneurship outreach and learning are delivered in a reactionary manner. For instance, individuals may be introduced to entrepreneurship in response to an economic shock such as a plant closing. Learning opportunities should occur proactively throughout the community and can start with young residents rather than waiting until they become adults. Importantly, learning opportunities are not just about developing existing and prospective entrepreneurs. Not everyone should be an entrepreneur and outreach also should stress how entrepreneurship is not a good fit for many people;

- *Mobilizing resources for entrepreneurs* – Resources can include technical assistance, access to capital, workforce development, broadband, business spaces, business support services, places to network and other forms of support;

- *Cultivating networks for entrepreneurs to thrive* – Entrepreneurs learn from each other, whether or not they are engaged in the same industry or produce a similar product. Connections can be fostered through entrepreneur networks, peer groups, mentors and advisory boards. These networks can occur in physical and virtual spaces;

- *Focusing on assets instead of deficits* – Too often communities focus on what is missing rather than what is present. Bioscience entrepreneurs in the Madison Region have access to many competitive assets such as a deepening talent pool, robust university resources, a growing number of entrepreneur networks, and other comparative advantages;

- *Building a shared vision about entrepreneurship* – Placing an emphasis on entrepreneurs does not mean that industry attraction or other economic development strategies should be abandoned. Instead, communities in the Region need a shared understanding about the importance of creating new firms and helping existing firms grow;

- *Fostering entrepreneurial leaders and advocates* – Communities need individuals and organizations who understand entrepreneurs and who can advocate for their needs. These leaders also tolerate failure and celebrate success.

While some areas of the Madison Region are actively and successfully pursuing these elements of developing an entrepreneurial culture, other areas have yet to fully embrace them. To fully grow the bioscience cluster (and other industry sectors), the Region will need to continue and expand these efforts.

## Conclusions – Bioscience Industries in the Madison Region

- Total bioscience industry employment and establishments are summarized in Figure 1.22. Within the Madison Region's bioscience cluster, the categories of drugs and pharmaceuticals and research and development in the physical, engineering and life sciences are among those that have consistently grown in employment, have businesses that have reached scale, show significant location quotients and rank highly among other metro areas for total establishments. These two industries also account for 50% and 71% respectively of Wisconsin's total employment in these industry categories. Accordingly, these two bioscience categories are currently the primary drivers of growth in Region's bioscience cluster. They also show the importance and prominence of the Madison Region in the state's overall bioscience industries.

**Figure 1.22 – Summary of Bioscience Establishments and Employment**

| Bioscience Category | Establishments | Employment |
|---|---|---|
| Drugs and Pharmaceuticals | 32 | 2,210 |
| Medical Devices and Equipment | 67 | 1,897 |
| Research, Testing and Medical Laboratories | 140 | 5,657 |
| Agricultural Feedstock and Industrial Biosciences | 12 | 785 |
| Bioscience-Related Distribution | 118 | 1,696 |
| **Total** | **369** | **12,245** |

Sources: Quarterly Census of Employment and Wages, County Business Patterns, IMPLAN and Author's Calculations
Note that some values in the table are missing due to suppression and others are estimated by the author

- The employment changes in medical device and equipment manufacturing may surprise some readers, but are not necessarily unexpected for several reasons detailed in this analysis. Despite these employment changes, the Madison Region remains an important location for the manufacturing of medical devices and equipment. Specifically, the Madison MSA ranks 29th among all MSAs for electromedical and electrotherapeutic apparatus establishments; 20th in analytical laboratory instrument manufacturing establishments; and 12th for irradiation apparatus manufacturing establishments. The Madison MSA also has location quotients either above 1.25 or well above 1.25 in these three manufacturing categories. Accordingly, the 20 or so firms in this category comprise a notable niche in the Madison Region's bioscience industry.

- Despite the presence of almost 50 establishments, the Madison MSA is not ranked in the top 50 metro areas for medical equipment and supplies manufacturing. Instead the Madison, WI MSA is ranked 78th in total establishments and has a location quotient of 1.09. Instead, the top metro areas for medical equipment manufacturing establishments include the large MSAs of New York, Los Angeles, Chicago, Miami, Minneapolis-St. Paul, Philadelphia, Dallas, Atlanta, San Francisco and Boston. Again, many of these areas are also highly ranked for pharmaceutical and drug manufacturing.

- While the data needed to fully assess the agricultural feedstock and bioscience-related distribution components of the Region's bioscience cluster are largely suppressed, the importance and contributions of these industries should not be ignored and underestimated. Firms in these industries should be considered and engaged when developing key strategic initiatives for the cluster. Furthermore, many of these establishments are important components of the Region's AFB cluster.

- Over 100 of the Region's bioscience establishments could potentially fit the definition of a second stage firm. Second-stage 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. Nationally, second stage firms are the largest source of employment growth. However, 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. While not all of these 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.

- In addition to second stage firms, another 220 bioscience establishments in the Madison Region have under 10 employees. While these numbers will change over time, economic development professionals and elected officials should be particularly mindful of these small firms (and second stage firms) as they scale their operations. 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.

- While the exact needs of individual entrepreneurs will vary, communities and EDOs can also broadly support entrepreneurship by creating an ecosystem where latent, new and existing entrepreneurs can succeed. In other words, the Region needs to continually enhance its entrepreneurial culture. An entrepreneurial culture can be broadly described as one in which a community is aware of the importance of entrepreneurs to the local economy. It is open to new and different ideas and it accepts failure. It is willing to experiment. Ultimately, it encourages and supports a breadth of entrepreneurs. The Madison Region has made strides in fostering its entrepreneurial culture, but there are additional opportunities to grow this culture in many parts of the Region.

# Section 2 – Human Capital in the Bioscience Industry Cluster

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 largely uses occupations to measure human capital in the bioscience industry cluster. Occupations are a useful measure as they 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 bioscience human capital include occupational structure, skill levels, metropolitan concentrations, wages and talent diversity.

## Bioscience Cluster Occupational Structure

The bioscience industry cluster broadly involves a diversity of occupations related to life sciences, engineering, production, sales, office support, management and computer science. More detailed examinations of occupations in most categories of bioscience industries can be considered using the Standard Occupational Classification (SOC) which classifies occupations based on job duties, skills, education, and/or training requirements. The primary exceptions are those related to agricultural feedstock and industrial biosciences and bioscience related distribution as occupational distributions for these industry categories are not available at a sufficient level of detail.

To examine specific occupations concentrated in bioscience industries, the 30 largest occupations by total employment are listed for bioscience subsectors in Figures 2.1 to 2.6. *Note that these figures are based on the national occupational distributions for bioscience industries as reported by the Bureau of Labor Statistics (BLS). Local occupational structures likely will vary in sub-categories of bioscience 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 rates of compensation. 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.

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

**Figure 2.1 – Drugs and Pharmaceutical 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 |
|---|---|---|---|---|---|---|---|---|
| 51-9111 | Packaging and Filling Machine Operators and Tenders | 2 | 8.77% | 1.63 | 1.82 | $34,480 | $33,200 | $38,110 |
| 19-2031 | Chemists | 4 | 5.73% | N/A | N/A | $78,300 | $68,850 | N/A |
| 51-9023 | Mixing and Blending Machine Setters, Operators, and Tenders | 2 | 4.76% | 2.01 | 1.88 | $42,180 | $36,730 | $37,640 |
| 51-9061 | Inspectors, Testers, Sorters, Samplers, and Weighers | 2 | 4.75% | 0.99 | 1.63 | $48,540 | $38,020 | $32,170 |
| 51-9011 | Chemical Equipment Operators and Tenders | 2 | 3.67% | 1.57 | 2.44 | $45,050 | $42,080 | $59,690 |
| 51-1011 | First-Line Supervisors of Production and Operating Workers | 2 | 3.36% | 1.22 | 1.7 | $71,390 | $58,670 | $61,580 |
| 41-4011 | Sales Representatives - Technical and Scientific Products | 4 | 3.14% | 0.83 | N/A | $89,810 | $72,770 | $108,340 |
| 17-2112 | Industrial Engineers | 4 | 2.29% | 0.97 | 1.15 | $94,640 | $76,900 | $77,180 |
| 19-1042 | Medical Scientists, Except Epidemiologists | 5 | 2.23% | 1.6 | N/A | $137,670 | $70,990 | N/A |
| 19-4031 | Chemical Technicians | 3 | 2.21% | 2.07 | N/A | $47,480 | $43,910 | N/A |
| 19-4021 | Biological Technicians | 4 | 1.82% | 1.94 | N/A | $50,800 | $46,520 | N/A |
| 11-3051 | Industrial Production Managers | 4 | 1.70% | 1.24 | 1.32 | $127,610 | $108,840 | $125,810 |
| 49-9041 | Industrial Machinery Mechanics | 3 | 1.68% | 0.64 | 1.38 | $59,700 | $51,420 | $54,850 |
| 13-1199 | Business Operations Specialists, All Other | 3 | 1.66% | 1.27 | 0.25 | $93,710 | $64,370 | $63,200 |
| 11-1021 | General and Operations Managers | 4 | 1.57% | 0.82 | 0.66 | $161,840 | $125,630 | $110,390 |
| 11-9121 | Natural Sciences Managers | 5 | 1.55% | 1.96 | N/A | $140,640 | $113,870 | N/A |
| 11-9199 | Managers, All Other | 4 | 1.54% | 1.6 | 1.47 | $141,440 | $92,520 | $91,590 |
| 49-9071 | Maintenance and Repair Workers, General | 3 | 1.53% | 1.16 | 1.12 | $50,460 | $41,330 | $35,500 |
| 51-2098 | Assemblers and Fabricators, All Other | | 1.48% | 1.13 | 1.68 | $31,540 | $32,260 | $30,850 |
| 53-7062 | Laborers and Freight, Stock, and Material Movers, Hand | 2 | 1.40% | 0.74 | 1.33 | $34,990 | $32,460 | $29,150 |
| 13-1041 | Compliance Officers | 4 | 1.36% | 1.22 | 0.45 | $83,810 | $62,340 | $66,170 |
| 19-1021 | Biochemists and Biophysicists | 5 | 1.29% | 2.27 | N/A | $86,620 | $76,540 | N/A |
| 19-1022 | Microbiologists | 5 | 1.27% | 2.84 | N/A | $74,220 | $62,650 | N/A |
| 43-5071 | Shipping, Receiving, and Traffic Clerks | 2 | 1.1% | 0.79 | 1.51 | $36,700 | $35,100 | $37,120 |
| 43-4051 | Customer Service Representatives | 2 | 1.09% | 1.4 | 1.55 | $41,150 | $37,680 | $36,640 |
| 51-9012 | Separating, Filtering, Clarifying, Precipitating & Still Machine Ops. | 2 | 1.05% | 1.95 | N/A | $46,690 | $40,550 | N/A |
| 13-2011 | Accountants and Auditors | 4 | 1.02% | 1.23 | 0.73 | $79,680 | $68,030 | $67,340 |
| 43-5061 | Production, Planning, and Expediting Clerks | 3 | 1% | 0.68 | 0.73 | $53,560 | $48,290 | $45,430 |
| 17-2031 | Biomedical Engineers | 4 | 0.91% | N/A | N/A | $98,610 | N/A | N/A |
| 51-8091 | Chemical Plant and System Operators | 2 | 0.9% | 1.29 | 4.29 | $50,880 | $43,980 | $57,680 |

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

**Figure 2.2 – Navigational, Measuring, Electromedical and Control Instruments Manufacturing Occupations by Share of Industry Employment – Top 30 Occupations**

| 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 | 10.83% | 1.69 | 3.60 | $36,330 | $37,340 | $25,740 |
| **51-2098** | Assemblers and Fabricators, All Other | 2 | 5.42% | 1.13 | 1.68 | $34,300 | $32,260 | $30,850 |
| **15-1133** | Software Developers, Systems Software | 4 | 4.75% | 1.13 | N/A | $120,340 | $82,390 | N/A |
| **17-2112** | Industrial Engineers | 4 | 3.32% | 0.97 | 1.15 | $96,110 | $76,900 | $77,180 |
| **17-2071** | Electrical Engineers | 4 | 3.18% | 0.96 | N/A | $101,760 | $94,820 | N/A |
| **17-2141** | Mechanical Engineers | 4 | 2.80% | 1.53 | 1.50 | $94,880 | $78,870 | $74,880 |
| **51-9061** | Inspectors, Testers, Sorters, Samplers, and Weighers | 2 | 2.74% | 0.99 | 1.63 | $46,140 | $38,020 | $32,170 |
| **17-2072** | Electronics Engineers, Except Computer | 4 | 2.29% | 0.13 | N/A | $115,680 | $88,980 | N/A |
| **11-1021** | General and Operations Managers | 4 | 2.27% | 0.82 | 0.66 | $165,180 | $125,630 | $110,390 |
| **11-9041** | Architectural and Engineering Managers | 5 | 2.26% | 0.95 | 0.53 | $156,830 | $127,110 | $111,160 |
| **17-3023** | Electrical and Electronics Engineering Technicians | 3 | 2.20% | 0.62 | N/A | $59,240 | $64,260 | N/A |
| **15-1132** | Software Developers, Applications | 4 | 2.17% | N/A | 0.45 | $102,710 | $85,070 | $80,470 |
| **51-1011** | First-Line Supervisors of Production and Operating Workers | 2 | 1.92% | 1.22 | 1.70 | $69,910 | $58,670 | $61,580 |
| **51-4041** | Machinists | 3 | 1.86% | 0.69 | 1.95 | $46,960 | $42,870 | $44,060 |
| **17-2011** | Aerospace Engineers | 4 | 1.85% | N/A | N/A | $117,290 | N/A | N/A |
| **13-1020** | Buyers and Purchasing Agents | | 1.68% | 1.07 | 1.31 | $74,050 | $56,460 | $53,980 |
| **41-4011** | Sales Representatives - Technical and Scientific Products | 4 | 1.66% | 0.83 | N/A | $87,320 | $72,770 | $108,340 |
| **43-4051** | Customer Service Representatives | 2 | 1.65% | 1.40 | 1.55 | $44,560 | $37,680 | $36,640 |
| **17-2199** | Engineers, All Other | 4 | 1.34% | 1.21 | N/A | $103,740 | $85,780 | N/A |
| **43-5061** | Production, Planning, and Expediting Clerks | 3 | 1.25% | 0.68 | 0.73 | $54,800 | $48,290 | $45,430 |
| **13-1199** | Business Operations Specialists, All Other | 3 | 1.24% | 1.27 | 0.25 | $91,820 | $64,370 | $63,200 |
| **11-3051** | Industrial Production Managers | 4 | 1.23% | 1.24 | 1.32 | $127,650 | $108,840 | $125,810 |
| **11-3021** | Computer and Information Systems Managers | 4 | 1.18% | 1.47 | 0.47 | $158,370 | $120,180 | $104,540 |
| **13-2011** | Accountants and Auditors | 4 | 1.16% | 1.23 | 0.73 | $77,910 | $68,030 | $67,340 |
| **43-5071** | Shipping, Receiving, and Traffic Clerks | 2 | 1.15% | 0.79 | 1.51 | $37,110 | $35,100 | $37,120 |
| **41-4012** | Sales Representatives - Except Technical and Scientific Products | 4 | 1.01% | 1.17 | 1.86 | $76,130 | $67,600 | $63,350 |
| **43-9061** | Office Clerks, General | 2 | 0.95% | 1.25 | 1.15 | $42,080 | $36,430 | $34,060 |
| **13-1161** | Market Research Analysts and Marketing Specialists | 4 | 0.89% | 1.57 | 0.82 | $85,790 | $59,310 | $53,660 |
| **15-1121** | Computer Systems Analysts | 4 | 0.89% | 2.52 | 0.63 | $101,210 | $88,000 | $65,020 |
| **43-6014** | Secretaries and Administrative Assistants | 3 | 0.83% | 0.50 | 0.43 | $46,060 | $38,880 | $34,970 |

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

**Figure 2.3 – Medical Equipment and Supplies 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 | 2 | 10.90 | 1.13 | 1.68 | $31,670 | $32,260 | $30,850 |
| **51-9081** | Dental Laboratory Technicians | 2 | 9.36 | N/A | N/A | $41,310 | $35,570 | N/A |
| **51-9061** | Inspectors, Testers, Sorters, Samplers, and Weighers | 2 | 4.04 | 0.99 | 1.63 | $40,400 | $38,020 | $32,170 |
| **51-1011** | First-Line Supervisors of Production and Operating Workers | 2 | 3.16 | 1.22 | 1.70 | $66,220 | $58,670 | $61,580 |
| **51-9083** | Ophthalmic Laboratory Technicians | 2 | 3.04 | 0.59 | N/A | $33,150 | $40,090 | N/A |
| **17-2112** | Industrial Engineers | 4 | 2.90 | 0.97 | 1.15 | $88,230 | $76,900 | $77,180 |
| **51-2028** | Electrical, Electronic, and Electromechanical Assemblers | 3 | 2.59 | 1.69 | 3.60 | $37,180 | $37,340 | $25,740 |
| **51-9082** | Medical Appliance Technicians | 3 | 2.41 | 1.24 | N/A | $38,940 | $40,650 | N/A |
| **51-4041** | Machinists | 3 | 2.31 | 0.69 | 1.95 | $44,880 | $42,870 | $44,060 |
| **43-4051** | Customer Service Representatives | 2 | 2.26 | 1.40 | 1.55 | $42,150 | $37,680 | $36,640 |
| **11-1021** | General and Operations Managers | 4 | 1.83 | 0.82 | 0.66 | $151,930 | $125,630 | $110,390 |
| **43-5071** | Shipping, Receiving, and Traffic Clerks | 2 | 1.83 | 0.79 | 1.51 | $34,080 | $35,100 | $37,120 |
| **53-7062** | Laborers and Freight, Stock, and Material Movers, Hand | 2 | 1.81 | 0.74 | 1.33 | $34,890 | $32,460 | $29,150 |
| **43-9061** | Office Clerks, General | 2 | 1.80 | 1.25 | 1.15 | $34,850 | $36,430 | $34,060 |
| **51-4072** | Molding, Coremaking, and Casting Machine Setters, Operators, etc. | 2 | 1.63 | 1.59 | N/A | $37,040 | $38,240 | $42,590 |
| **51-4081** | Multiple Machine Tool Setters, Operators, and Tenders | 2 | 1.56 | 2.41 | 0.91 | $36,670 | $35,560 | $38,840 |
| **17-2031** | Biomedical Engineers | 4 | 1.43 | N/A | N/A | $94,990 | N/A | N/A |
| **51-4011** | Computer-Controlled Machine Tool Operators, Metal and Plastic | 3 | 1.37 | 0.93 | 3.53 | $40,990 | $41,500 | $44,060 |
| **41-4012** | Sales Representatives - Except Technical and Scientific Products | 4 | 1.15 | 1.17 | 1.86 | $72,910 | $67,600 | $63,350 |
| **53-3033** | Light Truck or Delivery Services Drivers | 2 | 1.14 | 0.87 | 0.95 | $26,870 | $38,310 | $30,320 |
| **11-3051** | Industrial Production Managers | 4 | 1.09 | 1.24 | 1.32 | $119,480 | $108,840 | $125,810 |
| **51-9111** | Packaging and Filling Machine Operators and Tenders | 2 | 1.09 | 1.63 | 1.82 | $31,340 | $33,200 | $38,110 |
| **41-4011** | Sales Representatives - Technical and Scientific Products | 4 | 1.04 | 0.83 | N/A | $89,830 | $72,770 | $108,340 |
| **43-5061** | Production, Planning, and Expediting Clerks | 3 | 1.04 | 0.68 | 0.73 | $49,690 | $48,290 | $45,430 |
| **43-6014** | Secretaries and Administrative Assistants | 3 | 1.01 | 0.50 | 0.43 | $37,470 | $38,880 | $34,970 |
| **51-4033** | Grinding, Lapping, Polishing, and Buffing Machine Tool Setters, etc. | 2 | 1.01 | 1.03 | 2.07 | $34,130 | $35,980 | $34,680 |
| **51-9198** | Helpers--Production Workers | 2 | 1.01 | 0.35 | 0.67 | $29,710 | $33,300 | $30,560 |
| **29-2091** | Orthotists and Prosthetists | 5 | 0.95 | N/A | N/A | $77,400 | N/A | N/A |
| **49-9071** | Maintenance and Repair Workers, General | 3 | 0.94 | 1.16 | 1.12 | $46,950 | $41,330 | $35,500 |
| **43-5081** | Stock Clerks and Order Fillers | 2 | 0.93 | 0.82 | 1.10 | $34,430 | $27,030 | $24,030 |

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

**Figure 2.4 – Research and Development in the Physical, Engineering, and Life Sciences 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 |
|---|---|---|---|---|---|---|---|---|
| **19-1042** | Medical Scientists, Except Epidemiologists | 5 | 6.58 | 1.60 | N/A | $105,730 | $70,990 | N/A |
| **19-4021** | Biological Technicians | 4 | 3.83 | 1.94 | N/A | $49,840 | $46,520 | N/A |
| **17-2141** | Mechanical Engineers | 4 | 3.25 | 1.53 | 1.50 | $102,110 | $78,870 | $74,880 |
| **11-9121** | Natural Sciences Managers | 5 | 2.72 | 1.96 | N/A | $161,920 | $113,870 | N/A |
| **19-1021** | Biochemists and Biophysicists | 5 | 2.66 | 2.27 | N/A | $115,690 | $76,540 | N/A |
| **11-1021** | General and Operations Managers | 4 | 2.32 | 0.82 | 0.66 | $187,770 | $125,630 | $110,390 |
| **19-2031** | Chemists | 4 | 2.26 | N/A | N/A | $93,190 | $68,850 | N/A |
| **15-1133** | Software Developers, Systems Software | 4 | 2.19 | 1.13 | N/A | $117,650 | $82,390 | N/A |
| **13-1199** | Business Operations Specialists, All Other | 3 | 2.11 | 1.27 | 0.25 | $89,570 | $64,370 | $63,200 |
| **15-1132** | Software Developers, Applications | 4 | 2.01 | N/A | 0.45 | $111,140 | $85,070 | $80,470 |
| **17-2071** | Electrical Engineers | 4 | 2.01 | 0.96 | N/A | $112,850 | $94,820 | N/A |
| **43-6014** | Secretaries and Administrative Assistants, | 3 | 1.91 | 0.50 | 0.43 | $46,240 | $38,880 | $34,970 |
| **11-9041** | Architectural and Engineering Managers | 5 | 1.63 | 0.95 | 0.53 | $167,640 | $127,110 | $111,160 |
| **15-1121** | Computer Systems Analysts | 4 | 1.45 | 2.52 | 0.63 | $101,880 | $88,000 | $65,020 |
| **43-6011** | Executive Secretaries and Executive Administrative Assistants | 3 | 1.45 | 0.60 | 0.34 | $68,220 | $56,100 | $55,570 |
| **17-2072** | Electronics Engineers, Except Computer | 4 | 1.43 | 0.13 | N/A | $126,000 | $88,980 | N/A |
| **43-9061** | Office Clerks, General | 2 | 1.32 | 1.25 | 1.15 | $43,290 | $36,430 | $34,060 |
| **13-2011** | Accountants and Auditors | 4 | 1.29 | 1.23 | 0.73 | $90,720 | $68,030 | $67,340 |
| **11-9199** | Managers, All Other | 4 | 1.24 | 1.60 | 1.47 | $151,360 | $92,520 | $91,590 |
| **17-2112** | Industrial Engineers | 4 | 1.24 | 0.97 | 1.15 | $101,080 | $76,900 | $77,180 |
| **29-2010** | Clinical Laboratory Technologists and Technicians | 3 | 1.21 | 1.30 | 0.82 | $52,720 | $54,150 | $45,990 |
| **19-1029** | Biological Scientists, All Other | 5 | 1.16 | 2.16 | N/A | $90,050 | $77,880 | N/A |
| **13-1111** | Management Analysts | 5 | 1.08 | 2.05 | 0.40 | $108,040 | $78,110 | $72,390 |
| **17-2061** | Computer Hardware Engineers | 4 | 1.08 | 1.88 | N/A | $130,450 | $79,530 | N/A |
| **17-2199** | Engineers, All Other | 4 | 1.08 | 1.21 | N/A | $105,730 | $85,780 | N/A |
| **11-3021** | Computer and Information Systems Managers | 4 | 1.03 | 1.47 | 0.47 | $167,190 | $120,180 | $104,540 |
| **13-1041** | Compliance Officers | 4 | 1.03 | 1.22 | 0.45 | $87,380 | $62,340 | $66,170 |
| **19-2012** | Physicists | 5 | 1.01 | N/A | N/A | $132,830 | $102,720 | N/A |
| **19-4031** | Chemical Technicians | 3 | 1.00 | 2.07 | N/A | $60,950 | $43,910 | N/A |
| **19-1022** | Microbiologists | 5 | 0.97 | 2.84 | N/A | $91,540 | $62,650 | N/A |

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

**Figure 2.5 – Testing Laboratories 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 |
|---|---|---|---|---|---|---|---|---|
| **51-9061** | Inspectors, Testers, Sorters, Samplers, and Weighers | 2 | 11.93 | 0.99 | 1.63 | $46,250 | $38,020 | $32,170 |
| **19-4031** | Chemical Technicians | 3 | 7.35 | 2.07 | N/A | $42,360 | $43,910 | N/A |
| **17-2141** | Mechanical Engineers | 4 | 5.65 | 1.53 | 1.50 | $99,390 | $78,870 | $74,880 |
| **19-2031** | Chemists | 4 | 4.89 | N/A | N/A | $67,630 | $68,850 | N/A |
| **11-1021** | General and Operations Managers | 4 | 3.10 | 0.82 | 0.66 | $135,980 | $125,630 | $110,390 |
| **17-2112** | Industrial Engineers | 4 | 2.82 | 0.97 | 1.15 | $99,820 | $76,900 | $77,180 |
| **43-9061** | Office Clerks, General | 2 | 2.74 | 1.25 | 1.15 | $37,740 | $36,430 | $34,060 |
| **19-4091** | Environmental Science and Protection Technicians | 4 | 2.58 | 1.52 | 2.02 | $41,430 | $47,290 | $39,040 |
| **43-6014** | Secretaries and Administrative Assistants | 3 | 2.50 | 0.50 | 0.43 | $38,340 | $38,880 | $34,970 |
| **17-3029** | Engineering Technicians, Except Drafters, All Other | 2 | 2.42 | 0.64 | N/A | $53,710 | $60,520 | N/A |
| **17-3023** | Electrical and Electronics Engineering Technicians | 3 | 1.66 | 0.62 | N/A | $61,310 | $64,260 | N/A |
| **19-4021** | Biological Technicians | 4 | 1.65 | 1.94 | N/A | $43,000 | $46,520 | N/A |
| **19-2041** | Environmental Scientists and Specialists, Including Health | 4 | 1.57 | 1.32 | N/A | $62,050 | $61,730 | N/A |
| **41-3099** | Sales Representatives, Services, All Other | 4 | 1.43 | 0.72 | 1.33 | $76,250 | $60,810 | $58,860 |
| **43-4051** | Customer Service Representatives | 2 | 1.31 | 1.40 | 1.55 | $41,540 | $37,680 | $36,640 |
| **19-4099** | Life, Physical, and Social Science Technicians, All Other | 3 | 1.25 | 1.63 | N/A | $45,740 | $58,840 | N/A |
| **17-2071** | Electrical Engineers | 4 | 1.19 | 0.96 | N/A | $102,070 | $94,820 | N/A |
| **17-2199** | Engineers, All Other | 4 | 1.19 | 1.21 | N/A | $89,840 | $85,780 | N/A |
| **19-4041** | Geological and Petroleum Technicians | 4 | 1.19 | N/A | N/A | $49,770 | N/A | N/A |
| **11-9041** | Architectural and Engineering Managers | 5 | 1.17 | 0.95 | 0.53 | $131,070 | $127,110 | $111,160 |
| **17-3027** | Mechanical Engineering Technicians | 3 | 1.08 | 1.96 | 3.02 | $60,250 | $53,710 | $59,960 |
| **47-4011** | Construction and Building Inspectors | 3 | 1.03 | 0.46 | N/A | $67,520 | $62,040 | N/A |
| **43-3031** | Bookkeeping, Accounting, and Auditing Clerks | 3 | 0.99 | 1.06 | 1.38 | $41,980 | $39,610 | $34,460 |
| **13-2011** | Accountants and Auditors | 4 | 0.93 | 1.23 | 0.73 | $80,200 | $68,030 | $67,340 |
| **43-1011** | First-Line Supervisors of Office and Administrative Support | 3 | 0.93 | 0.89 | 1.01 | $66,470 | $59,190 | $52,260 |
| **51-1011** | First-Line Supervisors of Production and Operating Workers | 2 | 0.90 | 1.22 | 1.70 | $68,600 | $58,670 | $61,580 |
| **13-1199** | Business Operations Specialists, All Other | 3 | 0.89 | 1.27 | 0.25 | $66,450 | $64,370 | $63,200 |
| **41-4011** | Sales Representatives - Technical and Scientific Products | 4 | 0.89 | 0.83 | N/A | $90,500 | $72,770 | $108,340 |
| **19-1022** | Microbiologists | 5 | 0.82 | 2.84 | N/A | $61,440 | $62,650 | N/A |
| **11-9121** | Natural Sciences Managers | 5 | 0.78 | 1.96 | N/A | $122,530 | $113,870 | N/A |

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

**Figure 2.6 – Medical and Diagnostic Laboratories 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 |
|---|---|---|---|---|---|---|---|---|
| **29-2010** | Clinical Laboratory Technologists and Technicians | 4 | 21.86 | 1.30 | 0.82 | $52,280 | $54,150 | $45,990 |
| **31-9097** | Phlebotomists | 3 | 15.64 | 1.40 | N/A | $35,820 | $34,530 | N/A |
| **29-2034** | Radiologic Technologists | 3 | 5.64 | 1.09 | 0.94 | $60,860 | $58,440 | $54,420 |
| **43-4051** | Customer Service Representatives | 2 | 4.48 | 1.40 | 1.55 | $37,200 | $37,680 | $36,640 |
| **43-5021** | Couriers and Messengers | 2 | 3.64 | 1.87 | N/A | $31,160 | $25,000 | $18,350 |
| **29-2032** | Diagnostic Medical Sonographers | 3 | 2.80 | 0.96 | N/A | $74,310 | $79,690 | $62,580 |
| **29-2035** | Magnetic Resonance Imaging Technologists | 3 | 2.75 | 0.87 | N/A | $69,870 | $69,540 | N/A |
| **43-6013** | Medical Secretaries | 3 | 2.56 | 0.48 | 0.51 | $34,630 | $38,380 | $35,530 |
| **43-4171** | Receptionists and Information Clerks | 2 | 2.37 | 1.07 | 1.54 | $32,110 | $29,200 | $28,590 |
| **43-3021** | Billing and Posting Clerks | 2 | 2.26 | 0.40 | 0.44 | $37,730 | $39,700 | $37,670 |
| **29-1069** | Physicians and Surgeons, All Other | 5 | 2.09 | 1.76 | 2.57 | $253,670 | $255,030 | $260,310 |
| **41-3099** | Sales Representatives, Services, All Other | 4 | 2.08 | 0.72 | 1.33 | $67,970 | $60,810 | $58,860 |
| **11-9111** | Medical and Health Services Managers | 5 | 1.92 | 0.99 | 1.24 | $121,570 | $110,440 | $101,690 |
| **43-1011** | First-Line Supervisors of Office and Administrative Support | 3 | 1.67 | 0.89 | 1.01 | $60,450 | $59,190 | $52,260 |
| **43-9061** | Office Clerks, General | 2 | 1.57 | 1.25 | 1.15 | $35,490 | $36,430 | $34,060 |
| **19-1042** | Medical Scientists, Except Epidemiologists | 5 | 1.47 | 1.60 | N/A | $98,110 | $70,990 | N/A |
| **31-9092** | Medical Assistants | 3 | 1.24 | 0.93 | 1.09 | $37,740 | $36,700 | $35,800 |
| **31-9099** | Healthcare Support Workers, All Other | 3 | 1.16 | 1.02 | N/A | $32,670 | $38,020 | N/A |
| **43-6014** | Secretaries and Administrative Assistants | 3 | 1.03 | 0.50 | 0.43 | $36,880 | $38,880 | $34,970 |
| **11-1021** | General and Operations Managers | 4 | 0.99 | 0.82 | 0.66 | $144,860 | $125,630 | $110,390 |
| **43-9021** | Data Entry Keyers | 2 | 0.85 | 0.71 | N/A | $34,290 | $33,260 | N/A |
| **29-1141** | Registered Nurses | 3 | 0.71 | 0.96 | 1.00 | $70,590 | $78,910 | $66,950 |
| **31-9094** | Medical Transcriptionists | 3 | 0.59 | 1.54 | 1.77 | $41,860 | $35,310 | $43,090 |
| **43-3031** | Bookkeeping, Accounting, and Auditing Clerks | 3 | 0.59 | 1.06 | 1.38 | $42,600 | $39,610 | $34,460 |
| **29-2099** | Health Technologists and Technicians, All Other | 3 | 0.58 | 1.98 | 1.13 | $51,460 | $47,950 | $46,050 |
| **29-2071** | Medical Records and Health Information Technicians | 3 | 0.56 | 1.24 | N/A | $41,400 | $45,360 | $35,940 |
| **29-2031** | Cardiovascular Technologists and Technicians | 3 | 0.56 | 1.04 | N/A | $53,160 | $69,780 | N/A |
| **43-4111** | Interviewers, Except Eligibility and Loan | 2 | 0.52 | N/A | N/A | $33,700 | $34,730 | N/A |
| **15-1151** | Computer User Support Specialists | 3 | 0.51 | 1.60 | 0.78 | $49,850 | $54,840 | $45,480 |
| **15-1132** | Software Developers, Applications | 4 | 0.49 | N/A | 0.45 | $96,470 | $85,070 | $80,470 |

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

While each bioscience industry relies on a diversity of occupations, the overall bioscience cluster has several occupations that are common across multiple subsectors. Occupations that span multiple categories could provide opportunities for joint talent development initiatives such as recruitment, DACUM efforts, and internships. The frequency of an individual occupation appearing in the top 30 occupations for each subsector of bioscience shows that several occupational categories are found in the top 30 for several subsectors (Figure 2.7). These occupations include management, customer service, industrial engineers, and office support. Other commonly found occupations across the bioscience industry cluster include chemists and chemical technicians, mechanical engineers, and several production related occupations that are found in the manufacturing portions of the bioscience cluster (i.e. pharmaceutical manufacturing, electromedical devices, medical supplies, etc.).

Bioscience industries also have important concentrations of life science occupations that are foundations of the cluster. These include medical scientists, microbiologists, biological technicians, biochemists and biophysicists, and biomedical engineers. While these occupations are not found in large numbers like several other occupational categories, they drive the research and technical knowledge that are fundamental to the bioscience cluster.

**Figure 2.7 – Bioscience Occupational Frequency – Number of Times an Occupation Appears in the Top 30 Occupations for Each Bioscience Industry Category**


Source: Bureau of Labor Statistics and Author's Calculations

As suggested, sales and customer service occupations are also common across the bioscience industry cluster. Customer sales are driven by both in-house sales representatives or traveling sales reps. Due to the highly technical nature of many products produced by firms in the bioscience industry, particularly in pharmaceuticals and medical devices, salespeople often require extensive levels of training and product knowledge. They may often have an educational background in engineering or life science disciplines. The complexity of some bioscience products (such as electromedical machinery) also requires the sales of service packages and spare parts as a means of retaining customers and generating additional revenue.

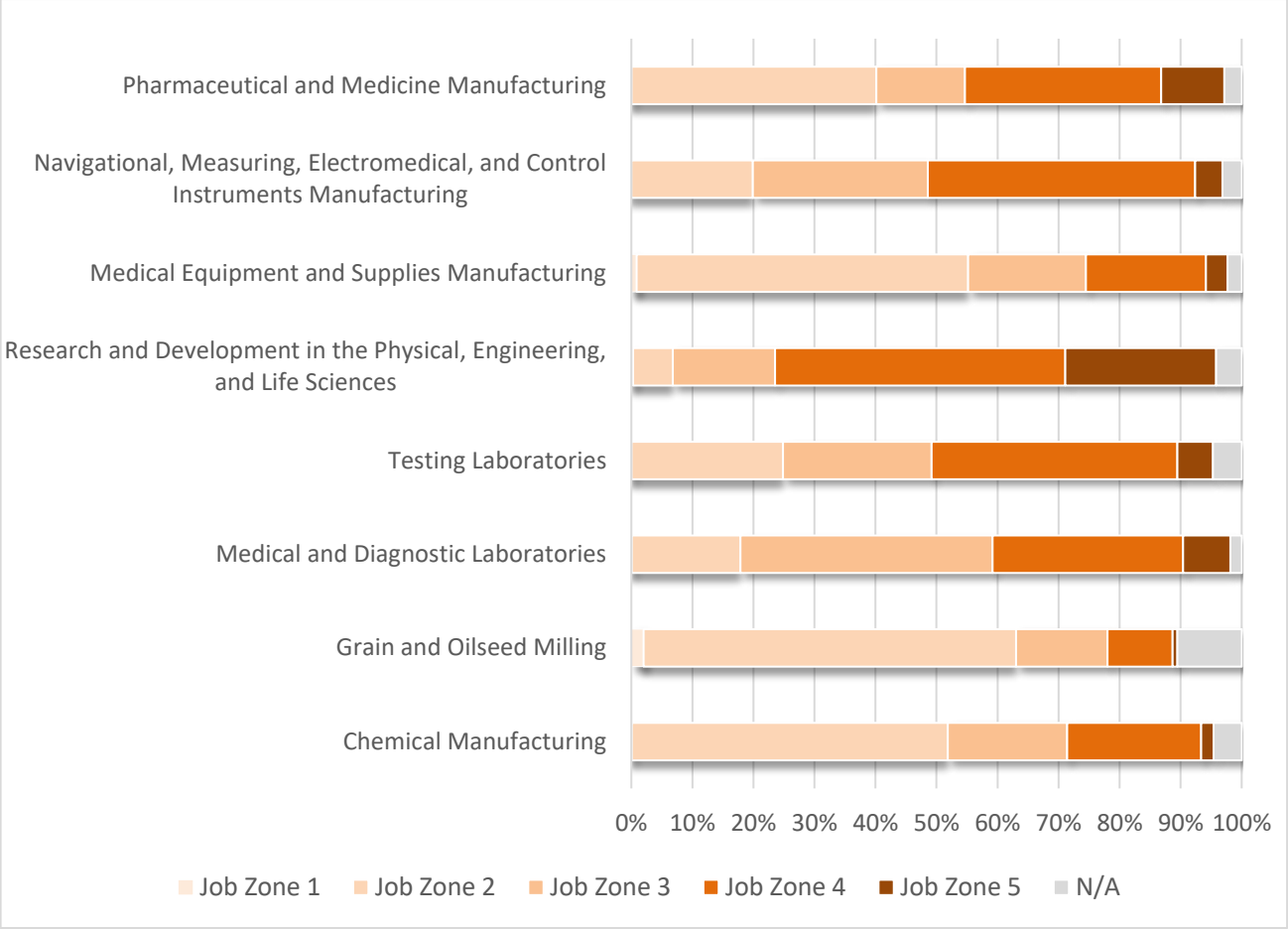
While management occupations are common in most industry sectors, bioscience and otherwise, the importance of management occupations in the bioscience cluster is often overlooked. Skilled managers and executives with expertise in a specific bioscience discipline is often a prerequisite for success. These individuals can help manage the unique regulatory aspects of the industry. They can efficiently operate diverse supply chains. They are also vital to raising capital that is often needed by small and mid-sized bioscience firms to achieve scale. Consequently, the recruitment and retention of these individuals in the Madison Region are important activities of the bioscience industry cluster.

As mentioned earlier, each occupation in the bioscience cluster also can be associated with a *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 bioscience industry employment is summarized by Job zone in Figure 2.8. When comparing Job zone distributions to other industry categories, the bioscience industry is highly reliant upon employment in occupations classified in Job Zone 3, Job Zone 4 and Job Zone 5. Indeed, the four categories of Navigational, Measuring, Electromedical, and Control Instruments Manufacturing; Research and Development in the Physical, Engineering, and Life Sciences; Testing Laboratories; and Medical and Diagnostic Laboratories all have 70% or more of their employment in Job Zone 3 or higher. As these industries tend to have the highest education and training requirements, it should not be surprising that these bioscience subsectors often have the highest average wages as well.

While the bioscience industry cluster is highly dependent on occupations that require higher levels of skill and education, a number of categories also provide opportunities for individuals working in occupations in Job Zone 2. Pharmaceutical and Medicine Manufacturing; Medical Equipment and Supplies Manufacturing and Chemical Manufacturing all have 40% to 55% of their employment concentrated in occupations with Job Zone 2. These concentrations of workers in Job Zone 2 should not necessarily suggest that these categories of the bioscience industry are reliant on unskilled workers. Instead, 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 bioscience cluster also provides a diversity of employment opportunities for people across the skill and education continuums.

**Figure 2.8 – Share of Bioscience Industry Employment by Job Zone**




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

In all, the location quotients and wages for the bioscience occupations listed in Figures 2.1 to 2.6 show the diversity of wages and specializations found in the Region. While it is difficult to draw numerous broad conclusions from these data, it is clear that many of these occupations are found in higher concentrations in the Madison MSA. These higher LQs show the greater reliance that the Madison MSA has on bioscience than other portions of the Madison Region. Nonetheless, as mentioned in Section 1, each county in Region has some magnitude of the bioscience industry cluster present.

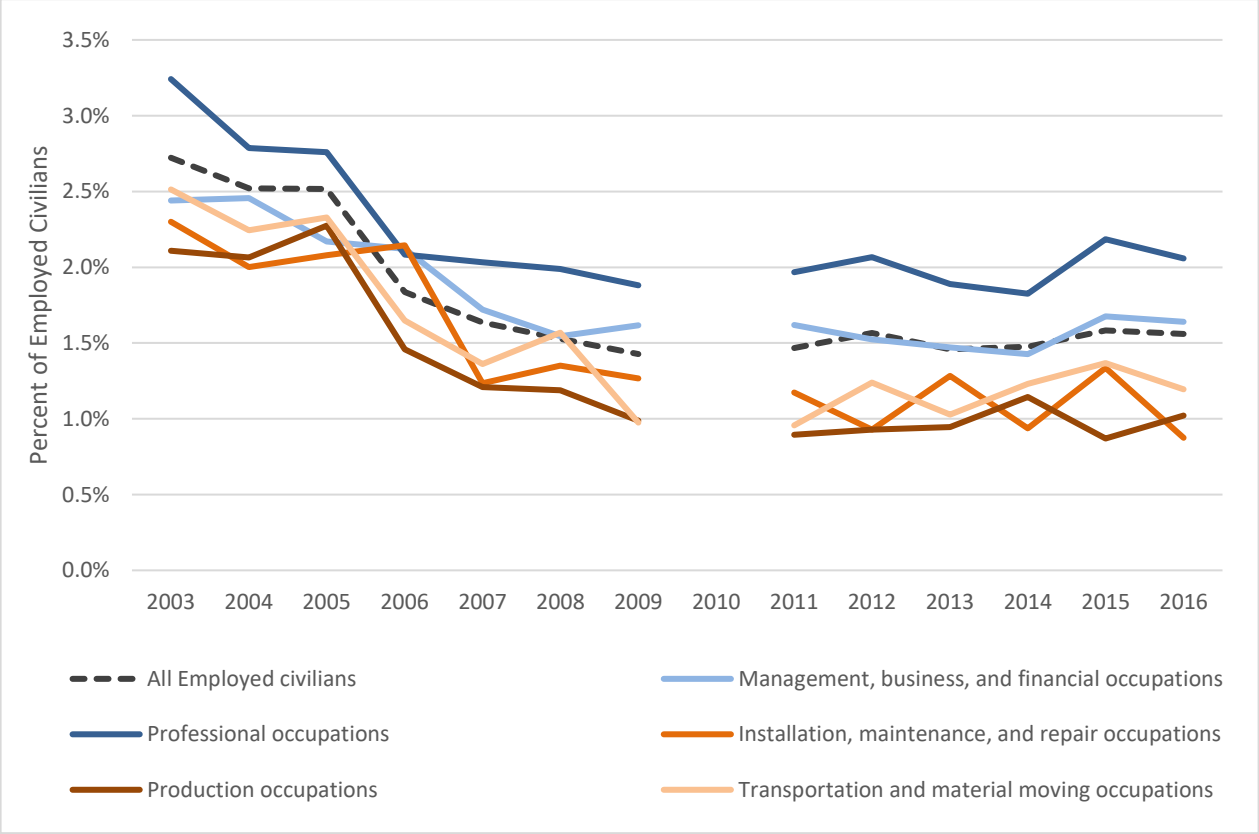
The occupational comparisons in Figures 2.1 to 2.6 also show that the Madison MSA trails the national average in wages for many occupations. Wages within several selected occupational categories are further considered below.

## Labor Mobility

As the Madison Region's bioscience industry considers how to meet its future talent requirements, it will likely need to consider how to attract talent from outside the Region while also growing its internal pipeline from within the Region. More specifically, there is a distinct difference in the mobility of professional and management occupations (such as engineers, life scientists and executives) relative to production occupations that are common in several categories of bioscience. Indeed, people working in production occupations are among the least mobile in terms of their movement from one state to another. In contrast, people working professional occupations and management are among the most mobile (Figure 2.9). The mobility trends in Figure 2.9 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 needed in the bioscience cluster 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.

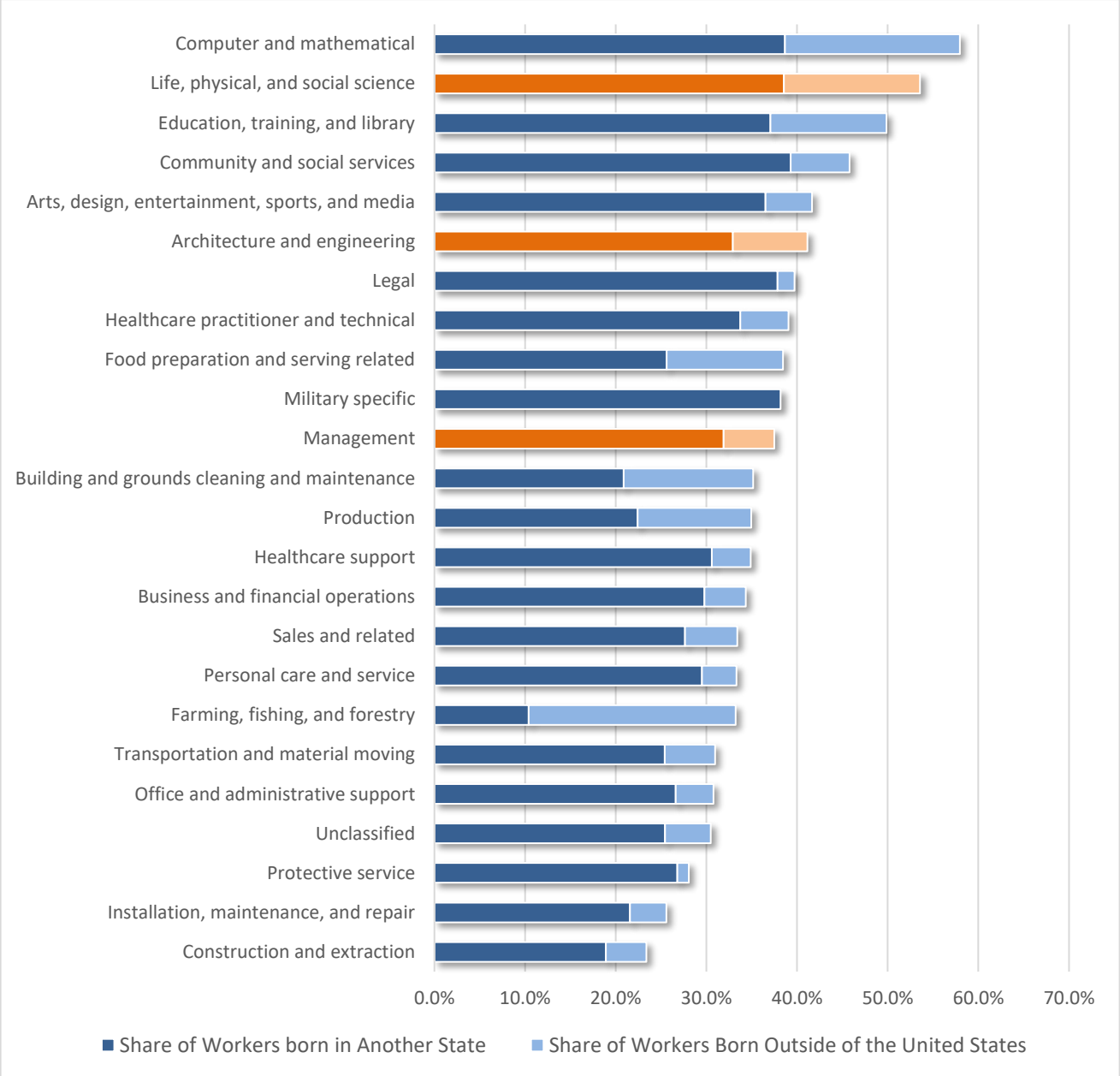
**Figure 2.9 - Share of Employed Civilians Moving Across State Lines by Occupation (2003 to 2015)**




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

While the figures depicted in Figure 2.9 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 and life, physical and social science have among the highest share of individuals who were either born in another state or born outside of the United States (Figure 2.10). In contrast, production occupations, sales occupations and office and administrative support have a much lower share of residents born in another state or another country.

**Figure 2.10 – 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 in several occupational categories important to the bioscience industry 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, moved here for educational opportunities, or resided in the Region for some time, the measure suggests that that the national mobility characteristics in Figure 2.9 are somewhat present in the Madison Region. Consequently, external talent attraction efforts are more likely to be effective for professional and occupations and internal approaches to talent development have a greater priority for production and other categories occupations important to the bioscience cluster.

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. Section 3 examines talent attraction and retention in greater detail.

## Metro Area Employment Comparisons

In terms of talent attraction and retention efforts, many of the occupations in the bioscience industry cluster are highly sought after by firms and regions across the nation. In the Madison Region, both UW-Madison and UW-Platteville have world-class engineering programs. UW-Madison has nationally ranked degree programs in many life science disciplines. Madison College, Blackhawk Technical College and Moraine Park Technical College also have a variety of programs that are vital to the bioscience industry. However, it is likely that local firms will also need to look beyond the Region to meeting their human capital needs.

When considering where an individual in a bioscience-related occupation may choose to live and work, labor market thickness is an important consideration. A thick labor market is one that offers an individual a diversity of opportunities for horizontal and vertical career progression rather than a more limited number of jobs. As noted in the Introduction, geographic clustering of talent in the form of thick labor markets also provides potential value to firms. More specifically, as bioscience talent gains experience at one firm, there is the potential that an individual may share this acquired knowledge with other firms in the cluster upon job-hopping. The benefits of knowledge sharing to employers may seem counterintuitive as a means of preserving intellectual property or maintaining other firm-specific advantages. However, Saxenian's (1994) classic study of Silicon Valley and Route 128 in Massachusetts suggests that the degree of collaboration between cluster members by sharing information amid competition is one of the primary factors of cluster success.

In considering the thickness of the Madison Region's bioscience labor market, the following analysis examines how the Madison MSA compares to other metro areas in six specific occupations: chemists, electrical engineers, medical scientists, microbiologists, biochemists and biophysicists, and biomedical engineers. These occupations are highly specialized in the bioscience industry cluster and are also potentially more mobile than many other occupations in the cluster. The top 50 MSAs in terms of total employment for each of these occupations in Figures 2.11 to 2.16. These figures also include location quotients and annual average wages for each MSA. *Note that not every measure is available for every metro area. That is, some figures are occasionally suppressed for metro areas that have important bioscience industry concentrations. Accordingly, these figures should not be viewed as absolute rankings, but rather more general comparisons.*

Mechanical engineers and industrial engineers are two additional occupations that are vital to the bioscience cluster. Figures for these occupations are included in Appendix 2B, but are not included here as they are examined in greater detail in the Madison Region's Advanced Manufacturing Industry Cluster Abstract.

Not surprisingly, many of the top MSAs for these selected bioscience-related occupations are found in some of the nation's largest metropolitan areas. Many of these metro areas have well established concentrations in bioscience industries such as Boston, San Francisco, Philadelphia, Seattle, San Diego, Washington DC, Austin, and San Jose. However, the presence and importance of R1 research universities in mid-sized metropolitan areas (and all metro areas in this analysis) cannot be understated. Specifically, Raleigh-Durham-Chapel Hill, NC (i.e. the Research Triangle); Columbus, OH (Ohio State University); Ann Arbor, MI (University of Michigan); Rochester, NY (University of Rochester), and Boulder, CO (University of Colorado) and Madison, WI among others are frequently found in the top 50 metro areas for these occupations. Accordingly, the importance of UW-Madison to the development of this sector should not be underestimated.

**Figure 2.11 - Top 50 MSAs for Total Chemists (2017)**

| Rank | Metropolitan Statistical Area | Total Chemists in 2017 | Location Quotient in 2017 | Annual Average Wage in 2017 |
|---|---|---|---|---|
| 1 | New York-Newark-Jersey City, NY-NJ-PA | 8,050 | 1.46 | $88,700 |
| 2 | San Francisco-Oakland-Hayward, CA | 3,190 | 2.28 | $107,560 |
| 3 | Washington-Arlington-Alexandria, DC-VA-MD-WV | 3,040 | 1.66 | $119,310 |
| 4 | Los Angeles-Long Beach-Anaheim, CA | 2,860 | 0.80 | $75,830 |
| 5 | Boston-Cambridge-Nashua, MA-NH | 2,580 | 1.60 | $93,670 |
| 6 | Chicago-Naperville-Elgin, IL-IN-WI | 2,570 | 0.95 | $76,080 |
| 7 | Houston-The Woodlands-Sugar Land, TX | 2,450 | 1.41 | $83,920 |
| 8 | Boston-Cambridge-Newton, MA NECTA Division | 1,710 | 1.57 | $98,460 |
| 9 | Minneapolis-St. Paul-Bloomington, MN-WI | 1,460 | 1.27 | $86,680 |
| 10 | Detroit-Warren-Dearborn, MI | 1,340 | 1.15 | $83,410 |
| 11 | St. Louis, MO-IL | 1,300 | 1.62 | $76,150 |
| 12 | San Diego-Carlsbad, CA | 1,220 | 1.44 | $87,280 |
| 13 | Cincinnati, OH-KY-IN | 1,210 | 1.94 | $70,940 |
| 14 | Durham-Chapel Hill, NC | 1,160 | 6.58 | $85,120 |
| 15 | Trenton, NJ | 1,140 | 8.41 | $95,060 |
| 16 | Pittsburgh, PA | 1,080 | 1.61 | $73,320 |
| 17 | Cleveland-Elyria, OH | 1,060 | 1.73 | $73,280 |
| 18 | Dallas-Fort Worth-Arlington, TX | 1,010 | 0.49 | $79,160 |
| 19 | San Juan-Carolina-Caguas, PR | 910 | 2.32 | $63,140 |
| 20 | Seattle-Tacoma-Bellevue, WA | 830 | 0.72 | $74,620 |
| 21 | Baltimore-Columbia-Towson, MD | 820 | 1.01 | $96,750 |
| 22 | Charlotte-Concord-Gastonia, NC-SC | 820 | 1.17 | $71,640 |
| 23 | Denver-Aurora-Lakewood, CO | 760 | 0.89 | $77,990 |
| 24 | Kansas City, MO-KS | 760 | 1.21 | $74,930 |
| 25 | Atlanta-Sandy Springs-Roswell, GA | 730 | 0.47 | $85,990 |
| 26 | Raleigh, NC | 650 | 1.80 | $76,520 |
| 27 | Miami-Fort Lauderdale-West Palm Beach, FL | 650 | 0.43 | $66,030 |
| 28 | San Jose-Sunnyvale-Santa Clara, CA | 610 | 0.94 | $105,470 |
| 29 | Kennewick-Richland, WA | 590 | 8.94 | $103,440 |
| 30 | Tampa-St. Petersburg-Clearwater, FL | 580 | 0.77 | $63,520 |
| 31 | Lancaster, PA | 580 | 4.09 | $58,040 |
| 32 | Austin-Round Rock, TX | 560 | 0.95 | $60,840 |
| 33 | Hartford-West Hartford-East Hartford, CT | 530 | 1.53 | $87,130 |
| 34 | Richmond, VA | 490 | 1.28 | $84,760 |
| 35 | Sacramento--Roseville--Arden-Arcade, CA | 480 | 0.84 | $79,310 |
| 36 | Columbus, OH | 460 | 0.75 | $70,470 |
| 37 | Salt Lake City, UT | 450 | 1.08 | $68,720 |
| 38 | Lowell-Billerica-Chelmsford, MA-NH NECTA Division | 440 | 4.75 | $78,160 |
| 39 | Portland-Vancouver-Hillsboro, OR-WA | 420 | 0.62 | $69,600 |
| 40 | Phoenix-Mesa-Scottsdale, AZ | 410 | 0.35 | $74,870 |
| 41 | Milwaukee-Waukesha-West Allis, WI | 410 | 0.83 | $66,500 |
| 42 | Riverside-San Bernardino-Ontario, CA | 400 | 0.47 | $71,800 |
| 43 | Greensboro-High Point, NC | 400 | 1.86 | $73,160 |
| 44 | Ann Arbor, MI | 390 | 3.09 | $72,620 |
| 45 | Albany-Schenectady-Troy, NY | 390 | 1.48 | $79,930 |
| 46 | College Station-Bryan, TX | 380 | 5.79 | $51,830 |
| 47 | Boulder, CO | 340 | 3.24 | $99,930 |
| 48 | Allentown-Bethlehem-Easton, PA-NJ | 310 | 1.44 | $74,680 |
| 49 | Orlando-Kissimmee-Sanford, FL | 300 | 0.42 | $53,120 |
| 50 | New Haven, CT | 290 | 1.78 | $109,060 |

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

Note that the total number of chemists in the Madison MSA is suppressed.

**Figure 2.12 - Top 50 MSAs for Total Electrical Engineers (2017)**

| Rank | Metropolitan Statistical Area | Total Electrical Engineers in 2017 | Location Quotient in 2017 | Annual Average Wage in 2017 |
|---|---|---|---|---|
| 1 | New York-Newark-Jersey City, NY-NJ-PA | 9,080 | 0.76 | $105,700 |
| 2 | Boston-Cambridge-Nashua, MA-NH | 8,400 | 2.40 | $114,470 |
| 3 | Los Angeles-Long Beach-Anaheim, CA | 7,790 | 1.00 | $111,500 |
| 4 | Detroit-Warren-Dearborn, MI | 6,940 | 2.74 | $90,680 |
| 5 | San Jose-Sunnyvale-Santa Clara, CA | 5,280 | 3.77 | $125,580 |
| 6 | Dallas-Fort Worth-Arlington, TX | 5,230 | 1.17 | $104,000 |
| 7 | Boston-Cambridge-Newton, MA NECTA Division | 4,620 | 1.95 | $116,180 |
| 8 | Chicago-Naperville-Elgin, IL-IN-WI | 4,420 | 0.75 | $92,970 |
| 9 | Seattle-Tacoma-Bellevue, WA | 4,390 | 1.76 | $114,760 |
| 10 | Washington-Arlington-Alexandria, DC-VA-MD-WV | 4,380 | 1.10 | $117,270 |
| 11 | San Francisco-Oakland-Hayward, CA | 3,870 | 1.27 | $113,670 |
| 12 | Houston-The Woodlands-Sugar Land, TX | 3,870 | 1.03 | $104,180 |
| 13 | Philadelphia-Camden-Wilmington, PA-NJ-DE-MD | 3,700 | 1.02 | $102,930 |
| 14 | Minneapolis-St. Paul-Bloomington, MN-WI | 3,280 | 1.32 | $95,560 |
| 15 | San Diego-Carlsbad, CA | 3,270 | 1.77 | $104,240 |
| 16 | Atlanta-Sandy Springs-Roswell, GA | 2,960 | 0.88 | $92,750 |
| 17 | Phoenix-Mesa-Scottsdale, AZ | 2,680 | 1.05 | $103,960 |
| 18 | Portland-Vancouver-Hillsboro, OR-WA | 2,380 | 1.60 | $96,550 |
| 19 | Baltimore-Columbia-Towson, MD | 2,290 | 1.31 | $105,910 |
| 20 | Kansas City, MO-KS | 2,220 | 1.64 | $90,110 |
| 21 | Denver-Aurora-Lakewood, CO | 2,130 | 1.15 | $92,220 |
| 22 | Pittsburgh, PA | 2,060 | 1.41 | $97,350 |
| 23 | Austin-Round Rock, TX | 2,000 | 1.56 | $116,980 |
| 24 | Raleigh, NC | 1,970 | 2.53 | $111,250 |
| 25 | St. Louis, MO-IL | 1,870 | 1.07 | $100,390 |
| 26 | Huntsville, AL | 1,860 | 6.50 | $101,940 |
| 27 | Albuquerque, NM | 1,630 | 3.32 | $101,750 |
| 28 | Milwaukee-Waukesha-West Allis, WI | 1,530 | 1.41 | $81,200 |
| 29 | Albany-Schenectady-Troy, NY | 1,490 | 2.58 | $104,360 |
| 30 | Charlotte-Concord-Gastonia, NC-SC | 1,420 | 0.93 | $103,850 |
| 31 | Tucson, AZ | 1,330 | 2.84 | $109,170 |
| 32 | Miami-Fort Lauderdale-West Palm Beach, FL | 1,290 | 0.39 | $82,560 |
| 33 | Framingham, MA NECTA Division | 1,280 | 5.75 | $118,360 |
| 34 | Virginia Beach-Norfolk-Newport News, VA-NC | 1,260 | 1.32 | $94,140 |
| 35 | Cleveland-Elyria, OH | 1,230 | 0.93 | $86,290 |
| 36 | Birmingham-Hoover, AL | 1,220 | 1.88 | $95,420 |
| 37 | Sacramento--Roseville--Arden-Arcade, CA | 1,220 | 0.99 | $122,500 |
| 38 | Columbus, OH | 1,200 | 0.90 | $79,970 |
| 39 | Indianapolis-Carmel-Anderson, IN | 1,150 | 0.87 | $81,990 |
| 40 | Cincinnati, OH-KY-IN | 1,130 | 0.83 | $83,730 |
| 41 | Nashua, NH-MA NECTA Division | 1,100 | 6.45 | $111,460 |
| 42 | Rochester, NY | 1,090 | 1.66 | $92,690 |
| 43 | Richmond, VA | 1,010 | 1.21 | $104,560 |
| 44 | Palm Bay-Melbourne-Titusville, FL | 960 | 3.62 | $107,810 |
| 45 | Salt Lake City, UT | 960 | 1.07 | $88,660 |
| 46 | San Antonio-New Braunfels, TX | 940 | 0.73 | $105,090 |
| 47 | Grand Rapids-Wyoming, MI | 930 | 1.30 | $75,190 |
| 48 | Tampa-St. Petersburg-Clearwater, FL | 920 | 0.56 | $92,160 |
| 49 | Hartford-West Hartford-East Hartford, CT | 880 | 1.17 | $93,790 |
| 50 | Orlando-Kissimmee-Sanford, FL | 870 | 0.56 | $90,030 |

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

**Figure 2.13 - Top 50 MSAs for Total Medical Scientists (2017)**

| Rank | Metropolitan Statistical Area | Total Medical Scientists in 2017 | Location Quotient in 2017 | Annual Average Wage in 2017 |
|---|---|---|---|---|
| 1 | Boston-Cambridge-Nashua, MA-NH | 10,600 | 4.96 | $90,490 |
| 2 | New York-Newark-Jersey City, NY-NJ-PA | 8,530 | 1.17 | $101,320 |
| 3 | San Francisco-Oakland-Hayward, CA | 8,200 | 4.42 | * |
| 4 | Los Angeles-Long Beach-Anaheim, CA | 7,590 | 1.60 | $90,080 |
| 5 | Philadelphia-Camden-Wilmington, PA-NJ-DE-MD | 6,500 | 2.95 | $114,470 |
| 6 | Seattle-Tacoma-Bellevue, WA | 4,820 | 3.16 | $87,060 |
| 7 | San Diego-Carlsbad, CA | 3,760 | 3.34 | $113,660 |
| 8 | Washington-Arlington-Alexandria, DC-VA-MD-WV | 3,630 | 1.49 | $117,530 |
| 9 | Chicago-Naperville-Elgin, IL-IN-WI | 3,030 | 0.84 | $82,020 |
| 10 | Minneapolis-St. Paul-Bloomington, MN-WI | 2,320 | 1.53 | $78,640 |
| 11 | Houston-The Woodlands-Sugar Land, TX | 2,190 | 0.95 | $69,620 |
| 12 | Durham-Chapel Hill, NC | 2,160 | 9.24 | $105,670 |
| 13 | San Jose-Sunnyvale-Santa Clara, CA | 1,660 | 1.94 | $117,550 |
| 14 | Baltimore-Columbia-Towson, MD | 1,480 | 1.39 | $108,750 |
| 15 | Portland-Vancouver-Hillsboro, OR-WA | 1,410 | 1.56 | $73,520 |
| 16 | Atlanta-Sandy Springs-Roswell, GA | 1,220 | 0.60 | * |
| 17 | Detroit-Warren-Dearborn, MI | 1,190 | 0.77 | $63,880 |
| 18 | Cincinnati, OH-KY-IN | 1,090 | 1.31 | $72,340 |
| 19 | Phoenix-Mesa-Scottsdale, AZ | 940 | 0.61 | $91,610 |
| 20 | Ann Arbor, MI | 900 | 5.35 | $59,120 |
| 21 | Raleigh, NC | 880 | 1.85 | $95,100 |
| 22 | Pittsburgh, PA | 790 | 0.89 | $72,210 |
| 23 | Denver-Aurora-Lakewood, CO | 780 | 0.69 | $86,210 |
| 24 | Nashville-Davidson--Murfreesboro--Franklin, TN | 760 | 1.03 | $87,280 |
| 25 | Iowa City, IA | 750 | 10.38 | $65,090 |
| 26 | Bridgeport-Stamford-Norwalk, CT | 750 | 2.30 | $119,690 |
| 27 | Sacramento--Roseville--Arden-Arcade, CA | 750 | 1.00 | $99,760 |
| 28 | Tucson, AZ | 730 | 2.56 | * |
| 29 | Buffalo-Cheektowaga-Niagara Falls, NY | 660 | 1.54 | $84,270 |
| 30 | Austin-Round Rock, TX | 630 | 0.80 | $80,780 |
| 31 | Riverside-San Bernardino-Ontario, CA | 630 | 0.56 | $95,520 |
| 32 | Kansas City, MO-KS | 560 | 0.68 | $77,800 |
| 33 | Salt Lake City, UT | 500 | 0.92 | $81,680 |
| 34 | Dallas-Fort Worth-Arlington, TX | 500 | 0.18 | $81,090 |
| **35** | **Madison, WI** | **490** | **1.60** | **$70,990** |
| 36 | Tampa-St. Petersburg-Clearwater, FL | 490 | 0.49 | $71,060 |
| 37 | Miami-Fort Lauderdale-West Palm Beach, FL | 480 | 0.24 | $74,840 |
| 38 | Worcester, MA-CT | 470 | 2.12 | $96,850 |
| 39 | Omaha-Council Bluffs, NE-IA | 420 | 1.11 | $50,380 |
| 40 | Orlando-Kissimmee-Sanford, FL | 410 | 0.43 | $87,760 |
| 41 | San Antonio-New Braunfels, TX | 380 | 0.48 | $87,530 |
| 42 | New Haven, CT | 330 | 1.53 | $141,770 |
| 43 | Vallejo-Fairfield, CA | 310 | 2.91 | $123,050 |
| 44 | Knoxville, TN | 300 | 1.00 | * |
| 45 | Modesto, CA | 280 | 1.96 | $99,210 |
| 46 | Wilmington, NC | 270 | 2.82 | $79,910 |
| 47 | Rochester, NY | 270 | 0.68 | $81,220 |
| 48 | Albuquerque, NM | 260 | 0.86 | $77,620 |
| 49 | Hartford-West Hartford-East Hartford, CT | 260 | 0.57 | $101,810 |
| 50 | Boulder, CO | 240 | 1.74 | $78,270 |

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

**Figure 2.14 - Top 50 MSAs for Total Microbiologists (2017)**

| Rank | Metropolitan Statistical Area | Total Microbiologists in 2017 | Location Quotient in 2017 | Annual Average Wage in 2017 |
|---|---|---|---|---|
| 1 | Washington-Arlington-Alexandria, DC-VA-MD-WV | 2,190 | 4.60 | $98,620 |
| 2 | San Francisco-Oakland-Hayward, CA | 1,150 | 3.15 | $100,930 |
| 3 | New York-Newark-Jersey City, NY-NJ-PA | 990 | 0.69 | $76,880 |
| 4 | Los Angeles-Long Beach-Anaheim, CA | 900 | 0.97 | $76,980 |
| 5 | Philadelphia-Camden-Wilmington, PA-NJ-DE-MD | 850 | 1.97 | $78,820 |
| 6 | Boston-Cambridge-Nashua, MA-NH | 720 | 1.73 | $86,250 |
| 7 | Atlanta-Sandy Springs-Roswell, GA | 680 | 1.69 | $87,470 |
| 8 | Chicago-Naperville-Elgin, IL-IN-WI | 680 | 0.97 | $58,860 |
| 9 | Houston-The Woodlands-Sugar Land, TX | 410 | 0.91 | $51,500 |
| 10 | Austin-Round Rock, TX | 390 | 2.54 | $47,790 |
| 11 | Minneapolis-St. Paul-Bloomington, MN-WI | 340 | 1.13 | $67,240 |
| 12 | Denver-Aurora-Lakewood, CO | 240 | 1.09 | $67,810 |
| 13 | Seattle-Tacoma-Bellevue, WA | 230 | 0.78 | $73,860 |
| 14 | Cincinnati, OH-KY-IN | 220 | 1.36 | $67,520 |
| 15 | Baltimore-Columbia-Towson, MD | 200 | 0.98 | $81,920 |
| 16 | St. Louis, MO-IL | 200 | 0.98 | $67,050 |
| 17 | Fort Collins, CO | 200 | 8.36 | $60,850 |
| 18 | Riverside-San Bernardino-Ontario, CA | 190 | 0.85 | $77,530 |
| 19 | San Juan-Carolina-Caguas, PR | 190 | 1.91 | $53,330 |
| **20** | **Madison, WI** | **170** | **2.84** | **$62,650** |
| 21 | Sacramento--Roseville--Arden-Arcade, CA | 150 | 0.99 | $79,720 |
| 22 | Durham-Chapel Hill, NC | 150 | 3.22 | $71,360 |
| 23 | Columbus, OH | 150 | 0.93 | $61,510 |
| 24 | Ames, IA | 130 | 18.68 | $94,000 |
| 25 | Worcester, MA-CT | 120 | 2.67 | $83,410 |
| 26 | Champaign-Urbana, IL | 120 | 8.07 | $51,290 |
| 27 | Dallas-Fort Worth-Arlington, TX | 110 | 0.20 | $80,590 |
| 28 | San Antonio-New Braunfels, TX | 110 | 0.74 | $70,020 |
| 29 | Vallejo-Fairfield, CA | 100 | 4.92 | $121,080 |
| 30 | Albany-Schenectady-Troy, NY | 100 | 1.42 | $83,840 |
| 31 | Salt Lake City, UT | 100 | 0.97 | $64,930 |
| 32 | Portland-Vancouver-Hillsboro, OR-WA | 100 | 0.59 | $62,970 |
| 33 | Lansing-East Lansing, MI | 100 | 3.02 | $57,630 |
| 34 | Nashville-Davidson--Murfreesboro--Franklin, TN | 100 | 0.68 | $52,980 |
| **35** | Athens-Clarke County, GA | 90 | 6.97 | $97,520 |
| 36 | Phoenix-Mesa-Scottsdale, AZ | 90 | 0.29 | $78,510 |
| 37 | Detroit-Warren-Dearborn, MI | 80 | 0.27 | $74,600 |
| 38 | Dover, DE | 80 | 8.11 | $67,760 |
| 39 | Springfield, MA-CT | 80 | 1.52 | $62,510 |
| 40 | Miami-Fort Lauderdale-West Palm Beach, FL | 80 | 0.21 | $57,120 |
| 41 | College Station-Bryan, TX | 80 | 4.51 | $57,020 |
| 42 | Omaha-Council Bluffs, NE-IA | 70 | 0.98 | $60,550 |
| 43 | Trenton, NJ | 60 | 1.60 | * |
| 44 | Memphis, TN-MS-AR | 60 | 0.65 | * |
| 45 | Kansas City, MO-KS | 60 | 0.36 | $81,590 |
| 46 | Richmond, VA | 60 | 0.64 | $72,610 |
| 47 | Urban Honolulu, HI | 60 | 0.79 | $66,310 |
| 48 | Ann Arbor, MI | 60 | 1.78 | $53,060 |
| 49 | Rochester, NY | 50 | 0.69 | $88,780 |
| 50 | Charlotte-Concord-Gastonia, NC-SC | 50 | 0.28 | $58,730 |

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

**Figure 2.15 - Top 50 MSAs for Total Biochemists and Biophysicists (2017)**

| Rank | Metropolitan Statistical Area | Total Biochemists and Biophyscists in 2017 | Location Quotient in 2017 | Annual Average Wage in 2017 |
|---|---|---|---|---|
| 1 | New York-Newark-Jersey City, NY-NJ-PA | 5,610 | 3.14 | $139,550 |
| 2 | Boston-Cambridge-Nashua, MA-NH | 3,820 | 7.29 | $112,110 |
| 3 | San Francisco-Oakland-Hayward, CA | 1,880 | 4.12 | $107,490 |
| 4 | Philadelphia-Camden-Wilmington, PA-NJ-DE-MD | 1,410 | 2.61 | $91,340 |
| 5 | San Diego-Carlsbad, CA | 1,020 | 3.72 | $102,120 |
| 6 | Washington-Arlington-Alexandria, DC-VA-MD-WV | 980 | 1.64 | $90,850 |
| 7 | Minneapolis-St. Paul-Bloomington, MN-WI | 930 | 2.51 | $79,900 |
| 8 | Chicago-Naperville-Elgin, IL-IN-WI | 820 | 0.93 | $107,290 |
| 9 | Los Angeles-Long Beach-Anaheim, CA | 690 | 0.59 | $100,130 |
| 10 | San Jose-Sunnyvale-Santa Clara, CA | 540 | 2.60 | $116,140 |
| 11 | Houston-The Woodlands-Sugar Land, TX | 530 | 0.94 | $85,730 |
| 12 | Baltimore-Columbia-Towson, MD | 380 | 1.46 | $78,890 |
| 13 | Nashville-Davidson--Murfreesboro--Franklin, TN | 300 | 1.66 | $66,250 |
| 14 | Boulder, CO | 270 | 8.01 | $85,460 |
| 15 | Austin-Round Rock, TX | 270 | 1.41 | $113,800 |
| 16 | Seattle-Tacoma-Bellevue, WA | 270 | 0.71 | $79,780 |
| 17 | Trenton, NJ | 240 | 5.43 | * |
| 18 | St. Louis, MO-IL | 210 | 0.79 | $82,980 |
| 19 | Indianapolis-Carmel-Anderson, IN | 180 | 0.90 | $114,950 |
| 20 | Kalamazoo-Portage, MI | 180 | 6.80 | * |
| 21 | Worcester, MA-CT | 170 | 3.08 | $113,880 |
| 22 | Memphis, TN-MS-AR | 170 | 1.44 | $92,550 |
| **23** | **Madison, WI** | **170** | **2.27** | **$76,540** |
| 24 | Denver-Aurora-Lakewood, CO | 160 | 0.57 | $87,450 |
| 25 | Salt Lake City, UT | 130 | 0.94 | * |
| 26 | Charlottesville, VA | 130 | 6.02 | $72,010 |
| 27 | Dayton, OH | 100 | 1.37 | $84,650 |
| 28 | Milwaukee-Waukesha-West Allis, WI | 100 | 0.64 | $83,070 |
| 29 | College Station-Bryan, TX | 90 | 3.97 | $55,660 |
| 30 | Fort Collins, CO | 80 | 2.58 | * |
| 31 | San Antonio-New Braunfels, TX | 80 | 0.41 | $100,580 |
| 32 | Cincinnati, OH-KY-IN | 70 | 0.35 | $75,280 |
| 33 | Atlantic City-Hammonton, NJ | 60 | 2.41 | $103,660 |
| 34 | Rochester, NY | 60 | 0.59 | $116,000 |
| **35** | Pittsburgh, PA | 60 | 0.28 | $99,940 |
| 36 | Riverside-San Bernardino-Ontario, CA | 50 | 0.20 | $128,960 |
| 37 | Lansing-East Lansing, MI | 50 | 1.32 | $47,470 |
| 38 | Kansas City, MO-KS | 50 | 0.24 | $116,340 |
| 39 | Allentown-Bethlehem-Easton, PA-NJ | 40 | 0.54 | $76,370 |
| 40 | Virginia Beach-Norfolk-Newport News, VA-NC | 40 | 0.26 | $48,830 |
| 41 | Portland-Vancouver-Hillsboro, OR-WA | 30 | 0.14 | $94,740 |
| 42 | Sacramento--Roseville--Arden-Arcade, CA | ** | ** | $69,610 |
| 43 | Atlanta-Sandy Springs-Roswell, GA | ** | ** | $87,630 |
| 44 | Durham-Chapel Hill, NC | ** | ** | $106,270 |
| 45 | Raleigh, NC | ** | ** | $82,400 |
| 46 | Albany-Schenectady-Troy, NY | ** | ** | $65,830 |
| 47 | Corvallis, OR | ** | ** | $89,560 |
| 48 | Richmond, VA | ** | ** | $93,030 |
| 49 | Miami-Fort Lauderdale-West Palm Beach, FL | ** | ** | $93,550 |

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

**Figure 2.16 - Top 50 MSAs for Total Biomedical Engineers (2017)**

| Rank | Metropolitan Statistical Area | Total Microbiologists in 2017 | Location Quotient in 2017 | Annual Average Wage in 2017 |
|---|---|---|---|---|
| 1 | Boston-Cambridge-Nashua, MA-NH | 2,410 | 6.28 | $94,320 |
| 2 | Minneapolis-St. Paul-Bloomington, MN-WI | 1,240 | 4.53 | $107,440 |
| 3 | Los Angeles-Long Beach-Anaheim, CA | 1,130 | 1.33 | $95,440 |
| 4 | San Diego-Carlsbad, CA | 820 | 4.06 | $100,660 |
| 5 | San Francisco-Oakland-Hayward, CA | 760 | 2.27 | $98,950 |
| 6 | San Jose-Sunnyvale-Santa Clara, CA | 540 | 3.52 | $138,440 |
| 7 | Washington-Arlington-Alexandria, DC-VA-MD-WV | 540 | 1.23 | $96,290 |
| 8 | Salt Lake City, UT | 470 | 4.80 | $80,680 |
| 9 | Philadelphia-Camden-Wilmington, PA-NJ-DE-MD | 430 | 1.08 | $90,040 |
| 10 | Cleveland-Elyria, OH | 380 | 2.59 | $75,970 |
| 11 | New York-Newark-Jersey City, NY-NJ-PA | 360 | 0.27 | $107,220 |
| 12 | Durham-Chapel Hill, NC | 300 | 7.15 | $75,720 |
| 13 | Houston-The Woodlands-Sugar Land, TX | 300 | 0.73 | $84,780 |
| 14 | Portland-Vancouver-Hillsboro, OR-WA | 290 | 1.78 | $92,660 |
| 15 | Dallas-Fort Worth-Arlington, TX | 290 | 0.58 | $111,280 |
| 16 | Seattle-Tacoma-Bellevue, WA | 260 | 0.94 | $96,100 |
| 17 | Denver-Aurora-Lakewood, CO | 250 | 1.21 | $89,990 |
| 18 | Austin-Round Rock, TX | 250 | 1.77 | $83,880 |
| 19 | Atlanta-Sandy Springs-Roswell, GA | 220 | 0.61 | $83,180 |
| 20 | Baltimore-Columbia-Towson, MD | 220 | 1.13 | $95,500 |
| 21 | Rochester, NY | 220 | 3.01 | $109,400 |
| 22 | Oxnard-Thousand Oaks-Ventura, CA | 210 | 4.88 | $98,810 |
| 23 | Miami-Fort Lauderdale-West Palm Beach, FL | 190 | 0.51 | $74,170 |
| 24 | Sacramento--Roseville--Arden-Arcade, CA | 160 | 1.21 | $78,960 |
| 25 | Riverside-San Bernardino-Ontario, CA | 130 | 0.64 | $91,410 |
| 26 | Gainesville, FL | 130 | 7.05 | $66,280 |
| 27 | Vallejo-Fairfield, CA | 120 | 6.19 | $101,900 |
| 28 | Tampa-St. Petersburg-Clearwater, FL | 120 | 0.69 | $68,720 |
| 29 | Kansas City, MO-KS | 120 | 0.78 | $78,780 |
| 30 | New Haven, CT | 110 | 2.94 | $102,450 |
| 31 | Cincinnati, OH-KY-IN | 110 | 0.76 | $74,130 |
| 32 | Boulder, CO | 100 | 3.91 | $111,650 |
| 33 | Milwaukee-Waukesha-West Allis, WI | 100 | 0.81 | $76,020 |
| 34 | Santa Rosa, CA | 90 | 3.24 | $115,100 |
| 35 | Allentown-Bethlehem-Easton, PA-NJ | 90 | 1.76 | $90,280 |
| 36 | Winston-Salem, NC | 70 | 1.91 | $82,320 |
| 37 | Knoxville, TN | 70 | 1.30 | $91,810 |
| 38 | Tucson, AZ | 60 | 1.21 | $124,260 |
| 39 | Augusta-Richmond County, GA-SC | 60 | 1.81 | $53,930 |
| 40 | St. Louis, MO-IL | 60 | 0.31 | $78,600 |
| 41 | Portland-South Portland, ME | 50 | 1.77 | $79,420 |
| 42 | Dayton, OH | 50 | 0.86 | $85,890 |
| 43 | San Antonio-New Braunfels, TX | 50 | 0.39 | $101,570 |
| 44 | Hartford-West Hartford-East Hartford, CT | 40 | 0.43 | $92,280 |
| 45 | Worcester, MA-CT | 40 | 0.98 | $94,450 |
| 46 | Providence-Warwick, RI-MA | 40 | 0.46 | $95,560 |
| 47 | Ogden-Clearfield, UT | 40 | 1.24 | 75,350 |
| 48 | Charlottesville, VA | 40 | 2.42 | 85,280 |
| 49 | Albany-Schenectady-Troy, NY | 30 | 0.54 | * |

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

Relative rankings for the Madison MSA are summarized in Figure 2.17. When comparing these rankings, consider that the Madison MSA ranks 86th among all metro areas in terms of total population. Again, not every measure is available for every metro area. That is, some figures are occasionally suppressed for metro areas that have important bioscience industry concentrations. Accordingly, these figures should not be viewed as absolute rankings, but rather more general comparisons.

Clearly the Madison Region's highest rankings in employment and location quotients are found in medical scientists, microbiologists, and biochemists and biophysicists. Average wages rank highly as well for microbiologists and biochemists and biophysicists. However, wages among chemists, electrical engineers and medical scientists are disproportionately low. As previously noted, relatively lower wages among bioscience occupations in the Madison MSA are also found among many other occupations when compared to the national average.

Some of these differences may be due to cost of living differences, but many lower cost of living metro areas pay higher average wages than those found in the Madison MSA. Some of these differences also could be attributed to the presence of UW-Madison producing a large amount of local talent which allows firms to recruit locally rather than having to offer greater wages to attract talent from elsewhere. Regardless, these differences should be further considered when assessing the competitiveness of the Madison Region relative to other metro areas with high concentrations of bioscience industries.

**Figure 2.17 – Madison MSA Relative Rankings for Selected Bioscience Industry Occupations (2017)**

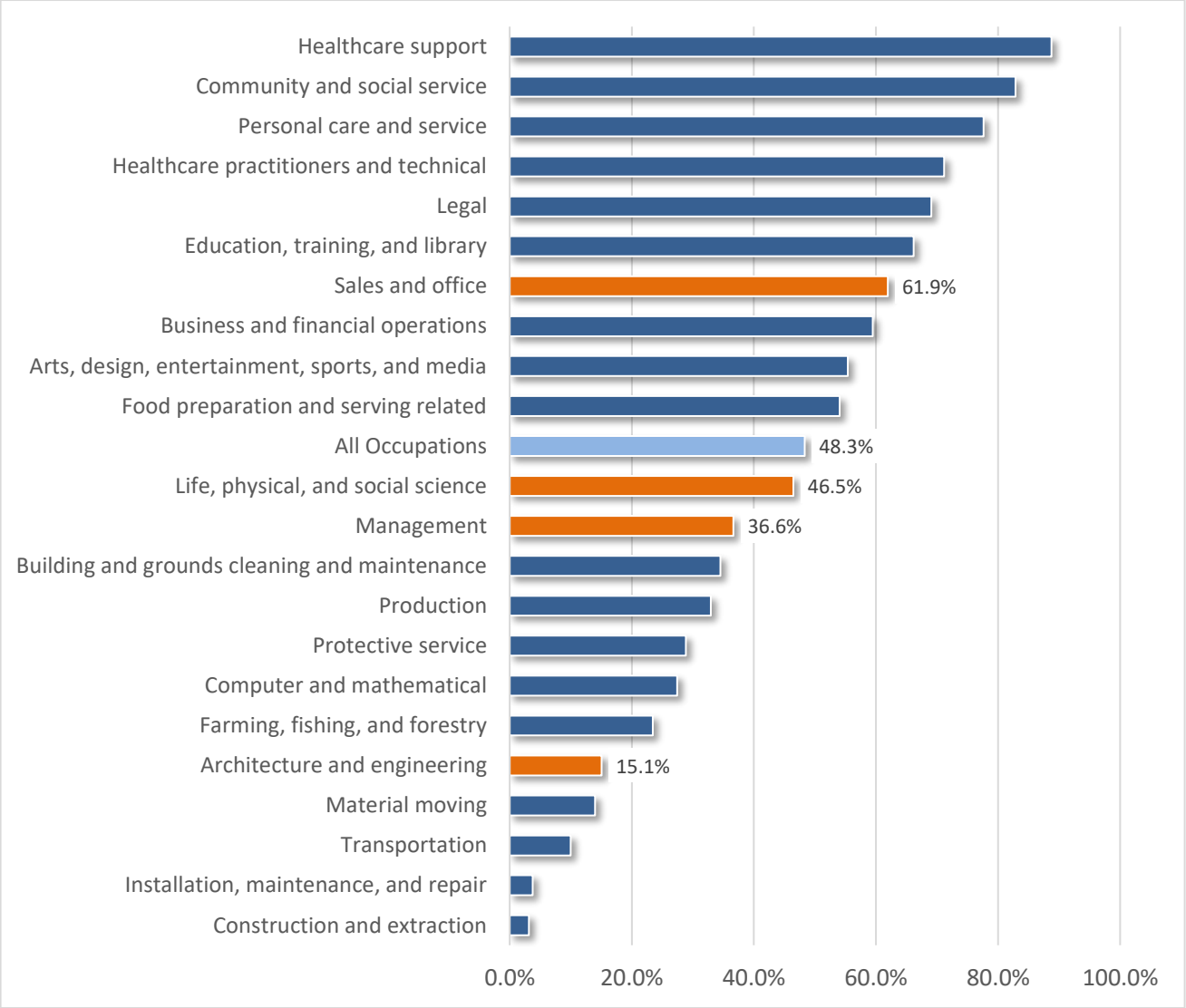
| Bioscience Occupation | Total Employment Relative Ranking | Location Quotient Relative Ranking | Annual Average Wage Relative Ranking |
|---|---|---|---|
| Chemists | N/A | N/A | 139 |
| Electrical Engineers | 73 | 118 | 111 |
| Medical Scientists | 35 | 21 | 98 |
| Microbiologists | 20 | 12 | 48 |
| Biochemists and Biophysicists | 23 | 16 | 36 |
| Biomedical Engineers | N/A | N/A | N/A |

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

## Talent Diversity

In 2015, women filled 47% of all U.S. jobs, but held only 24% of science, technology, engineering and mathematics (STEM) occupations. Similarly, women constitute slightly more than half of college-educated workers, but only account for 25% of college-educated STEM workers (U.S. Department of Commerce, 2017). Given these disparities, it should not be surprising that the bioscience industry cluster also struggles with women as a share of total employment among several occupational categories occupations. In the Madison MSA, women account for 48.3% of all occupations. In contrast, women comprise just 15.1% of engineering and architecture occupations and 36.6% of management occupations (Figure 2.18).

**Figure 2.18– Women as a Share of Total Employment by Occupation - Madison MSA in 2016**



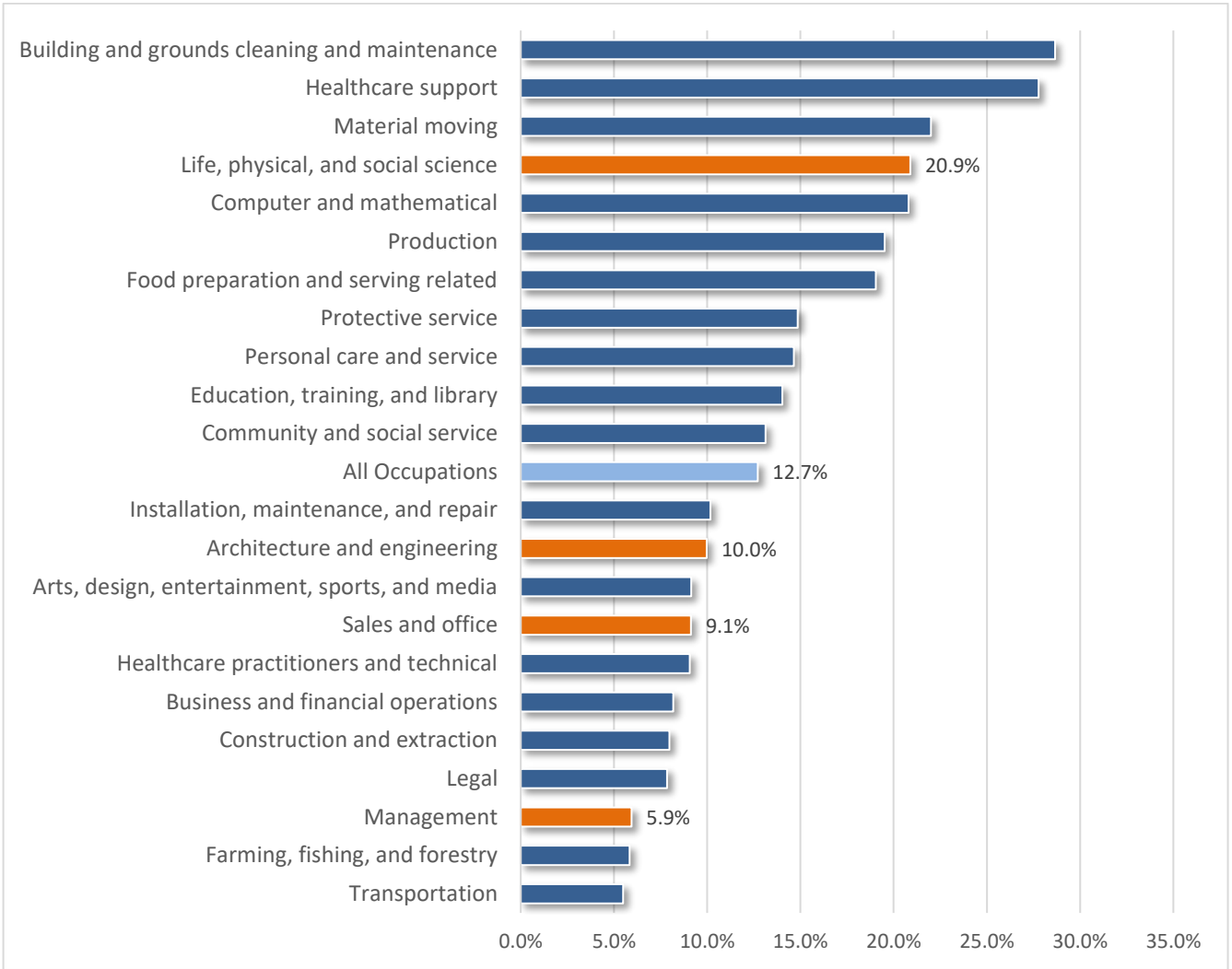

Source: U.S. Census Bureau American Community Survey and Authors' Calculations

Similar to women, underrepresented minorities (URMs) show comparable gaps in STEM occupations. 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. As a share of all occupations, underrepresented minorities comprise 12.7% of all employment in the Madison MSA. However, underrepresented minorities account for 10.0% of engineering and architectural occupations and 5.9% of management occupations (Figure 2.19).

In contrast, URMs have a disproportionately large share of employment in life, physical and social science occupations. However, this relatively high share of employment found among URMs in does not necessarily mean that the Madison MSA is diverse. In comparison to many other metropolitan areas with large concentrations of bioscience industries, 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 bioscience-related occupations found among underrepresented minorities. Accordingly, efforts to increase diversity in the Region's bioscience industry should continue to grow.

**Figure 2.19 – Underrepresented Minorities as a Share Total Employment by Occupation (Madison MSA 2016)**




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

## Conclusions and Summary

- The Madison Region's bioscience industry cluster involves a breadth and depth of occupations that require many different skills. Occupations that span multiple bioscience industry categories could provide opportunities for joint talent development initiatives such as recruitment, DACUM efforts, and internships. Specifically, occupations that are common across multiple bioscience categories include management, customer service, industrial engineers, and office support, chemists and chemical technicians, mechanical engineers, and several production related occupations that are found in the manufacturing categories of the bioscience cluster (i.e. pharmaceutical manufacturing, electromedical devices, medical supplies, etc.)

- Bioscience industries also have important concentrations of life science occupations that are foundations of the cluster. These include medical scientists, microbiologists, biological technicians, biochemists and biophysicists, and biomedical engineers. While these occupations are not found in large numbers like several other occupational categories, they drive the research and technical knowledge that are fundamental to the bioscience cluster.

- Sales and customer service occupations are common across the bioscience industry cluster. Due to the highly technical nature of many products produced by firms in the bioscience industry, particularly in pharmaceuticals and medical devices, salespeople often require extensive levels of training and product knowledge. They may often have an educational background in engineering or life science disciplines.

- While management occupations are common in most industry sectors, bioscience and otherwise, the importance of management occupations in the bioscience cluster is often overlooked. Skilled managers and executives with expertise in a specific bioscience discipline are often prerequisites for success. These individuals can help manage the unique regulatory aspects of the industry. They can efficiently operate diverse supply chains. They are also vital to raising capital that is often needed by small and mid-sized bioscience firms to achieve scale. Consequently, the recruitment and retention of these individuals in the Madison Region are important activities of the bioscience industry cluster.

- The four categories of Navigational, Measuring, Electromedical, and Control Instruments Manufacturing; Research and Development in the Physical, Engineering, and Life Sciences; Testing Laboratories; and Medical and Diagnostic Laboratories all have 70% or more of their employment in Job Zone 3 or higher. As these industries tend to have the highest education and training requirements, it should not be surprising that these bioscience subsectors often have the highest average wages as well.

- While the bioscience industry cluster is highly dependent on occupations that require greater levels of skill and education, a number of categories also provide opportunities for individuals working in occupations in Job Zone 2. Pharmaceutical and Medicine Manufacturing; Medical Equipment and Supplies Manufacturing; and Chemical Manufacturing all have 40% to 55% of their employment concentrated in occupations found in Job Zone 2. The concentrations of workers in Job Zone 2 should not necessarily suggest that these occupational categories of the bioscience industry are reliant on unskilled workers. Instead, 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 bioscience cluster also provides a diversity of employment opportunities for people across the skill and education continuums.

- Overall, the broad mobility characteristics of people working in different occupations have two important characteristics: First, talent attraction efforts may help to fill management, professional or technical occupations, but it is less likely that production workers needed in the bioscience cluster 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.

- Many of the top MSAs for bioscience-related occupations are found in some of the nation's largest metropolitan areas. Many of these metro areas have well established concentrations in bioscience industries such as Boston, San Francisco, Philadelphia, Seattle, San Diego, Washington DC, Austin, and San Jose. However, the presence and importance of R1 research universities in mid-sized metropolitan areas (and all metro areas in this analysis) cannot be understated. Accordingly, the importance of UW-Madison to the development of this sector should not be underestimated.

- The Madison Region has high employment and location quotient rankings for medical scientists, microbiologists, and biochemists and biophysicists. Average wages also rank highly for microbiologists and biochemists and biophysicists. However, wages among chemists, electrical engineers and medical scientists are disproportionately low. Relatively lower wages among bioscience occupations in the Madison MSA are also found among many other occupations when compared to the national average. Some of these differences may be due to cost of living differences, but many lower cost of living metro areas pay higher average wages than those found in the Madison MSA. These differences also could be attributed to the presence of UW-Madison producing a large amount of local talent which allows firms to recruit locally rather than having to offer greater wages to attract talent from elsewhere. Regardless, these differences should be further considered when assessing the competitiveness of the Madison Region relative to other metro areas with high concentrations of bioscience industries.

- In 2015, women filled 47% of all U.S. jobs, but held only 24% of science, technology, engineering and mathematics (STEM) occupations. Similarly, underrepresented minorities (URMs) show comparable gaps in several STEM occupations. Given these disparities, it should not be surprising that the bioscience industry cluster also struggles with women and URMs as a share of total employment among several occupational categories. Resources for growing the share of women and underrepresented minorities in the Region's bioscience industry cluster are further explored in Section 3 of this analysis.

## 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 – Mechanical and Industrial 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  Madison MSA in footnote

**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

# Section 3 – Bioscience 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 bioscience support and development ecosystem. Accordingly, the following analysis builds upon the prior analyses of bioscience talent, industries and niches by considering:

- Broadband availability and distribution;
- Regional assets that influence talent attraction and retention;
- Research Parks, certified and gold shovel sites, and specialized commercial spaces;
- Educational institutions;
- Support organizations that foster innovation and connect firms and resources. These organizations may provide technical assistance, mentoring, access to capital or other forms of assistance.

## Broadband Infrastructure

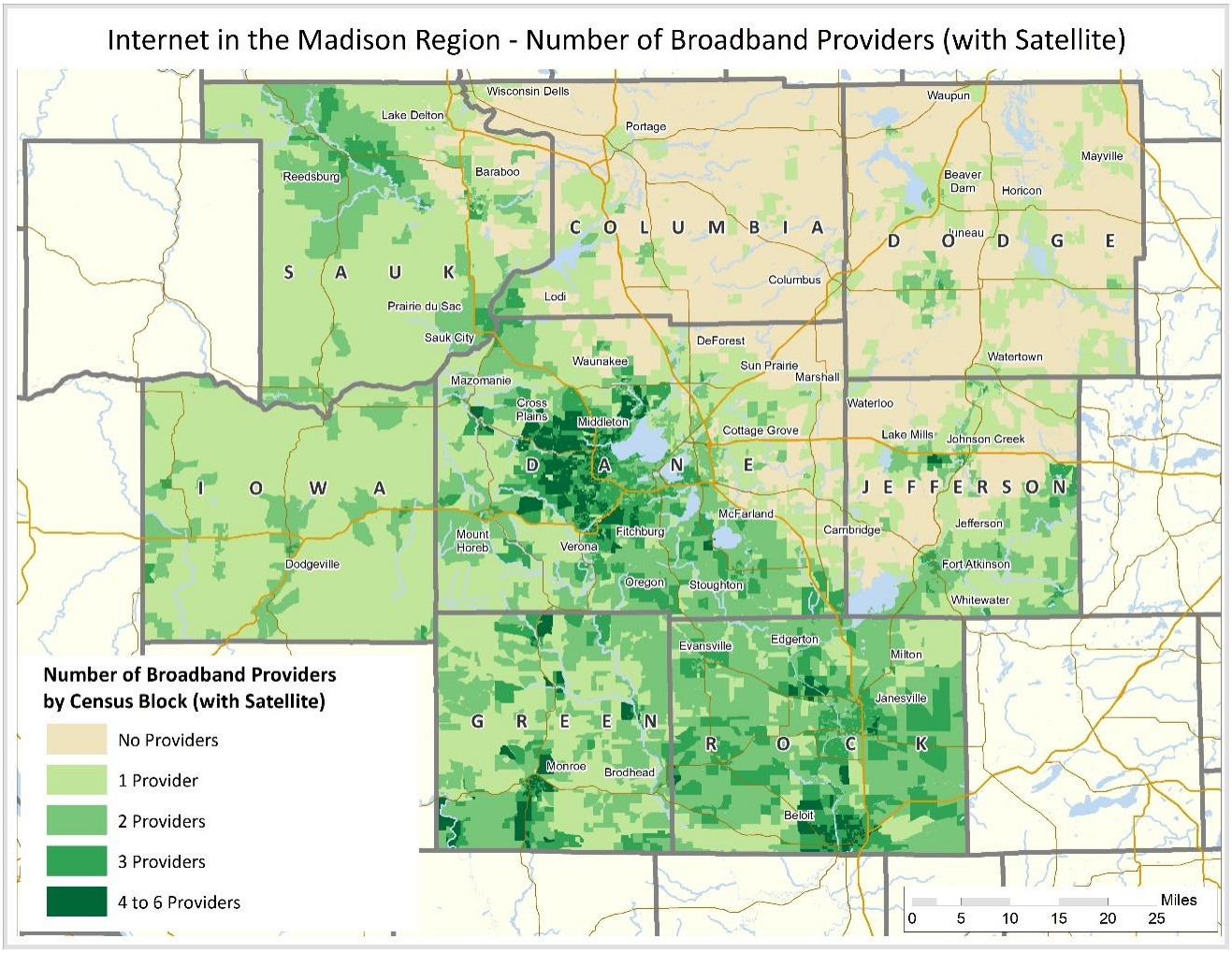
While all industries increasingly rely on broadband availability, inexpensive and reliable high-speed Internet access is becoming very important to the bioscience industry cluster. Companies will increasingly require connectivity to drive their Internet of Things (IoT) technologies, monitor research, maintain databases, share discoveries, monitor patient interactions, and implement 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.[6]

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. 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.

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

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)**

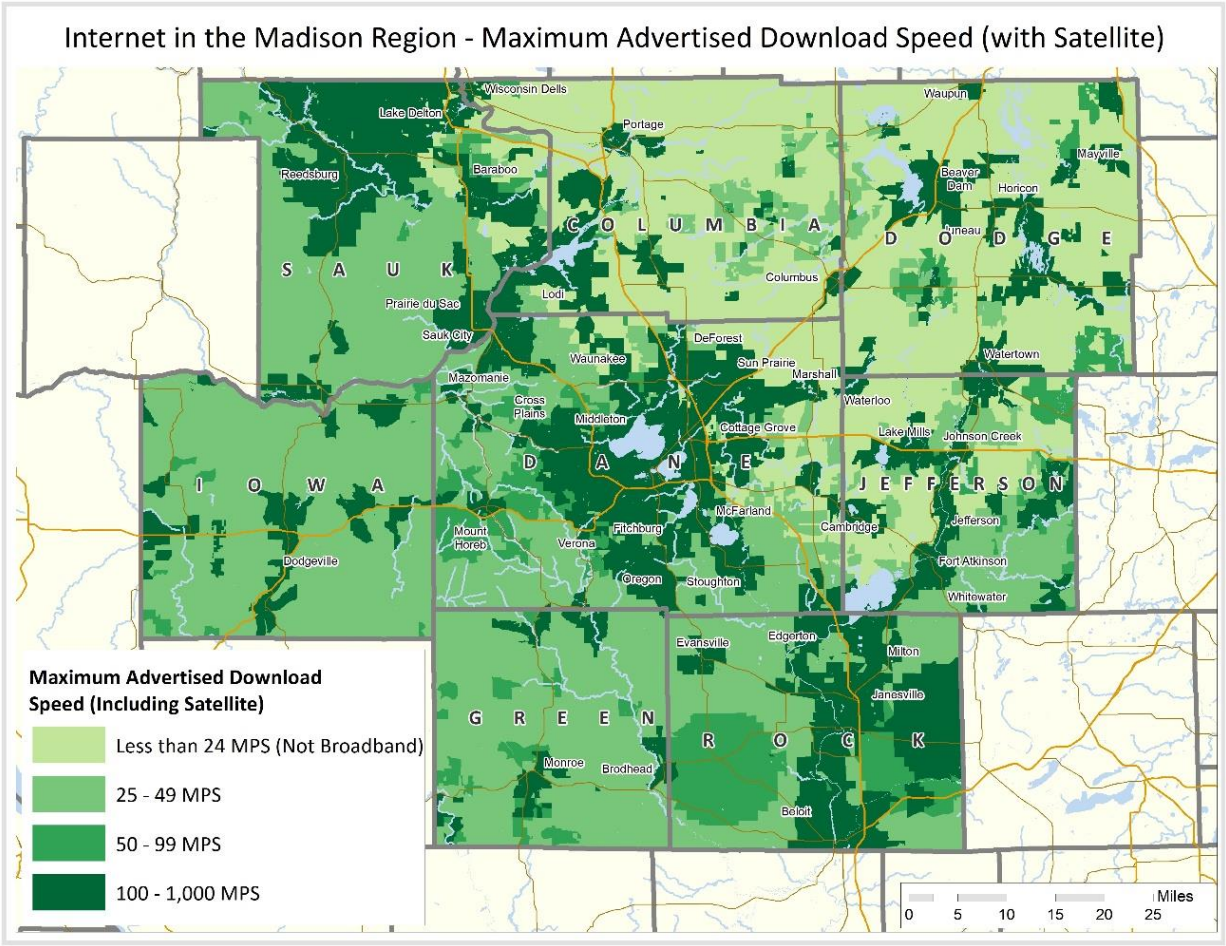



Source: Fixed Broadband Deployment Data - Federal Communications Commission Form 477 and Author's Calculations

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).*

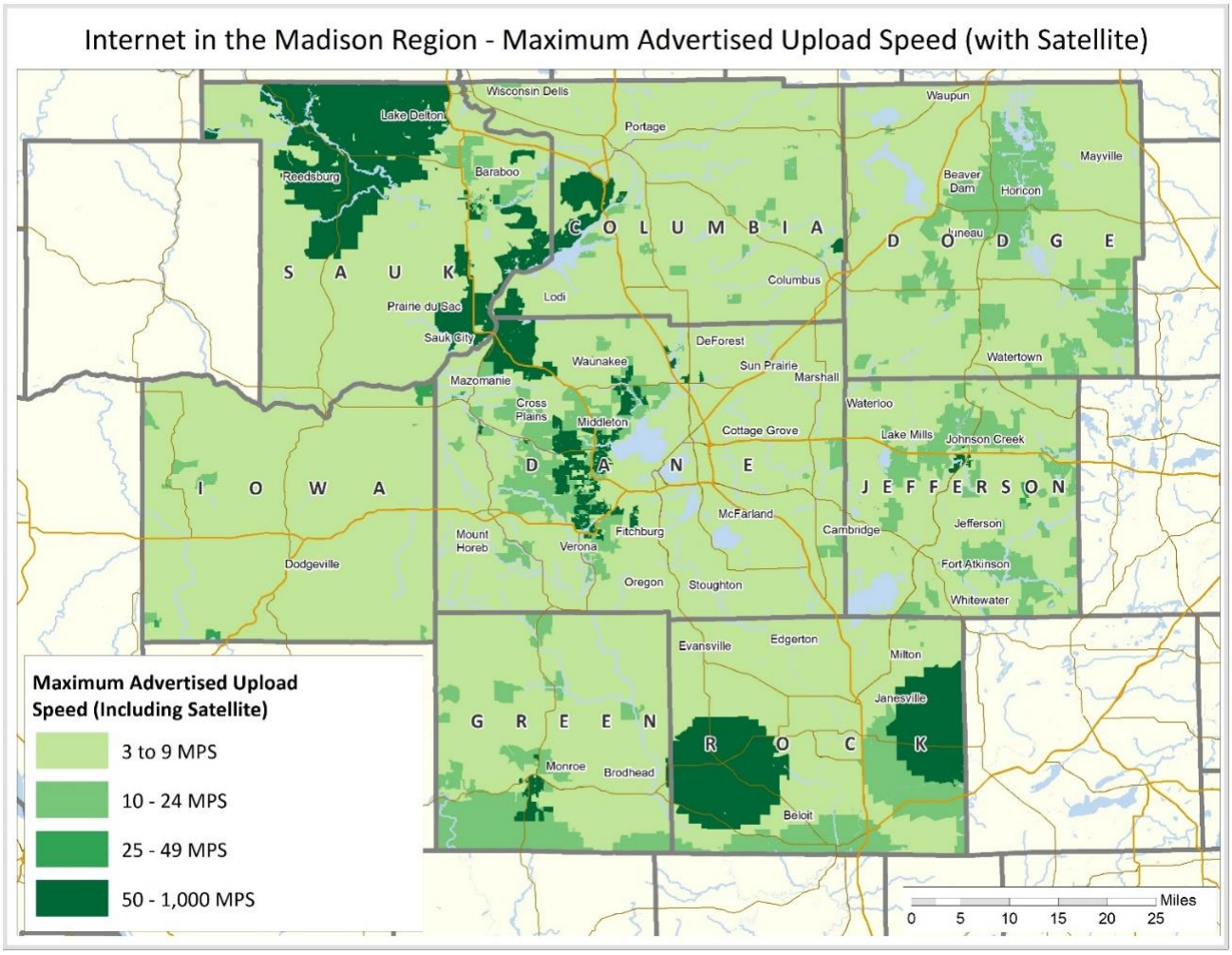
Download speeds also vary considerably across the Madison Region. Most of Madison and its surrounding communities have access to speeds of at least 100 Mbps, with some communities (such as Sun Prairie) having access to 1 gigabits per second (Gbps or 1,000 Mbps) download speeds (Figure 3.2). Most communities 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 hospitals, clinics and ambulatory care facilities that work with the Region's bioscience businesses and provide access to patients 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 bioscience businesses to increase operating efficiencies through deployment of their connected factory and research related 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, advanced manufacturing, telehealth and other forms of precision medicine, and research simulation technologies;

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.

**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). Bioscience businesses that are currently investing in IoT technologies, including Promega, Accuray, Fuji, Covance, Illumina, Thermo Fisher Scientific, GE Healthcare, Exact Sciences, and Lucigen, 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 bioscience businesses.

## Mobility Trends Influencing the Attraction and Retention of Bioscience Talent

As noted throughout this analysis, the quantity and quality of bioscience talent is a primary factor in driving the success and growth of the overall cluster. Furthermore, there is evidence that jobs, particularly those in the knowledge economy, increasingly flow to areas with high levels of talent rather than people moving to areas with a large number of jobs. That is, knowledge economy jobs follow talent rather than talent following jobs (see Hicks and Faulk, 2016 for one summary of this research). These trends suggest that economic development strategies should incorporate talent attraction, expansion and retention rather than simply trying to attract, expand and retain companies. Accordingly, talent attraction and retention strategies should be an emphasis of bioscience cluster development in the Madison Region.

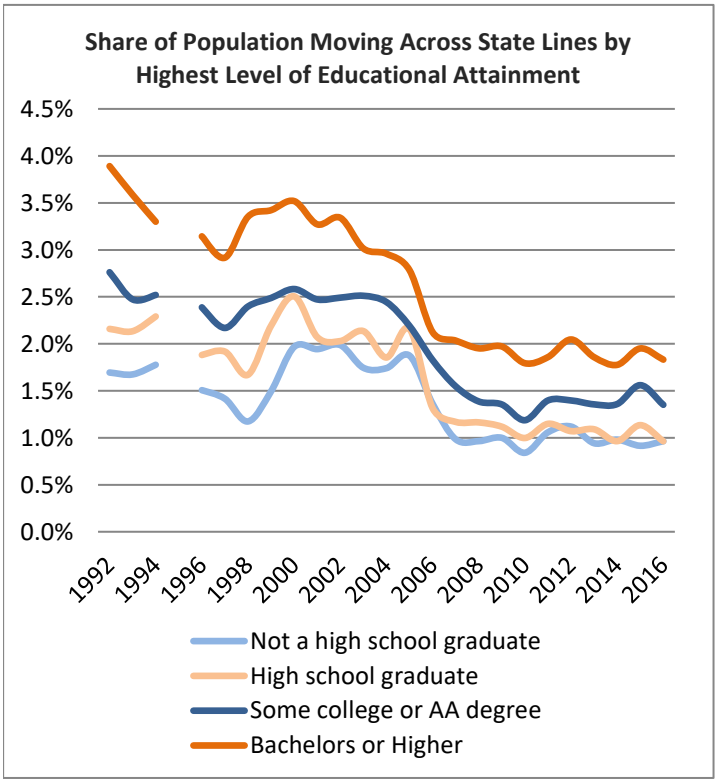
What factors drive the movement and locational decisions of bioscience talent? While a large body of research specific to the locational factors of talent working in bioscience industries does not yet exist, other research on the movement of college graduates and individuals by age group provides some insights. The movement of college graduates is an important consideration as Section 2 noted that the several industries in the bioscience cluster tends to rely heavily on occupations that often require a college degree. Subsequently, those factors that influence the location and concentration of highly educated individuals also could inform talent attraction and retention strategies related to the bioscience cluster. Furthermore, several industries in the bioscience cluster have a higher concentration of young workers. Accordingly, the locational decisions made by younger workers may also inform attraction and retention strategies.

For purposes of this analysis, talent attraction is considered from an interstate rather than an intrastate perspective. While the Madison Region will continue to attract individuals from other parts of Wisconsin, the Madison Region is focused more so on bringing new talent into the area from other states rather than trying to actively poach talent from within the state.

### Interstate Mobility Rates by Educational Attainment and Age

The ability of the Madison Region to attract talent is influenced by trends in the interstate mobility of workers. This mobility is influenced by many factors. For instance, mobility across state lines varies by levels of educational attainment. Nationally, individuals with a Bachelor's degree or higher tend to be the most mobile with almost two percent of this demographic group moving across state lines in recent years (Figure 3.4). In contrast, only one percent of individuals with a high school degree or less move across state lines.

**Figure 3.4 – Interstate Mobility by Educational Attainment**

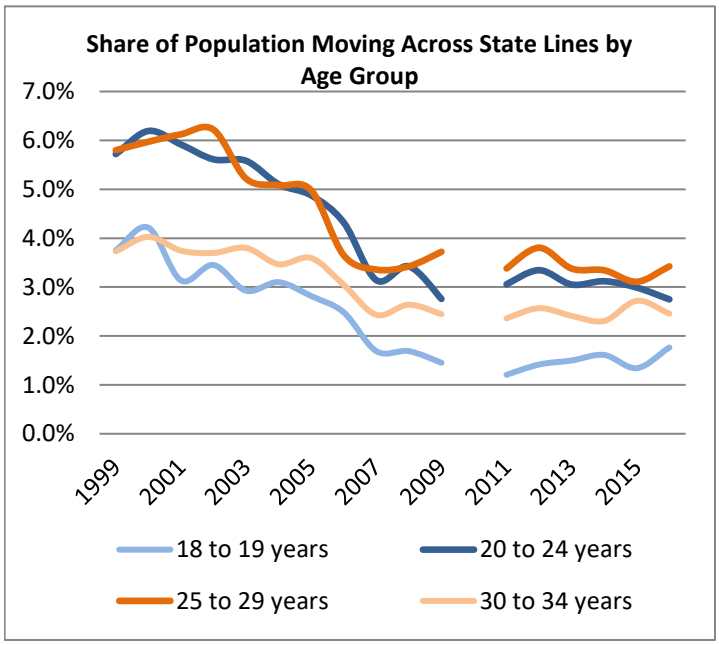



Source: Current Population Survey and Authors' Calculations

Accordingly, college graduates, who comprise a large share of potential bioscience talent, are more likely to make this type of move than individuals with lower levels of educational attainment. These rates should not be surprising as Section 2 noted that many bioscience-related occupations in the Madison Region have the highest share of individuals who were born in another state among all occupational categories.

Mobility rates also vary by age group with individuals between the ages of 20 and 34 being the most mobile in terms of moves across state lines (Figure 3.5). While other age groups not depicted on Figure 3.5 do also move from state to state, mobility rates decline dramatically for individuals over the age of 40 who are in the labor force. However, mobility does increase somewhat again as individuals approach retirement.

**Figure 3.5 – Interstate Mobility by Selected Age Group**




Source: Current Population Survey and Author's Calculations

An important trend depicted in Figure 3.4 and Figure 3.5 is the downward share of people moving across state lines. While the young and college educated still remain one the most mobile demographic segments, their interstate mobility rates have declined notably since the late 1990s. Similar trends are also apparent among other demographic categories as overall interstate mobility has been on the decline over the last several decades. Indeed, recent mobility rates are among the lowest recorded. Some of these declines are attributed to economic cycles (such as the Great Recession), but the trend is also secular in nature (Benetsky and Fields, 2015). *Accordingly, regions that are trying to attract talent from other states are faced with a population that is increasingly rooted in place*. These trends also suggest that producing talent locally and retaining existing talent are important strategies for the bioscience cluster.

**Migration Characteristics from a Life Stage Perspective**

As young, educated workers are increasingly pursued by regions and states through a variety of direct and indirect incentives, it is worth noting that the factors influencing the migration of these individuals change from a life stage perspective. While an in-depth analysis of these factors is beyond the scope of this report, it is broadly important to recognize that the factors influencing the movement of college graduates vary by recent graduates, young households without children, and somewhat older households with children (Whisler, Waldorf, Mulligan and Plane, 2008). For instance, the availability of recreational opportunities are important to all three categories, while cultural environments are more important to recent graduates and young households without children (Figure 3.6). Job markets are also important to all three broad life stages considered here. The importance of diversity and tolerance has also been cited as a factor in attracting and retaining creative, educated talent (Florida, 2002). However, diversity was not explicitly identified as a factor in a study of recent college graduates who were raised in rural areas (Fiore et al., 2015). Accordingly, preferences may vary according to the locales where talent originates.

These types of differences among college educated individuals are important as a talent attraction strategy cannot be solely based on an all-encompassing message for the Madison Region. Furthermore, recognizing how these factors change could also help in talent retention as individuals move from one life stage to the next. Indeed, the Region should highlight the strength of its job market in bioscience industries. The Region should also highlight its diverse quality of life assets that are desired by each life stage. While basing economic development strategies on rankings often leads to poor policy, talent attraction and retention in the bioscience sector is an exception to this statement. That is, the Madison Region should highlight all of its accolades and rankings to showcase its desirability to individuals and households across these different life stages. Finally, individual communities in the Region should be prepared to tailor their messages to their target audiences, be they recent graduates, households without children or households with children.

**Figure 3.6 – Selected Factors Influencing Migration among College Graduates**

| Recent Graduates | Young households without children | Middle aged households with children |
|---|---|---|
| • Recreational opportunities | • Recreational opportunities | • Crime rates |
| • Cultural Environment | • Cultural Environment | • Recreational Opportunities |
| • Cost of Living | • Climate | • Job Market |
| • Job Market | • Crime Rates | • Climate |
| | • Job Market | |

Source: Whisler, Waldorf, Mulligan and Plane, 2008

**Housing Market**

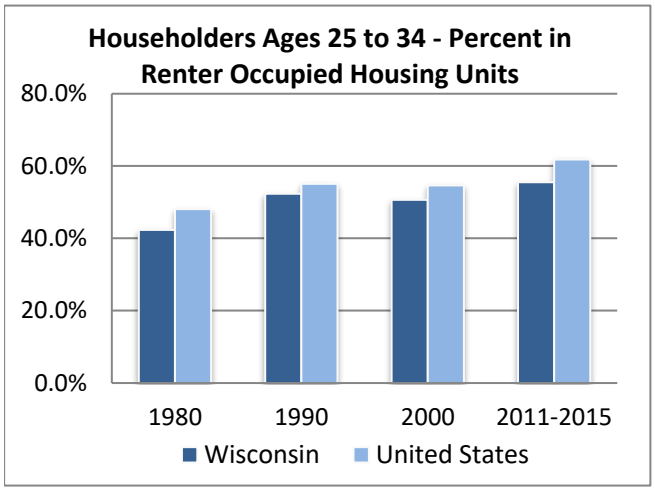
The Region's housing market should also be considered as a factor in talent attraction and retention, not only for the bioscience sector, but all industries in the Region. Conversations with the Region's economic development professionals, employers and workforce development organizations suggest that housing cost and availability, particularly for first-time buyers, is emerging as a challenge for many communities. These changes may be particularly relevant to talent attraction as cost of living is particularly important to new college graduates and cost of living is greatly influenced by housing costs (Figure 3.6). While a full housing market study is beyond the scope of this analysis, it worth examining several measures of the regional housing market.

Housing costs are a potential advantage of the Madison metro area compared to the many of the large metro areas with large bioscience industry and talent concentrations (see Section 1 and Section 2). When comparing housing costs, it is important to recognize that these costs can vary considerably within a metro area. Furthermore, we do not necessarily compare similar homes across metro areas in terms of size, number of bedrooms, year of construction, and other characteristics that may influence housing costs. However, comparisons of gross median monthly rent and median monthly owner costs for owners with a mortgage do provide some perspectives on housing cost variations (and cost of living differences).

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 3.7). 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.

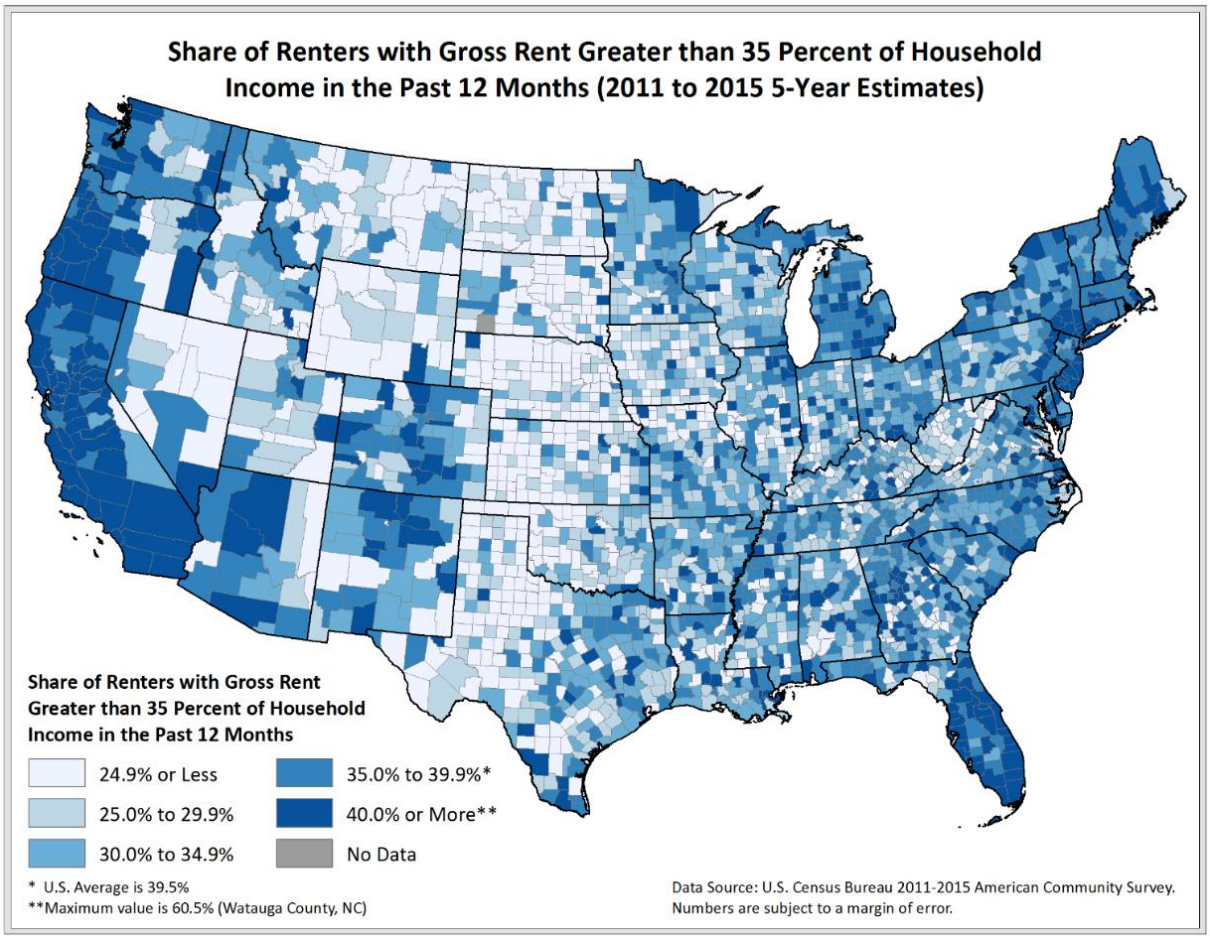
**Figure 3.7 – Trends in Renter Occupied Housing**




Source: U.S. Census Bureau and Authors' 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. 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 3.8).

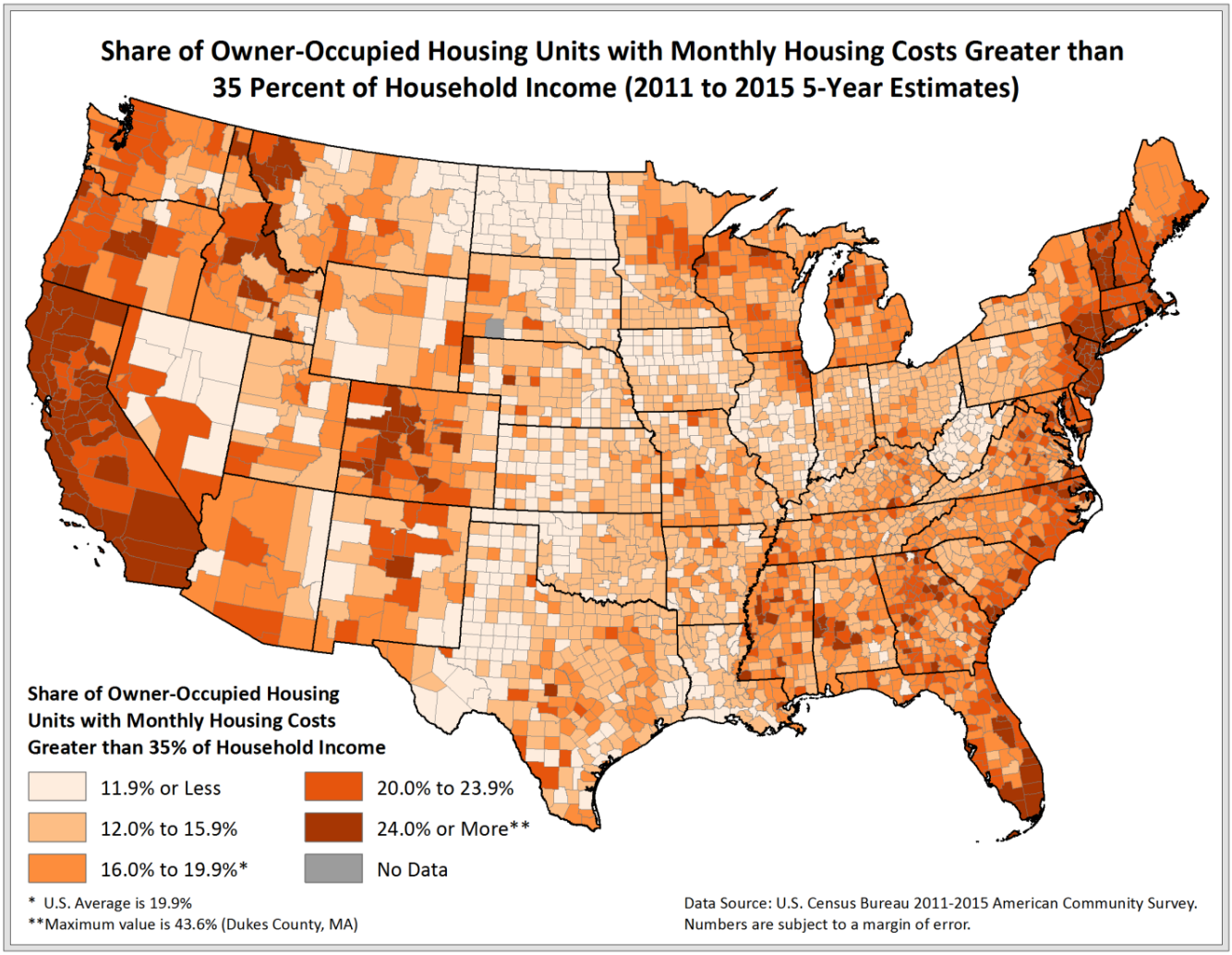
**Figure 3.8 – Renter Occupied Housing Units with Monthly Housing Costs Greater than 35% of Income**



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.

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 3.9). 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. Again, many of these areas have large concentrations of bioscience industries and talent.

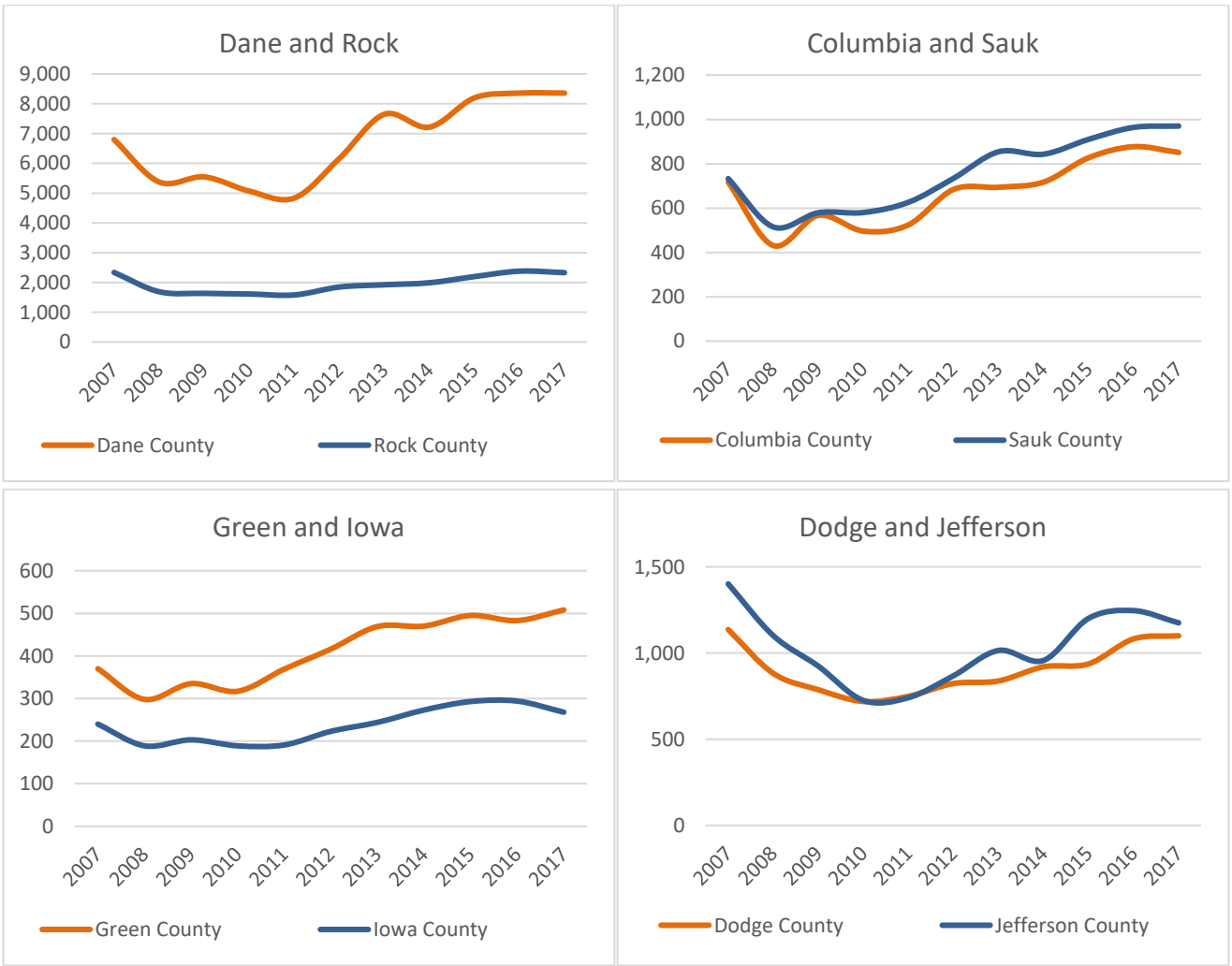
**Figure 3.9 – Owner Occupied Housing Units with Monthly Housing Costs Greater than 35% of Income**



While the Madison MSA fares well in terms of median housing costs, the Madison metro area also has lower annual average salaries for many bioscience-related occupations when compared to many competing metro areas (See Section 2). As a result, the housing cost advantages may not be as large as they appear. Consequently, the Region should consider whether its advantage in housing costs may be eroding, at least in terms of bioscience talent.

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 3.10). The recent growth in home sales is partially driven by Millennials who are increasingly entering the housing market.

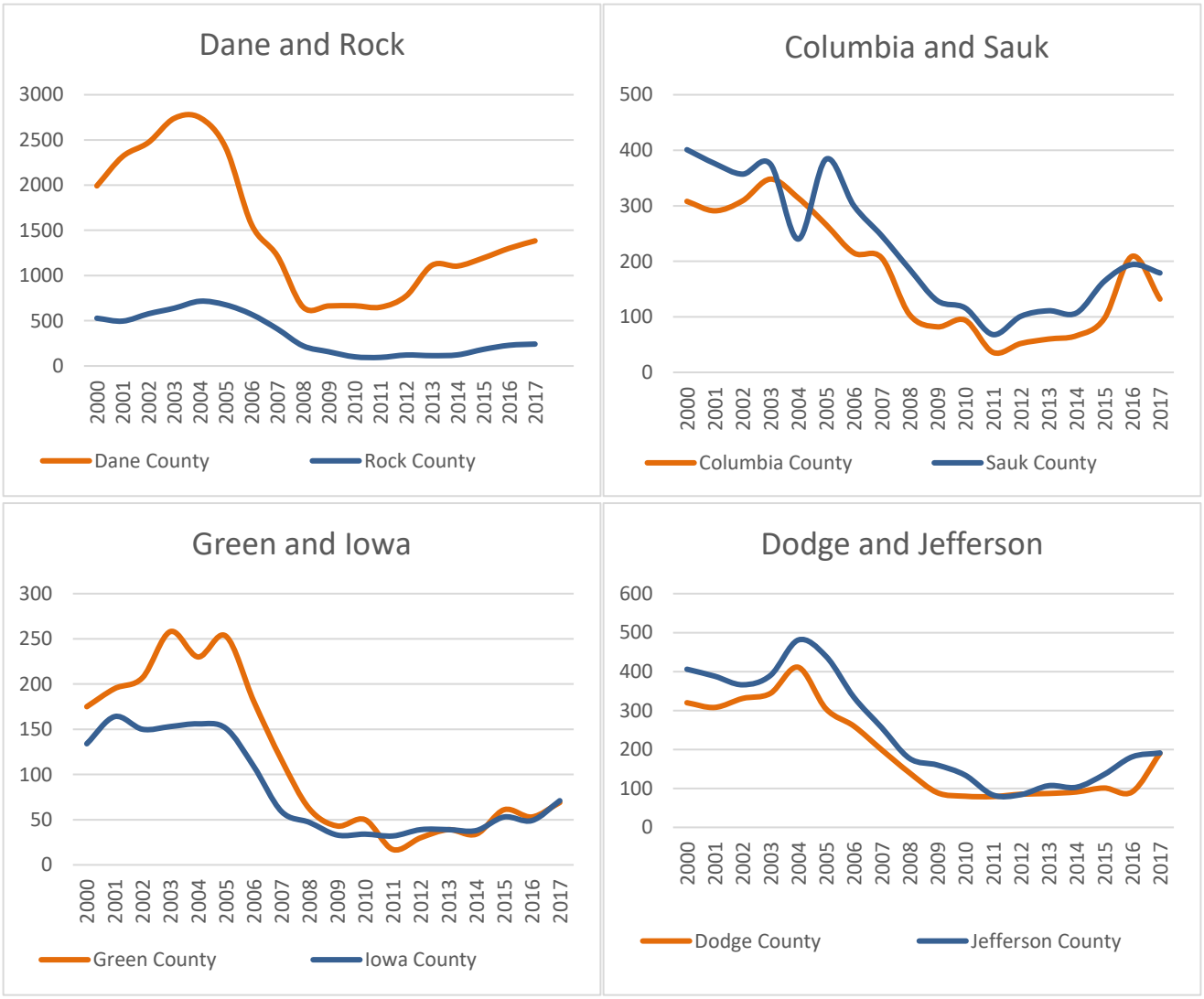
**Figure 3.10 – Annual Home Sales by County in the Madison Region**




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 3.11). 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 3.11 – Single Family Home Permits by County in the Madison Region**




Source: U.S. Census Bureau Business Permits Survey

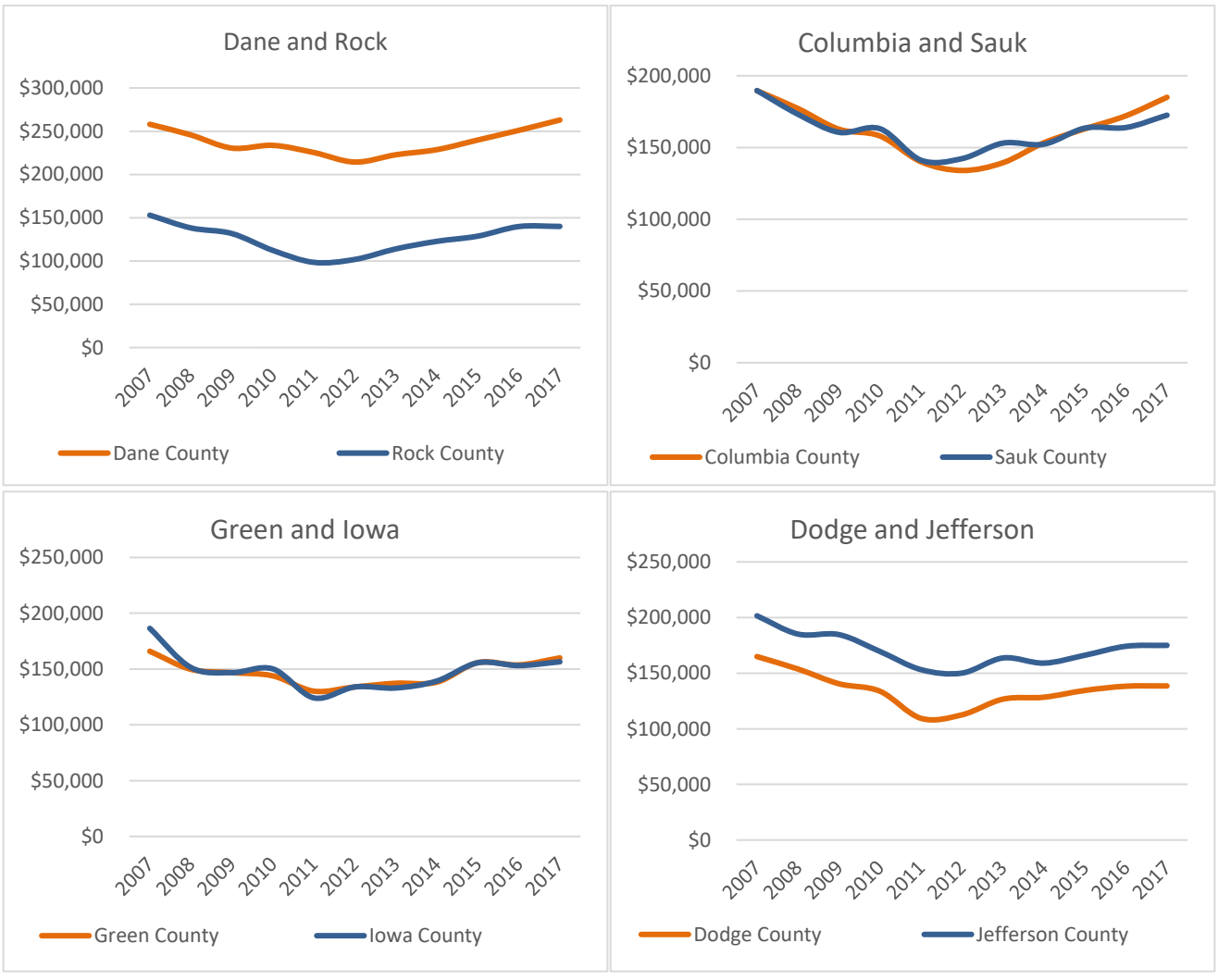
While not included in this analysis, it is important to note that Dane County has continued to add a significant number of multi-family units, averaging almost 2,500 units per year over the past five years. In 2016 and 2017, Dane County added approximately 3,000 units each year, which were the highest 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 home prices in the Region 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 3.12). 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 3.12 – Median Sales Price by County in the Madison Region**



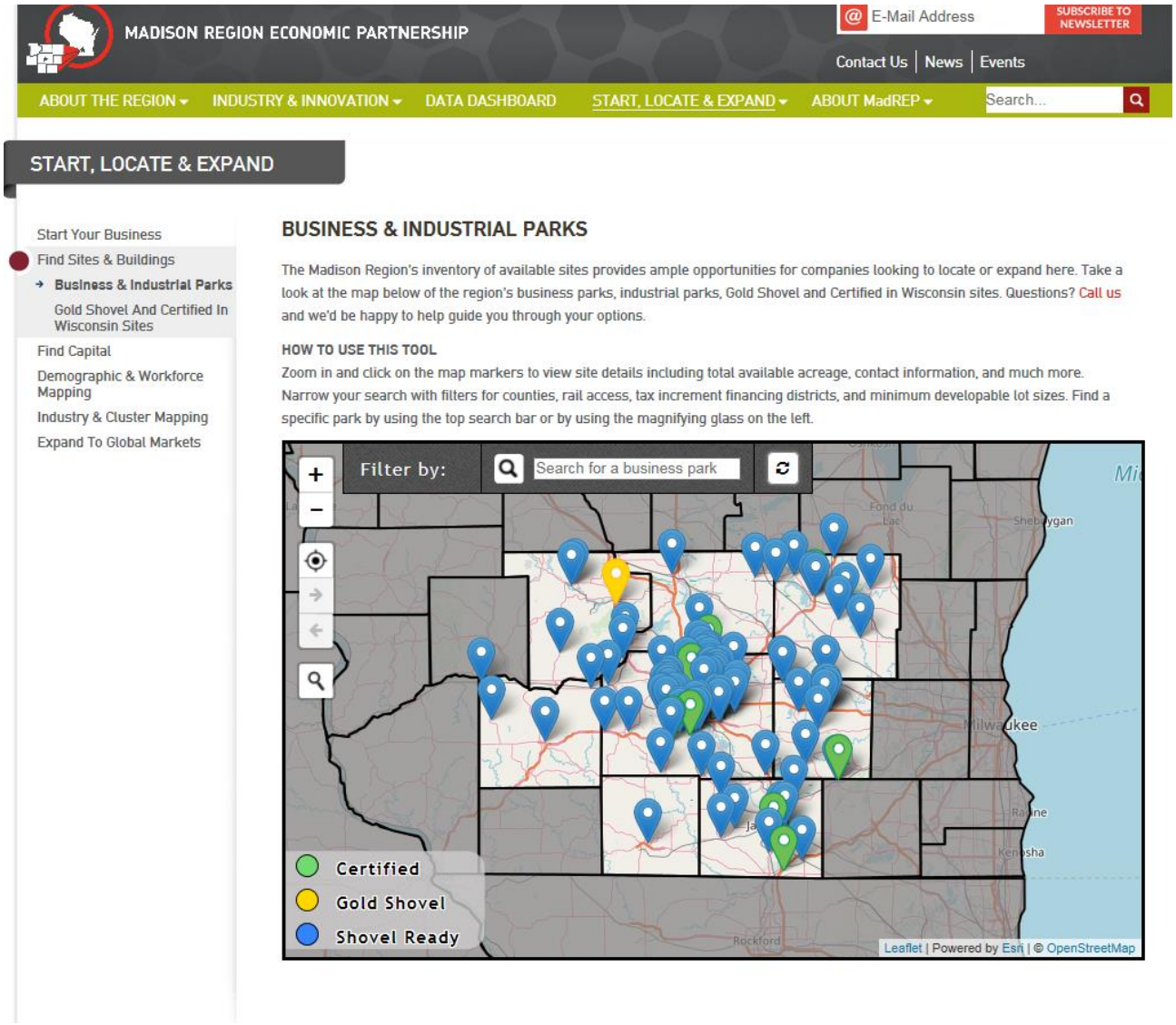

Source: Wisconsin Realtors Association

## Research Parks, Certified and Gold Shovel Sites, and Specialized Commercial Spaces

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

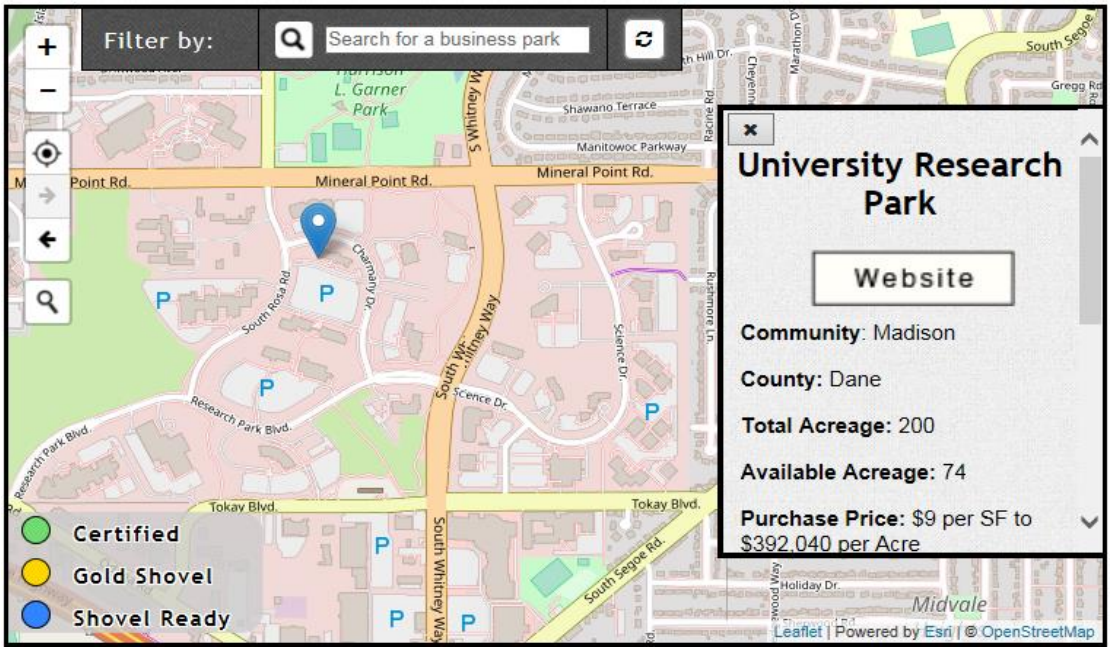
- *Business, Industrial and Research Parks* - MadREP maintains an interactive map of all 103 business, industrial and research parks located in the Region. In 2017, these parks totaled a combined 11,000 acres (115 acres average) of which 4,200 acres were available for development (48 acres average). 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 University Research Park showing the information included when a user clicks on the map markers.

**Figure 3.13 – Screen Shot of MadREP Interactive Business and Industrial Park Mapping Tool**




Source: MadREP

**Figure 3.14 – Screen Shot of Dialogue Box for University Research Park**




Source: MadREP

These types of parks allow for the co-location of firms, or the presence of similar firms locating near one another in a metropolitan area, create localization economies that generate additional benefits for firms in those locations (Niu et al, 2015). Similar firms may co-locate in many different types of commercial districts including but not limited to central business districts, industrial parks, suburban office parks and research parks. To help understand office market conditions and space availability in these types of commercial districts, Appendix C includes several key statistics related to office market transactions, vacancy rates and absorption rates.

Another way to consider opportunities for co-locating bioscience firms is through the lens of *innovation districts*. As defined by Katz and Wagner (2014), innovation districts are "geographic areas where leading-edge anchor institutions and companies cluster and connect with start-ups, business incubators, and accelerators. They are also physically compact, transit accessible, and technically wired and offer mixed-use housing, office, and retail." Katz and Wagner suggest that innovation districts are emerging throughout metropolitan areas and are being driven by innovative firms and talent choosing to concentration and co-locate in compact downtowns or employment centers that are amenity rich and foster networking, knowledge spillovers and access to resources that support innovation. Specifically, innovation districts can be largely described by three different archetypes:

1. *Anchor Plus Model* – The Anchor Plus type of innovation districts are largely located in downtowns and mid-towns of central cities. These districts are characterized by large scale, mixed-used development with proximity to anchor institutions and a concentration of similar firms, entrepreneurs and start-ups involved in the commercialization of innovation.

2. *Re-imagined Urban Area Model* – This type of innovation district is characterized by historic industrial and warehouse districts that are undergoing transformations. Historical building stocks, transit access and

proximity to downtowns in higher rent cities are features of the Re-imagined Urban Area Model. Many of these districts are often found near historic waterfronts.

3. *Urbanized Science Park Model* – Science parks, university or otherwise, were traditionally located in suburban or exurban areas that avoided mixed use development in favor of single uses that focused solely on research and innovation. However, science parks are increasingly recognizing that these isolated facilities are no longer optimal for fostering innovation and attracting young talent to the firms found in these locations. Accordingly, many research parks are undergoing a mixed use transformation that increase the density and amenities offered by these innovation centers. In addition to the North Carolina Research Triangle, the University of Virginia Research Park, the University of Arizona Tech Park and the University Research Park at UW-Madison are all pursuing this type of redevelopment.

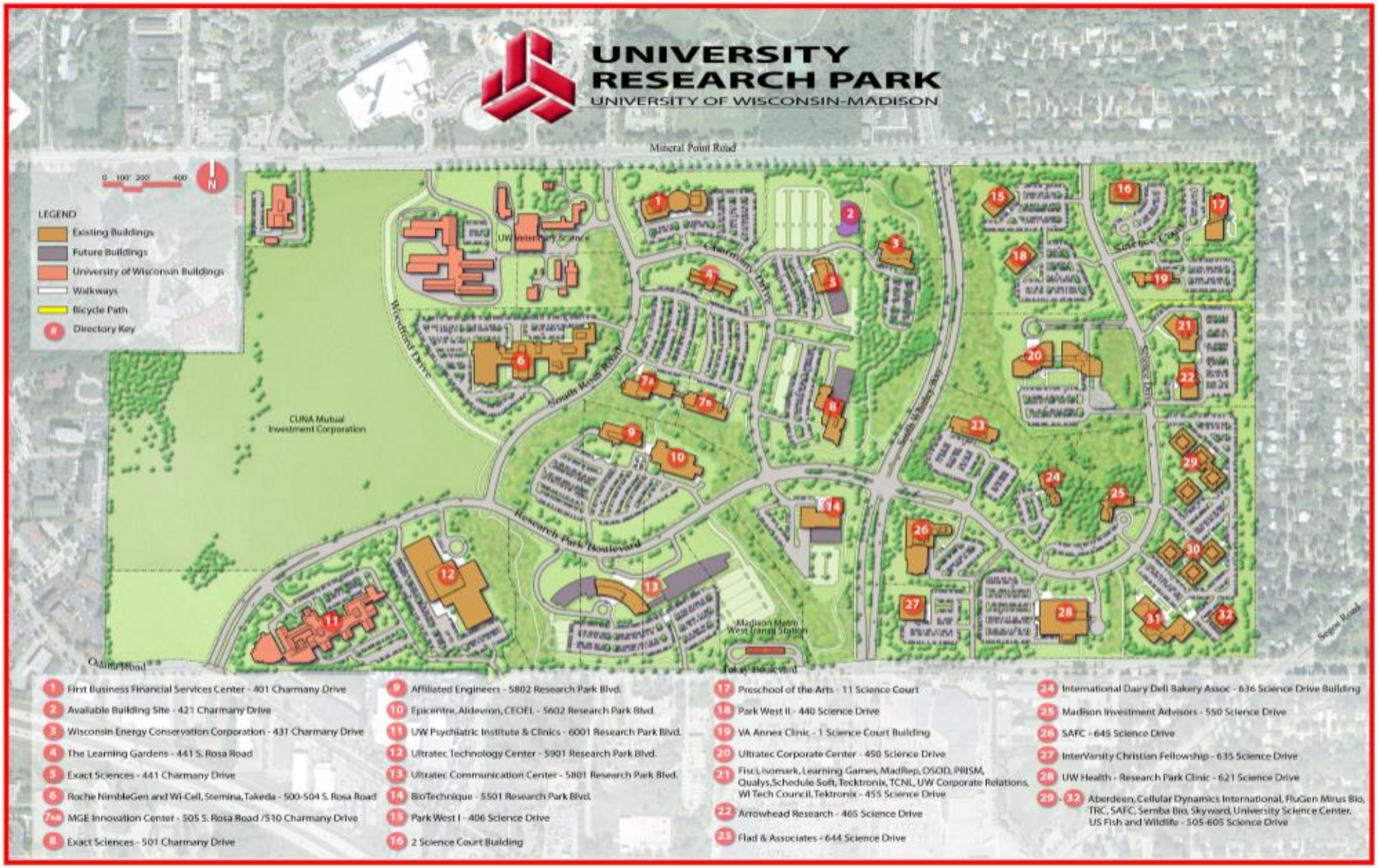
In the Madison Region, bioscience businesses tend to cluster in or around several research parks. Two of the largest are operated by a non-profit affiliate of UW-Madison and are designated as URP and URP^2. Details regarding URP, which is located on the near west side of Madison, are provided below and a map for the park in provided in Figure 3.15.

- Established in 1984
- Currently 274 acres – 200 acres developed; 74 available
- 37 buildings
- 1.8 million square feet under roof
- $183.3 million in value
- $3.6 million per year paid in property taxes
- 121 tenants
- More than 3,800 employees
- More than $260 million in annual payroll

URP^2 consists of 270 acres located on the far west side of Madison. Early designs call for the property to be developed with a “New Urbanism” feel consisting of 64 sites containing a mixture of office, commercial and residential development. Emphasis will be placed on environmentally friendly design, including walkable neighborhoods where people can live and work. A conceptual plan for the property is provided in Figure 3.16.

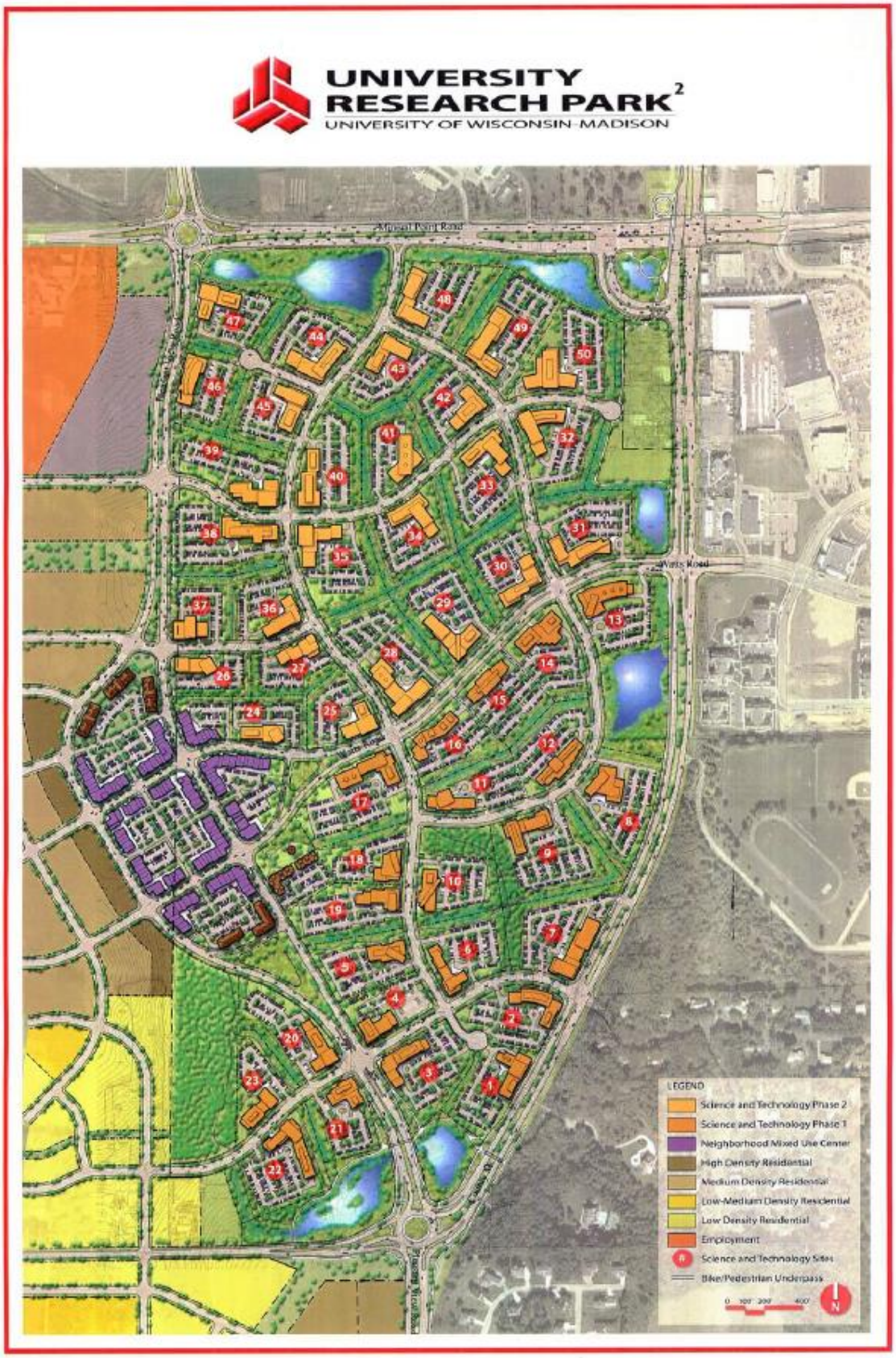
In addition, Promega and Epic Systems have developed campuses in Fitchburg and Verona respectively that provide opportunities to leverage the Urbanized Science Park model (see Appendix 3D). The concept also serves as a model for other current and future office parks/commercial developments in the Region to offer the types of amenities desired by bioscience and (other knowledge industries).

**Figure 3.15 University Research Park**




Source: University Research Park

**Figure 3.16 – University Research Park^2**




Source: University Research Park

- *Certified and Gold Shovel Sites* – The WEDC developed the Certified In Wisconsin® program to set consistent standards for the certification of commercial and industrial sites, putting in place all the key reviews, documents and assessments most commonly required for office or 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 in Figure 3.17).

**Figure 3.17 – 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

- *Specialized Commercial Spaces* – A robust inventory of specialized commercial spaces that cater to research and technology-based firms 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. The Region has several spaces that are specialized for bioscience businesses that are profiled below:

  - MG&E Innovation Center - 2840 Innovation Way, Madison
    Website: https://universityresearchpark.org/the-property/mge-innovation-center/


Picture credit: University Research Park and Vogel Bros Building Company

**Figure 3.18 – MG&E Innovation Center**

| | |
|---|---|
| **Size** | 113,000 sf |
| **Available for Incubation** | 50,000 sf |
| **Number of Office Suites** | 27 |
| **Number of Lab Suites** | 34 |
| **Total Suites** | 61 |
| **Amenities-Office Suites** | Open floor plan; phone and high-speed Internet connections |
| **Amenities-Lab Suites** | Sink and water; 12-foot bench with cabinets; increased electrical service capacity; chemical exhaust fume hoods |

Source: University Research Park

- University Research Park Accelerator – 5602 Research Park Boulevard, Madison
  Website: https://universityresearchpark.org/the-property/university-research-park-accelerator/

Picture Credit: University Research Park and Vogel Bros Building Company

**Figure 3.19 - Building Specifications: URP Accelerator**

| | |
|---|---|
| **Size** | 80,000 sf |
| **Divisibility** | 3,000 to 6,000 sf |
| **Construction** | 3 stories |
| **Key Building Features** | Mechanical equipment redundancy for reliability |
| | Unlimited HVAC zoning capacity |
| | Computerized monitoring for precision climate control |
| | 280 to 400 tons of building cooling |
| | 80,000 to 120,000 cfm of supply air |
| | 4.0M to 7.0M BTU's of heating capacity |
| | 22,000 to 44,000 cfm of exhaust capacity |
| | 2 megawatts of power; variety of voltage options |
| **Key Lab Features** | BSL wet labs; clean rooms; fume hoods |

Source: University Research Park

- @1403 (including Madworks Accelerator) – 1403 University Avenue, Madison
  Website: https://urpat1403.com/

  @1403 is an approximately 15,000 square foot innovation center that is located on the campus of UW-Madison and managed by the URP. The center is home to gBETA, Madworks Coworking, Madworks Accelerator, UW-Madison Discovery to Product (D2P) and UW-Madison Law & Entrepreneurship Clinic.

- Fitchburg Center (including the Faraday Center) – 2800 S. Fish Hatchery Road, Fitchburg
  Website: http://www.fitchburgcenter.com/

Source: Promega Corporation

The Fitchburg Center is a mixed-use community located on over 400 prairie, woodland, and wetland acres, which was developed by Promega Corporation and caters to a mix of high technology businesses with civic, retail, educational, and residential opportunities (see Appendix 3D). Protection of the environment, quality design, community and sustainability are the Center's guiding principles. The Center has rental space available for new and existing bioscience and technology-based businesses. It also is home to the Faraday Center, a 2,800 square foot research and development facility, and the BioPharmaceutical Technology Center Institute (BTCI). The key features of the development include:

- Ten minutes to downtown Madison, University of Wisconsin campus, and the arts district. Twenty minutes to the Dane County International Airport (MSN)
- Four-lane access to interstate system and air transportation
- 16-acre Wi-Fi canopy for wireless outdoor access to the Internet
- Access to premium high-speed communication technology. On-site Internet service provider with Sonnet Ring connectivity
- Extensive trail system for walking, biking, and cross-country skiing
- Conference and meeting rooms for 300+ within development
- On-site services including: day care, clinic, restaurants, and printing
- Private school, city government and community center located within Center
- Lodging, financial centers, health club and a variety of housing choices

- Wisconsin Information Security Research Center, University Research Park, Madison
  Website: https://universityresearchpark.org/the-property/wisc/

The Wisconsin Information Security Research Consortium operates and maintains a Sensitive Compartmented Information Facility (SCIF) in the URP on the near west side of Madison. The facility is designed to meet federal standards for conducting classified research. Its mission is to foster collaborative and strategic alliances between government agencies, private industry and academic institutions. It is available for lease to businesses with enhanced cybersecurity needs or that require a secure facility in order to perform contract work with government entities including the Department of Defense and Department of Energy or private businesses requiring extraordinary project secrecy.

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

As noted in Section 2, a large share of bioscience -related talent requires graduates at the Bachelor's level or higher. Furthermore, connections to universities also creates opportunities for developing new technologies though research. Accordingly, the connections between firms and universities are often an important component of bioscience sector development initiatives. However, bioscience 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 bioscience 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 bioscience companies. In 2016-2017, higher education institutions in and adjacent to the Madison Region conferred 11,178 degrees and certificates applicable to bioscience positions (See Figure 3.20).

**Figure 3.20 - 2016-17 Degrees Conferred: Bioscience**

| Institution | Certificate | Associate | Bachelor | Master | Doctor | Total |
|---|---|---|---|---|---|---|
| UW-Madison | 961 | | 2,440 | 682 | 879 | **4,962** |
| UW-Milwaukee | 94 | | 1,038 | 211 | 106 | **1,449** |
| UW-Platteville | | | 164 | 4 | | **168** |
| UW-Whitewater | | | 267 | 14 | | **281** |
| Beloit College | | | 75 | | | **75** |
| Blackhawk Technical College | 150 | 106 | | | | **256** |
| Edgewood College | | | 167 | 47 | 4 | **218** |
| Herzing University – Madison | 166 | 208 | 129 | 129 | | **632** |
| Madison College | 1,395 | 549 | | | | **1,944** |
| Moraine Park Technical College | 460 | 222 | | | | **682** |
| Southwest Wisconsin Technical College | 399 | 112 | | | | **511** |
| **Total** | **3,625** | **1,197** | **4,280** | **1,087** | **989** | **11,178** |
| Total Degrees Conferred | 7,315 | 2,794 | 15,741 | 4,463 | 1,759 | 32,072 |
| Percent (Bioscience) | 49.6% | 42.8% | 27.2% | 24.4% | 56.2% | 34.9% |

*Source: National Center for Education Statistics. Note: Includes programs and award levels that are offered as a distance education program. Degree programs in bioscience include biological and biomedical sciences; natural resources and conservation; physical sciences; biomedical/medical engineering; chemical engineering; mathematics and statistics; computer information sciences and support services; and health professions and related programs.*

- *University of Wisconsin-Madison* – UW-Madison is a powerhouse in generating research and talent for the bioscience industry. The University granted a total of 4,962 total degrees in bioscience majors during the 2016-17 school year or 36.5% of the 13,604 total degrees conferred across all programs (Figure 3.x). The top

bioscience fields included: health professional and related programs (1,558 degrees) and biological and biomedical sciences (1,343). UW-Madison also provides significant course and degree offerings in chemical, engineering, biomedical engineering, and mathematics and statistics. Almost 60% of all the Doctorate degrees conferred in 2016-17 were in bioscience programs. The UW School of Medicine and Public Health is one of the nation's leaders in securing funding for NIH research. The University also excels in generating talent from its top ranking Schools of Pharmacy and Veterinary Medicine, as well as geneticists from the College of Agriculture and Life Sciences (CALS).

**Figure 3.21 - 2016-17 Degrees Conferred by University of Wisconsin-Madison: Bioscience**

| Degree Program | Certificate | Bachelor | Master | Doctor | Total |
|---|---|---|---|---|---|
| Biological and Biomedical Sciences | 92 | 1,037 | 84 | 130 | **1,343** |
| Natural Resources and Conservation | 258 | 148 | 66 | 16 | **488** |
| Physical Sciences | | 152 | 69 | 100 | **354** |
| Biomedical/Medical Engineering | | 107 | 34 | 6 | **147** |
| Chemical Engineering | | 99 | 5 | 17 | **121** |
| Mathematics and Statistics | 84 | 173 | 80 | 35 | **372** |
| Computer Information Sciences & Support | 144 | 288 | 127 | 20 | **579** |
| Health Professions and Related Programs | 350 | 436 | 217 | 555 | **1,558** |
| Total | **961** | **2,440** | **682** | **879** | **4,962** |
| Total Degrees Conferred (UW Madison) | 2,664 | 7,198 | 2,262 | 1,480 | 13,604 |
| Percent (Bioscience) | 36.1% | 33.9% | 30.2% | 59.4% | 36.5% |

*Source: National Center for Education Statistics*

- *University of Wisconsin System* - Wisconsin's four UW System schools, located in or immediately adjacent to the Madison Region (UW-Madison, UW-Milwaukee, UW-Whitewater, and UW-Platteville), support the Region's strong history and exceptional strength in the bioscience industry. Independently and collectively, all four universities conferred 6,860 degrees in bioscience related fields including: nursing, chemistry, chemical engineering, biomedical/medical engineering, biology, microbiology, and natural resources and conservation. Bioscience degrees represented 25.1% of all degrees conferred at UW-Milwaukee, 10.1% of all degrees at UW-Whitewater, and 9.4% of all degrees at UW-Platteville from 2016-17.

- *Beloit College* – This private liberal arts college offers Bachelor's degrees in computer sciences, engineering, chemistry, biological and biomedical sciences, mathematics, and natural resources and conservation.

- *Blackhawk Technical College (Janesville)* **–** Blackhawk Technical College offers certificates and Associate's degrees in nursing, emergency medical technician (EMT), biotechnology technician, medical laboratory technician, diagnostic medical sonography, medical assistant, pharmacy assistant, and computer technologies. These programs represented 47% of the degrees conferred in 2016-17.

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

- *Herzing University (Madison)* **–** Associate's degree programs include nursing, health information records administration, medical insurance coding, computer networking and security technology, and software development. Bachelor's degrees offered include Registered Nurse, information technology, software

development, and modeling virtual environments and simulation. Master's degrees are offered in family practice nursing and nursing education. These programs represented 73% of all degrees conferred in 2016-17.

- *Madison College (Madison)* - Degrees and certificates in bioinformatics, biotechnology, physical therapy, animal health, nursing, radiology, optometrics, horticulture and stem cell technologies are among the programs offered at Madison College, while information technology, manufacturing and laboratory technician programs offer supporting and supplementary education for the bioscience workforce. These programs conferred 1,944 degrees or 51% of all degrees in 2016-17.

- *Moraine Park Technical College (Beaver Dam)* **-** Several specializations are available within Associate's degree and certificate programs including: nursing, respiratory care, surgical technology, EMT, chiropractic assistant, medical laboratory technician, health information records administration, medical office management, radiologist assistant, web designer/developer, information security, and computer programming.

- *Southwest Wisconsin Technical College (Fennimore)* **-** Southwest Tech provides Associate's degrees in nursing, EMT, medical insurance coding, mental health services, physical therapy, dental assistant, 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 bioscience 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 Region's bioscience industry potentially struggles with diversity issues. 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, universities and other educational institutions also have a role beyond providing a qualified and diverse workforce for the bioscience cluster. Educational institutions also 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 bioscience cluster. Indeed, the Wisconsin Alumni Research Foundation (WARF) currently lists numerous inventions and patents in bioscience.

While new bioscience 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 bioscience support organizations that could provide a means of establishing these types of connections.

## Bioscience Support Organizations

In addition to MadREP, many local agencies and institutions operate in the Region with the purpose of helping bioscience 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 bioscience 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 noted in Section 1. Several, including the MG& Innovation Center and the URP Accelerator, were profiled earlier as part of the discussion on specialized commercial spaces located in the Region.

### 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 bioscience 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 bioscience workforce pipeline.

**Mentor Programs and Technical Assistance**

- *Biopharmaceutical Technology Center Institute* – The BTCI provides educational opportunities that support scientific understanding and develop talent for the biotechnology industry. Programming is focused on developing skills in bioscience fields and is designed for a wide range of learners – from upper elementary school students to scientists in academia and industry, as well as the general public. Engaged participation is emphasized and many activities are laboratory-based.

- *Clinical Trails Education Network* – The Clinical Trials Education Network of Wisconsin is focused on defining clinical research in a way that educates all to the role the bioscience and healthcare industries play the state's economy. The organization strives to be recognized nationally and internationally as a leader in innovation and collaboration for the benefit of patients. In 2010, Wisconsin was home to 1,311 active clinical trials, or nearly 9% of the 15,134 clinical trials in the United States. This clinical research was concentrated on: cancer (744 trials), rare diseases (419), respiratory disorders (157), cardiovascular diseases (82), diabetes (44), mental behavioral disorders (42) and HIV/AIDS (8) (http://wiclinicaltrials.com/education/).

- *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.

- *Post Doc Industry Consultants* – PICO is a bioscience consulting group comprised of postdoctoral fellows at the Medical College of Wisconsin. The group's mission is to provide research-based, actionable business recommendations on key projects for biotechnology and pharmaceutical firms. Concurrently, consultants broaden their business acumen and learn how to navigate the evolving biotechnology and pharmaceutical sectors.

- *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 and UW System Centers and Institutes* – Several Centers, Research Consortiums and Institutes have been created within the UW System which serve the bioscience and healthcare industries in various capacities including the six that are highlighted below. UW-Madison qualifies for over $1.0B in research dollars annually from sources including the National Institute of Health (NIH), and much of this research benefits from access to these facilities.

    1. *UW-Madison, Biotechnology Center* - The UWBC, located in the heart of the College of Agriculture and Life Sciences (CALS) campus at UW-Madison, offers state-of-the-art research services at competitive user fees to companies and university scientists. The services are designed to increase the quality and quantity of biological science research and enhance the competitiveness of applications for federal grant support. These services include: DNA synthesis and sequencing, peptide synthesis, peptide sequencing and mass spectrometry of phosphopeptides and small metabolites, production of transgenic/knockout mice and rats, and education programs and multimedia technology resources.

    2. *Clinical and Translational Science Institute* – CTSI members work to translate research discoveries more quickly into preventive, diagnostic and therapeutic interventions for patients. Consortium members share resources, technology, knowledge and expertise to work towards those goals. The CTSI's research portfolio includes an archive of more than 185 studies, with more than 47 collaborative research studies currently underway.

    3. *Center for Predictive Computational Phenotyping* – CPCP develops, conducts and evaluates training activities that reach a broad set of audiences whose education, research and practice can significantly benefit from having state-of-the-art knowledge about data science, predictive models for biomedicine, and computational phenotyping. These audiences include biomedical scientists, clinicians, data scientists, postdocs, graduate students, undergraduates, and the general public.

    4. *UW-Madison, Advance Materials Industrial Consortium* – The AMIC offers members' opportunities to leverage resources focused around, but not limited to, the College of Engineering. These resources include: taking advantage of senior capstone student projects, which can be guided by industrial goals (through the Materials Science, Mechanical Engineering, and Biomedical Engineering programs). This allows industry to explore important side project ideas while also providing access to potential future hires. Finally, businesses can leverage powerful and unique instrumentation on campus and have an

easy point of access to university staff to assist in problem solving based upon relevant research topics or faculty expertise.

5. *Wisconsin Institute for Discovery and Morgridge Institute for Research* – WID-MIR is a 330,000 square foot facility located near the center of the UW-Madison campus which houses two research institutes: the private Morgridge Institute for Research and the public Wisconsin Institute for Discovery. It also houses a public space called the Town Center, managed by WARF. The two research institutes share a common goal of supporting experimentation across campus disciplines and collectively generate a great deal of research relevant to the Region's bioscience and healthcare industries.

6. *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.

- *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.

- *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.

- *WiSolve Consulting Group* - WiSolve is a non-profit organization composed of graduate students and postdoctoral researchers at UW-Madison that provides research-based business recommendations to solve challenging problems in the Madison business community. Teams consisting of 3 to 6 members are drawn from a pool of over 40 consultants with expertise in the biological sciences, business, pharmacy and engineering to provide services including: market analysis, cost benefit analysis, corporate acquisition analysis, SBIR and STTR grant writing, business plan writing, and marketing strategy development.

**Networking Programming**

- *BioForward* – A member organization representing over 200 companies including biotech, biopharma, medical device, diagnostics, digital health, as well as research institutions, and service providers. The organization sponsors biohealth related networking events and educational 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. Innovation Roadmap: The Speaker Series - Speakers from across the country who have used an entrepreneurial approach to push boundaries and spur innovation share their stories;

    2. Innovation Roadmap: The Workshop Series - 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. Noon @ the Niche - 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. UpStart – 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. WARF Ambassadors - 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: bioscience, 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 bioscience 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 43 or 20% that were classified as bioscience businesses.[7] 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, $81.7M or 29% was invested in bioscience 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 3.22. Twenty-two of these funds, or 47%, are located in the Region.

Some of the most active funds that have or could possibly make investments in the Region's bioscience 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 invested in Gentueri, a bioscience company based in Madison. 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 bioscience companies. Key investments to date include: Cellectar Biosciences, ConjuGon, Deltanoid Pharmaceuticals, Invenra, iVMD, Madison Vaccine Corporation, NeoClone, Quintessence Biosciences, Stratatech, Stemina Biomarker Discovery, Swallow Solutions, and Zurex Pharma;

[7] "2016 QNBV Report," Wisconsin Economic Development Corporation, September 2017.

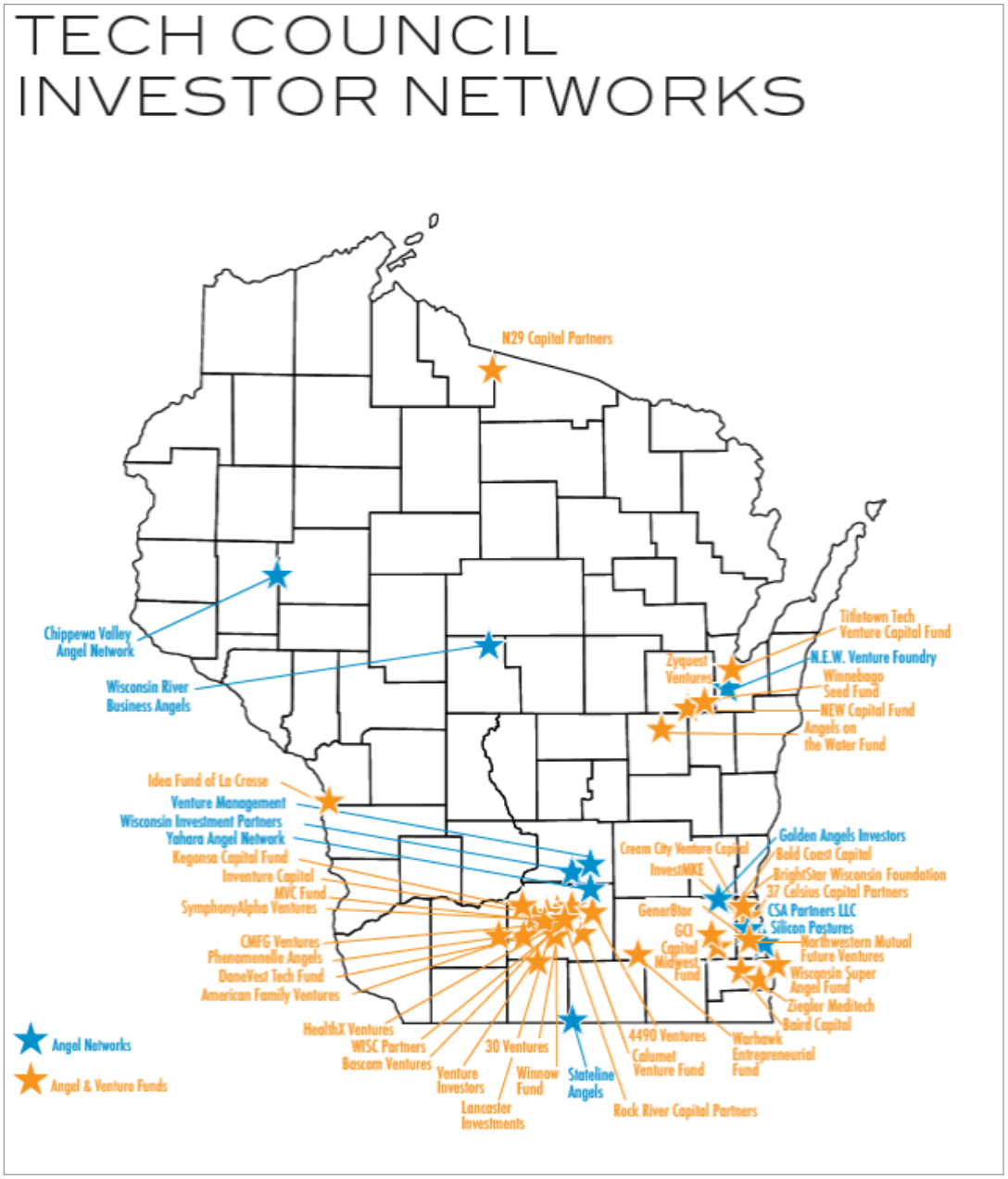
3. HealthX Ventures – HealthX is a $20M digital healthcare focused seed fund founded in 2015. The Fund has made 14 investments to date in primarily HIT companies including: EnsoData, Redox, Image MoverMD, Medable, Moving Analytics, Health iPass, and Pacifica;

4. 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 bioscience companies originating from research conducted at UW-Madison including: Aerpio, Akebia Therapeutics, Blue Willow Biologics, Cellectar Biosciences, Deltanoid Pharmaceuticals, EBI Life Sciences, Euthymics Bioscience, FluGen, Gala Biotech, GDXI, Invenra, Inviragen, Juentas Therapeutics, MVI Immunotherapies, NeuMoDx, Neurovance, NimbleGen, Preva Cept Infection Control, Promega, and ThirdWave Molecular Diagnotics;

5. Drive Capital – A venture capital fund located in Columbus Ohio, which was formed in 2014 by two former Silicon Valley based investors with the mission of investing in technology based start-ups located in the Midwest. Drive has raised two funds totaling $550M and placed investments in 33 companies to date, including the bioscience start-ups Olive (Columbus) and Triggr Health (Chicago);

6. 4490 Ventures – 4490 is a venture fund created in 2014 with a $30M investment from the SWIB and WARF. Managers raised a second $49M fund in 2018. The Fund has the mission of investing in ICT companies located in the Midwest, including the health IT companies HealthMyne and PhysIQ.

**Figure 3.22 – Investor Networks**




Source: Wisconsin Technology Council, 2018 Wisconsin Portfolio

**Bioscience and Healthcare 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 bioscience and healthcare Industries (often referred to as biohealth) from 2015 to 2017, are presented in Figure 3.23. Key findings include:

- The combined industries represent on average 56% of all equity investment activity across the state over the last three years.

- Investments in subsectors for the same period have been mixed, rising dramatically in pharmaceuticals from $4.3M (3.9%) to $53.2M (36.7%), remaining stable for health IT at $30.6M (27.3%) and $32.2M (22.2%), and declining steeply for devices and biotechnology from $41.0M (36.5%) to $14.8M (10.2%) and $25.6M (22.8%) to $12.6M (8.7%) respectively.
- Many of the companies that received investment are located in the Region, including Propeller Health ($21.5M), Redox ($10.0M), Cellectar Biosciences ($7.8M), Healthfinch ($7.5M), Elucent Medical ($7.25M), Datica ($6.46M), Zurex Pharma ($6.24M), Moxe Health ($5.5M), Forward Health Group ($4.02M), FluGen ($3.6M), Stemina Biomarker Discovery ($3.1M), Madison Vaccines ($3.3M), Invenra ($2.9M), Healthmyne ($2.37M), Kiio ($1.9M), Imbed Biosciences ($1.6M), and ImageMoverMD ($1.2M).

**Figure 3.23 - Wisconsin Angel and Venture Capital Investment - Bioscience and Healthcare Industries, 2015 to 2017**

| Category | Year | | | | | |
|---|---|---|---|---|---|---|
| | 2015 | % | 2016 | % | 2017 | % |
| **Biotechnology** | $25,553,180 | 22.8% | $4,811,908 | 3.3% | $12,628,719 | 8.7% |
| **Devices** | $41,001,202 | 36.5% | $35,639,061 | 24.6% | $14,814,151 | 10.2% |
| **Diagnostics** | $9,233,900 | 8.2% | $15,000,750 | 10.4% | $30,340,255 | 20.9% |
| **Health IT** | $30,649,702 | 27.3% | $32,727,330 | 22.6% | $32,166,666 | 22.2% |
| **Pharmaceuticals** | $4,341,640 | 3.9% | $26,656,348 | 18.4% | $53,207,244 | 36.7% |
| **Services** | $1,482,050 | 1.3% | $30,005,000 | 20.7% | $1,710,000 | 1.2% |
| **Total** | $112,261,674 | 100.0% | $144,840,397 | 100.0% | $144,867,035 | 100.0% |
| **All Industries** | $209,479,099 (128 Deals) | | $276,191,739 (138 Deals) | | $231,040,882 (127 Deals) | |
| **Percent ($)** | | 53.6% | | 52.4% | | 62.7% |

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 - Bioscience 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 bioscience 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.

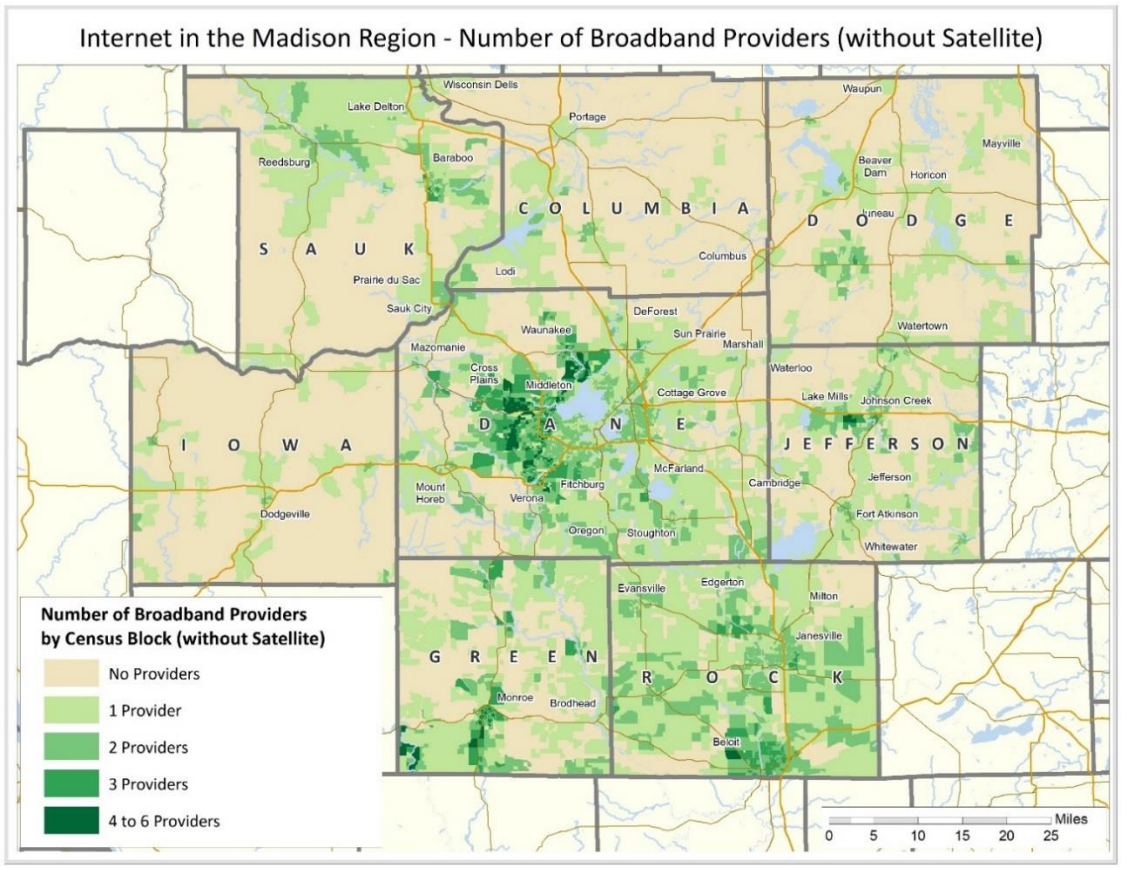
- While college graduates and individuals under the age of 35 remain among the most mobile segments of society, their mobility rates have declined over the last two decades. Accordingly, growing talent from within the Region and talent retention should remain important considerations to building the bioscience talent pool. Talent attraction should remain a bioscience cluster development effort, but the Region should consider attraction from a life stage perspective rather than a one-size-fits all approach. That is, the factors that attract talent from outside the Region vary somewhat by recent college graduates, young college graduates without children, and middle aged college graduates with children. For instance, all of these segments value a robust job market and recreational opportunities, but cost of living is more important to recent grads and cultural opportunities are less of an influence among households with children. Communities attempting to attract talent should be prepared to tailor their message accordingly by building upon their assets that may cater to a specific life stage.

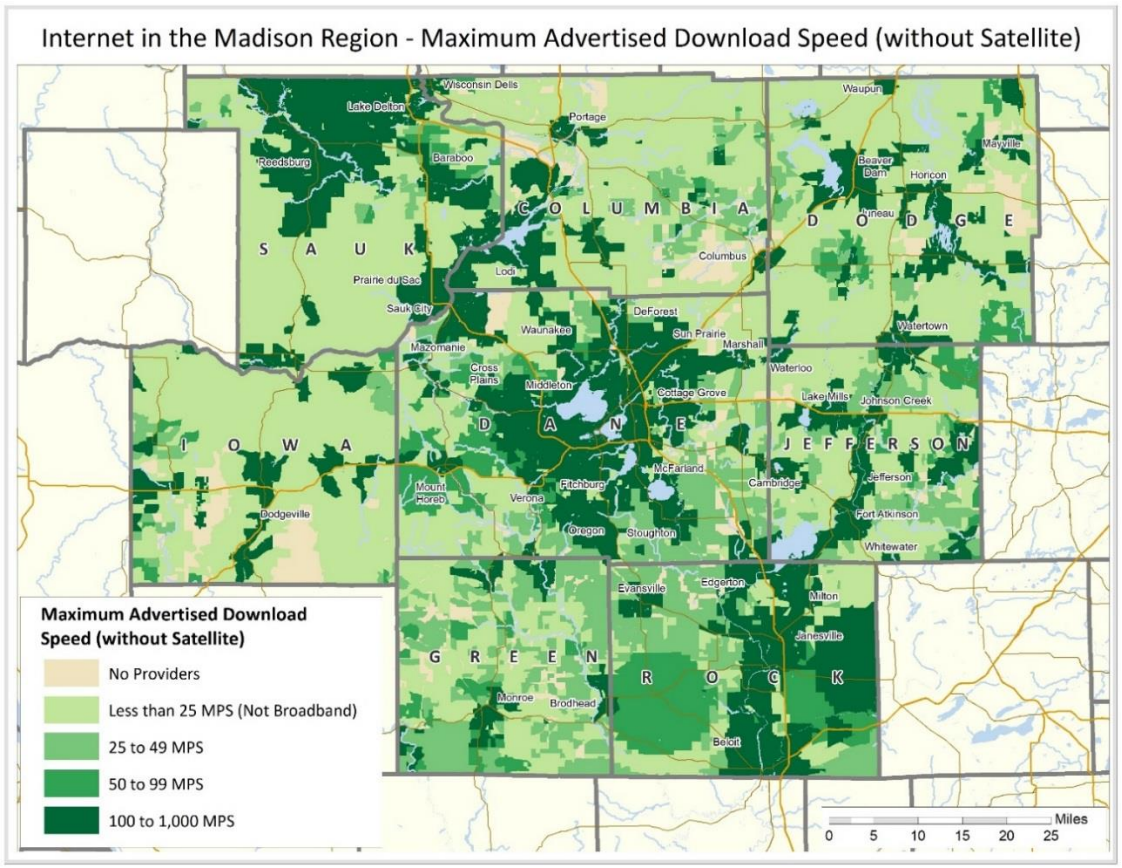
- The Region's housing market provides both opportunities and challenges related to attracting and retaining talent. Compared to other competing bioscience regions, overall housing costs in the Madison Region are somewhat favorable. However, this potential advantage may be lessened when considering the Madison metro area's somewhat lower wages in many bioscience-related occupations. 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.

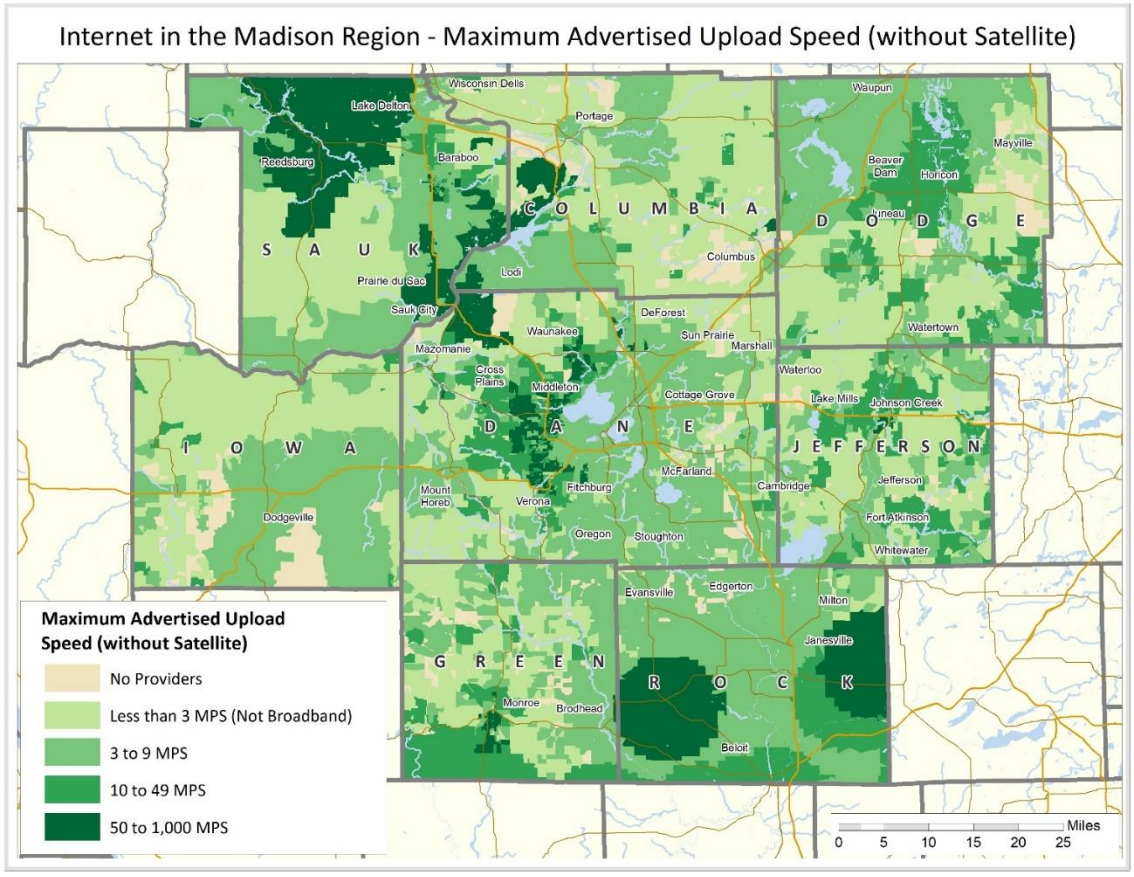
- The connections between firms and universities are often an important component of bioscience sector development initiatives. However, bioscience support from educational institutions extends beyond 4-year universities to include colleges and technical schools that may provide Associate's degrees, certificates or continuing education. The development of bioscience 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 bioscience 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 bioscience 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, bioscience firms and bioscience talent.

## Appendix 3A – Internet Availability Characteristics without Satellite




Internet in the Madison Region - Maximum Advertised Upload Speed (without Satellite)
Wisconsin Dells
Lake Delton
Portage
Waupun
Mayville
Reedsburg
Baraboo
Beaver Dam
Horicon
COLUMBIA
DODGE
SAUK
Columbus
Lodi
Prairie du Sac
Sauk City
DeForest
Watertown
Waunakee
Sun Prairie
Marshall
Mazomanie
Waterloo
Cross Plains
Middleton
Cottage Grove
Lake Mills
Johnson Creek
DANE
IOWA
JEFFERSON
McFarland
Cambridge
Jefferson
Mount Horeb
Fitchburg
Verona
Fort Atkinson
Dodgeville
Oregon
Stoughton
Whitewater
Evansville
Edgerton
Milton
Janesville
GREEN
ROCK
Monroe
Brodhead
Beloit
Maximum Advertised Upload Speed (without Satellite)
No Providers
Less than 3 MPS (Not Broadband)
3 to 9 MPS
10 to 49 MPS
50 to 1,000 MPS
Miles
0 5 10 15 20 25

## Appendix 3B – 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**

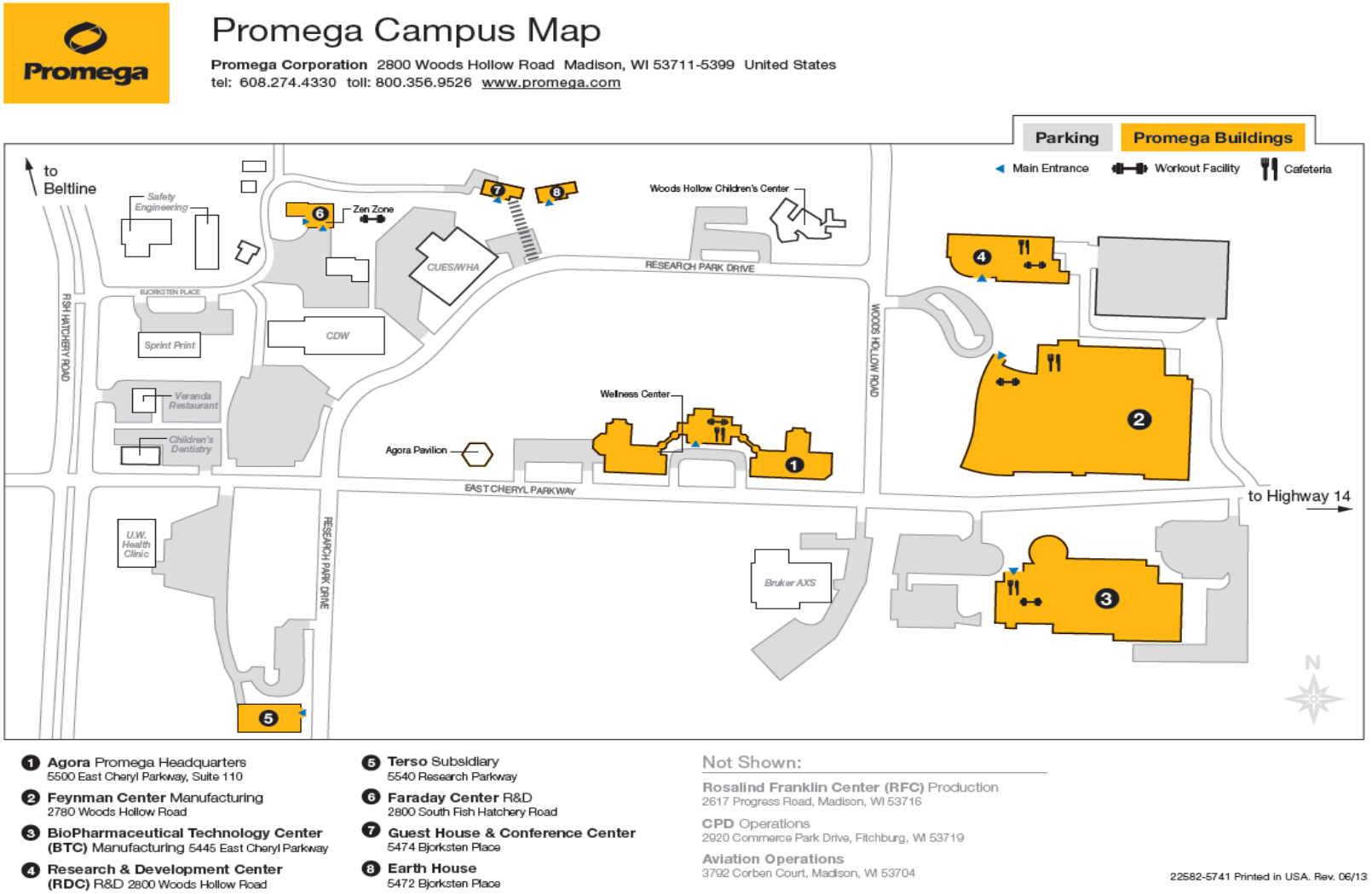
| TENANT | SUBMARKET | TYPE | SF |
|---|---|---|---|
| Exact Sciences | Near West | Lease/Purchase | 150,000 |
| Illumina | Near West | BTS/Lease | 132,000 |
| Navitus | Far West | Exp./Relocate | 100,000 |
| NSI/West Bend | Far West | Consolidation | 80,000 |
| Zendesk | Downtown | Relo./Expand | 78,000 |
| 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 |

## Appendix 3C – Promega Campus Map

Source: Promega Corporation




Source: Promega Corporation

# Addendum 1 - Key Bioscience 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 bioscience industry targets for the Madison Region. These subsectors include: 1) regenerative medicine, 2) genomics, 3) biomanufacturing, 4) pharmaceutical and nutraceutical products and 5) research tools. 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.

## Regenerative Medicine

Stem cells

## Genomics

Human genome mapping and genetics.

## Biomanufacturing

Biomanufacturing of cells and tissues. Forward BIO Initiative, a new center of excellence launched in 2018 in partnership with UW-Madison School of Medicine and Public Health, WARF and WEDC.

## Pharmaceutical and Nutraceutical Products

Covance

## Research Tools

Promega

Other important areas for the advancement of the cluster that are captured in other reports, but repeated here include: HIT, IT Security (Cybersecurity), and IoT.

## Health Information Technology (HIT)

Health information technology (HIT) is an industry subsector which has experienced remarkable growth in the Region over the last decade. Anchored by industry leader Epic Systems, the subsector also includes other notable companies such as Nordic Consulting, Redox, Propeller Health, Health eFilings, EnsoData, and Image MoverMD. Growth in the subsector has been driven in part through federal regulation including the 2009 Health Information Technology for Economic and Clinical Health Act (HITECH) which established Medicare and Medicaid incentives to encourage the widespread adoption of electronic health record (EHR) systems among ambulatory and inpatient healthcare providers. Since 2015, healthcare providers that lack "meaningful use" of EHR's have been subject to a 1.0% penalty on their Medicare reimbursements, which progressively increased to 3.0% in 2017 (U.S. Department of Health and Human Services, 2017). Considering that Medicare alone accounts for about 20.0% of total U.S. health spending, the penalty provides a huge incentive for providers to act in order to avoid a potentially large drain on revenue (Centers for Medicare & Medicaid Services, 2008).

As a result of this regulatory environment, as well as investments made by healthcare providers, the HIT subsector grew significantly over the past decade. While revenue growth is expected to continue, the rate of growth over the next several years will likely change according to several factors described below.

**A Shift toward System Maintenance**

Over the next five years, a growing portion of HIT revenue will come from maintenance and support rather than new sales, as the market reaches saturation and the industry matures. Companies will incorporate additional features into their software, such as new services and enhancements that increase the interoperability across providers, to keep revenue growth steady. Innovation and investment moving forward will concentrate on the development of new platform applications. Experts believe that these advancements will mainly occur in medical simulation and artificial intelligence (AI) applications which mine the data generated by the EHR systems (Burril and Cooper, 2017). The goal of these advancements will be to better predict the outcomes of therapies and treatments (predictive medicine) and then use these predictive algorithms to align treatment protocols to patient symptoms and/or genomics (precision medicine).

Recently, *Xconomy* published an article indicating that Epic Systems was making a move into artificial intelligence in partnership with Ochsner Health Systems and Microsoft (Buchanan, 2018). This potentially signals that the market leading company is indeed attempting to innovate and develop enhancements for its MyChart base systems. The effort is being headed up by Seth Hain, Director of Analytics and Machine Learning. This type of investment in capability and talent is extremely positive for the Region. It not only indicates that Epic sees and is responding to a fundamental shift in the marketplace, staff believes it will result in Epic recruiting more talent to the Region with AI coding experience and expertise. This will incent educational institutions to introduce programming that generates this type of talent and potentially starts a virtuous cycle that helps attract other AI type companies (healthcare based or otherwise) to the Region.

**The Digitization of Everything**

EHR technology has been broadly adopted domestically and is beginning to gain traction internationally as the benefits from the digitization of health records become apparent to both providers and patients. As health data is centralized and directly accessed through massive data storage systems, and more popularly through the cloud, AI will begin to mine the data for actionable intelligence. Experts believe that this process will accelerate innovation in the healthcare space and begin the era of global precision medicine (Meeker, 2017).

The adoption of system interoperability and middleware communications technology protocols will be extremely important to maximize the impact of big data analytics and AI capability in this evolving marketplace. Equally important will be developing cybersecurity protocols that will protect the privacy of patient's health records, while still assuring that records are portable between providers. Blockchain technology could play an important role in the development and codification of these security and portability standards.

Redox is an example of a regional business that has taken a leadership role in developing software that helps competing EHR systems communicate and share data. A key to solving these problems long term will be for software developer's to directly connect with local health care providers to share experiences and expertise. The Nashville Center for Medical Interoperability can represent a best practice for how developers and providers can work together to unlock the power of digitization. Staff believes the Madison Region has the ability to develop a similar best practice and lead in the innovation of applying AI to health records and help accelerate the implementation of precision medicine.

**Clinical Trial Acceleration**

Faster and more sophisticated digital technologies have also advanced and accelerated data collection and analysis serving the biotechnology, life science and medical devices industries. These industries are all key strengths in the Madison Region as detailed in this analysis. Experts believe that these data points will be used to develop robust AI based simulation technologies that shorten the regulatory approval process for drugs and devices, primarily by accelerating the clinical trial process (Meeker, 2017). This will provide a boost to the innovation coming out of the University of Wisconsin-Madison supported by the Wisconsin Alumni Research Foundation (WARF), as well as local bioscience companies. Not only will the cost of trials be potentially reduced, but the speed at which new innovations go to market can be radically increased, reversing a long-standing trend of increasing time and cost to market.

**Consumer Adoption**

Both businesses and consumers are becoming more comfortable with HIT technologies in the form of wearables, preventative health systems, and telemedicine. Consumers in this subsector are both health professionals as well as the patient. The increasing rate of adoption of these technologies will create the robust data sets that will form the foundational element of precision medicine. The ability to use this data to analyze individual health conditions and predict the interplay between diagnosis and treatment of various disease states is what allows this technology to generate a high return on investment (ROI) for healthcare providers.

**Rise of Telemedicine**

Telemedicine (or Telehealth) is forecasted to grow the fastest of all niche HIT markets at a compound annual growth rate (CAGR) of 35.7% (Beaton, 2017). This niche is well represented in the Madison Region by companies such as Dotcom Therapy, HealthMyne, and Eyecor. Development of the niche is important in providing remote healthcare access to rural and underserved metro areas. It also begins the process of developing a global network of healthcare providers. Finally, it has the effect of moving healthcare toward a basic or export industry, wherein services can be delivered from any location to anywhere in the world with reasonable Internet speeds (ideally a connection which operates at a minimum symmetrical rate of 10 Mbps).

Staff believes that the Madison Region has the ability to establish a leadership position in this market through the promotion of its ever-evolving collection of telehealth related companies. It recommends researching the creation of an industry cluster focused on telehealth very similar to what was recently accomplished with the formation of the Wisconsin Games Alliance (WGA) in the local game development niche.

**Evolution of Genomics**

High throughput computing, metadata management, robust sample sizes, and cheaper and more powerful computing technologies have driven the cost of genomic sequencing down from millions to hundreds of dollars per sample (Buhr, 2017). Advancements in this space have accelerated to the point where laptops have replaced super computers for analysis. This innovation, and in particular the reduced cost of sequencing the human genome, have accelerated the implementation of personalized or precision medicine. It is important to note the role that UW-Madison and local genomic companies like Lucigen and Illumina have played in this evolution. Foreign companies have taken notice and have recently acquired several local companies operating in this space. Most importantly, they have chosen to keep the companies local following the acquisition and, in many cases, made additional investments to grow the size and staffing of the business in-place.

**Other HIT Headwinds**

Potential headwinds to the HIT subsector include the politically vulnerable nature of Medicare and Medicaid funding as well as equal access to quality broadband infrastructure, especially in rural and underserved metro areas. As of 2013, more than 25% of all US households lacked high speed internet (File and Ryan, 2014).[8] Staff and firms need to be aware of and monitor these and other headwinds whenever possible and push for solutions that will mitigate these obstacles and continue to advance the subsector.

## IT Security (Cybersecurity)

The cybersecurity subsector benefits from the increasing adoption of e-commerce, social networking and cloud computing, all of which necessitate the use of mobile devices and cloud servers to store sensitive data requiring security. In 2016, International Data Corporation (IDC) estimated that 14.2% of all services were

[8] Regional snapshots of broadband access are examined in Section 4.

conducted online, up significantly from 7.0% in 2011. This percentage is forecasted to increase to 21.6% by 2021 (Columbus, 2017). These dynamics have driven up the demand for talent and expertise in this subsector.

In addition, many small companies view the outsourcing of IT consulting services as a more efficient alternative to a large internal IT support team due to cost and the rapidly evolving nature of the technology (Overby, 2016). This further drives demand for IT based services including cybersecurity. As a result, the global cybersecurity market reached $115B in 2015 and is expected to grow by a CAGR of 7% to 12% depending on the Region (Gartner, 2016). Key trends and opportunities driving the cybersecurity market are noted below.

**Data Breaches and Privacy Concerns**

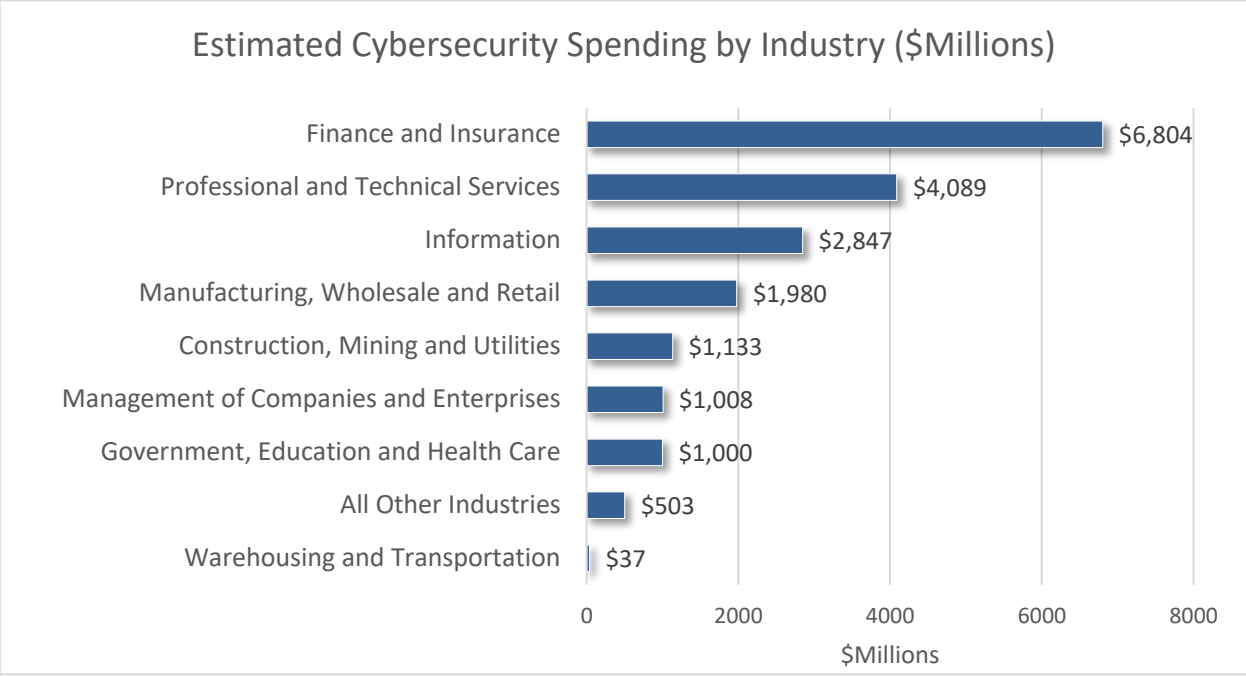
The industry will continue to perform well as downstream markets across all sectors, including banking and financial services, telecommunications, retail, and government, react proactively to the risk of high-profile, reputation threatening breaches. As noted by TechWorld (2018) several of these prominent breaches include:

- In 2010, Wikileaks leaked thousands of confidential documents, including US State Department diplomatic cables;
- In 2011, Sony's PlayStation Network leaked 101.6M customer records including 12M credit card numbers;
- In January 2012, Amazon's shoe selling subsidiary Zappos leaked personal information for 24M customers;
- In June 2012, LinkedIn leaked passwords for 6.5M users;
- In 2013, Edward Snowden leaked classified information from the National Security Agency;
- In the two-year period from 2015-16, high-profile data breaches occurred at CVS, Walmart, Home Depot and JP Morgan Chase.

One of the key difficulties for this subsector is to develop standard protocols and techniques that secure data located in increasingly popular and complex cloud based systems. Cloud infrastructures represent the best-known platform for organizations to store and analyze the massive quantities of data accumulated through the proliferation of smartphones, social networks and machine-to-machine communications (Senyo, Addae and Boateng, 2018). This fact, combined with the knowledge that individuals are becoming increasingly concerned with how their personal information is used and secured online, necessitates a quick and lasting solution to this problem. Without it, consumers will be reluctant to share the data which is critically important to monetizing the Internet, and taking maximum advantage of the big data analytics afforded by machine learning and other AI technologies across multiple industries. As a result, IT spending is becoming increasing important in both the private and public sectors. In 2016, U.S. companies spent an estimated $19.4B on cybersecurity services either internally or through contracting with outside firms (Figure 3.1).

While health care spending on cybersecurity is not yet as large as other industry sectors, market analysts project that this segment will grow significantly over the next five-years as providers continue to integrate big data solutions with predictive analytics throughout their operations. Healthcare companies may require the assistance of security consultants to either bring their current systems into compliance with new healthcare legislation or to develop entirely new system architecture, representing a significant new source of future demand for the industry (Siwicki, 2018). As alluded to in the previous HIT section, this is a priority growth market for EHR companies as health records need to make significant gains to achieve the security level which will make patients feel secure and allow records to become portable.

**Figure 3.1 – Estimated U.S. Spending on Cybersecurity by Industry (2016)**




Data Sources: Bureau of Labor Statistics, IMPLAN and Author's Calculations

**Cloud Computing and Web3 Design**

While cloud computing and back-end data centers are the dominate platforms in the current Internet marketplace, new and more robust data uses such as autonomous vehicles and smart cities, will require a new decentralized Internet architecture that the industry refers to as Web3 design. In this system, more processing occurs at the edge of the network system in order to reduce latency and generate causality, such as an autonomous vehicle stopping for a pedestrian, in real time. It is not seen as a replacement of the centralized cloud based system, but is currently envisioned as complementary. Businesses utilize an early version of edge design with their internal enterprise resource planning (ERP) systems. The cloud is currently deemed a security risk by many businesses, and is perceived as slow relative to the speed of a good ERP system (Brinkman, 2018). Web3 design and increased security could allow businesses ultimately to operate with hybrid systems (processing both in the cloud and at the edge) depending upon what might be the best for maximizing operational efficiencies.

Implementation of edge systems will require the development of new network standards, chip sets and edge device protocols before it can become fully commercialized (Hilton, 2018). The Internet will also need to operate at higher speeds with more reliability and less latency as is currently proposed with 5G networks. As discussed in Section 4, the rollout of these networks is scheduled to begin in the U.S. in 2018 and 2019. Cloud systems will still be a necessary component of Web3 design, as edge devices will not have the storage capacity, nor in many cases the processing speed, necessary to serve the needs of AI and big data. Again, cloud and edge systems will need to work together to mine data and feed the predictive algorithms which make AI a powerful tool for business and will help maximize Web3 based system performance.

**Blockchain**

Blockchain has been around over a decade, having made its initial appearance with the cryptocurrency bitcoin. Since it began trading in 2009, the aggregate value of this digital currency has exploded from $11 billion to over $300 billion in 2017 (Shaw, 2017). During this formative period, the market also began to realize that the decentralization of data authority and encryption technology applied to the money transfer processes of the global banking industry via blockchain had the potential to revolutionize as well as disrupt other important markets. Developers began exploring blockchain applications for energy trading, replacement of state-issued identification cards, tracking supply-chain logistics, tracking and transporting healthcare records, and the management of Internet of Things (IoT) networks.

Many believe this is just the beginning of the peer-to-peer (P2P) economy which allows consumers (including individuals and businesses) to complete transactions without the need for a middleman.[9] Bitcoin is an example of a P2P network in which money is transacted without the need for banks. In P2P design there is no need to share data with the platform (which is the middleman) including applications like Uber, Airbnb, and Facebook. This could be popular for consumers with privacy concerns. The cost of completing the transaction is also cheaper due to fewer fees. The key to developing blockchain to its full potential will be to agree upon universal, preferably global, standards to assist with the commercialization of the technology.

**Regional Assets and Opportunities**

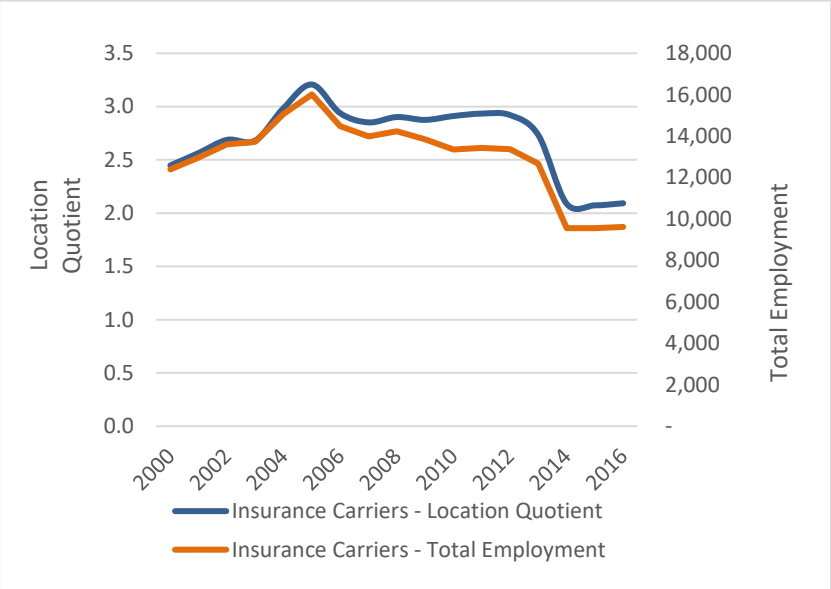
Cybersecurity services in the Madison Region appear to be primarily served by outside providers as the Region does not have a significant agglomeration of cybersecurity firms like other Midwestern regions such as Chicago, Milwaukee and Detroit. This gap occurs even though cybersecurity issues impact all industry sectors of significance in the Region. Staff believes this represents an opportunity to market cybersecurity businesses looking to expand their footprint using the Region's customer base, talent base and quality of life as the pitch. There is also a potential opportunity to work with firms in Milwaukee and Chicago on developing and leveraging expertise in this niche, particularly targeting the fintech firms that provide leadership in the Milwaukee market, such as Northwest Mutual and BMO/Harris Bank.

Other recommendations for developing the niche in the Madison Region include:

[9] "What is the Web3?," BlockchainHub.net, p 1

- While the location quotient and employment levels associated with insurance carriers or Insurtech-related businesses have dropped somewhat, this industry continues to be a significant strength of the Madison Region (Figure 3.2). Accordingly, there may be an opportunity to approach regional Insurtech businesses, including American Family, QBE, WPS and Cuna Mutual, to determine if they are either investing in and/or have an interest in recruiting cybersecurity firms to the Region. Also, staff should determine if they either are or are interested in developing profit centers around writing insurance policies covering cybersecurity threats.

**Figure 3.2 – Location Quotient and Employment Trends in Madison Region Insurance Carriers**




Data Sources: Bureau of Labor Statistics, QCEW and Author's Calculations

- Encourage UW-Madison to develop additional talent and start generating research in the areas of cybersecurity, Blockchain and Web3 design.

- Support the efforts of 100state to launch an incubator branded 100crypto which will provide space and services to entrepreneurs seeking to develop and commercialize Blockchain related technologies.

- Market to cybersecurity firms, as well as regional businesses that have data security needs, the capabilities of the Sensitive Compartmented Information Facility (SCIF). This facility is designed to meet federal standards for conducting classified research. It is operated by the Wisconsin Security Research Consortium in the University Research Park (URP) on the near west side of Madison.

## 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.[10] 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 |
|---|---|---|---|
| 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

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

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.[11] 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 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.

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

# Addendum 2 – Opportunities and Key Strategic Initiatives to Support the Madison Region's Bioscience 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 bioscience industry sector. When adjusted for population size, the Madison Region competes with the best and largest regions/metros in the United States and is more dynamic, more diversified, and better positioned for bioscience driven innovation and entrepreneurship serving the global economy than other regions in the State of Wisconsin.

*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 Bioscience 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 bioscience 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 bioscience 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 330 bioscience 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.

It is important to recognize how many organizational resources have been developed to support the bioscience 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 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.

## Bioscience Subsectors and Niches

When drilling down into the subsectors within the overall bioscience 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, the research skills associated with their technology and staff, 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 bioscience niches stand out as the strongest opportunities for success: regenerative medicine, genomics, biomanufacturing, pharmaceutical and nutraceutical products, and research tools.

**Regenerative Medicine**

**Genomics**

**Biomanufacturing**

**Pharmaceutical and Nutraceutical Products**

**Research Tools**

Other important areas for the advancement of the cluster that are captured in other reports, but repeated here include: HIT, IT Security (Cybersecurity), and IoT.

**Health IT (HIT)**

Perhaps the most obvious subsector is HIT, with the dominance of Epic Systems in the national market for electronic health care records. Epic, which exploded after the passage of the 2009 Federal Health Information Technology for Economic and Clinical Health Act (HITECH), has changed Dane County fundamentally forever. Moving forward however, the HIT subsector is forecasted to continue growing but at a slower rate.

Rarely, especially in Wisconsin, can a privately-held company fund a billion-dollar campus build-out from cash flow and average 500-person net employment growth annually for a decade. Its facilities are world class. West coast site selectors that have been to Google, Facebook, Amazon and Apple campuses have told MadREP during site visits to the Region that these west-coast campuses have nothing on Epic's campus in Verona.

Epic has entered a new phase of its company's growth. It is obvious that the physical construction that has accompanied Epic's revenue and employment growth over the last decade has slowed down as there are fewer cranes towering over the site. In the near future, Epic real estate development in Verona is estimated to be concentrated on building one more themed office pod and physical densification of their 1000+ acre campus in Verona, with non-Epic retail and service firms serving their employment base. Talks with City planners in Verona have confirmed that multi-family housing is currently not being considered on the Verona Epic site. It is also estimated that the next use of their original Tokay Boulevard facility in Madison, once on the market, will be used as a location for key strategic industry partners.

Epic CEO Judy Faulkner, and thus the company, have a history of being very private in terms of discussing where the company is going with respect to innovation, markets, and partnerships. As outsiders looking in, we feel the following might logically be occurring in Epic:

- After a 3 to 5-year innovation implementation run, Epic has begun a new era of innovation both inside Epic and with strategic partners related to expanding their software platform. This could involve blockchain, artificial intelligence, machine learning, telehealth, mobile app development, and cyber security technologies.
    - **KSI:** The Center for Medical Interoperability in Nashville can represent a best practice for how developers and providers can come together to unlock the power of digitization. Staff believes the Region could develop a similar best practice that helps competing Electronic Health Records (EHR) systems communicate and share data and lead in the innovation of applying AI to health records and help accelerate the implementation of precision medicine.

- Markets for EHR software for all major hospitals and clinics in the United States have been saturated by Epic Systems and their competitors. New markets for Epic in the United States could involve applying their software platform to senior care facilities.

    - **KSI:** Work with government and state industry leaders that oversee senior care in Wisconsin to make sure both rural and urban senior care facilities have access to this software and opportunity for advancement.

- The *Epic App Orchard* is very promising given that it appears to be a market place that feels somewhat outward facing. It is hoped that the October 2018 *App Orchard Conference* where private sector app developers interface with Epic developers while Epic leadership shares their vision for 2019 will take on the look and feel of a "reverse pitch" event where Epic explains their future directions along with roadblocks and requirements to reach their vision.

    - **KSI:** Additional means are needed for creating connections to potential value-added partners at Epic, especially in terms of the bioscience subsector in Dane County and the rest of the state. It would benefit the state if Epic hosted a Reverse Pitch Event annually for Wisconsin, preferably in Madison.

- Epic Systems is expanding globally in countries that have robust populations, financial resources, and health care systems. Europe and the Middle East dominate these growing opportunities. Furthermore, additional direct flights to the east and west coasts will facilitate or follow growth. Epic is currently one of the top five customers in the world of Delta Airlines and other major airlines (United, Alaskan) have taken note of this opportunity.

    - **KSI:** Work with existing Madison Region companies, including Epic, on helping Dane County Regional Airport (MSN) create stronger business arguments for future direct flights to Phoenix, Seattle, Houston, Boston and Charlotte.

- Over the past several years, Epic was hiring an average of almost 1,500 employees per year. However, a decrease in these hiring trends may have started. Going forward, new CSM hires at the Verona campus are likely to have strong technology skills in AI, machine learning, blockchain, cybersecurity, and EHR system maintenance.

    - **KSI:** Support UW-Madison and Madison College/Blackhawk Technical College talent development in these skills. Investigate the creation of an EHR technical college degree for system maintenance. Explore if Madison College could serve as a beta testing and training facility for senior care Epic software implementation.

- Epic has located a major data center at Mayo Clinic in Rochester, Minnesota, while bringing online Mayo's entire patient and staff database nationally. Growth and maturation of existing partnerships with Mayo Clinic is shrewd given that it may be the most globally successful hospital and clinic business model. This relationship will increase Epic's footprint and partnerships within the Rochester and (more importantly) the Minneapolis-St Paul Region.

    - **KSI:** Develop stronger relationships among economic development leadership in the Madison Region and Minneapolis-St. Paul Region.

- Epic has a strong relationship with the UW for sourcing talent. Logically, UW graduates are the highest concentration of Epic employees of any university. Furthermore, there are research partnership opportunities for both technology and talent at the UW that could likely center around, AI, AR/VR, blockchain, and machine learning.

    - **KSI:** Continue to grow research partnerships and talent pipelines with UW-Madison. The UW should open and share research findings with other Wisconsin companies, when possible, as technologies and findings may be useful in non-EHR platforms.

    - **KSI:** Explore if UW Foxconn FIRST research can impact EPIC's growth and development. If so, MadREP would like to be a partner to help both parties.

The financial services industry has historically led all industry sectors for cybersecurity investment and protection. Health care systems and the records they manage have not reached this level of security

protection, especially when record portability will be implemented. Market analysts project that the healthcare segment will grow significantly over the next five years as providers continue to integrate big data solutions with predictive analytics throughout their operations. Health care companies will require the assistance of security consultants to either bring their current systems into compliance with new health care legislation or to help develop entirely new system architectures, representing a significant new source of future demand for the industry.

Continued improvement on global cybersecurity protections of electronic health care records will be important. The European GDPR regulation will impact Epic's growth and costs in Europe. It is also expected that this GDPR exposure will help Epic in the United States if, and when, similar regulations are implemented in this country.[12]

- **KSI:** Create and enhance a pipeline of innovation, technology and talent coming from Wisconsin universities and colleges serving Epic and the EHR industry's cyber security needs. Establish a goal for Epic and UW-Madison to become the epicenter of EHR cybersecurity and data protection technology and regulation development for the United States.

Churn may not seem ideal to employers, but it is an important component in the development of the bioscience cluster. Many companies understand that talent coming from other employers also brings new knowledge and ideas that may benefit their own firms. Nonetheless, this churn is not desirable to all firms. In fact, some companies in the Madison Region have enacted non-compete agreements that place restrictions on future employment upon an employee's separation.

- **KSI:** While these agreements are understandably advantageous to the firms that require them, MadREP would like to work with those that use them to educate on the potential unintended consequence of slowing the development of the Region's bioscience cluster.

Telemedicine/Telehealth is forecasted to grow the fastest of all niche HIT markets at a compounded annual growth rate (CAGR) of 35.7% (Beaton, 2017). This niche is well represented in the Madison Region by companies such as Dotcom Therapy, HealthMyne, and Eyecor. As smart homes become synergistic with smart cities through devices such as Amazon's Echo and Google's Home, there are additional opportunities for our health care system for residents to receive feedback from health care professionals on health activity, rehabilitation and physical therapy progress from home.

- **KSI:** Development of this niche is important in providing remote healthcare access to rural and underserved metro areas. It also begins the process of developing a global network of health care providers. Telehealth has the effect of moving healthcare toward a basic or export industry, wherein services can be delivered from any location to anywhere in the region (or the world) with reasonable Internet speeds (ideally a connection which operates at a minimum symmetrical rate of 10 Mbps).

[12] 2018 General Data Protection Regulation (EU) 2016/679 ("GDPR") is a regulation in EU law on data protection and privacy for all individuals within the European Union (EU) and the European Economic Area (EEA). It also addresses the export of personal data outside the EU and EEA areas.

- **KSI:** Broadband upgrades in our Region and the state are critical to making this market a real opportunity in the next 5-10 years.

- **KSI:** Staff recommends researching the creation of an industry cluster focused on telehealth very similar to what was recently accomplished with the formation of the Wisconsin Games Alliance (WGA) in the local game development niche.

- **KSI:** Explore whether the UW/Foxconn FIRST research impact can accelerate Telemedicine implementation through the Region.

**Cybersecurity**

In recent years, cyber-attacks have become the new normal. From Target, to Home Depot, to Goodwill Industries and JP Morgan Chase, sensitive consumer financial information has been lost by these organizations (and many more) to hackers. While major companies take a temporary PR and operational hit, their customers absorb the longer-lasting impacts. For smaller companies and government, the PR and operational hit could be much more impactful and sustaining.

Business, industry and government can address this new normal by pivoting on cyber protection. This requires new thinking, planning, workforce, investment and prioritization. In 2016 U.S. companies spent an estimated $19.4B on cybersecurity services either internally or through contracting with outside firms. These expenditures are part of the greater global cybersecurity market that reached $115B in 2015 and is expected to grow by a CAGR of 7% to 12% to 2020 depending on the region (Gartner, 2016).

Aside from a few major firms in Detroit and Chicago, the Midwest has very few cybersecurity firms of significance. Instead, many of the Region's companies contract out cybersecurity services to firms from the coasts. In general, these professional service firms study the threat landscape, conduct risk assessments, implement baseline protections, help purchase cyber insurance, and hire consultants to help manage internal and external relations if an attack is successful. While billions of dollars in venture capital have been raised by cybersecurity and Insurtech startups to analyze the actuarial science (underwriting of deals) and cybersecurity technologies, many Wisconsin companies likely need more proactive cybersecurity approaches to protect themselves from attacks.

- **KSI:** There is an opportunity to market cybersecurity businesses looking to expand their footprint using the Region's customer base, talent base and quality of life as a pitch to expansion or relocation. There is also a potential opportunity to work with firms in Milwaukee and Chicago on developing and leveraging expertise in this niche, particularly targeting the Fintech firms that provide leadership in the Milwaukee market such as Northwestern Mutual and BMO/Harris Bank.

- **KSI:** Approach the Region's Insurtech businesses, including American Family, QBE, WPS and CUNA Mutual, to determine if they are either investing in and/or have an interest in recruiting cybersecurity firms to the Region. Also determine if they already are developing or are interested in developing profit centers around writing insurance policies covering cybersecurity threats.

- **KSI:** Encourage UW-Madison to develop additional talent and start generating research in the areas of cybersecurity, blockchain and Web3 design.

- **KSI:** Support the efforts of 100State to launch an incubator branded as 100Crypto which will provide space and services to entrepreneurs seeking to develop and commercialize blockchain related technologies.

- **KSI:** Market to cybersecurity firms, as well as regional businesses that have data security needs, the capabilities of the Sensitive Compartmented Information Facility (SCIF). This facility is designed to meet federal standards for conducting classified research. It is operated by the Wisconsin Security Research Consortium in the University Research Park (URP) on the near west side of Madison.

Bioscience businesses that deploy IoT technologies are also 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 they are going 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 cyber security 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.

## Bioscience Talent

### Diversity

Workforce inclusion is major challenge that is starting to be addressed. Dane County, where most of the bioscience companies are located, has reached critical mass in size and breadth which has the potential to make diversity in employment and entrepreneurship easier. Academia, at all levels (UW, Technical Colleges, MMSD), co-working spaces (100State, Sector67, and StartingBlock Madison), and non-profit leaders (Doyenne Group, Urban League, WWBIC, Forward Community Investments and MadREP) are leaders that are making strategic investments in time, programming and philosophy to effectively change diversity and inclusivity in our workforce and entrepreneurs. Bigger companies are beginning to follow suit. This level of effort was not present a decade ago.

- **KSI:** Continue to use the annual Madison Region Economic Development and Diversity Summit as a bridge for underrepresented populations to access technologies, education, and employment throughout the bioscience sector. MadREP and the Urban League of Greater Madison need to ensure that programming at future summits accommodates this effort.

- **KSI:** Mobility and External Recruitment - When compared to other occupations in the Madison Region, life, physical and social science occupations have the second highest share of individuals who were either born in another state or born outside of the United States (see Section 2). Furthermore, college graduates are the most likely among all levels of educational attainment to move from one state to another. These trends suggest that mobility and external recruitment may play a greater role in growing bioscience talent than with other occupations. The Region needs to recognize this and do more to recruit talent and start-ups to the Region.

- **KSI:** Welcoming of Outsiders - The State of Wisconsin has one of the highest share of residents (~70%) who were born in their state of residence. 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 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.

- **KSI:** The American Family Insurance Institute for Corporate and Social Impact has been created on the 8$^{th}$ floor inside the Spark Building in the Cap East District. In tandem with StartingBlock Madison, the Institute will target educational disparities, resilient communities, and economic opportunities for all in American Family's efforts to grow technologies and entrepreneurial opportunities that serve the Madison Region and beyond. This corporate effort should be promoted by both the City of Madison and MadREP.

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 bioscience 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 computer science and math-dominant companies (Filament Games, Widen, Moonshot Learning, Moonstruck Media Production, Understory, Singlewire Software, and Synqronus Communications) 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 and industries in the bioscience 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.

- **KSI:** Promote the FieldDayLab.org to K-12 teachers to accelerate the K-12 talent pipeline. FieldDayLab.org, housed at the Wisconsin Institute for Discovery, explores the intersection of current learning science and media design through mobile media, video games and simulation. The FieldDayLab fosters wonder by creating learning games, virtual reality experiences and citizen science apps. Teachers and subject experts work with FieldDayLab to design fun ways to connect people (and kids) to research. Their mission is to explain big ideas in playful ways, bridging the gap between the university and the public and helping kids learn in creative ways.

- **KSI:** Staff believes that getting bioscience faculty and academic staff off campus, interacting with entrepreneurs, inventors and integrated to the physical spaces with private sector bioscience 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.

**Specific Talent Opportunities of Significance in Bioscience Sector Niches**

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

- *Health IT*: Epic Systems Maintenance experts, EHR App integration technicians and implementers; UW Medical Students trained in precision medicine, and data mining and info cybersecurity;

- *Telehealth / Telemedicine*: Medical Software developers, IT System Management, Software Engineering/Coding, Information and Imaging Technology, and IT Business, Software and Medical professionals;

- *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 bioscience, 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 needs 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, telehealth/ telemedicine, 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 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). A new class of companies will develop to drive innovation and help transition from 4G to 5G. Companies that are already located in the Region, such as MIOsoft, Hardin Design, Bendyworks, Adorable, Widen and Zendesk will be part of this innovation and transition process.

- **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 IoT dependent bioscience 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.[13] 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.

[13] 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.

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 the base standard.[14] 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**. NTIA (National Telecommunications and Information Administration) 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.

[14] *100 Mbps symmetry means 100 Mbps up and download speeds.*

- **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 in order to keep the Madison Region connected in the bioscience sector. 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 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.

**Innovation Districts**

Creating physical neighborhoods for co-locating bioscience firms where anchor institutions and companies cluster and connect with start-ups, business incubators, and accelerators is very important to the competitiveness of the Region. As noted by Katz and Wagner (2014), these innovation districts are "physically compact, transit accessible, and technically wired and offer mixed-use housing, office, and retail." MadREP has received several site searches tied to regional HQ's in the past two years that have focused on identifying these districts or neighborhoods first before seeking more information on existing leasable space.

The three archetypes of Innovation districts in the Region can be largely described as:

1. *Anchor Plus Model* – The Anchor Plus type of innovation districts are largely located in downtowns and mid-towns of central cities and have anchor institutions and a concentration of similar firms, entrepreneurs and start-ups involved in the commercialization of innovation.

    - **KSI:** Efforts need to be enhanced to reinforce Downtown Madison (American Family in the Cap East District and 316 W. Washington), Downtown Mt. Horeb (Duluth Trading and the Innovation Center), Downtown Fitchburg (Promega and BioPharma Tech Center) and similar innovation efforts in other communities throughout the Region.

2. *Re-imagined Urban Area Model* – This type of innovation district is characterized by historic industrial and warehouse districts that are undergoing transformations. Many of these districts are often found near historic waterfronts.

    - **KSI:** Downtown Beloit (Ironworks) is a strong example in Rock County that continues to succeed, grow, and foster more development in the immediate environs. This example needs to be replicated throughout the Region.

3. *Urbanized Science Park Model* – Research and science parks that were traditionally located in suburban or exurban areas are undergoing a mixed-use transformation that increase the density and amenities offered by these innovation centers. Their tenants and the staff they employ are driving this densification.

    - **KSI:** The University Research Park at UW-Madison and UW-Whitewater are pursuing this type of redevelopment and require community and tenant support to accelerate the change.

**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. These changes may be particularly relevant to talent attraction as cost of living is particularly important to new college graduates and cost of living is greatly influenced by housing costs. 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.

If we calculate the median monthly rent as a percentage of median earnings for computer and mathematical occupations, the Madison MSA moves from the 20th least expensive to the 31st least expensive MSA in the country. Calculating monthly owner housing costs as a share of median earnings places the Madison MSA as having the 12th highest (most expensive) among the top 50 (See Appendix 4B).

- **KSI:** The Region should consider whether its advantage in housing costs may be eroding, at least in terms of bioscience talent. MadREP will work with communities throughout the Region to site, fund, and maintain 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.