Transforming Manufacturing in a Digital Economy Workgroup (Making It in Maryland)

FINAL REPORT

Pursuant to Chapters 581 & 582, Acts of 2021
Respectfully submitted to the General Assembly of Maryland by

Delegate Lily Qi, Chair
Transforming Manufacturing in a Digital Economy Workgroup (Making It in Maryland)

December 19, 2022

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- **Suzy Ganz**, Lion Brothers
- **Mike Galiazzo**, Regional Manufacturing Institute
- **Kelly Koermer**, Carroll Community College
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- **Lindsay Ryan**, Interim Executive Director of Economic Development, University System of Maryland
- **Mike Kelleher**, Executive Director, Maryland Manufacturing Extension Partnership
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1.0 Executive Summary

Maryland has a proud history in Manufacturing and is still home to some of the global brands that speak to our competitive advantages and economic strengths, from Under Armour to McCormick, and from Northrop Grumman to AstraZeneca. Despite significant manufacturing job losses due to offshoring and technological advancement over the past half century, manufacturing is coming back. In fact, there has never been a better alignment of market forces and political leadership than now to grow Maryland manufacturing.

The pandemic has made it abundantly clear that beefing up domestic production is not only a market necessity but also a national security imperative. With the Biden administration's focus on "Buy America" and "Make it in America," this is an opportune time to revive Maryland's manufacturing leadership and usher in a new era of modernization that reflects Maryland's rich institutional and human assets. The recently passed Inflation Reduction Act includes approximately $28 billion in new manufacturing investment, and the CHIPS and Science Act provides another $52.7 billion for American semiconductor research, development, manufacturing, and workforce development.

Maryland is well-positioned to capitalize on these opportunities. The state's manufacturing jobs in 2022 are well above pre-pandemic levels and since the pandemic, the recovery in manufacturing jobs has outpaced the overall Maryland economy. Maryland has already seen success in new manufacturing companies and jobs directly associated with pandemic-related domestic production such as Ellume in Frederick County make COVID home test kits, and United Safety Technology in Baltimore County making nitrile gloves.

Manufacturing is a key sector (or industry cluster) of Maryland's economy. Manufacturing accounts for 4.3% of Maryland jobs, but 8% of Maryland economic activity and 62% of Maryland exports. Manufacturing jobs in our state pay an average annual wage of $88,979, well above the State average. Five-year employment grew at 5%, while the overall private sector employment in the state fell.

But compared to the rest of the country, Maryland is punching below our weight in manufacturing capacity. Maryland has a relatively small manufacturing industry, ranking 46th in the proportion of private-sector workers employed in manufacturing. In fact, the state would have twice as many manufacturing workers if manufacturing made up the same proportion of the Maryland economy as it does nationwide. According to data from the Jacob France Institute, Maryland's manufacturing sector has the 8th highest employee compensation and 4th highest productivity. This demonstrates significant room for growth and increasing the size of Maryland's manufacturing sector would be a strong strategy to provide a pathway to the middle class for even more Marylanders.

The manufacturing sector is undergoing a rapid transformation. Increasingly, manufacturers are incorporating advanced technologies, automation, big data, and more interconnected systems into their production processes. These changes, often referred to as Industry 4.0, come with an increased

up-front cost to producers but enable companies to make increasingly complex products more efficiently than ever before.

The Industry 4.0 initiative aligns with Maryland's strategic focus of advanced manufacturing and continues to extend Maryland's rich manufacturing heritage and technological know-how to develop the innovative, high-tech products of the future. An increased investment in advanced manufacturing workforce in the state secures continued opportunity and stability for Maryland's manufacturing workforce for years to come.

In recognition of a rapidly growing global transformation in manufacturing based on Industry 4.0 technologies, Maryland manufacturers advocated for legislation in 2021 to put Maryland on a competitive playing field with other states and countries. The Regional Manufacturing Institute of Maryland, the state's primary advocacy group for Maryland manufacturers, was instrumental in initiating and advocating for the legislation during the 2020 and 2021 legislative sessions. SB444 was introduced by Senator Chris West (R-Baltimore County, MD) and HB658, was introduced by Delegate Lily Qi (D- Montgomery County, MD). These companion bills became law on July 1, 2021. The bills created the "Transforming Manufacturing in a Digital Economy Workgroup (Making It in Maryland)" to address the need for policies and programs to help Maryland manufacturers adopt new Industry 4.0 technologies and to identify skills gaps in emerging advanced tech environments. The Department of Commerce was assigned to staff the workgroup.

Now is the time for the State to step up our support of Maryland manufacturing. Not only has the sector experienced strong recent employment growth, but the national trend of reshoring coupled with the productivity enhancing capabilities of Manufacturing 4.0 have the potential to support a manufacturing renaissance nationally and in Maryland. Providing incentives to manufacturers to invest in advanced production technologies and expanding the pipeline of skilled workers is critical to creating quality jobs, growing Maryland's economy, and expanding the State's tax base.

While there needs to be a comprehensive roadmap for rebuilding manufacturing, this workgroup was tasked with helping Maryland manufacturers ease the transition to the digital economy by derisking the adoption of new technologies. In particular, the workgroup focused on supporting **small and medium enterprises** that make up the vast majority of Maryland manufacturing landscape.

The 24-member workgroup, made of industry, academic, nonprofit and government representatives, started its work since September 2021 and concluded with this report in December 2022. The detailed meeting minutes can be found on our webpage at https://commerce.maryland.gov/commerce/boards-and-commissions. The Jacob France Institute of the University of Maryland Baltimore County was engaged by the workgroup through the Department of Commerce to conduct research and analysis in support of the workgroup.

At the conclusion of the workgroup, members voted on and approved the following recommendations to enable manufacturers to adopt Industry 4.0 technology and to better prepare Maryland workers for the jobs of the future:

1. Establish a special fund of $50,000,000 in FY24 to be used for small and mid-sized (SME) manufacturers to be used for the purchase, implementation and related employee training of industry 4.0 technology. This would include advanced sensors, embedded software, robotics that collect data, ERP and supply chain integration, cloud computing, AI, and the infrastructure needed to implement these solutions.

2. Commit $10,000,000 as seed funding to establish a Manufacturing Innovation Center, with an industry-led partner to be selected by the state to manage and operate the center. As a public-private partnership, the Center would raise additional funds to support the operations. The purpose of the center is to build a national showcase for next-generation manufacturing technology, talent, and transformation. The Center will be a public-private sector digital network and physical Center offering a quick response system that promotes the technological Future of Maryland manufacturing. The Center is a catalyst for forging new systems of success serving manufacturers with an improved system of service.

3. Align manufacturing industry skills needs with statewide curriculum development through the efforts of the CTE Committee and other reforms resulting from the Kirwan legislation. Require the CTE Committee to partner with MD Labor's Division of Workforce Development Adult Learning, RMI, MD MEP, and local workforce boards to analyze existing programs, identify gaps, and make investments in programs to fill those gaps.

4. Pass legislation that would open PEO (professional employer organization) access to any manufacturer under 50 employees. Manufacturers want to offer the best benefits to our employees, but Maryland law currently prohibits manufacturers under 50 employees to get together to offer "large company benefits" to their employees.

5. To further encourage manufacturers to invest in Industry 4.0 technologies and to help enable the free flow of information from factory floor to cloud and other computer systems, amend Sec. 03.06.01.32-2, Section C (1) to include indirect digital product purchases, such as software.

6. Pass legislation to create a Buy Maryland Manufacturing tax credit program – modeled after the Buy Maryland Cyber program, a Buy Maryland Manufacturing Tax Credit would promote the manufacturing industry in Maryland by encouraging other Maryland businesses to purchase products manufactured in Maryland.

7. Encourage local land use and zoning regulations, as well as local incentives, to ensure an adequate inventory of properties for the expansion of existing, and attraction of new manufacturers in the state. State agencies should work with local officials to identify best practices in land use and zoning regulations to meet the needs of today's manufacturing sector.

8. Create a state matching fund to buy-down the costs and improve the ROI to 3-4 years for the purchase of major facility systems such as HVAC systems, electrical switchgear, transformer, industrial logic controllers and similar advanced controls. This fund would be managed by the Maryland Energy Administration and promoted by the Regional Manufacturing Institute (RMI) and Maryland MEP.

9. Establish a program within Maryland Commerce to identify Maryland companies that make products or components that support sustainability and reduce carbon footprints. Identify strategies for developing this emerging sector. Market Maryland as a State that wants to attract Green Manufacturing companies. Research shows that younger workers are attracted to companies that support green initiatives. Promote in schools and colleges careers in Maryland Green Manufacturing companies.

2.0 Introduction

Maryland has a proud history in Manufacturing and is still home to some of the global brands that speak to our competitive advantages and economic strengths, from Under Armour to McCormick, and from Northrop Grumman to AstraZeneca. Despite significant manufacturing job losses due to offshoring and technological advancement over the past half century, manufacturing is coming back. In fact, there has never been a better alignment of market forces and political leadership than now to grow Maryland manufacturing.

Manufacturing is a key sector (or industry cluster) of Maryland's economy. Manufacturing accounts for 4.3% of Maryland jobs, but 8% of Maryland economic activity and 62% of Maryland exports. Manufacturing jobs in our state pay an average annual wage of $88,979, well above the State average, Five-year employment grew at 5% while Maryland's overall private sector employment fell.

But compared to the rest of the country, Maryland is punching below our weight in manufacturing capacity. The state ranks 46th in the proportion of private-sector workers employed in manufacturing. In fact, the state would have twice as many manufacturing workers if manufacturing made up the same proportion of the Maryland economy as it does nationwide. According to data from the Jacob France Institute, Maryland's manufacturing sector has the 8th highest employee compensation and 4th highest productivity. This demonstrates significant room for growth and increasing the size of Maryland's manufacturing sector would be a strong strategy to provide a pathway to the middle class for even more Marylanders.

The manufacturing sector is currently undergoing a rapid transformation. Increasingly, manufacturers are incorporating advanced technologies, automation, big data, and more interconnected systems into their production processes. These changes, often referred to as Industry 4.0, often come with an enormous up-front capital cost to manufacturers but are necessary and critical investments to enable companies to produce increasingly complex products more efficiently. Industry 4.0 aligns with Maryland's strategic focus area of advanced manufacturing and continues to extend Maryland's rich manufacturing heritage and technological know-how to develop the innovative, high-tech products of the future. An increased investment in advanced manufacturing workforce in the state secures continued opportunity and stability for Maryland's manufacturing workforce for years to come.

Not only has the sector experienced strong recent employment growth, but the national trend to reshoring coupled with the productivity enhancing capabilities of Manufacturing 4.0 have the potential to support a manufacturing renaissance nationally and in Maryland. Providing incentives to Maryland manufacturers to invest in Manufacturing 4.0 and related advanced production technologies and investing in expanding the pipeline of skilled workers needed by the industry has the potential to create high quality jobs, grow Maryland's economy, and expand the State's tax base.

CASE STUDIES: The Impact of Industry 4.0

Independent Can

Founded in 1929, Independent Can is a world leader in manufacturing specialty metal packaging and metal lithography. To stay globally competitive, the company commissioned a new 9-color metal printing line at their Belcamp facility in 2022. This line cost over $13 million and is the first of its kind in the Western Hemisphere.

Unfortunately, because this investment will not add any net new jobs, and did not require additional land or space, none of the programs that the State of Maryland currently offers for supporting business investment were applicable. Recently, the company had to make another significant investment of a similar amount to double the current production capacity and compete against lower-cost producers in Asia.

For companies like Independent Can to thrive here, Maryland needs to support manufacturers who not only add jobs by moving to the State or expanding their jobs base, but also those who protect jobs by staying in Maryland and investing in the technologies necessary to compete in the 21st-century economy. Not all high-tech investments lead to direct or proportional job growth, but the increased productivity means additional tax revenues for the state and higher-wage jobs for workers.

Marlin Steel Wire Products

Founded in 1968, Marlin Steel Wire Products specializes in making custom metal forms, including stainless steel parts, washing baskets, racks, S-hooks and sheet metal material handling containers. Aerospace companies had been Marlin's largest customer base, but COVID-19 changed all that when travel was halted.

Then Marlin received an unexpected purchase order to make test tube racks for the Centers for Disease Control. The request came on a Friday after hours and was due before the research lab's opening on Monday. Thanks to the variety of advanced technologies Marlin had adopted, the company's employees were able to work over the weekend to fulfill the order on time. Over the last five years, Marlin has invested more than $6,000,000 in Industry 4.0 technology arsenal, including laser cutters, medium frequency welders, CNC machines, and robotics.

The investment allowed Marlin to pivot and meet immediate and urgent demands by expanding factory space by 56% and hiring more workers. But at the same time, the company also took on tremendous upfront risks for such technology adoptions.

CASE STUDIES: The Impact of Industry 4.0

Lion Brothers
Founded in 1899, Lion Brothers is a woman-owned business that has been a leading designer and manufacturer of apparel brand identity systems. Its products include NASA's insignia for astronauts' uniforms, as featured in the Maryland Public Television's series on Maryland manufacturing.

The apparel industry has been hit hard by the decades-long offshoring of production to lower-cost countries. At the same time, technologies in apparel manufacturing have also advanced dramatically over the years. By modernizing its production lines, Lion Brothers transformed itself from a domestic producer of embroidered identification and embellishments into a global partner of choice in apparel customization for leading global brands in sports, lifestyle, fashion and workwear.

Recently, Lion Brothers invested $4,800,000 in advanced printing, coating, lamination and laser technologies to optimize the production platform for manufacturing apparel embellishments on-demand in the U.S. While the company expects a long-term return on this investment, the upfront cost required is significant and risky for a mid-sized manufacturer to compete with lower-cost global competitors.

Fabpro Technologies
Fabpro Technologies is a minority-owned precision manufacturer producing complex components for clients in Aerospace, Defense, and Cybersecurity. Due to the reshoring of manufacturing and the growth of the industries they serve, the company has experienced a major increase in client demand and made significant technology investments to meet the demand.

In 2022 Fabpro Technologies acquired its most extensive equipment, onboarding a fiberoptic laser to increase cutting capacity while incorporating Industry 4.0 technology. The approximately $400,000 laser project increased cutting capacity by approximately 10-fold and allowed the company to diversify the types of materials it can process.

As the above cases show, updating technologies is a necessary but risky proposition for manufacturing industries. Despite the expected long-term returns on investments, such significant upfront capital costs can be a barrier for many small and mid-sized companies. The State's investments in technology adoption would be critical to easing the burdens of modernization and ensuring the future competitiveness of our manufacturing economy.

In recognition of a rapidly growing global transformation in manufacturing based on Industry 4.0 technologies, Maryland manufacturers advocated for legislation in 2021 to put Maryland on a competitive playing field with other states and countries. The Regional Manufacturing Institute of Maryland was instrumental in initiating and advocating for the legislation during the 2020 and 2021 legislative sessions. SB444 was introduced by Senator Chris West (R-Baltimore County, MD) and HB658, was introduced by Delegate Lily Qi (D- Montgomery County, MD). These companion bills became law on July 1, 2021. The bills created the "Transforming Manufacturing in a Digital Economy Workgroup (Making It in Maryland)" to address the need for policies and programs to help Maryland manufacturers adopt new Industry 4.0 technologies and to identify skills gaps in emerging advanced tech environments. The Department of Commerce was assigned to staff the workgroup. The bill tasked the Workgroup with the following:

1. Identify the new and emerging digital technologies that are shaping the work of the future, the education and skills needed, and the viable strategies for businesses to adopt these technologies;
2. Examine the research conducted by the Massachusetts Institute of Technology (MIT) on the relationships between emerging technologies and the workforce to enable a future of shared prosperity, entitled "The Work of the Future: Shaping Technology & Institutions", MIT Work of the Future, Fall 2019 Report;
3. Examine existing financial resources available to manufacturers seeking to invest in Industry 4.0 technology.
4. Make recommendations to facilitate the State's robust entry into Industry 4.0 technology to improve the perception of manufacturing careers, including:
    a. promoting the technological advancements of Industry 4.0 to shift the perception of manufacturing careers for the entry–level workforce; and
    b. creating and advancing public–private partnerships between manufacturers, supportive community stakeholders, and education systems;
5. Examine new and viable tax credits and programs for manufacturers to be more competitive and marketable in the new digital economy;
6. Examine the State's current statutory and regulatory authority over manufacturing to examine potential reforms to attract new manufacturing businesses brought by Industry 4.0 to invest in the State's economy and workforce;
7. Recommend additional financial support delivery mechanisms, as needed, to enable State manufacturers to adopt Industry 4.0 technology and enhance the ability of industry service providers to increase the scope of their industry support;
8. Propose annual State funding to create a statewide training program to address the growing skills gap in the manufacturing workforce; and
9. Develop recommendations for long–term private–public partnerships between educational institutions and manufacturers to develop curriculums that address the rapidly changing needs of the manufacturing industry.

The Department of Commerce contracted with the Jacob France Institute (JFI) to provide data analysis consistent with the workgroup's goals. JFI presented on key findings of their analysis during

workgroup meetings and a report detailing their research is attached to this report in Appendix B. The workgroup met a total of 14 times between September 2021 and November 2022; all meeting minutes are available to the public at https://commerce.maryland.gov/commerce/transforming-manufacturing-workgroup.

The remainder of this report is laid out as follows:

- Section 3 - overview of Industry 4.0 and the current state of Maryland manufacturing
- Section 4 - findings from JFI on how Maryland's statutory, regulatory, and financial frameworks impact Maryland manufacturers
- Section 5 - analysis of best practices from other states as reported by JFI
- Section 6 - recommendations from the workgroup
- Section 7 - conclusions

3.0 The State of Maryland Manufacturing and Industry 4.0

Manufacturing is currently undergoing a rapid transformation worldwide. Increasingly, manufacturers are incorporating advanced technologies, automation, big data, and more interconnected systems into their production processes. These changes, often referred to as Industry 4.0, come with an increased up-front cost to producers but enable companies to make increasingly complex products more efficiently than ever before.

3.1 Industry 4.0 and the Work of the Future

A fall 2019 report entitled 'The Work of the Future: Shaping Technology and Institutions' produced by the Massachusetts Institute of Technology (MIT) Task Force on the Work of the Future contains an excellent overview of the trends leading to Industry 4.0.[1] The MIT task force's report notes that "demographic trends point towards rising labor scarcity in the decades ahead." The report notes that labor force growth has slowed in the United States and other industrialized countries due to a combination of declining fertility and restrictive immigration policies. The report notes that the task force anticipates "that in the next two decades industrialized countries will have more job openings than workers to fill them, and that robotics and automation will play an increasingly crucial role in closing these gaps."

[1] Available at the following link: https://workofthefuture.mit.edu/wp-content/uploads/2020/08/WorkoftheFuture_Report_Shaping_Technology_and_Institutions.pdf.

The MIT report stresses that one challenge with a continued shift towards automation and increased technology is that, while firms may need fewer workers than before, the workers who remain will need to be highly skilled. This poses significant challenges for workers with less education and job training who may be left behind by technological progress. The report highlights community colleges as playing a central role in training workers for the work of the future "given their scale, their ability to adapt offerings to local market news, and their ongoing engagement with non-baccalaureate adults at all career stages."

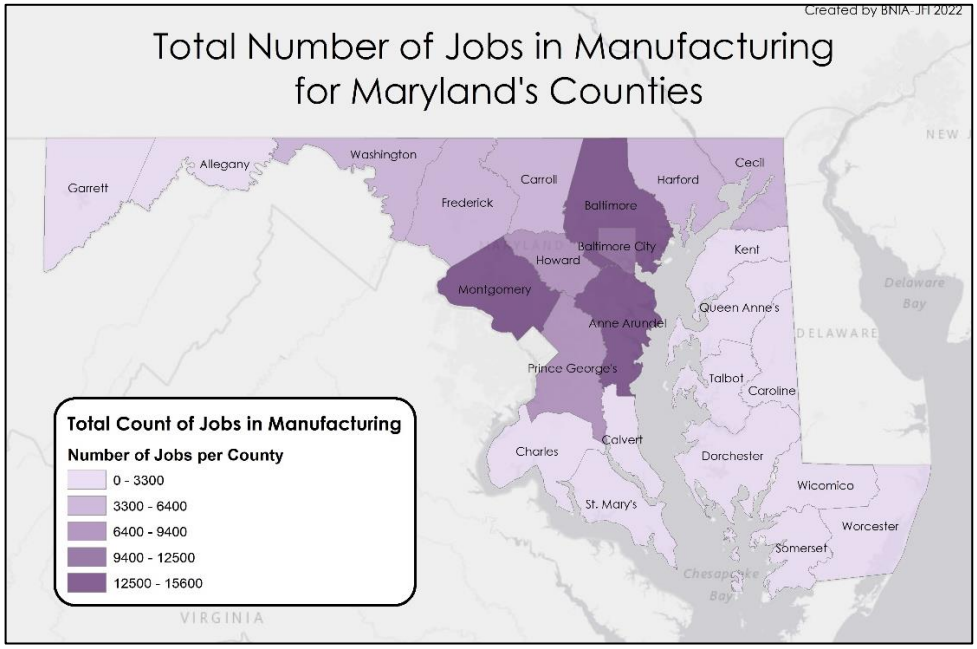
A new emphasis on technology and computing within manufacturing has the potential to benefit Maryland's manufacturing sector. Maryland currently has a strong advanced technology workforce. According to the Bureau of Labor Statistics, Maryland currently has the second highest proportion of STEM workers of all 50 states. A continued focus on integrating technologies such as AI, robotics, and advanced analytics into manufacturing means Maryland is well positioned for the work of the future. However, research presented to the workgroup indicates that Maryland must proactively take action to allow manufacturers in the state to benefit from this shift in the industry.

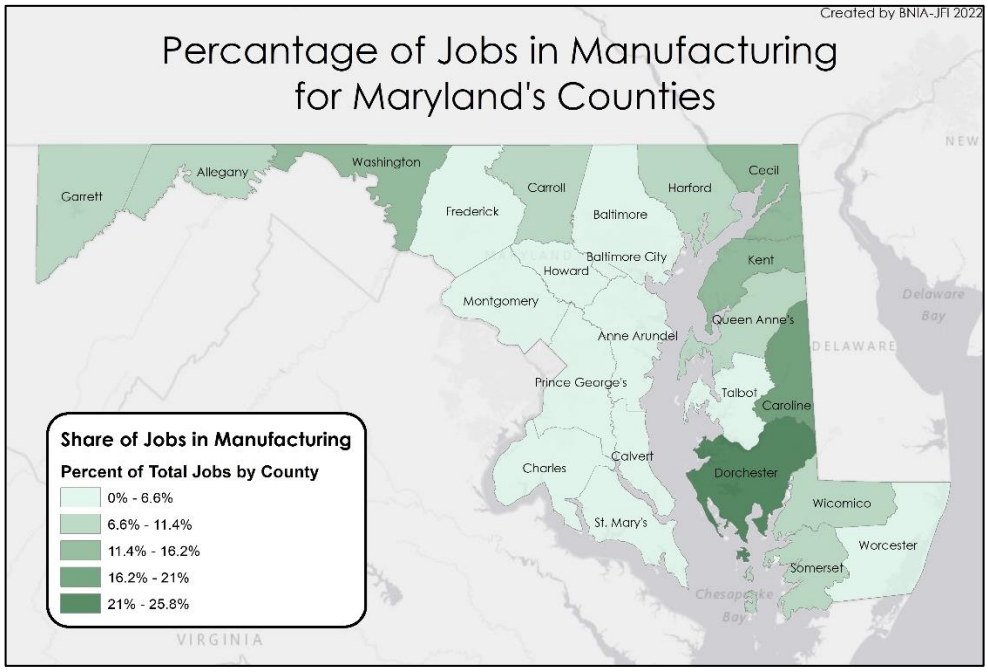
3.2 The State of Maryland Manufacturing

Manufacturing is a driver of the state's economy. According to data from JFI presented to the workgroup (and available in more detail in Appendix B), Manufacturing employed 108,691 Maryland workers in 2021. Between 2016 and 2021 the industry grew at a 5% growth rate, well above the statewide growth rate of negative 2%. However, data from JFI also places Maryland's manufacturing in a national context. Maryland's manufacturing sector has a location quotient of 0.48, indicating that Maryland has roughly half as many manufacturing workers as it would if it followed national employment patterns.

Figure 1, sourced from JFI's report in Appendix A, highlights how manufacturing employment varies across Maryland based on data from the Bureau of Labor Statistics. Central Maryland is home to a significant density of manufacturing employment in the State. However, in Rural Maryland, manufacturing accounts for a significant proportion of overall jobs in those communities. Manufacturing is an important driver of job opportunities in community in Maryland, and investment in strengthen this sector benefits residents from Western Maryland to the Eastern Shore.

Figure 1: Manufacturing Jobs by Maryland Counties

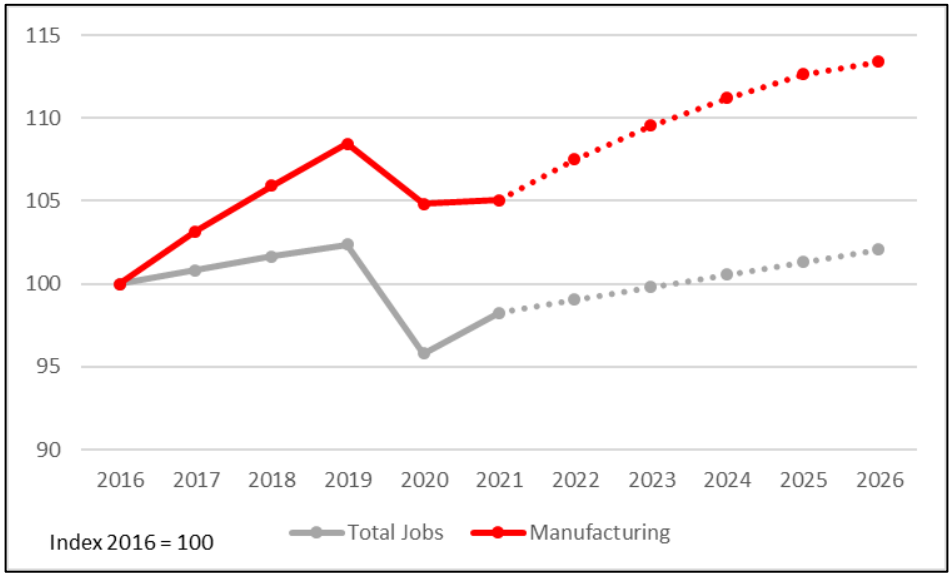




Source: Jacob France Institute

As noted earlier, Maryland's manufacturing sector has outpaced total job growth in Maryland over the past five years. As the graph below, from JFI's report in Appendix A, shows, manufacturing growth outperformed total employment growth in the state between 2016 and 2019 and fell less steeply during the pandemic. Over the next five years, the sector is also forecasted, by LightCast (formerly EMSI), to grow faster than the Maryland economy.

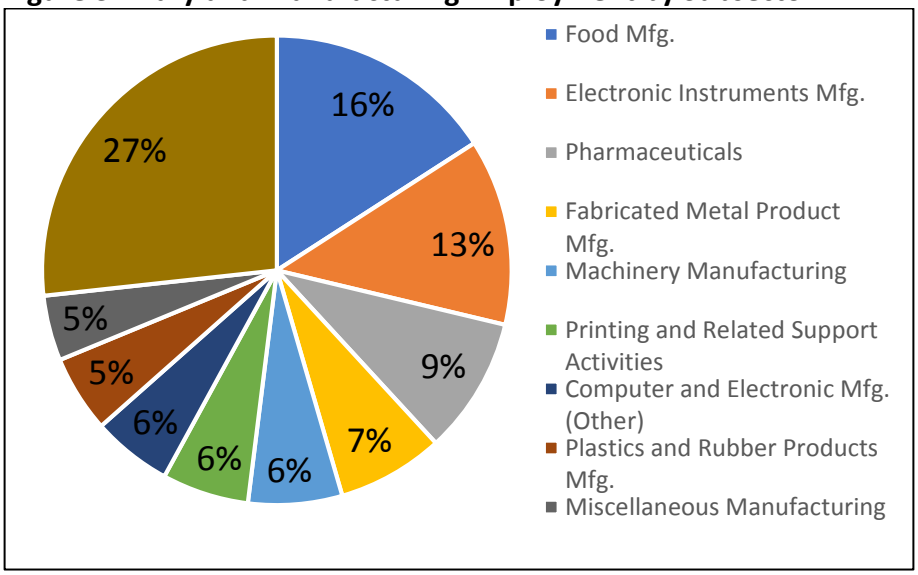
Figure 2: Employment and Manufacturing Sector Growth



Source: Jacob France Institute

JFI analyzed Maryland's manufacturing industry by subsector to identify where Maryland is most specialized and which areas are growing the most. JFI measured specialization using a location quotient. As discussed previously, a location quotient measures the level of concentration of an industry in an area relative to national employment patterns. A location quotient of 2, for example, indicates that there are twice as many workers in the industry as would be expected given national employment patterns. A more detailed breakout of JFI's findings is presented in Appendix A of this report.

Figure 3: Maryland Manufacturing Employment by Subsector



Source: Jacob France Institute

According to JFI's research, seven manufacturing subsectors had location quotients greater than 1.25 as of 2020, indicating 25% more employment in the state than expected given national patterns. As displayed below, three of these sectors, which currently employ nearly 29,000 workers, are projected to grow by nearly 20% or more through 2030.

Figure 4: Key High-Growth Manufacturing Subsectors in Maryland, 2020 – 2030

Subsector	Location Quotient	Establishments, 2020	Employment, 2020	Percent Growth, 2020 - 2030
Navigational, Measuring, Electromedical, and Control Instruments Manufacturing	1.88	258	14,155	19%
Pharmaceutical and Medicine Manufacturing	1.69	138	9,593	25%
Other Food Manufacturing	1.27	97	5,208	42%

Source: Jacob France Institute

The Navigation, Measuring, Electromedical, and Control Instruments Manufacturing subsector employs the most workers of any Maryland subsector and has grown by 22% over the past five years. Over the next ten years, JFI data projects the sector will continue to grow by 19%. Similarly strong is the Pharmaceutical and Medicine Manufacturing subsector which grew by 40% over the past five years and employed nearly 10,000 workers in 2020. Capitalizing on these and other growing manufacturing sectors has the potential to significantly boost employment moving forward.

For example, another opportunity for Maryland lies in **clean energy manufacturing**. In 2022, the **Climate Solutions Now Act** was passed by the General Assembly. The bill mandates a 60% reduction in greenhouse gas emissions by 2030 and net zero emissions by 2045. This bill, along with other discussed changes to Maryland's Renewable Portfolio Standards, will lead to a significant increase in the demand for new wind and solar capacity in Maryland. Much of this capacity does not have to be built in Maryland and can be delivered to the state from anywhere in the broader PJM Interconnection (the electricity market covering Maryland). However, if the state moves to develop wind and solar manufacturing capacity, it is likely to gain first mover benefits and can become a hub for green energy manufacturing.

Maryland has led the nation in reducing greenhouse gas emissions. Based on the most recent data from the US Energy Information Administration, Maryland has had the steepest drop in energy-related CO2 emissions between 2005 and 2020.[2] While Maryland leads the pack, more states are moving to decarbonize their electric markets. If Maryland can develop a robust network of manufacturers supporting wind and solar projects, the state stands to gain from decarbonization efforts in neighboring states as developers will source from Maryland businesses rather than focus on creating manufacturing ecosystems from scratch.

[2] Energy-related emissions by year and by state available in Table 1 at the following link: https://www.eia.gov/environment/emissions/state/

The start of this strategy can be seen in the recent announcement of US Wind locating in the Tradepoint Atlantic site in Baltimore County. The new facility will employ up to 550 workers and produce up to 100 monopiles (wind turbine foundations) each year starting in 2024. With the attraction of US Wind's facility to Maryland, the state can now develop a network of suppliers and similar manufacturers drawn to the state for access to experienced labor and key producers. As Maryland considers the future of manufacturing, supporting growing industries where Maryland already has a competitive advantage, like green energy or pharmaceuticals, is one key to expanding the industry and securing more high-paying jobs.

But growth also comes with worker shortages. Currently, one of the major challenges manufacturers face in Maryland is finding workers to fill open positions at current salary levels. According to data from the Maryland Workforce Exchange, the manufacturing industry has the third highest number of job openings of any sector of the state economy. In August 2022, there were just over 14,000 job openings in Maryland for manufacturing, roughly 8% of all job openings in the state.

Figure 5: Maryland Job Openings, August 24, 2022 (Maryland Workforce Exchange)

Industry	Job Openings	% of Total
Total Postings	**175,004**	**100%**
Health Care and Social Assistance	35,284	20%
Professional, Scientific, and Technical Services	27,397	16%
***Manufacturing**	14,052	8%
Retail Trade	10,156	6%
Educational Services	9,796	6%
Accommodation and Food Services	6,224	4%
Administrative and Support and Waste Management	4,425	3%
Wholesale Trade	3,138	2%
Other Services (except Public Administration)	2,757	2%
Finance and Insurance	2,603	1%
Construction	2,448	1%
Public Administration	2,396	1%
Information	1,990	1%
Transportation and Warehousing	1,544	1%
Real Estate and Rental and Leasing	1,390	1%
Arts, Entertainment, and Recreation	1,153	1%
Management of Companies and Enterprises	369	0%
Utilities	269	0%
Agriculture, Forestry, Fishing and Hunting	187	0%
Government	132	0%
Mining, Quarrying, and Oil and Gas Extraction	111	0%
Local Government, Exc. Education & Hosp.	10	0%
Unclassified establishments	47,173	27%

Source: Jacob France Institute analysis of MDOL Maryland Workforce Exchange Data

3.3 Industry 4.0 and Maryland Manufacturing

According to data presented to the workgroup by JFI, Maryland manufacturing already requires a highly skilled workforce and one that is ready for Industry 4.0. JFI analyzed job posting data for open manufacturing positions in Maryland and found that pharmaceuticals and computer science were the top two most requested skills. Systems engineering was the fifth most requested skill and other skills requested almost as much included data analysis, automation, Python, and software engineering. This is not to say that traditional manufacturing does not make up a large portion of Maryland's current workforce. Of the nearly 109,000 workers JFI reported working in the sector in 2021, just over 50,000 (46%) work in either production occupations or transportation and material moving occupations. Similarly, in a recently completed report published by the Maryland Manufacturing Extension Partnership, roughly 80% of the manufacturing workforce does not work in an occupation which potentially enables Industry 4.0.[3]

However, Maryland's manufacturing sector is quickly making the transition to Industry 4.0. According to data from JFI, the manufacturing sector's growth over the last five years has been driven almost entirely by growth in technology-intensive occupations which require higher levels of education. Additionally, the report published by the Maryland Manufacturing Extension Partnership estimates that Industry 4.0 'enabling' occupations are a higher proportion of Maryland's manufacturing workforce than nationally (21% in Maryland compared to 13% nationwide).

Maryland's future manufacturing workforce will likely continue to shift toward Industry 4.0 occupations. JFI analyzed forecasted employment growth from LightCast and found that many of the manufacturing occupations with the highest forecasted growth included those in technology-intensive occupations. For example, between 2021 and 2031, industrial engineers and software developers are expected to add the third- and fourth-most new jobs. JFI's analysis also found a resurgence in middle-skill production jobs predicted over the next ten years. As Industry 4.0 enables more reshoring of manufacturing jobs and a stronger national sector, workers who do not work explicitly in Industry 4.0 occupations will also benefit. This is one of the reasons Maryland should move proactively to ensure the manufacturing industry is prepared for the work of the future: a strong technology-intensive workforce creates jobs for workers in traditional manufacturing roles as well.

4.0 State Statutory, Regulatory, and Financial Impacts on Manufacturing

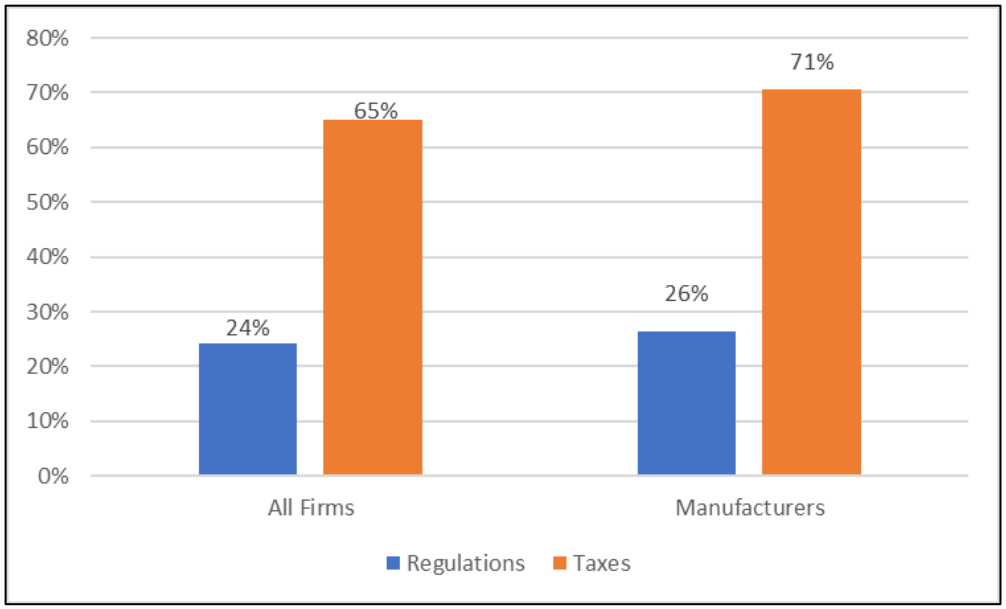
The workgroup spent several sessions examining the state's statutory, regulatory, and financial impacts on manufacturing and the implications of these impacts on Industry 4.0 adoption. This section outlines key findings from those meetings and more complete information is located in the report from JFI located in Appendix B of this report.

[3] Report may be accessed at: https://mdmep.org/wp-content/uploads/2022/09/Maryland-MEP-Industry-4-Strategic-Plan.pdf

4.1 Impact of Regulations and Taxes on Maryland Manufacturers

Businesses are not stationary and can relocate from Maryland to states with more favorable business climates. Likewise, if Maryland's business climate improves then the state will have an easier time attracting companies and building a strong workforce. After a strong local workforce, some of the top concerns businesses have center around regulations and taxes. JFI reported to the workgroup on data from a business climate survey they conducted in 2019. This data, as illustrated in Figure 6 below, shows that Maryland businesses are more adversely impacted by taxes than by regulations. While 65% of surveyed businesses reported being adversely impacted by taxes, only 24% of respondents reported being negatively impacted by regulations. Maryland manufacturers reported being slightly more negatively impacted by both taxes and regulations than businesses as a whole, but these differences are minor.

Figure 6: 2019 Maryland Business Climate Survey – Percentage of All Firms and Manufacturing Firms Reporting They are Negatively Impacted by Regulations and Taxes



Source: Jacob France Institute

In the 2019 business climate survey, JFI asked Maryland businesses which regulations and taxes they found most burdensome. In general, manufacturers did not name a specific regulation that was most burdensome, indicating instead that the combination of all regulations was burdensome. While 41% of manufacturers replied that 'all regulations' were most burdensome, 21% indicated that 'tax regulations' were most burdensome. This is consistent with the data from Figure 6 which shows Maryland manufacturers care more about taxes than regulations. As reported in Figure 7, manufacturers reported that taxes in general were too high, rather than naming a specific tax. However, the proportion of manufacturers who reported that all taxes were too high (47%) is not appreciably different from the proportion of all businesses who selected this answer (46%).

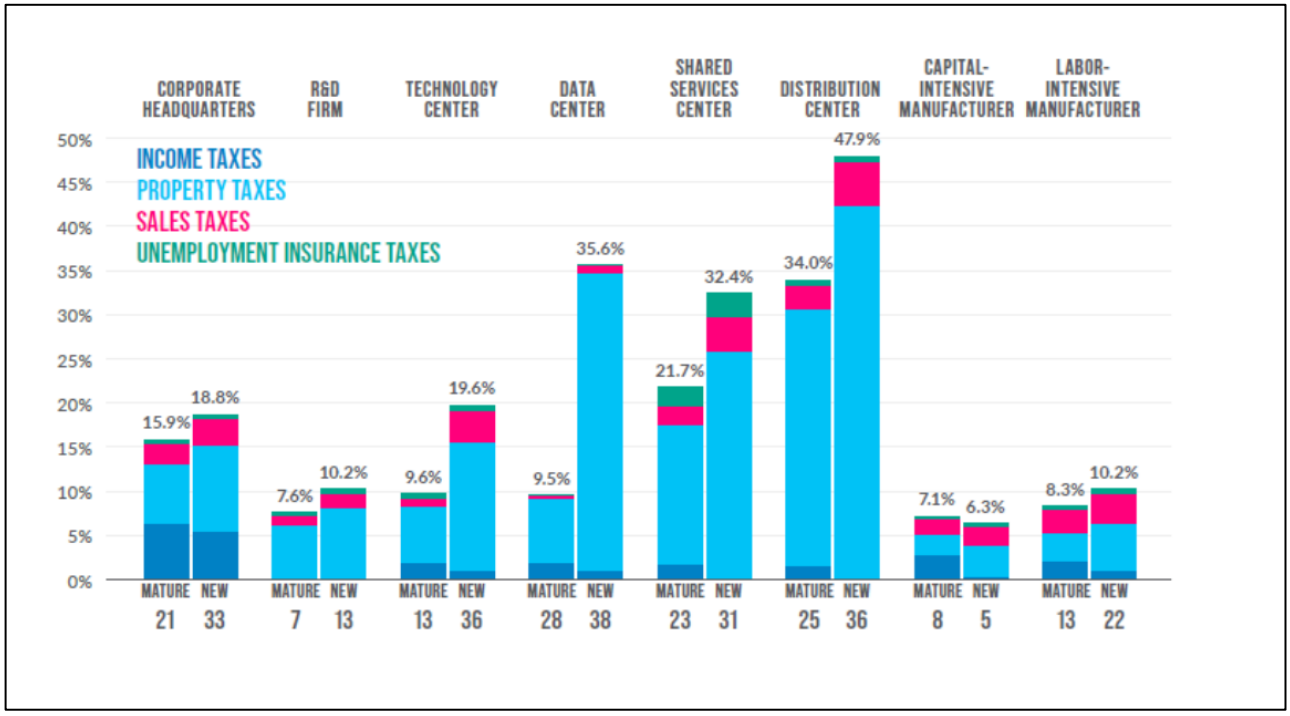
Figure 7: Most Burdensome Regulation and Tax

Which Regulation?	All Firms	Manufacturers
Environmental Regulations	9%	5%
Labor Regulations	17%	3%
Health Care Regulations or Medical Coverage	8%	8%
Problems with dealing with Regulatory Agencies	5%	3%
Tax Regulations	15%	21%
Occupational Safety (MOSH, OSHA)	1%	0%
Building Permits	5%	8%
General or Other Regulations	12%	13%
All Regulations	29%	41%
Which Tax?	**All Firms**	**Manufacturers**
Income Taxes	20%	14%
Payroll Taxes	16%	17%
Sales or Use Taxes	6%	7%
Property Taxes	12%	15%
Taxes in General	46%	47%

Source: JFI/MPPI Business Climate Survey

It is well known that Maryland has a higher tax burden than many other states and this data point is often reflected in the state's rankings for the cost of doing business. However, as Figure 8 shows, Maryland manufacturers pay a much lower effective cost than many other firms in the state. According to estimates from the Tax Foundation, a mature capital-intensive manufacturer generally pays an effective tax rate of 7.1% (8th best rate in the country) and a mature labor-intensive manufacturer generally pays an effective tax rate of 8.3% (13th best rate in the country). These tax rates are much higher than for other types of businesses. For example, an average mature corporate headquarters in the state pays an effective tax rate of 15.9%, roughly double the rate for manufacturers. While this effective tax burden may be lower, it does not mean that all manufacturers benefit from tax breaks equally or are aware of assistance they may qualify for to offset taxes and other costs. Many of the tax offsets and other relief require the manufacturer to be aware of the benefit and either apply for a program or appropriately claim the tax exemption on their tax returns.

Figure 8: Effective Maryland State Tax Rates and National Rankings by Type of Firm



Source: Jacob France Institute Report; Tax Foundation - Location Matters 2021 The State Tax Costs of Doing Business

4.2 State Financial Assistance to Manufacturers

As part of JFI's research, the team analyzed data on manufacturers' awareness of and usage of existing financial assistance programs. JFI's analysis of a 2021 survey of Maryland manufacturers conducted by the Maryland Department of Commerce found that Maryland manufacturers generally had limited awareness of existing programs. The program manufacturers reported being most aware of was the Job Creation Tax Credit (JCTC); however, only 28% of respondents reported being aware of this. Only 10% of respondents were aware of the new More Jobs for Marylanders program which explicitly targets manufacturers. Advantage Maryland (MEDAAF) and Maryland Industrial Development Financing Authority (MIDFA) had the lowest levels of reported awareness (5% and 4% respectively).

However, although manufacturers have low awareness of the types of assistance that are available, manufacturers are utilizing existing state programs. JFI analyzed recipients of assistance from the Maryland Department of Commerce and the Maryland Department of Labor and found that manufacturers account for a more than representative share of the firms utilizing the programs. An overview of how manufacturers have utilized a number of selected state programs is presented in Figure 9.

Figure 9: Manufacturing Utilization of Selected State Programs

Loans and Grants	Department	Notes
Advantage Maryland	Commerce	89 Recipients – 34 Manufacturers
Maryland Industrial Development Financing Authority	Commerce	8 Recipients – 1 Manufacturer
ExportMD	Commerce	199 Recipients – 47 Manufacturers
Maryland Defense Cybersecurity Assistance Program	Commerce	
Supply Chain Resiliency Program	Commerce	
Tax Credits/Exemptions	**Department**	**Notes**
More Jobs for Marylanders Tax	Commerce	29 Recipients – 29 Manufacturers
Job Creation Tax Credit	Commerce	81 Recipients – 23 Manufacturers
R&D Tax Credit	Commerce	1,892 Recipients – 599 Manufacturers
Workforce Training	**Department**	**Notes**
Partnership for Workforce Quality (PWQ)	Commerce	97 Recipients – 63 Manufacturers 2,493 Trainees – 1,336 in Manufacturers
Maryland Business Works	Labor	$500k – 4 Programs
EARN	Labor	64 Active SIPs – 9 Manufacturing Specific and 3 in Biotechnology and 17 in Cyber/IT 4,761 Participants – 1,979 Credentials Awarded – 2,843 Gained Skills
Maryland Apprenticeship and Training Program		
Registered Apprenticeship Programs	Labor	258 Programs – 27 Manufacturing Specific 102 Manufacturers
Youth Apprenticeship Programs	Labor	260 Employers – 34 Manufacturers

Source: JFI Analysis of MD Commerce and MD Labor Data

4.3 State Resources Around Industry 4.0

Over the course of the workgroup's meetings, the Maryland Department of Commerce presented twice on a new program at the Department – the Maryland Manufacturing 4.0 Grant Program. This program, which was open for applications in the fall of 2022, provides matching grants to small and mid-sized Maryland manufacturers to invest in Industry 4.0-related technology, machinery and robotics, and digital business practices. The program currently has a total budget of $1 million. Grants through the program match 50% of project costs up to a maximum of $50,000. To qualify for a grant a business must meet a number of requirements, including:

- Be an existing manufacturer in good standing with the State of Maryland;
- Have between 3 and 150 total full-time employees;

- Have minimum annual revenue of $1 million;
- Have been established for a minimum of three years;
- Demonstrate an ability to successfully implement the proposed project;
- Demonstrate an overall commitment to, or strategy for, Industry 4.0 adoption; and
- Demonstrate ability to provide matching funds.

This program is currently the only program solely dedicated to providing assistance around Industry 4.0 and the $1 million budget does not even begin the address the enormous needs and challenges of Maryland manufacturers in technology adoption. Since the program's inception, 56 companies have applied for the grants, speaking to the enormous pent-up demand for such investments from the state.

However, JFI presented on several other programs within Maryland which provide technical assistance to manufacturers, including around Industry 4.0 adoption. One program is the Maryland Manufacturing Extension Partnership (Maryland MEP), which is a nonprofit organization funded by industry and the State of Maryland. Maryland MEP mostly serves manufacturers with fewer than 500 employees and provides a number of services, including strategic assessment, training and leadership development, ISO certification assistance, Enterprise Resource Planning (ERP) implementation, and supply chain assessment. One of Maryland MEP's focus areas is technology and cybersecurity, and Maryland MEP works with businesses to incorporate advanced technologies such as robotics and automation. Maryland MEP also recently published a strategic plan around statewide Industry 4.0 adoption. Another organization dedicated to assisting manufacturers as they adopt new technologies is the Fraunhofer USA Center Mid-Atlantic (CMA). The Fraunhofer CMA, based in Riverdale, serves manufacturers (and other businesses in the state) by researching and providing solutions to companies' existing software problems. Further detail on these and other programs is available in JFI's report in Appendix B.

5.0 Best Practices

In their report and presentations to the workgroup, JFI explored how other states were supporting manufacturing and Industry 4.0 efforts in order to guide recommendation development. Broadly, JFI categorized statewide best practices to support Manufacturing 4.0 as spanning three areas:

1. Planning
2. Financial support
3. Technology test beds

The sections below summarize JFI's key findings and more detail on each best practice area is available in Appendix B.

5.1 Planning Best Practices

States that take the time to engage with industry, understand existing assets, determine skills gaps and training needs, and identify clear pathways for companies to adopt Industry 4.0 will have better results than states that do not. Maryland has taken the first steps towards successful statewide planning efforts through this workgroup and also through the recent report commissioned by the Maryland Manufacturing Extension Partnership as highlighted earlier in the report. JFI identified two states (Connecticut and Iowa) whose planning efforts Maryland can look to as the state continues to find ways to encourage Industry 4.0 adoption.

In Connecticut, legislative action established the Manufacturing Technology Working Group in 2021 similar to Maryland's workgroup. This group has the express goal of designing a strategic plan (due in the fall of 2022) to ensure manufacturers can successfully integrate Industry 4.0 technology into their production processes. To arrive at this goal, the working group is cataloguing all organizations and services that may help small and mid-size manufacturers adopt Industry 4.0 technology. The working group is made up of representatives from industry, higher education, and service providers.

In Iowa, the Iowa Innovation Council (IIC) established the Manufacturing 4.0 Study and Programming effort. The IIC is made up of business leaders and higher education representatives. The state's strategic plan was released in January 2021.[4]

Maryland has taken the first steps in statewide planning through the establishment of this workgroup. The lessons for Maryland are to build off current efforts with additional stakeholder engagement and that the most successful efforts are led by and driven by industry with the state helping to convene stakeholders.

5.2 Financial Support Best Practices

After states have evaluated the assets available to local manufacturers and laid out pathways for technology adoption, providing financial support to manufacturers helps overcome one of the most difficult challenges for businesses – the cost. Technology adoption is expensive and many small and mid-size companies are not able to afford the upfront costs. Helping manufacturers adopt these new technologies benefits states because it ensures manufacturers are healthier and better able to compete in a global marketplace. JFI summarized the financial support best practices from four states (Connecticut, Massachusetts, Indiana, and Iowa) and a high-level overview of those funding programs is available in Figure 10. Additional detail on each program is available in JFI's report in Appendix B.

[4] The plan may be accessed at: https://www.iowamfg.com/UserDocs/pages/IAMfg4_0_Plan.pdf

Figure 10: Selected State Programs to Support Manufacturing 4.0 Adoption

State	Program	Part of a Larger Manufacturing Center	Most Recent Year's Program Funding	Project Funding	Required Linkages
CT	Industry 4.0 IoT Integration Voucher Program (IVP)	Connecticut Center for Advanced Technology	$900k	$20,000	None
	Manufacturing Innovation Fund Voucher Program (MVP)		$5 Mil. $3 Mil. More in 2022	$49,000	
	Additive Manufacturing Adoption Program		$600K	$100,000	
MA	Massachusetts Manufacturing Accelerate Program (MMAP)	Massachusetts Center for Advanced Manufacturing	$2 Mil.	$250,000	MEP/ Higher Ed.
	Mass. Manufacturing Innovation Initiative (M2I2)		$100 Mil. Invested 6 Years ago - $80 Mil. Spent	No Cap	University
IN	Manufacturing Readiness Grant	Conexus Indiana	$4 Mil.	$200,000	
IA	Manufacturing Innovation Equipment Grants	No - Part of Iowa Economic Development Authority - Long Term Plan to Develop a Center	$5 Mil.	$50,000	MEP
	Manufacturing Industrial Internet of Things (IIoT) Infrastructure Investment Grants			$25,000	

Source: JFI Analysis

In reviewing these four states' funding practices, JFI noted that successful Industry 4.0 investment programs have five key traits:

1. They are based on existing long-term plans to support the manufacturing sector;
2. They provide stable funding across multiple years;
3. They are linked to other industry-led efforts;
4. They are targeted to small and mid-size manufacturers; and
5. Several are linked to Manufacturing Extension Partnership (MEP) technical assistance efforts.

5.3 Technology Test Bed Best Practices

A third best practice identified by JFI in their review of state efforts to foster Industry 4.0 adoption is to create a dedicated demonstration, testing, and training facility. This facility can be used by companies to test equipment and get examples of successful technology integration; it can also be used as a training facility for students to become acquainted with state of the art technology.

Workgroup members virtually toured such a demonstration facility in March 2022: Stanly Black and Decker's Manufactory located in Hartford, Connecticut. JFI identified similar projects in Oregon (the Factory of Tomorrow) and Virginia (GENEDGE Alliance Mobile Technology Insertion Program). While state funding can help support a technology test bed, industry-led efforts maximize these programs' effectiveness.

6.0 Recommendations

The Transforming Manufacturing in a Digital Economy Workgroup met several times in the summer and fall of 2022 to develop recommendations for the final report. This section focuses on the recommendations developed by the Workgroup in response to the tasks outlined in the legislation.

Financial and technical support to assist manufacturers with the adoption of Industry 4.0 technology (Tasks 5 and 7) – Significant barriers to the adoption of technology are the initial risk associated with such adoption, the costs associated with these technologies, and the delayed return on investment that creates short-term strain on resources. Financial assistance is critical to reduce risk and accelerate adoption of these technologies to ensure a more competitive and advanced manufacturing sector.

1. Establish a special fund of $50,000,000 in FY24 to be used for small and mid-sized (SME) manufacturers to be used for the purchase, implementation and related employee training of industry 4.0 technology. This would include advanced sensors, embedded software, robotics that collect data, ERP and supply chain integration, cloud computing, AI, and the infrastructure needed to implement these solutions.

   The funds would be available as grants between $25,000 to $500,000, and the manufacturer will be required to match the grant on a sliding scale based on size (see below). The applications would be evaluated based upon criteria such as alignment with adoption of Industry 4.0 technologies; a demonstrated overall commitment to, or strategy for, Industry 4.0 adoption; and a demonstrated positive impact of the Industry 4.0 technology on the business operations and competitiveness of the company. To be eligible, the business must be a manufacturing company (NAICS 31-33) that is in good standing with the state, has business operations in MD, and has been in existence for over one year. Preference would be given during the evaluation to minority-owned manufacturers, and ensure that personal net worth is not an evaluation criteria as this represents a significant barrier in accessing capital for minority businesses.

   Match Requirements:
   - Less than 25 employees – 10% match from the business for grants of $25,000-$50,000; 25% match for larger grants
   - 26-75 employees – 25% match from the business

- 75-150 employees – 50% match from the business
- More than 150 employees – 75% match from the business

2. Commit $10,000,000 as seed funding to establish a Manufacturing Innovation Center, with an industry-led partner to be selected by the state to manage and operate the center. As a public-private partnership, the Center would raise additional funds to support the operations. The purpose of the center is to build a national showcase for next-generation manufacturing technology, talent, and transformation. The Center will be a public-private sector digital network and physical Center offering a quick response system that promotes the technological Future of Maryland manufacturing. The Center is a catalyst for forging new systems of success serving manufacturers with an improved system of service. Center goals include:
    - Connect manufacturers to resources that 1) promote the adoption of new and emerging technologies; 2) the attraction, retention and promotion of a diverse workforce that enables and participates in manufacturing; 3) supports entrepreneurship in manufacturing, with particular focus on minority participation; and 4) promotes culture within business organizations to successfully adopt new technology and develop a diverse workforce.
    - Build digital online Smart Wizards for manufacturers to easily find funding resources offered by government programs beginning with Energy Efficiency and Renewable Energy programs offered by the Maryland Energy Administration (MEA) .
    - Demonstrate new and emerging technologies at locations around the state
    - Provide policymakers with data to support priorities for funding and economic strategy.
    - Include $500k for marketing of both Center programs and resources, as well as the promotion of the technological face of manufacturing and new careers using new approaches like micro museums focused on manufacturing tech, Maryland Public Television and Kirwan CTE strategies driven by the private sector.
    - Develop innovative training for manufacturers to include mobile systems, virtual reality, online training, peer group learning and Center Leadership development programs. Align training and education around new and emerging technologies.
    - Serve as convener and facilitator between higher education, technical education programs and minority communities to increase participation in manufacturing.

3. Utilize existing, or establish a new, loan and loan guarantee program to assist small and minority manufacturers with access to capital. Access to capital is a significant barrier for small and minority companies.
    - Evaluate the potential utilization of existing program such as the Maryland Industrial Development Fund Authority (MIDFA), Video Lottery Terminal Fund (VLT) loans, and the Maryland Small Business Development Financing Authority (MSBDFA) loans and loan guarantee programs to enhance access to capital.

- Determine the need for new programs, or changes to existing programs, to facilitate better access to capital for small and minority-owned manufacturers.

Statewide Education and Training (Tasks 8 and 9) - As noted in Appendix B (JFI report), manufacturing workers are and will continue to be in high demand in Maryland. The manufacturing sector: 1) is projected to create over 14,000 net new jobs over the next ten years; 2) currently has over 14,000 job postings for needed positions, 8% of all job openings posting on the Maryland Workforce Exchange; and 3) will need fill more than 12,000 openings each year over the next ten years. Expanding investment in Maryland's workforce development system will be essential to meeting the current and future workforce demands of the manufacturing sector and expanding the pipeline of in-demand workers for the sector. Significant opportunities exist as well for expanding the pipeline of manufacturing workers from underrepresented populations, promoting equitable access to these good jobs in Maryland and strengthening Maryland's middle-class families.

4. Align manufacturing industry skills needs with statewide curriculum development through the efforts of the CTE Committee and other reforms resulting from the Kirwan legislation. Require the CTE Committee to partner with MD Labor's Division of Workforce Development Adult Learning, RMI, MD MEP, and local workforce boards to:
    - Analyze the existing landscape of workforce programs, including CTE offerings, apprenticeship (including youth apprenticeship, School to Apprenticeship and Registered Apprenticeship), community college courses, and other workforce programs that support Maryland manufacturers' workforce development efforts to determine gaps;
    - Identify opportunities to fill gaps that expand existing programs and/or create new programming with consideration for high school students, returning citizens, skilled immigrants, and other special populations as viable talent pipelines to be considered;
    - Invest in programming that fills gaps based on quantifiable metrics for determining success.

Other Regulatory and Statutory Changes (Task 6) – In addition to specific recommendations on adoption of Industry 4.0, the Workgroup was tasked with identifying other recommendations on regulations and other aspects of the business climate in Maryland to foster an operating environment in which manufacturing can thrive and grow.

5. Pass legislation that would open PEO (professional employer organization) access to any manufacturer under 50 employees. PEOs provides comprehensive payroll, benefits and HR services to small businesses. Manufacturers want to offer the best benefits to their employees, but Maryland law currently prohibits manufacturers under 50 employees to join PEOs in order to offer "large company benefits" to their employees.

6. The current Maryland tax code allows for certain exemptions for manufacturers on the purchase of tangible personal property, a digital code or a digital product used in production activity. While this exemption helps manufacturers, the use of Industry 4.0 blurs the lines

between data and physical equipment, and the exemption does not apply to many technologies related to Industry 4.0 that are used indirectly in production, such as software.

To further encourage manufacturers to invest in Industry 4.0 technologies and to help enable the free flow of information from factory floor to cloud and other computer systems, the workgroup recommends amending Sec. 03.06.01.32-2, Section C (1) to the following: "Tangible personal property, a digital code, or a digital product used directly ***or indirectly*** and predominantly in a production activity at any stage of operation on the production activity site, from the handling of raw material or components to the shipment of finished product, if the tangible personal property, digital code, or digital product is not installed so that it becomes real property".

7. Pass legislation to create a Buy Maryland Manufacturing tax credit program – modeled after the Buy Maryland Cyber program, a Buy Maryland Manufacturing Tax Credit would promote the manufacturing industry in Maryland by encouraging other Maryland businesses to purchase products manufactured in Maryland. The Buy Maryland Manufacturing Tax Credit will promote the manufacturing industry in Maryland by encouraging other Maryland businesses to purchase products manufactured in Maryland. Additionally it will create opportunities to expand opportunities for local economic growth and encourage supply chain resiliency through the support of our local manufacturers and suppliers.

8. Encourage local land use and zoning regulations, as well as local incentives, to ensure an adequate inventory of properties for the expansion of existing, and attraction of new manufacturers in the state. State agencies should work with local officials to identify best practices in land use and zoning regulations to meet the needs of today's manufacturing sector.

Green Manufacturing and Sustainability: Maryland can be a national showcase for next-generation American manufacturing. To achieve this vision, we need to 1) reduce the carbon footprint in manufacturing, and 2) support the growth of a manufacturing sector that makes products for the sustainability markets.

9. Reduce carbon footprint in manufacturing. Green manufacturing establishes renewable production processes and environmentally friendly practices in manufacturing businesses. The processes help limit a manufacturer's impact on the plant, enact positive change, and encourage other businesses to follow suit. Maryland needs to increase the number of manufacturers that participate in Maryland Energy Administration (MEA) programs to include energy efficiency, renewable energy, and offshore wind.

Recommendation:
Major facility systems such as HVAC systems, electrical switchgear, transformer, industrial logic controllers and similar advanced controls are a major source of energy inefficiencies in manufacturing facilities. The ROI on upgrading these systems, or

installing new systems such as solar panels, is long-term. Reducing the time to realize an ROI is critical to assist manufacturers with investments in energy efficiency and sustainability.

Create a state matching fund to buy-down the costs and improve the ROI to 3-4 years for the purchase of major facility systems such as HVAC systems, electrical switchgear, transformer, industrial logic controllers and similar advanced controls. This fund would be managed by the Maryland Energy Administration and promoted by the Regional Manufacturing Institute (RMI) and Maryland MEP.

10. Develop and nurture a "Maryland Green Manufacturing Sector" to grow existing and attract new companies that make products and components that promote sustainability. This would include a wide variety of products like solar panels, monitoring systems, sensor technologies, energy-efficient equipment, and products and components for the offshore wind industry.

    Recommendation:
    Establish a program within Maryland Commerce to identify Maryland companies that make products or components that support sustainability and reduce carbon footprints. Identify strategies for developing this emerging sector. Market Maryland as a State that wants to attract Green Manufacturing companies. Research shows that younger workers are attracted to companies that support green initiatives. Promote in schools and colleges careers in Maryland Green Manufacturing companies.

7.0 Conclusion

Maryland's manufacturing sector is a source of stable, high-paying jobs. As the sector advances with the onset of Industry 4.0, it will be critical for industry, education, and government stakeholders to work together to ensure Maryland is well positioned to take advantage of the future of work. During its inception, the Transforming Manufacturing in a Digital Economy Workgroup has covered such topics as the manufacturing sector in Maryland, how taxes and regulations impact manufacturers, best practices from other states on supporting Industry 4.0 adoption, how workforce needs will look in the future, and strategies for Maryland to best support Industry 4.0.

As stated before, now is the time for the State to step up support of Maryland manufacturing. Not only has the sector experienced strong recent employment growth, but the national trend to reshoring coupled with the productivity enhancing capabilities of Manufacturing 4.0 have the potential to support a manufacturing renaissance nationally and in Maryland. Manufacturing jobs are critically important to residents across Maryland, and account for a significant proportion of job opportunities in rural Maryland. Investing in the growth of Maryland's manufacturing sector is a strong strategy to provide a pathway to the middle class for even more Marylanders.

Providing incentives to Maryland manufacturers to invest in Manufacturing 4.0 and related advanced production technologies and investing in expanding the pipeline of skilled workers needed by the industry has the potential to create high quality jobs, grow Maryland's economy, and expand the State's tax base.

The recommendations in this report should not be considered the end of this discussion but rather a starting point; if Maryland is to take advantage of the opportunity of Industry 4.0 then the types of conversations spurred by this body will need to continue and grow.

Appendix A – Report from Jacob France Institute

The Department of Commerce contracted with the Jacob France Institute to provide analysis supporting the workgroup's goals as outlined in the statute. This appendix, beginning on the next page, contains the report submitted to the Department of Commerce by the Jacob France Institute.

Report on Transforming Manufacturing in a Digital Economy

Submitted To: The Maryland Department of Commerce

November 30 , 2022

Richard Clinch
DIRECTOR, THE JACOB FRANCE INSTITUTE

UNIVERSITY OF BALTIMORE
Jacob France Institute

Appendix A: Report on Transforming Manufacturing in a Digital Economy
Authored by: Jacob France Institute

Executive Summary and Key Findings

The Jacob France Institute of the Merrick School of Business at the University of Baltimore (JFI) was retained by the Maryland Department of Commerce to provide analytical support to the legislatively created Transforming Manufacturing in a Digital Economy Workgroup. The JFI provided analytical support in four areas: 1) identifying national best practices for supporting technology adoption and implementation in manufacturing; 2) describing regulatory, tax and policy topics that impact Maryland manufacturers; 3) assessing critical workforce development issues impacting the Maryland manufacturing sector; and 4) developing suggested high level recommendations on supporting Manufacturing 4.0 adoption and meeting the critical workforce development needs of Maryland's manufacturing sector. The key findings of this analysis are as follows:

Importance of Manufacturing

- ***Manufacturing matters in Maryland.*** Manufacturing accounts for 4.3% of Maryland jobs, but generates 6.4% of Gross Regional Product and 62% of Maryland exports. Manufacturing output per worker is $464,061, the third highest across all of Maryland core industry sectors. Each $1 million in Maryland manufacturing activity generates $1.5 million in Maryland economic activity, supports 4.6 overall jobs in the State, and generates more than $56,000 in State and local tax revenues.
- ***Manufacturing is a growing high wage driver of the Maryland economy.*** With 108,887 manufacturing jobs distributed across all of Maryland's regions; average annual employee compensation of $107,131, which is well above the State average; and five-year employment growth of 5%, ***manufacturing is a key sector of the State's economy***.
- ***Manufacturing directly accounts for 4% of Maryland jobs and 8% of Maryland economic activity, and when multiplier effects are included, the sector supports 9% of jobs and 12% of economic activity in Maryland***.

Manufacturing Technological Changes

- ***Technological changes are reshaping manufacturing***. Automation, the cyber economy, and new technologies are changing workforce needs and the *Work of the Future* (as described by the MIT Work of the Future Report) – will be radically different than in the past – especially in manufacturing. The integration of advanced automation, new materials processes, and cyber/big data, described as the *Fourth Industrial Revolution* or *Industry/Manufacturing 4.0,* are changing the competitive landscape of Manufacturing. ***These new technologies can lead to a manufacturing renaissance and restore national and Maryland competitiveness in manufacturing***.

States are Investing to Support Manufacturing 4.0 Adoption

- Many states are supporting their manufacturing sectors' investments in new, Manufacturing 4.0 technologies through targeted programs, including developing manufacturing strategic plans/roadmaps, Manufacturing 4.0 investment grants/tax credits; and the development of technology test beds. ***Maryland's $1 million Maryland Manufacturing 4.0 Grant Program and***

Maryland MEP's Manufacturing 4.0 plan are both steps in the right direction, but are below the levels of investment support and fully integrated planning being done by best practice states.

Maryland Taxes and Regulations

- Regulations were not identified by the Workgroup as a key competitive issue, and while the overall business tax burden in Maryland was seen as high, the impact of this high tax burden on the Manufacturing sector was moderated by State tax credit and incentives programs.
- While Maryland does offer a variety of tax credit and other programs to support business and manufacturing, and manufacturing firms account for a more than representative share of firms utilizing these programs, there is a general lack of knowledge in the Maryland manufacturing community of the programs that exist. ***As a result, expanding the marketing and utilization of existing programs was seen as a more important immediate step than creating new broad-based tax manufacturing programs, outside of the specific area of creating programs to support Manufacturing 4.0 adoption recommended by the Workgroup***.

Manufacturing Workforce Development Demand, Supply and Gaps Analysis

- ***Manufacturing workers are and will continue to be in high demand in Maryland***. The manufacturing sector: 1) is projected to create over 14,000 net new jobs over the next ten years; 2) currently has over 14,000 job postings for needed positions, 8% of all job openings posting on the Maryland Workforce Exchange; and 3) will need fill more than 12,000 openings each year over the next ten years.
- In terms of net new job creation, the Maryland manufacturing sector will create 5,717 high skill, 6,144 middle skill, and 2,391 low skill net new jobs over the next ten years.
- In terms of annual job openings, which includes jobs from both growth and replacement demand, the Maryland manufacturing sector will need to annually fill 2,947 high skill, 5,800 middle skill and 3,681 low skill job openings each year over the next ten years.
- The ***Maryland workforce development system is well aligned to meet the manufacturing sector's needs for high skill professional, information technology, and engineering workers***, but manufacturers face competition for these workers from other growing sectors of the State's economy. However, ***the Maryland workforce development system's pipeline for middle skill technical and production workers is significantly below industry needs***.
- The Maryland manufacturing workforce is older and less diverse than the Maryland workforce as a whole.
- Changing automation and production technologies are increasing the skills requirements of manufacturing jobs.
- Expanding investment in Maryland's workforce development system will be essential to meeting the current and future workforce demands of the manufacturing sector and expanding the pipeline of in-demand workers for the sector. Significant opportunities exist as well for expanding the pipeline of manufacturing workers from underrepresented populations (women, African Americans, Hispanics) for these good jobs in Maryland.

Appendix A: Report on Transforming Manufacturing in a Digital Economy
Authored by: Jacob France Institute

States are Investing to Increase Their Supply of Manufacturing Workers

- Manufacturing workers are in short supply nationally as well as in Maryland. Across the nation, states are investing in the development of innovative programs to meet the employment needs of the manufacturing sector and increase the diversity of and inclusion of underrepresented populations in the manufacturing workforce. These innovative programs include efforts to: increase the pipeline of high school students interested in manufacturing; expanding manufacturing training in community colleges; developing manufacturing curriculum in cooperation with manufacturing companies; training underrepresented populations/returning citizens for careers in manufacturing; and developing integrated manufacturing workforce development training and certificate planning and delivery efforts.

Manufacturing 4.0 has the potential to transform Maryland's manufacturing sector. Strategic investments to support the adoption of these new technologies and provide the workforce needed by Maryland's economy has the potential to support and enhance the growth of this important industry and create good, high wage jobs and increase Maryland's tax base.

Appendix A: Report on Transforming Manufacturing in a Digital Economy
Authored by: Jacob France Institute

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Appendix A: Report on Transforming Manufacturing in a Digital Economy
Authored by: Jacob France Institute

Introduction

Senate Bill 444/House Bill 658, passed by the Maryland General Assembly during the 2021 Legislative Session, created the Transforming Manufacturing in a Digital Economy Workgroup (Making It In Maryland), and assigned the Department of Commerce as staff to the workgroup. The bill tasked the Workgroup with the following:

- Identify the new and emerging digital technologies that are shaping the work of the future, the education and skills needed, and the viable strategies for businesses to adopt these technologies;
- Examine the research conducted by the Massachusetts Institute of Technology (MIT) on the relationships between emerging technologies and the workforce to enable a future of shared prosperity, entitled "The Work of the Future: Shaping Technology & Institutions", MIT Work of the Future, Fall 2019 Report;
- Examine existing financial resources available to manufacturers seeking to invest in Industry 4.0 technology.
- Make recommendations to facilitate the State's robust entry into Industry 4.0 technology to improve the perception of manufacturing careers, including:
    - Promoting the technological advancements of Industry 4.0 to shift the perception of manufacturing careers for the entry–level workforce; and
    - Creating and advancing public–private partnerships between manufacturers, supportive community stakeholders, and education systems;
- Examine new and viable tax credits and programs for manufacturers to be more competitive and marketable in the new digital economy;
- Examine the State's current statutory and regulatory authority over manufacturing to examine potential reforms to attract new manufacturing businesses brought by Industry 4.0 to invest in the State's economy and workforce;
- Recommend additional financial support delivery mechanisms, as needed, to enable State manufacturers to adopt Industry 4.0 technology and enhance the ability of industry service providers to increase the scope of their industry support;
- Propose annual State funding to create a statewide training program to address the growing skills gap in the manufacturing workforce; and
- Develop recommendations for long–term private–public partnerships between educational institutions and manufacturers to develop curriculums that address the rapidly changing needs of the manufacturing industry.

In order to inform the deliberations of and assist in the generation of recommendations by the Workgroup, the Maryland Department of Commerce retained the Jacob France Institute (JFI) of the University of Baltimore to:

1. Identify national best practices for supporting technology adoption and investment in manufacturing;
2. Assess regulatory, tax and policy issues that impact Maryland manufacturers;
3. Assess critical workforce development issues impacting the Maryland manufacturing sector; and

4. Develop suggested high level recommendations on supporting Manufacturing 4.0 adoption and meet the critical workforce development needs of Maryland's manufacturing sector.

This report summarizes the research and analyses conducted by and suggested recommendations for the Workgroup to consider developed by the Jacob France Institute.

Importance of the Maryland Manufacturing Sector

Manufacturing Matters and is important to the national as well as to the Maryland economy. According to the National Association of Manufacturers Facts about Manufacturing report:

- Manufacturers contributed $2.77 trillion to the U.S. economy based on Q1 2022 data;
- For every $1.00 spent in manufacturing, there is an impact of $2.68 to the overall economy;
- The majority of manufacturing firms in the United States are quite small. In 2019, there were 243,687 firms in the manufacturing sector, with all but 4,036 firms considered to be small (i.e., having fewer than 500 employees);
- The manufacturing sector employed 12.83 million workers in July 2022;
- Manufacturing workers earned on average $92,832 including pay and benefits and 95% of manufacturing employees were eligible for health insurance benefits in 2020; and
- There were 790,000 manufacturing job openings in June and 4 million manufacturing jobs will be needed by 2030.[5]

Manufacturing Matters in Maryland. In Maryland, manufacturing has average annual employee compensation of $107,131, well above the Maryland average of $86,429. Manufacturing accounts for 4.3% of Maryland jobs, but generates 6.4% of Gross Regional Product and 62% of Maryland exports. Manufacturing output per worker is $464,061, the third highest across all of Maryland core industry sectors. Each $1 million in Maryland manufacturing activity generates $1.5 million in Maryland economic activity, supports 4.6 overall jobs in the State, and generates more than $56,000 in State and local tax revenues.

Table 1: Selected Measures of the Importance of Manufacturing

Measure		Data
Annual Compensation	Overall	$86,429
	Manufacturing	$107,131
Output per Worker	Overall	$180,887
	Manufacturing	$464,061
Manufacturing as a % of:	Maryland	62%
	Jobs	4.3%
	GRP	6.4%
Multiplier Effects (per $1 Mil.)	Output	$1,489,925
	Jobs	4.6
	State and Local Gov't Revenues	$56,624

Source: JFI Analysis of Lightcast, BEA and IMPLAN data

Supporting the technology investment and workforce needs of the Maryland manufacturing sector has the potential to support the growth and competitiveness of this high impact, high value-added sector and create good, high wage jobs. The technological changes impacting and

[5] https://www.nam.org/facts-about-manufacturing/.

post-COVID 19 efforts to reshore manufacturing production and supply chains has the potential to enhance the growth and competitiveness of Maryland's manufacturing sector.

Overview of Maryland's Manufacturing Sector

Maryland has a vibrant and growing manufacturing sector. While the State is not specialized in Manufacturing, with a location Quotient (LQ) of 0.48, signifying a concentration of employment less than half the national average,[6] manufacturing is growing in the State and manufacturing activity occurs across the State of Maryland.

Role of Manufacturing in the Maryland Economy

Manufacturing is a growing high wage driver of the Maryland economy. With 108,887 manufacturing jobs distributed across 4,304 business establishments, manufacturing is Maryland's eighth largest business sector in terms of employment and tenth largest in terms of business establishments. Average annual employee compensation in the Maryland manufacturing sector are $107,131, well above the State average of $86,429,and offers the seventh highest compensation across all of Maryland's core business sectors. Over the past five years, Maryland manufacturing employment grew by 5%, while overall state-level Private Sector employment fell. Manufacturing employment is projected to continue to experience stronger growth than the overall State economy over the next five years (Figure 2). Despite this growth, Maryland's concentration of manufacturing employment remains at less than half the national average, with an LQ of .48, signifying a concentration of manufacturing jobs 48% of the national average.

Table 2: Overview of the Maryland Economy

NAICS	Description	Employment	% of State	Establishments	% of State	LQ	Employee Compensation
		2,779,779	100%	176,928	100%		$86,429
11	Agriculture, Forestry, Fishing and Hunting	7,663	0.3%	664	0.4%	0.28	$51,407
21	Mining, Quarrying, and Oil and Gas Extraction	1,169	0.04%	82	0.05%	0.12	$86,282
22	Utilities	9,538	0.3%	259	0.1%	0.96	$182,352
23	Construction	164,572	6%	16,078	9%	1.19	$85,824
31	**Manufacturing**	**108,887**	**4%**	**4,304**	**2%**	**0.48**	**$107,131**
42	Wholesale Trade	81,563	3%	9,163	5%	0.78	$110,087
44	Retail Trade	268,897	10%	17,417	10%	0.95	$46,845
48	Transportation and Warehousing	108,011	4%	4,092	2%	0.95	$62,966

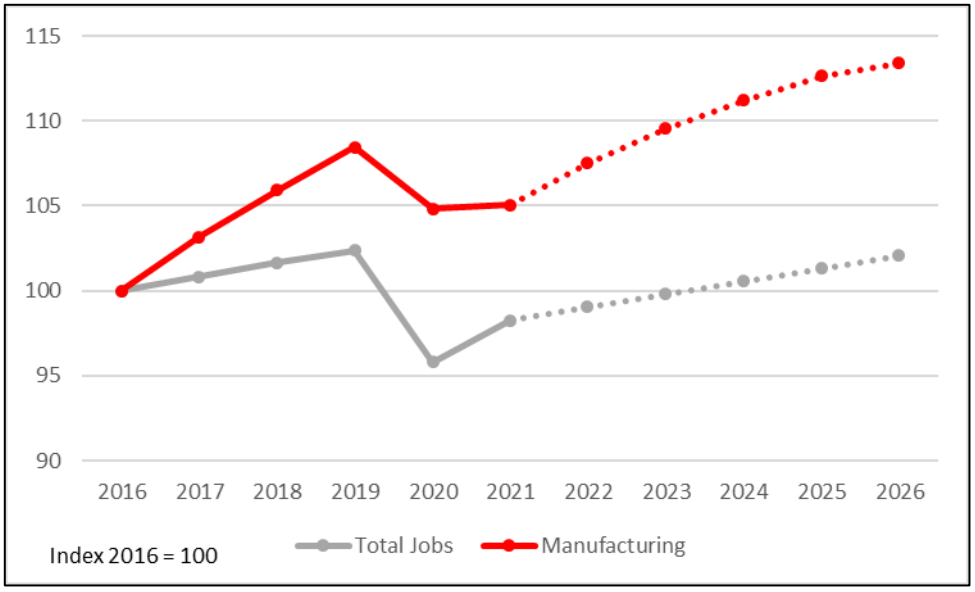
[6] A location quotient (LQ) measures the concentration of employment in an industry to the national average with a value above 1 indicating a higher than U.S. average concentration of employment in that industry. LQs can be used to measure the level of specialization in an industry, with a LQ above 1.2 often interpreted as identifying an industry where a jurisdiction is "specialized" and can be a leading sector of the region's economy.

Appendix A: Report on Transforming Manufacturing in a Digital Economy
Authored by: Jacob France Institute

NAICS	Description	Employment	% of State	Establishments	% of State	LQ	Employee Compensation
51	Information	33,486	1%	3,346	2%	0.65	$173,215
52	Finance and Insurance	94,840	3%	8,645	5%	0.78	$154,003
53	Real Estate and Rental and Leasing	42,751	2%	7,391	4%	1.02	$85,424
54	Professional, Scientific, and Technical Services	267,428	10%	32,571	18%	1.47	$129,720
55	Management of Companies and Enterprises	27,946	1%	880	0%	0.65	$155,529
56	Administrative and Support and Waste Management and Remediation Services	168,126	6%	12,131	7%	1.01	$64,843
61	Educational Services	86,583	3%	3,248	2%	1.19	$68,168
62	Health Care and Social Assistance	364,291	13%	18,639	11%	0.99	$75,641
71	Arts, Entertainment, and Recreation	35,140	1%	2,538	1%	0.95	$47,455
72	Accommodation and Food Services	197,510	7%	12,046	7%	0.88	$30,892
81	Other Services (except Public Administration)	128,124	5%	19,369	11%	1.05	$47,121
90	Government	582,640	21%	3,540	2%	1.33	$107,351
99	Unclassified Industry	614	0.02%	529	0.30%	0.16	$74,232

Source: JFI Analysis of Lightcast Data

Figure 1: Employment and Manufacturing Sector Growth



Source: Lightcast

Manufacturing employment is distributed across the State. Maryland's manufacturing industry is distributed across the state; in fact, with the exception of Cecil County (13% of private sector employment in manufacturing), the Maryland counties where manufacturing makes up the highest share of private sector employment are located in the Eastern Shore (Dorchester, 26%, Caroline 16%, Kent 14%, Queen Anne's 11%) or Western Maryland (Washington 12% and Allegany 9%). With 60,140 manufacturing jobs, Central Maryland accounts for 55% of Maryland's manufacturing jobs, higher than the region's 51% of total jobs, with both the Eastern Shore and Western Maryland having 10% and 8% of Maryland's manufacturing jobs, twice their share of Maryland private sector employment (Figure 2).

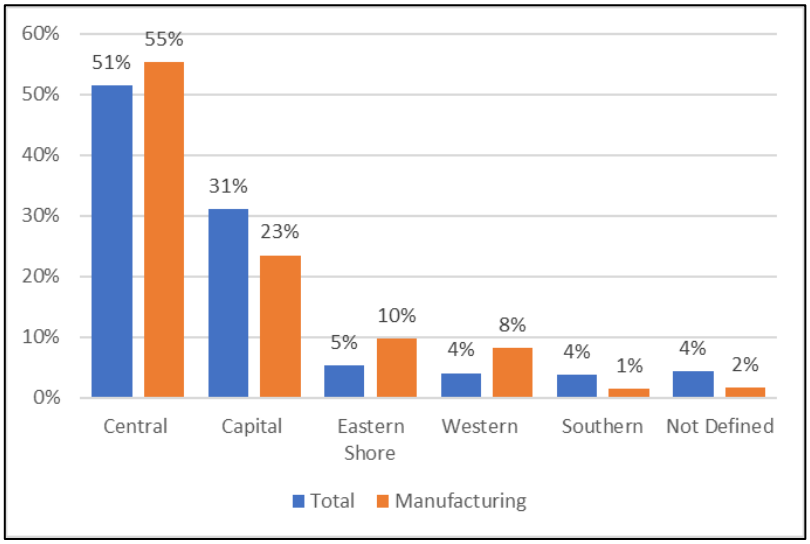
Table 3: Total Private Sector and Manufacturing Employment, By County

	Total Private		Five Year Change		Manufacturing		Five Year Change	
State/County	2016	2021	#	%	2016	2021	#	%
Maryland -- Statewide	2,141,805	2,096,129	(45,676)	(2%)	103,586	108,691	5,105	5%
Allegany County	23,282	20,772	(2,510)	(11%)	2,772	1,915	(857)	(31%)
Anne Arundel County	221,166	213,402	(7,764)	(4%)	11,755	12,982	1,227	10%
Baltimore County	318,120	305,779	(12,341)	(4%)	13,687	15,641	1,954	14%
Calvert County	19,965	17,126	(2,839)	(14%)	574	437	(137)	(24%)
Caroline County	7,600	8,029	429	6%	1,164	1,317	153	13%
Carroll County	49,747	47,702	(2,045)	(4%)	3,746	3,966	220	6%
Cecil County	25,180	28,466	3,286	13%	4,227	3,623	(604)	(14%)
Charles County	33,267	29,342	(3,925)	(12%)	636	566	(70)	(11%)
Dorchester County	8,905	9,859	954	11%	2,230	2,543	313	14%
Frederick County	84,180	83,801	(379)	(0%)	5,201	5,474	273	5%
Garrett County	10,045	10,195	150	1%	984	754	(230)	(23%)

State/County	Total Private 2016	Total Private 2021	Five Year Change #	Five Year Change %	Manufacturing 2016	Manufacturing 2021	Five Year Change #	Five Year Change %
Harford County	71,008	71,321	313	0%	4,875	4,800	(75)	(2%)
Howard County	151,313	147,419	(3,894)	(3%)	7,819	8,643	824	11%
Kent County	6,838	6,319	(519)	(8%)	769	875	106	14%
Montgomery County	374,115	354,467	(19,648)	(5%)	11,938	13,292	1,354	11%
Prince George's County	223,413	213,267	(10,146)	(5%)	7,445	6,760	(685)	(9%)
Queen Anne's County	12,135	12,397	262	2%	1,040	1,332	292	28%
St. Mary's County	29,006	31,324	2,318	8%	377	586	209	55%
Somerset County	3,728	3,372	(356)	(10%)	210	246	36	17%
Talbot County	17,520	14,618	(2,902)	(17%)	797	496	(301)	(38%)
Washington County	58,171	53,993	(4,178)	(7%)	6,350	6,261	(89)	(1%)
Wicomico County	37,074	36,389	(685)	(2%)	3,005	3,092	87	3%
Worcester County	20,870	20,908	38	0%	662	747	85	13%
Baltimore City	268,372	263,761	(4,611)	(2%)	10,490	10,485	(5)	(0%)
Unknown/Undefined	66,787	92,100	25,313	38%	834	1,859	1,025	123%

Source: BLS

Figure 2: Share of Total Private Sector and Manufacturing Employment by Region



Source: BLS

Key Maryland Manufacturing Sectors

Maryland's manufacturing sector is distributed across 21 key subsectors (3 digit NAICS Codes), the largest subsectors include: Computer and Electronic Product Manufacturing, with 19,974 jobs; Food Manufacturing, with 17,304 jobs; and Chemical Manufacturing, with 14,384 jobs; and these three subsectors account for nearly half of all manufacturing jobs in the State. Computer and Electronic Product Manufacturing is the only manufacturing subsector where the concentration of jobs in Maryland is above the national average, with an LQ of 1.04, and Maryland has a near average level of employment in the Printing and Related Support Activities (LQ of .97) and

Chemical Manufacturing (LQ of .91). The Beverage and Tobacco Product Manufacturing and Chemical Manufacturing are leading the State in growth, with five year employment growth of 28% and 25% respectively (Table 4).

Table 4: Overview of Maryland Manufacturing

NAICS	Description	2016 Jobs	2021 Jobs	2016 - 2021 Change	2016 - 2021 % Change	Avg. Earnings Per Job	2021 Location Quotient	2021 Establishments
Total		**103,666**	**108,887**	5,221	5%	$107,131		4,304
311	Food Manufacturing	15,199	17,304	2,105	14%	$68,476	0.58	524
312	Beverage and Tobacco Product Manufacturing	3,178	4,069	892	28%	$64,882	0.74	240
313	Textile Mills	424	332	(92)	(22%)	$73,627	0.19	25
314	Textile Product Mills	801	738	(63)	(8%)	$68,021	0.39	118
315	Apparel Manufacturing	1,130	974	(156)	(14%)	$51,562	0.58	70
316	Leather and Allied Product Manufacturing	191	157	(34)	(18%)	$80,167	0.33	24
321	Wood Product Manufacturing	2,308	2,729	421	18%	$86,518	0.36	136
322	Paper Manufacturing	2,628	1,803	(825)	(31%)	$73,118	0.28	39
323	Printing and Related Support Activities	7,675	6,509	(1,166)	(15%)	$66,906	0.97	382
324	Petroleum and Coal Products Manufacturing	833	694	(140)	(17%)	$159,183	0.36	50
325	Chemical Manufacturing	11,528	14,394	2,866	25%	$179,800	0.91	317
326	Plastics and Rubber Products Manufacturing	5,861	5,780	(81)	(1%)	$87,470	0.44	120
327	Nonmetallic Mineral Product Manufacturing	4,389	3,762	(627)	(14%)	$84,392	0.51	202
331	Primary Metal Manufacturing	960	784	(176)	(18%)	$80,341	0.12	38
332	Fabricated Metal Product Manufacturing	7,897	7,996	99	1%	$82,682	0.32	456
333	Machinery Manufacturing	6,418	7,050	632	10%	$97,527	0.37	258
334	Computer and Electronic Product Manufacturing	17,573	19,974	2,401	14%	$150,481	1.04	483
335	Electrical Equipment, Appliance, and Component Manufacturing	1,985	1,811	(174)	(9%)	$102,593	0.25	110
336	Transportation Equipment Manufacturing	4,446	4,281	(164)	(4%)	$112,230	0.14	125
337	Furniture and Related Product Manufacturing	3,871	2,843	(1,028)	(27%)	$58,746	0.42	168
339	Miscellaneous Manufacturing	4,371	4,902	531	12%	$102,616	0.45	423

Source: JFI Analysis of Lightcast Data

The analysis of key manufacturing sectors (above) analyzed the entire manufacturing sector at the 3 digit NAICS level. In order to identify key specialized and growing subsectors within these broad manufacturing sectors, Maryland manufacturing employment was also analyzed at the Industry Group (4 digit NAICS) and more detailed (5 and 6 digit NAICS) levels to identify key specialized and growing industries within the manufacturing sector.

Specialized Maryland Manufacturing Subsectors

Key specialized manufacturing industry subsectors, where the concentration of employment is above the national level in Maryland are presented in Table 5. Generally, industries in which the concentration of employment 20% above the national average (LQ of 1.2 or above) are considered specialized and may indicate that Maryland has a comparative advantage in these industries. Key specialized manufacturing sectors in Maryland include:

- ***Manufacturing and Reproducing Magnetic and Optical Media*** – with an LQ of 4.33 and 893 jobs across 40 establishments;
- ***Communications Equipment Manufacturing*** – with an LQ of 2.04 and 3,183 jobs across 71 establishments;
- ***Navigational, Measuring, Electromedical, and Control Instruments Manufacturing*** – with an LQ of 1.85 and 13,981 jobs across 263 establishments;
- ***Other Furniture Related Product Manufacturing*** – with an LQ of 1.72 and 1,158 jobs across 11 establishments;
- ***Pharmaceutical and Medicine Manufacturing*** – with an LQ of 1.69 and 10,265 jobs across 144 establishments;
- ***Lime and Gypsum Product Manufacturing*** – with an LQ of 1.28 and 353 jobs across 4 establishments; and
- ***Other Food Manufacturing*** – with an LQ of 1.25 and 5,388 jobs across 125 establishments.

At the more detailed 6-digit NAICs level – several clusters of related industries stand out, including:

  - ***Food related manufacturing***, which include: Cane Sugar Manufacturing – LQ of 4.39 and 509 jobs across 3 establishments; Ice Cream and Frozen Dessert Manufacturing – LQ of 2.2 and 913 jobs across 16 establishments; Rendering and Meat Byproduct Processing – LQ of 1.55 and 223 jobs across 2 establishments; Commercial Bakeries – LQ of 1.31 and 3,122 jobs across 103 establishments, Soft Drink Manufacturing – LQ of 1.27 and 1,854 jobs across 33 establishments; and Fats and Oils Refining and Blending – LQ of 1.25 and 162 jobs across 4 establishments;
  - ***Musical Instrument Manufacturing*** – LQ of 2.32 and 477 jobs across 11 establishments;
  - ***Power-Driven Handtool Manufacturing*** – LQ of 1.95 and 423 jobs across 6 establishments;
  - ***Construction related materials***, which includes: Truss Manufacturing – LQ of 1.82 and 1,104 jobs across 14 establishments; Ornamental and Architectural Metal Work Manufacturing– LQ of 1.31 and 1,018 jobs across 46 establishments; Cement Manufacturing – LQ of 1.30 and 355 jobs across 7 establishments;
  - ***Other Communications Equipment Manufacturing*** – LQ of 1.72 and 557 jobs across 17 establishments;
  - ***Adhesive Manufacturing*** – LQ of 1.67 and 693 jobs across 14 establishments; and
  - **Sawmill, Woodworking, and Paper Machinery Manufacturing** -- LQ of 1.58 and 351 jobs across 5 establishments.

Table 5: Key Specialized Manufacturing Industries

NAICS	Description	2016 Jobs	2021 Jobs	2016 - 2021 Change	2016 - 2021 % Change	Avg. Earnings Per Job	2021 Location Quotient	2021 Establishments
3346	Manufacturing and Reproducing Magnetic and Optical Media	1,229	893	(336)	(27%)	$224,258	4.33	40
3342	Communications Equipment Manufacturing	3,075	3,183	108	4%	$143,664	2.04	71
3345	Navigational, Measuring, Electromedical, and Control Instruments Manufacturing	11,472	13,981	2,509	22%	$155,867	1.85	263
3379	Other Furniture Related Product Manufacturing	1,519	1,158	(361)	(24%)	$52,946	1.72	11
3254	Pharmaceutical and Medicine Manufacturing	7,247	10,265	3,019	42%	$206,141	1.69	144
3274	Lime and Gypsum Product Manufacturing	359	353	(6)	(2%)	$105,983	1.28	4
3119	Other Food Manufacturing	3,553	5,388	1,835	52%	$82,795	1.25	125
3255	Paint, Coating, and Adhesive Manufacturing	1,353	1,374	21	2%	$107,372	1.16	29
3365	Railroad Rolling Stock Manufacturing	492	392	(100)	(20%)	$97,412	1.12	5
3159	Apparel Accessories and Other Apparel Manufacturing	48	214	166	349%	$70,783	1.01	20
3336	Engine, Turbine, and Power Transmission Equipment Manufacturing	1,590	1,643	53	3%	$99,697	1.01	16
3231	Printing and Related Support Activities	7,675	6,509	(1,166)	(15%)	$66,906	0.97	382
3118	Bakeries and Tortilla Manufacturing	4,512	4,555	43	1%	$53,505	0.82	226

Source: JFI Analysis of Lightcast Data

High Growth Maryland Manufacturing Sectors

There are 84 manufacturing Industry Groups (4 digit NAICs) operating in Maryland. Of these 41 added jobs over the past five years. Key growing manufacturing Industry Groups in Maryland, where employment grew by 20% or more, are presented in Table 6 and include:

- The highly specialized Pharmaceutical and Medicine Manufacturing (3,019 new jobs and 42% growth); Navigational, Measuring, Electromedical, and Control Instruments Manufacturing (2,509 jobs and 22%); and Other Food Manufacturing (1,835 and 52%) added the most jobs; and
- Other strong growth Industry Groups included: Apparel Accessories and Other Apparel Manufacturing (166 jobs and 349% growth); Nonferrous Metal (except Aluminum) Production and Processing (23 jobs and 149%); Grain and Oilseed Milling (123 jobs and 93%); Fiber, Yarn, and Thread Mills (51 jobs and 91%); and Other Transportation Equipment Manufacturing (36 jobs and 64%).

Table 6: Key Growing Manufacturing Industries

NAICS	Description	2016 Jobs	2021 Jobs	2016 - 2021 Change	2016 - 2021 % Change	Avg. Earnings Per Job	2021 Location Quotient	2021 Establishments
3159	Apparel Accessories and Other Apparel Manufacturing	48	214	166	349%	$70,783	1.01	20
3314	Nonferrous Metal (except Aluminum) Production and Processing	15	38	23	149%	$91,400	0.04	3
3112	Grain and Oilseed Milling	132	255	123	93%	$86,342	0.23	13
3131	Fiber, Yarn, and Thread Mills	57	108	51	91%	$65,316	0.23	2
3369	Other Transportation Equipment Manufacturing	56	92	36	64%	$90,551	0.13	8
3119	Other Food Manufacturing	3,553	5,388	1,835	52%	$82,795	1.25	125
3326	Spring and Wire Product Manufacturing	383	576	194	51%	$78,100	0.79	14
3212	Veneer, Plywood, and Engineered Wood Product Manufacturing	769	1,142	373	49%	$71,228	0.76	19
3333	Commercial and Service Industry Machinery Manufacturing	247	355	107	43%	$100,400	0.22	43
3254	Pharmaceutical and Medicine Manufacturing	7,247	10,265	3,019	42%	$206,141	1.69	144
3362	Motor Vehicle Body and Trailer Manufacturing	127	179	52	41%	$74,856	0.06	12
3121	Beverage Manufacturing	3,141	4,028	887	28%	$64,523	0.76	224
3391	Medical Equipment and Supplies Manufacturing	1,877	2,376	499	27%	$116,353	0.4	173
3339	Other General Purpose Machinery Manufacturing	1,656	2,067	411	25%	$110,377	0.43	63
3279	Other Nonmetallic Mineral Product Manufacturing	454	565	111	24%	$74,886	0.4	42
3344	Semiconductor and Other Electronic Component Manufacturing	1,373	1,700	327	24%	$85,164	0.25	69
3325	Hardware Manufacturing	24	30	6	24%	$91,143	0.07	8
3345	Navigational, Measuring, Electromedical, and Control Instruments Manufacturing	11,472	13,981	2,509	22%	$155,867	1.85	263
3219	Other Wood Product Manufacturing	1,020	1,239	220	22%	$107,970	0.29	98
3331	Agriculture, Construction, and Mining Machinery Manufacturing	293	355	62	21%	$80,591	0.1	22
3251	Basic Chemical Manufacturing	800	956	156	20%	$174,695	0.36	36

Source: JFI Analysis of Lightcast Data

The Economic Impact of the Maryland Manufacturing Sector

Manufacturing supports the larger Maryland economy. The JFI analyzed the economic contribution of the Maryland manufacturing sector using the IMPLAN input-output model for the State of Maryland. Input-output modeling allows for measurement of the linkages between the manufacturing sector and the rest of the Maryland economy. To conduct this analysis, the JFI input the 2021 manufacturing jobs into the IMPLAN input-output model and adjusted for intra-industry purchases to avoid double counting. The manufacturing sector purchases goods and services from local suppliers to support production and pays salaries and wages to its employees. These generate "multiplier" effects that lead to "ripple" effects in the economy as local purchases, or *indirect effects,* and local payrolls, or *induced effects*, stimulate successive rounds of additional

spending, leading to additional State of Maryland impacts larger than the direct jobs and sales associated with the manufacturing sector. Overall, the Maryland manufacturing sector directly employs 108,887 workers, 4% of Maryland jobs[7], and has revenues of $57.0 billion, accounting for 8% of Maryland economic activity. When multiplier effects are included, the sector supports $83.7 billion in Maryland economic activity, or more than 12% of the Maryland total, and 246,563 jobs, 9% of all jobs in Maryland.

Table 7: Economic Contribution of the Maryland Manufacturing Sector, 2021

Item	Output (Mil. $s)	Labor Income (Mil. $s)	Employment	State/Local Tax Revenue (Mil. $s)
Total Manufacturing Sector				
Direct Effect	$57,035.8	$10,748.9	108,887	$1,259.0
Indirect Impacts	$15,205.4	$5,509.7	70,301	$852.9
Induced Impacts	$11,501.1	$3,797.9	67,375	$801.4
Total Impact	$83,742.3	$20,056.6	246,563	$2,913.3
State Impact Multiplier	1.47	1.87	2.26	

Source: JFI and IMPLAN

The Work of the Future, Manufacturing 4.0 and the Changing Technology Needs of the Maryland Manufacturing Sector

In 2018, The Massachusetts Institute of Technology (MIT) convened the MIT Task Force on the Work of the Future with the goal of understanding the relationships between emerging technologies and work, and to explore strategies to enable a future of shared prosperity. In 2019, the Task Force released *The Work of the Future: Shaping Technology and Institutions* report[8] to assess how technology is reshaping the economy and workforce needs. According to the report,

> Technological change has been reshaping human life and work for centuries. The mechanization that began with the Industrial Revolution enabled dramatic improvements in human health, well-being, and quality of life—not only in the developed countries of the West, but increasingly throughout the world. At the same time, economic and social disruptions often accompanied those changes, with painful and lasting results for workers, their families, and communities. Along the way, valuable skills, industries, and ways of life were lost. Ultimately new and unforeseen occupations, industries, and amenities took their place. But the benefits of these upheavals often took decades to arrive. And the eventual beneficiaries were not necessarily those who bore the initial costs.

[7] The IMPLAN model uses a broader measure of jobs than the wage and salary employment discussed above.
[8] https://workofthefuture.mit.edu/wp-content/uploads/2020/08/WorkoftheFuture_Report_Shaping_Technology_and_Institutions.pdf.

Appendix A: Report on Transforming Manufacturing in a Digital Economy Authored by: Jacob France Institute

Two key findings of this report are that:

1. Between 1940 and 1980, rapid technological advances and well-functioning institutions in the United States delivered rising productivity and rapid, relatively evenly distributed wage gains to the vast majority of workers; and
2. Since the 1980s, productivity growth continued, but the distribution of these gains was not evenly shared, with only more educated workers experiencing sustained wage growth.

The more recent, uneven distribution of the benefits of productivity growth has led to pessimism about the future of work, contributed to the current uneven distribution of income, reduced inter-generational mobility, and contributed to the polarization of our society. Coinciding with these changes in productivity and wage growth, the growth of the working age population slowed and the national workforce is aging. According to the report, "In the U.S. and throughout the industrialized world, employment is polarizing. At the top end, high-education, high-wage occupations offer strong career prospects and rising lifetime earnings. At the other end, low-education, low-wage occupations provide little economic security and limited career earnings growth. As a result, the pathways to economically stable and secure careers for workers without college degrees are becoming narrower and more precarious." The report summarizes the impacts of these changes on the future of work as follows, "***We see no shortage of good careers for highly educated workers. And we see no shortage of jobs for less educated workers. But we find a paucity of good careers for workers without significant post-secondary training."***

Productivity growth is driven by capital investment and technological change. More recently, rapid progress in robotics, artificial intelligence, and machine learning are changing the work environment, and according to the MIT Taskforce, "digitalization does differ from prior waves of automation: it has spurred growth of high- and low-wage jobs at the expense of the middle (labor market polarization); it has concentrated earnings growth among the most educated and highest-ranked workers, while earnings growth for the majority of workers has lagged (rising inequality); and it has delivered only modest productivity growth in the recent decade, even while displacing many categories of work, particularly those done by workers with high school or lower education."

In 2020, the Work of the Future Task Force released *The Work of the Future: Building Better Jobs in an Age of Intelligent Machines r*eport[9], expending on the previous analyses and drawing six conclusions:

1. Technological change is simultaneously replacing existing work and creating new work. It is not eliminating work altogether.
2. Momentous impacts of technological change are unfolding gradually.
3. Rising labor productivity has not translated into broad increases in incomes because labor market institutions and policies have fallen into disrepair.
4. Improving the quality of jobs requires innovation in labor market institutions.

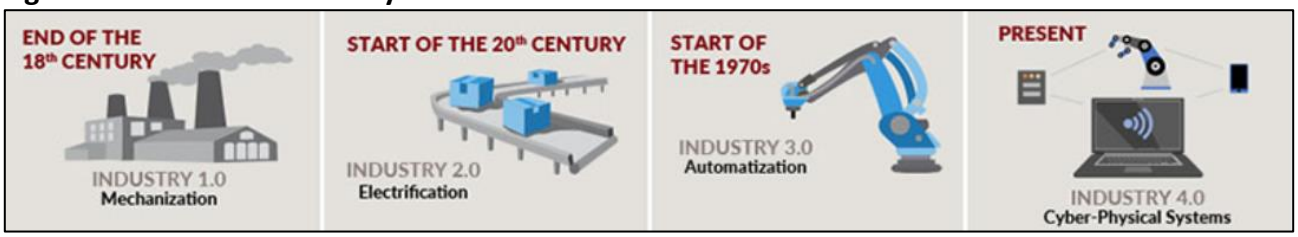
[9] https://workofthefuture.mit.edu/research-post/the-work-of-the-future-building-better-jobs-in-an-age-of-intelligent-machines/.

5. Fostering opportunity and economic mobility necessitates cultivating and refreshing worker skills.
6. Investing in innovation will drive new job creation, speed growth, and meet rising competitive challenges.

According to the MIT report, reforms and investments in manufacturing innovation and workforce development are essential. The Work of the Future Task Force report goes on to make three recommendations on how to accelerate and shape innovation while bringing the employment rates, earnings levels, and economic mobility of rank and-file U.S. workers back into alignment with the trajectory of U.S. innovation and productivity growth, these include: 1) Invest and Innovate in Skills and Training; 2) Improve Job Quality; and 3) Expand and Shape Innovation. These are also the core areas of focus for the Maryland Transforming Manufacturing in a Digital Economy Workgroup.

The Work of the Future reports highlight the role of technological changes such as robotics, artificial intelligence, and machine learning on the future of work. These, along with new materials, production processes and the cyber revolution are at the center of what has been termed Industry 4.0 or Manufacturing 4.0. The term Industry 4.0 to describe what is in effect a fourth industrial revolution (see Figure 3) originated from a high-tech strategy program of the German government in 2011.[10] Automation and technological changes are not new especially to manufacturing; however, the integration of automation, internet communications, and big data, the three core elements of Manufacturing 4.0 are reshaping industrial production.

Figure 3: The Birth of Industry 4.0



Source: Automation.com

The Maryland Manufacturing Extension Program's April 2022 The *Future is Now, Realizing the Promise of Industry 4.0* report[11] describes the role, importance and impacts of Industry/Manufacturing 4.0, so only a brief summary will be provided in this report, as an introduction to the analyses conducted. While there are many different and competing definitions, Industry/Manufacturing 4.0 refers to the Fourth Industrial Revolution – or the integration of cyber and physical systems. McKinsey, defines Manufacturing 4.0 as "the next phase in the digitization of the manufacturing sector, driven by four disruptions: the astonishing

[10] Industry 4.0 and Manufacturing 4.0 are largely interchangeable terms. For the remainder of this report, the term Manufacturing 4.0 is used due to the focus of the Workgroup on manufacturing in Maryland.
[11] https://mdmep.org/the-future-is-now-realizing-the-promise-of-industry-4-0/#StrategyReportDownload

rise in data volumes, computational power, and connectivity, especially new low-power wide-area networks; the emergence of analytics and business-intelligence capabilities; new forms of human-machine interaction such as touch interfaces and augmented-reality systems; and improvements in transferring digital instructions to the physical world, such as advanced robotics and 3-D printing."[12]

Manufacturing 4.0 is important to Maryland because not only is it reshaping manufacturing production, it has the significant potential to make manufacturing in the state more competitive nationally and internationally. The McKinsey Global Research Institute's *Building a More Competitive US Manufacturing Sector* report identifies investing in these technologies as critical to enhancing the competitive position of manufacturing.[13] Similarly, by supporting investment in these technologies, Maryland can enhance the competitiveness of its own manufacturing sector. Other states are making these investments. In supporting these investments, Maryland however, must recognize the issues raised in the *Work of the Future* reports cited above. Technological change and investments in automation have significant workforce implications, most importantly by increasing the workforce skills requirements of the manufacturing sector. Automation and technology investment can reduce the need for labor, while simultaneously increasing the skills requirements for manufacturing jobs. Combined, this can support a renaissance in manufacturing not only nationally, but also in a higher cost location such as Maryland.

The changes in manufacturing production technologies embodied in Manufacturing 4.0 have the potential to reshape manufacturing, nationally and here in Maryland. The transformative potential of Manufacturing 4.0 technologies was explicitly recognized in the creation of the Maryland Transforming Manufacturing in a Digital Economy Workgroup and its specific charge to *describe the new and emerging digital technologies that are reshaping manufacturing production; assess the barriers to investing in these technology; and identify potential State of Maryland programs to address these barriers*. Manufacturing 4.0 involves changes in both production technology (through automation, additive manufacturing, and robotics) and the integration of advanced computer/information technologies (such as the Internet of Things (IoT), big data analytics, artificial intelligence, and autonomous systems) into the manufacturing process. As a result of these technological changes, the workforce needs of the manufacturing workforce is changing, increasing the need for computer (analytics, coding, and programming) as well as STEM (Science, Technology, Engineering and Math) skills. Workers with these skill sets are already in short supply.

As described in the deliberations of the Maryland Transforming Manufacturing in a Digital Economy Workgroup, Maryland manufacturing companies, especially smaller/mid-sized and women/minority owned companies face significant financial and operational barriers to identifying, investing in, and deploying new Manufacturing 4.0 technologies. Similarly, Maryland manufacturing companies not only currently face significant shortages of qualified workers, these

[12] https://www.mckinsey.com/business-functions/operations/our-insights/manufacturings-next-act.
[13] https://www.mckinsey.com/featured-insights/americas/building-a-more-competitive-us-manufacturing-sector.

shortages can be expected to get worse as Manufacturing 4.0 and related technological changes increase the already demanding technological requirements of manufacturing jobs. As a result of these issues, as laid out in Senate Bill 444/House Bill 658, in addition to assessing the potential to support Manufacturing 4.0 investments, Maryland needs to identify and develop programs to support Manufacturing 4.0 investment and to meet the increasingly technical workforce needs of the sector. These issues will be addressed in the report below.

Combining support for manufacturing investments in Manufacturing 4.0 with reforms and investments in workforce training to address the unmet workforce needs of Maryland's manufacturing sector has the significant potential to improve and restore our basic competitiveness in manufacturing and create good jobs for Marylanders.

Assessment of State Efforts Underway to Support Manufacturing 4.0 Adoption

In order to inform two of the Transforming Manufacturing in a Digital Economy Workgroup's nine goals, specifically to:

- Examine existing financial resources available to manufacturers seeking to invest in Industry 4.0 technology; and
- Recommend additional financial support delivery mechanisms, as needed, to enable State manufacturers to adopt Industry 4.0 technology and enhance the ability of industry service providers to increase the scope of their industry support;

The JFI:

1) conducted an internet search and interview-based effort to identify existing Maryland programs to support Manufacturing 4.0 adoption; and
2) conducted a literature review and interviews with key national organizations, such as the National Institute of Standards and Technology (NIST) and best practice programs, to identify and describe state programs to support Manufacturing 4.0 investment and adoption.

Maryland State Programs to Support Manufacturing Technology Adoption

At the time the initial research was conducted, the Maryland Manufacturing 4.0 Grant Program had not yet initiated operations. Prior to the initiation of this program, Maryland had no specifically targeted program to provide Manufacturing 4.0 ***investment support*** other than its core business assistance programs, described below. However, the JFI identified three core programs, described in Table 8 below, that are focused on providing ***technical assistance and support*** to the manufacturing sector, including support for Manufacturing 4.0 adoption:

- **Maryland Manufacturing Extension Partnership** (Maryland MEP) is part of the NIST national manufacturing extension program. Maryland MEP is a non-profit organization funded by industry and the State of Maryland focused on growing and strengthening Maryland manufacturers. Serving mostly small and mid-size manufacturers (500 employees or less) across all industries, Maryland MEP provides an array of programs and service in five core areas: Strategy and Growth; Process and Innovation; Talent and

Workforce; Technology and Cybersecurity; and Supply Chain and Defense; to help Maryland manufacturers operate more efficiently, grow profitability, implement new technologies and create more jobs and opportunities in Maryland. Maryland MEP is spearheading efforts to support Manufacturing 4.0 adoption in the State and in April 2022 completed *The Future is Now, Realizing the Promise of Industry 4.0: A Strategic Plan to Ensure a Competitive Future for Manufacturing in Maryland* strategy to support Manufacturing 4.0 adoption.

- **Fraunhofer USA Center Mid-Atlantic (CMA)** is a component of the Fraunhofer USA Center, a national research and development organization affiliated with Fraunhofer-Gesellschaft, Europe's largest application-oriented research and development organization. Fraunhofer USA has three U.S. centers and works with industry, universities, and government on contract research projects. The Fraunhofer CMA Center comprises two divisions: Software and Systems Engineering and Molecular Biology. Located in Riverdale, Maryland, the Software Engineering Division drives critical thinking and software-enabled solutions for its customers in industry, government and academia. Affiliated with the University of Maryland, the Center conducts applied research aimed at designing and developing software-intensive systems that are safe, secure, tested and verified. Key focus areas include advanced AI applications for manufacturing, healthcare and life sciences, and supply chain illumination and management. The Biotechnology Division, located in Newark, Delaware, develops advanced technologies, emphasizing applications in human health and has recent grants with the NIH, DoD, and the Bill and Melinda Gates Foundation.

- **Maryland Technology Enterprise Institute** (Mtech) is a unit of the A. James Clark School of Engineering at the University of Maryland, College Park (UMCP). Mtech applies the diverse faculty, student, research and technical capabilities of UMCP's nationally engineering program, ranked 22nd best nationally according to U.S. News and World Report's national rankings, to support entrepreneurship and innovation education and venture creation in Maryland and is a pioneer in building successful university-company partnerships. Mtech offers a variety of programs to support entrepreneurship, technology commercialization and venture creation. Of its many programs, two play an especially important role in supporting Manufacturing 4.0:
    - **The Maryland Industrial Partnerships (MIPS)** program provides funding for tech product development projects teaming Maryland-based companies with University System of Maryland faculty to develop and deploy technologies, with a total of 54 of MIPS's 956 projects being with manufacturers; and
    - **The University of Maryland MakerBot Innovation Center** is a centralized, scalable 3D printing space that empowers everyone to invent, innovate, iterate, and replicate. With the establishment of the MakerBot Innovation Center, students, faculty, staff and the surrounding community are given a unique opportunity to learn about the benefits that 3D printing can provide, both inside and outside the research/prototyping setting. The Innovation Center boosts innovation by building capability while concentrating resources and knowledge in one centralized location

that everyone can use. The Innovation Center boosts innovation by building capability while concentrating resources and knowledge in one centralized location that students, companies and others can use.

In Fiscal 2023, the Maryland Department of Commerce initiated the **Maryland Manufacturing 4.0 Grant Program** to provide grants to small and mid-sized Maryland manufacturers to invest in Industry 4.0-related technologies, machinery and robotics, and digital business practices in order to remain competitive and drive growth. This pilot program is funded by $1 million in the state's fiscal year 2023 budget. The Program provides matching funds to small and mid-sized manufacturers (3-150 employees) to cover hardware, software and training costs associated with Manufacturing 4.0 investment. Awarded grants will cover 50 % of project costs, with a minimum grant of $15,000 and a maximum grant of $50,000. Projects must clearly demonstrate a tie to Industry 4.0, and a long term strategy for Industry 4.0 adoption.

Table 8: Selected Maryland Programs to Support Manufacturing Technology Adoption

Provider	Program	Services
Maryland Manufacturing Extension Partnership	The Maryland Manufacturing Extension Partnership (MD MEP) is a non-profit organization funded by industry and the State of Maryland focused on growing and strengthening Maryland manufacturers. Serving mostly small and mid-size manufacturers (500 employees or less) across all industries, MD MEP provides an array of programs and services to help these local companies operate more efficiently, grow profitability, implement new technologies and create more jobs and opportunities in Maryland. Selected programs include:	
	Talent & Workforce	The MD MEP team provides training, consulting, financial and technical assistance related to skills development, talent acquisition and training.
	Technology & Cybersecurity	• Cybersecurity
		• Robotics and Automation
		• ERP Implementation
		• Advanced Manufacturing Equipment, Technology and Processes
	Process & Innovation	• Operational Assessment
		• Lean Manufacturing
		• Quality
		• Facility Layout and Optimization
		• ISO Certification Assistance
		• Food Safety Practices and Certification(s)
Fraunhofer USA Center Mid-Atlantic (CMA)	Software and Systems Engineering	The Software Engineering Division drives critical thinking and software-enabled solutions for its customers in industry, government and academia. Affiliated with the University of Maryland, the Center conducts applied research aimed at designing and developing software-intensive systems that are safe, secure, tested and verified. Key focus areas include advanced AI applications for manufacturing, healthcare and life

Provider	Program	Services
		sciences, and supply chain illumination and management.
Maryland Technology Enterprise Institute (Mtech)	The Maryland Technology Enterprise Institute (Mtech) is a national leader in entrepreneurship and innovation education and venture creation and is a pioneer in building successful university-company partnerships. Selected Programs Include:	
	Maryland Industrial Partnerships (MIPS) program	MIPS provides funding, matched by participating companies, for university-based research projects that help the companies develop new products.
	MakerBot Innovation Center	A centralized, scalable 3D printing space that empowers everyone to invent, innovate, iterate, and replicate. Students, faculty, staff and the surrounding community are given a unique opportunity to learn about the benefits that 3D printing can provide.
Maryland Manufacturing 4.0 Grant Program	The Maryland Manufacturing 4.0 grant program provides grants to small and mid-sized Maryland manufacturers to invest in Industry 4.0-related technologies, machinery and robotics, and digital business practices in order to remain competitive and drive growth. This pilot program is funded by $1 million in the state's fiscal year 2023 budget.	

Source: JFI Review of Online Materials and Working Group Discussion

Programs in Other States

While Maryland's new and existing programs to support Manufacturing 4.0 adoption are impressive and a step in the right direction, more can and must be done to support the needed investments to more fully deploy this game changing technology in Maryland. The Maryland MEP's *The Future is Now, Realizing the Promise of Industry 4.0: A Strategic Plan to Ensure a Competitive Future for Manufacturing in Maryland* plan identifies fourteen Action Items across four Strategic Priority areas to enhance and support Manufacturing 4.0 adoption. These include:

STRATEGIC PRIORITY 1: ESTABLISHING RESOURCES FOR STARTING THE INDUSTRY 4.0 JOURNEY

- Action 1.1: Offer Manufacturing 4.0-specific assessments and facilitation for Maryland SMEs
- Action 1.2: Invest in and support a Maryland Manufacturing 4.0 Tech Demonstration and Training Lab primarily targeted toward SMEs.
- Action 1.3: Catalog and showcase "Use Cases" in communicating the ROI and the journey for other manufacturers that have successfully implemented Industry 4.0 technologies and to assist in making the business case for investments.
- Action 1.4: Provide assessment and informational resources for systems integration and addressing interoperability challenges.
- Action 1.5: Implement regular survey efforts to gauge progress on Industry 4.0 adoption among Maryland SMEs.

STRATEGIC PRIORITY 2: ADDRESSING BARRIERS AND CHALLENGES TO INDUSTRY 4.0 TECHNOLOGY ADOPTION, INTEGRATION

- Action 2.1: Develop and deploy a state incentives program—The Maryland Manufacturing Innovation Fund—to de-risk and address cost challenges for SMEs to invest in digital, Manufacturing 4.0 Technologies.
- Action 2.2: Build awareness among Maryland manufacturers of existing state incentives and programs, particularly those applicable to Industry 4.0 investments and workforce and talent development.
- Action 2.3: Advance broad-based assistance and strategic partnerships in addressing cybersecurity threats to manufacturers.
- Action 2.4: Support both up-skilling and broad-based training of Maryland's manufacturing workforce—both among incumbent workers and across the education pipeline—at an appropriate scale for impending rise of Industry 4.0.

STRATEGIC PRIORITY 3: STRENGTHENING INTRA-STATE SUPPLY CHAIN CONNECTIONS

- Action 3.1: Develop Maryland supply chain mapping and directory resources for targeted manufacturing clusters.
- Action 3.2: Incent, promote in-state supply chain connections, sourcing, purchasing.
- Action 3.3: Proactively pursue potential "reshoring" opportunities in targeted industries.

STRATEGIC PRIORITY 4: SEIZING EMERGING MANUFACTURING INDUSTRY AND MARKET OPPORTUNITIES FOR ENGAGEMENT AND ASSISTANCE BY MD MEP

- Action 4.1: Increase engagement between MD MEP and the Maryland life sciences cluster to leverage strategic partnerships and collaborations with life sciences-focused state organizations and strategic life sciences assets.
- Action 4.2: Identify and seize Federal procurement opportunities for Maryland manufacturers.

In order to assist the Task Force in its goal to *Recommend additional financial support delivery mechanisms, as needed, to enable State manufacturers to adopt Industry 4.0 technology and enhance the ability of industry service providers to increase the scope of their industry support*, the JFI identifies and describes key successful national programs to support Manufacturing 4.0 Investment in three areas:

1) Planning;
2) Investment support; and
3) Technology test beds.

State Planning to Support Manufacturing 4.0 Investment

In order to fully realize the potential of Manufacturing 4.0 states need to: prepare strategic plans or roadmaps to identify industry technology needs; assess existing resources; determine the alignment of resources to need; and develop programs to meet areas of unmet needs to enhance and incentivize Manufacturing 4.0 adoption. These plans need to go beyond basic planning documents and be based on substantial manufacturing industry and related stakeholder engagement and a thorough assessment of both assets and needs to support sector growth. Based on the JFI's review of existing programs, two states stand out in planning for Manufacturing 4.0 adoption, Connecticut and Iowa.

Connecticut, though legislative action, similar to that enacted in Maryland, established the Manufacturing Technology Working Group in 2021 to:

- Compile comprehensive profiles, including mission statements, and lists of services, for all entities that receive state or federal funding for the purpose of researching, developing, training, marketing, consulting or deploying Industry 4.0 technology or associate services, directly to, or for the benefit of, manufacturing startups, small and mid-sized manufacturers or other businesses primarily engaged in manufacturing;
- Conduct value-stream mapping and other analyses, as needed, to assess the flow of services from the entities identified; and
- Submit a strategic plan to ensure that manufacturers in the state have a strategy for the lean application and integration of Industry 4.0 technology into their product development and production processes.

This working group is made up of representatives from the Connecticut Center for Advanced Technology; CONNSTEP (Connecticut's NIST MEP site); manufacturing companies (small, medium and large); and representatives from higher education and service providers.[14] Connecticut will be

[14] https://trackbill.com/bill/connecticut-senate-bill-1021-an-act-establishing-a-manufacturing-technology-working-group/2057640/.

releasing this strategy in October, but as will be described below is already a national leader in programs to support Manufacturing 4.0 investment.

Iowa's Manufacturing 4.0 Study and Programming was initiated by the Iowa Innovation Council (IIC), an advisory group comprised of business leaders, public universities, representatives and community college officials charged with developing strategies to encourage and support innovation. The Innovation Council works to promote advanced industries, including: Biosciences; Advanced Manufacturing; Ed Tech; Finance; and Renewable Energy. The Council's Advanced Manufacturing Work Group, a subgroup of the Iowa Economic Development Authority's (IEDA) Iowa Innovation Council, led the Manufacturing 4.0 effort and created a focused Manufacturing 4.0 Working Group and commissioned the development of an Industry 4.0 Strategy.[15]

In many ways, Maryland has implemented a similar Manufacturing 4.0 planning effort, combining elements of both Connecticut, through the creation of this legislatively mandated task force, and Iowa, with Maryland MEP commissioning *The Future is Now, Realizing the Promise of Industry 4.0: A Strategic Plan to Ensure a Competitive Future for Manufacturing in Maryland* strategy. However, more could be done to more fully identify resources and needs for Manufacturing 4.0 and better engage the Maryland manufacturing and related stakeholder community in program development and design.

Given the impending change in State administration, this would be a good time for Maryland to develop a strategy not only to support Manufacturing 4.0 investment and adoption, but to better identify the overall needs of the manufacturing sector to guide the incoming administration to support the growth of this important sector.

Investment Support

While Maryland has made the first step in supporting Manufacturing 4.0 investment through the creation of the Maryland Manufacturing 4.0 Grant Program, ***other states have gone much further in deploying much larger Manufacturing 4.0 investment grant, loan and tax incentive programs***. The JFI, in its review of national efforts identified nine state level efforts to provide financial support to Manufacturing 4.0 investment. Four of these (summarized in Table 7) stand out as models for Maryland to potentially emulate in designing a Manufacturing 4.0 investment strategy.

The **Connecticut Center for Advanced Technology** (CCAT) is an applied technology development, demonstration and training center that innovates, validates, demonstrates, and assists with the adoption of leading-edge technologies into Connecticut and the nation's advanced manufacturing supply chain, while providing vital workforce training and upskilling necessary for companies to fully-utilize the technology advancement. Selected programs include:

- Advanced Technology Centers;
- Career, Employer, Educational and Workforce Development Programs;
- Industry/Manufacturing 4.0 Programs and Working Group; and
- Research.

[15] https://www.iowamfg.com/iowa-manufacturing/.

CCAT has three Manufacturing 4.0 Investment programs:

1. Industry 4.0 IoT Integration Voucher Program (IVP) - matching grants up to $20,000 to assist with the implementation of IoT solutions and the creation of smart factories. $900K and 30 Companies to date.
2. Manufacturing Innovation Fund - $5,000 to a maximum of $50,000 in matching grants to improve manufacturing productivity, efficiency and competitiveness. To date, 540 Connecticut companies have leveraged over $23.8 million in grants to upgrade their equipment and processes, train employees, and incorporate the latest software into their IT systems. Connecticut has allocated $20 million for the MIF to be allocated in fiscal years 2022 and 2023.
3. Additive Manufacturing Adoption Program (AMAP) awarded matching grants of $100,000 each to six manufacturers in Connecticut to facilitate the adoption of additive manufacturing in their operations.

The **Massachusetts Center for Advanced Manufacturing** (CAM)'s mission is to foster the most complete, collaborative and agile manufacturing ecosystem, to enable business growth from innovation through production. The CAM is a division of the Massachusetts Technology Collaborative (MassTech), a public economic development agency tasked with supporting business formation and growth in the Commonwealth's tech and innovation sectors. CAM provides a path for manufacturing growth through a connected, accessible ecosystem that supports innovation, workforce development and a business friendly environment. CAM managed programs include the Massachusetts Manufacturing Innovation Initiative (M2I2), the MassBridge manufacturing training program, and the mamanufacturing.com portal. Key Manufacturing 4.0 Programs:

1. Massachusetts Manufacturing Accelerate Program (MMAP) - invests in small- to medium-sized manufacturers to help coordinate and prepare our supply chain to respond to increasing demands and to spur new opportunities for growth.
    - $2 million per year, with each award being no greater than $250,000 (matching) – 5 Years of Funding.
    - Applicants must be a collaboration between a manufacturer and an institution of higher education, non-profit, or other public or quasi-public entity (manufacturing ecosystem partner)
2. Mass. Manufacturing Innovation Initiative (M2I2)
    - Capital cost sharing program.
    - Project must be aligned with CAM's 12 manufacturing institute focus area.
    - Most Grantees are Universities
    - $70M invested to date on business expansion and educational projects to secure our advanced manufacturing leadership
        - $90 Million Leveraged
        - 150 Company Partners

Conexus Indiana is a nonprofit initiative founded in 2007 to position the Hoosier State as the best place for advanced manufacturing and logistics industries to innovate, invest, employ and succeed.

Appendix A: Report on Transforming Manufacturing in a Digital Economy
Authored by: Jacob France Institute

It is a network of industry, education, and public-sector leaders that's strengthening Indiana's competitive advantage in advanced manufacturing and logistics (AML). We leverage innovation and technology and address the most pressing talent needs to make AML more productive and profitable. Its goal is to make Indiana a global AML powerhouse and to ensure our state will be a leader in this sector for generations to come. Conexus supports Manufacturing 4.0 investment through its Manufacturing Readiness Grant, which is:

- A partnership with the Indiana Economic Development Corporation/ Next Level Manufacturing Institute.
- Had $4 Mil. 2020 and $10 Mil. Annual Funding for 2021 and 2022
- Made 169 Awards for $13.4 Mil. Awarded –and $93 Mil. in related investments
- Provides $200,000 Matching Grants (Projects Range from $9k - $200k)
- Focuses on Hardware – but also can be used for Software
- Requires that qualifying technology adoption should be transformative for Indiana manufacturing operations by enhancing capacity, capability, speed and quality.
- Funded Projects include: Internet of Things (IoT), cloud computing and analytics, advanced modeling, additive manufacturing, artificial intelligence and cobots.

Iowa - Manufacturing 4.0 Initiative- Led by the Iowa Economic Development Authority, creates strategies and actions focused on ensuring Iowa is a global leader in the next generation of manufacturing.
Industry 4.0 Assessments, with the following efforts:

- Monitor and Track Manufacturing 4.0 Adoption.
- Support cross-industry and industry-university collaborations and implement company specific assessments to address critical manufacturing-specific cybersecurity challenges.
- Provide resources to Iowa manufacturing SMEs to help address interoperability challenges in a dynamic Industry 4.0 operating environment.
- Form an Iowa OEM Advisory Council to advise, counsel, and support supply chain SMEs in adopting Manufacturing 4.0 technologies.
- Collaborate to scale Manufacturing 4.0 training/re-training.

Manufacturing 4.0 Grant Programs

1. Manufacturing Innovation Equipment Grants
    - Eligible companies can apply for matching grants up to $50,000 for the purchase of specialized equipment aimed at helping manufacturers increase productivity, efficiency and competitiveness.
2. Manufacturing Industrial Internet of Things (IIoT) Infrastructure Investment Grants
    - Eligible companies can apply for matching grants up to $25,000 for the purchase of specialized hardware or software in the Industry 4.0 technology groups

The Grant Program is linked to the state's MEP, with firms required to undergo an assessment by the Center for Industrial Research and Service (CIRAS) to develop a plan for their investment in advance of submitting a grant application. The program is:

- Focused on Small Business, with 3-75 Employee;
- Provides $7.0 million for small manufacturers; with
- $2.5 Mil. deployed– 41 companies.

Based on the JFI review of these programs, successful Manufacturing 4.0 investment programs are:

1. ***Based on long term plans to support the manufacturing sector;***
2. ***Provide stable long-term funding – nearly all programs reviewed have been extended with increased funding based on strong industry demand;***
3. ***Are linked to larger industry led efforts or manufacturing support organizations;***
4. ***Are targeted on small to mid-sized manufacturing where the need for support is the greatest; and***
5. ***Several are linked to MEP Manufacturing 4.0 technical assistance efforts.***

Table 7: Selected State Programs to Support Manufacturing 4.0 Adoption

State	Program	Part of a Larger Manufacturing Center	Most Recent Year's Program Funding	Project Funding	Required Linkages
CT	Industry 4.0 IoT Integration Voucher Program (IVP)	Connecticut Center for Advanced Technology	$900k	$20,000	None
	Manufacturing Innovation Fund Voucher Program (MVP)		$5 Mil. $3 Mil. More in 2022	$49,000	
	Additive Manufacturing Adoption Program		$600K	$100,000	
MA	Massachusetts Manufacturing Accelerate Program (MMAP)	Massachusetts Center for Advanced Manufacturing	$2 Mil.	$250,000	MEP/ Higher Ed.
	Mass. Manufacturing Innovation Initiative (M2I2)		$100 Mil. Invested 6 Years ago - $80 Mil. Spent	No Cap	University
IN	Manufacturing Readiness Grant	Conexus Indiana	$4 Mil.	$200,000	
IA	Manufacturing Innovation Equipment Grants	No - Part of Iowa Economic Development Authority - Long Term Plan to Develop a Center	$5 Mil.	$50,000	MEP
	Manufacturing Industrial Internet of Things (IIoT) Infrastructure Investment Grants			$25,000	

Source: JFI Analysis

There are several other examples of states offering financial support for investments in manufacturing automation. One example of a broad-based tax incentive is the ***North Dakota Automation Credit – 21st Century Manufacturing Workforce Initiative***, under which taxpayer is allowed up to a 20% income tax credit for the purchase or capital lease of manufacturing machinery and equipment for the purpose of automating manufacturing processes in North Dakota. The state has allotted $1 million in credits for deliveries made in each calendar year (calendar years 2019-2022).

Technology Demonstration Training Labs

One of the fourteen recommendations in the Maryland MEP's *The Future is Now, Realizing the Promise of Industry 4.0: A Strategic Plan to Ensure a Competitive Future for Manufacturing in Maryland* plan report is *Action 1.2: Invest in and support a Maryland Manufacturing 4.0 Tech Demonstration and Training Lab primarily targeted toward SMEs*. Creating a dedicated Manufacturing 4.0 demonstration, testing and training facility can offer multiple benefits,

including both allowing companies to test equipment and providing equipment for students to train on state-of-the-art equipment. Creating these spaces was identified in the MIT *Benchmarking Advanced Manufacturing Education: A study from the MassBridge Workforce Education Program* report on manufacturing education as follows:

> ***Ensure access to advanced manufacturing equipment***. Employers want students who have actual experience with the latest production technologies. Because of the cost of equipment, there is a significant challenge in getting students hands-on learning, particularly with advanced equipment. One approach, noted in the Asnuntuck Community College example above, is for a state to create regional technology centers shared by consortia of community colleges, high schools and employers. In addition to providing efficient student access to equipment, providing companies access can help them test and experiment with new equipment, evaluating how it can improve their production process and assist in training for their workers. However, since travel to shared centers can be a barrier for students, other creative approaches may be required. For example, programs could provide basic equipment in all sites and specialized equipment in shared sites, or programs could be designed to provide required hands-on e equipment, there is a significant challenge in getting students hands-on learning, particularly with advanced equipment. One approach, noted in the Asnuntuck Community College example above, is for a state to create regional technology centers shared by consortia of community colleges, high schools and employers. In addition to providing efficient student access to equipment, providing companies access can help them test and experiment with new equipment, evaluating how it can improve their production process and assist in training for their workers. However, since travel to shared centers can be a barrier for students, other creative approaches may be required. For example, programs could provide basic equipment in all sites and specialized equipment in shared sites, or programs could be designed to provide required hands-on experience in the least possible number of trips.

The Workgroup has been briefed on a private sector – Manufacturing 4.0 demonstration facility, the 23,000-square-foot **Advanced Manufacturing Center of Excellence** in Hartford, Connecticut. Called "Manufactory 4.0," the facility will serve as the epicenter for the company's global Industry 4.0 "smart factory" and workforce upskilling initiatives. The facility features Industry 4.0 systems the company has successfully adopted in recent initiatives, new technologies that the lab will be focusing on moving forward, as well as a showcase of how they can be implemented into SB&D facilities around the world in the years ahead. The Manufactory serves as the nerve-center of Stanley Black & Decker's Industry 4.0 transformation. It is designed to more rapidly test and deploy technologies at the company's manufacturing facilities and deeply engage with a wide range of public and private partners. ***The Manufactory is also an innovation hub for the local region, helping Connecticut's manufacturing community, including suppliers and customers, evolve into advanced manufacturing and to re-develop Connecticut as a leading market for advanced manufacturing in the United States.***

Several states have developed similar facilities, with the JFI's research identifying the Oregon Factory of Tomorrow as a potential best practice.

Oregon - Factory of Tomorrow The Oregon Manufacturing Extension Partnership (OMEP) and Oregon Manufacturing Innovation Center Research and Development (OMIC R&D) partnered to create an advanced manufacturing technology lab designed for Oregon's small and mid-sized manufacturers. This lab will empower manufacturers to adopt current and emerging technologies that are driving productivity around the globe. The lab provides a space for companies to test technologies, and achieve proof of concept for adopting new technologies before investing. All hardware and software in the lab are integrated to show that Smart Factories and Industry 4.0 advanced technologies are within reach. The Factory of Tomorrow demonstrates real world applications in a low volume, high mix environment.

Another Manufacturing 4.0 technology demonstration is Virginia's **GENEDGE Alliance - Mobile Technology Insertion Program** (MTIP) a mobile demonstration facility that will educate and train small and mid-sized manufacturers on advanced manufacturing technologies and how they could potentially benefit their operations.

High Level Assessment of Selected Tax and Regulatory Issues

In order to inform the Workgroup's charge to *Examine the State's current statutory and regulatory authority over manufacturing to examine potential reforms to attract new manufacturing businesses brought by Industry 4.0 to invest in the State's economy and workforce*, the JFI conducted a high level assessment of key business climate, tax and regulatory issues impacting the Maryland manufacturing sector. While tax and regulatory issues clearly impact the manufacturing sector, neither were a core focus of the Workgroup's deliberations, which focused on the dual and related needs for supporting Manufacturing 4.0 investment and adoption and addressing workforce needs and issues.

Business and Manufacturing Climate Rankings

Maryland has been perceived as having business climate issues that impact the competitiveness of its entire business base. A states' business climate can broadly be defined as the perceived hospitality of a state or locality to the needs and desires of businesses located in, or considering a move to, that jurisdiction. Business climate has multiple, and in some cases conflicting components, including infrastructure; workforce; taxes; regulations; and entrepreneurship/technology. According to the 2014, Interim Report of the Maryland Economic Development and Business Climate Commission (the Augustine Commission):

> "Three independent rankings of "business climate" place Maryland in twentieth, thirty-fifth, and fortieth place. While there are many surveys reflecting somewhat differing viewpoints, the evidence presented in this report is believed to fairly represent an overall consensus of those surveys. In fact, the strongest message conveyed by witnesses appearing before MEDBCC, whether representing small or

large businesses, was dissatisfaction with the attitude towards business from State and local government units."

There are multiple national reports ranking state's business climates, and Maryland's ranking varies based on the emphasis in each business climate ranking effort. Maryland's position in a selected number of these rankings are as follows:

- Site Selection Magazine (2021) – Maryland not in Top 10 – Ranked 7th of 8 states in South Atlantic Region
- Chief Executive (2022) – Maryland 32nd
- Beacon Hill (2018) – Maryland 26th
- Forbes (2019) Maryland 34th overall and 41st in Regulation
- CNBC (2022) – Maryland 27th
- The Milken Institute's 2020 STATE TECHNOLOGY AND SCIENCE INDEX: OVERALL RANKINGS ranks Maryland 4th nationally in terms of its knowledge economy.
  In terms of specific areas of business climate, the Tax Foundation 2022 State Business

Tax Climate Index ranks Maryland 46th, down from 39th in 2014, in its tax climate; in terms of regulation, the Mercatus Center ranks Maryland as "Highly Regulated"; and for manufacturing the Ball State Center for Business and Economic Research *2020 Manufacturing and Logistics National Report* gives Maryland a "D" grade in terms of the health of its manufacturing sector.

Growing the Maryland Manufacturing Base Requires an emphasis on improving the State's Business Climate. Based on national business climate rankings, Maryland generally performs well in terms of the assets available to support economic development, such as workforce, location, research and development, and technology assets. However, when rankings focus on business costs, such as taxes, regulations, and labor costs, Maryland generally performs more more poorly. According to the Augustine Commission report, "Highly publicized surveys that rank Maryland low in its business climate stand as a significant deterrent to entrepreneurs and relocating businesses, as well as to retaining existing businesses. Even the most well-run economic development programs cannot excel if there is a perception that the State is unfriendly to business."

Maryland Business Climate Survey

Another way to assess perceptions of Maryland's business climate is to survey firms on their perceptions of the State as a place to do business. In 2019, the JFI teamed with the Maryland Public Policy Institute to restart the Maryland Business Climate Survey. This survey of 1,010 Maryland businesses in "mobile industries" collected information on firm perceptions of Maryland's business climate as well as taxes and regulations. While the data is from 2019, it does allow for the analysis of how the perceptions of Maryland's business climate varies between manufacturing and nonmanufacturing firms and has the advantage of establishing a base line to pre-pandemic conditions. Overall, manufacturing firms had a slightly less favorable perception of Maryland as a place to to business, with 47% of manufacturing respondents ranking Maryland's business climate as pro-business or business friendly, compared to 48% of non-manufacturing

firms, but 21% of manufacturing respondents ranking Maryland's business climate as either unfriendly to business, or anti-business, compared to 17% of non-manufacturing firms. When asked about taxes and regulations in Maryland:

- 26% of manufacturing firms compared to 24% of non-manufacturing firms reported being negatively impacted by Maryland regulations (Figure 4);
- 71% of manufacturing firms compared to 65% of non-manufacturing firms reported being negatively impacted by Maryland taxes (Figure 4); and
- When asked which regulations and taxes, manufacturing and non-manufacturing firms reported similar responses with an overall focus on taxes in general and regulations in general (Table 10).

Figure 4: 2019 Maryland Business Climate Survey – Percentage of All Firms and Manufacturing Firms Reporting They are Negatively Impacted by Regulations and Taxes

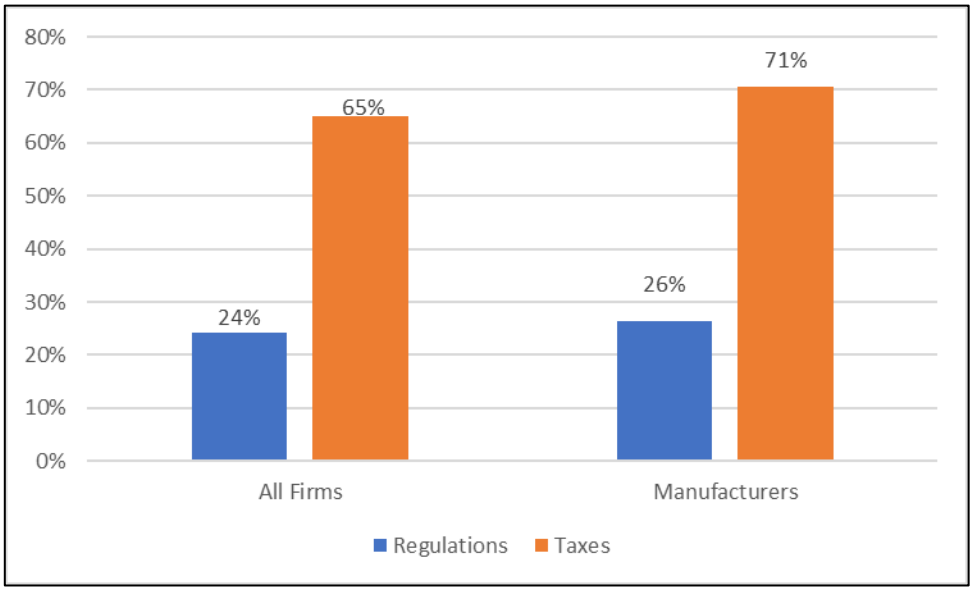


Table 10: Most Burdensome Regulation and Tax

Which Regulation?	All Firms	Manufacturers
Environmental Regulations	9%	5%
Labor Regulations	17%	3%
Health care Regulations or Medical Coverage	8%	8%
Problems with dealing with Regulatory Agencies	5%	3%
Tax Regulations	15%	21%
Occupational Safety (MOSH, OSHA)	1%	0%
Building Permits	5%	8%
General or Other Regulations	12%	13%
All Regulations	29%	41%
Which Tax?	**All Firms**	**Manufacturers**
Income Taxes	20%	14%
Payroll Taxes	16%	17%
Sales or Use Taxes	6%	7%
Property Taxes	12%	15%
Taxes in General	46%	47%

Source: JFI/MPPI Business Climate Survey

Regulatory Issues

Few regulatory issues directly impacting the manufacturing sector were discussed in the Workgroup meetings or identified in the reports and materials reviewed or interviews held.

There was a general consensus in the Workgroup meetings and discussions/interviews not to the spend limited time and resources available on regulatory issues, but to instead focus on the need for Manufacturing 4.0 investment support and devote additional JFI resources to the manufacturing sector's workforce issues – discussed in the next section of this report. The 2016 Augustine Commission report was discussed in Workgroup and discusses Maryland's regulatory environment, with the following findings:

> **"Regulatory Structure**
>
> Business costs, quality of life, regulatory environment, and workforce quality are among the factors typically evaluated to determine the best states for business. The regulatory environment, which is sometimes evaluated as a part of another category such as the cost of conducting business, generally includes State oversight of the environment, infrastructure, workers' benefits, and construction.
>
> MEDBCC heard from a number of witnesses about obstacles that businesses face when interacting with State agencies. Complaints included: State agencies (1) refusing to grant "common sense" exceptions to newly adopted regulations; (2)

exceeding the timeframe prescribed for determining the final outcome of a permit, license, or other agency decision; and (3) refusing to openly discuss issues with businesses regarding the interpretation of regulations. The 2014 Forbes Best states for business survey corroborates much of this witness testimony; Maryland ranks thirty-sixth in the "regulatory environment" category, which examines factors such as a state's labor regulations, health-insurance coverage mandates, and occupational licensing. (Virginia, which many business owners praise for its regulatory environment, ranks number one in the 2014 Forbes Best States for Business survey insofar as regulatory environment is concerned.)

Finding 5. Business in the State suffers from a lack of certainty and inconsistent timeframes for agency decisions.
Too often, agencies exceed the time limit in which they are prescribed to issue a decision or amend a previous compliance or enforcement decision. The overarching theme of most witness testimony before MEDBCC regarding the State's regulatory environment was the lack of certainty in State agency decisions and the seemingly indefinite period of time a State agency had to make decisions about permits and licenses. Few witnesses cited any specific regulation that routinely impedes business growth; instead, most witnesses expressed frustration with a State agency's ability to unilaterally extend the time it has to process a permit application, as well as to change its decision regarding conditions for compliance with a regulation. Others cited State agency unwillingness to address or explain what appeared to be illogical applications of regulatory provisions."

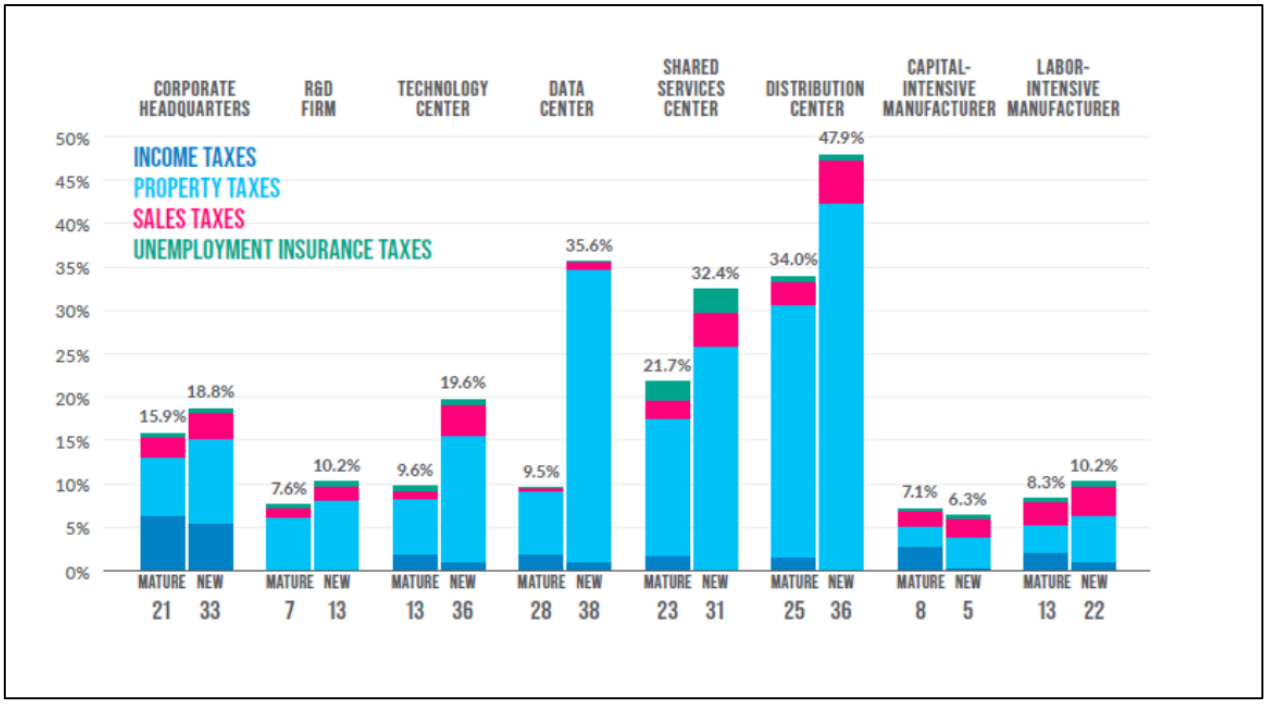
Tax Climate Assessment

While regulatory issues did not rise to the forefront of key issues for the JFI research, or Workgroup discussions, Maryland's tax climate was considered a barrier to the success of the manufacturing sector. The Workgroup agreed with the JFI research that Maryland does have an overall high tax burden. The Workgroup as surprised at the finding that while Maryland's overall tax burden was high, tax policies and abatements mitigate the impact of taxes somewhat on Maryland manufacturers and based on an industry facility specific study of tax burdens nationally, Maryland was competitive in terms of taxes for manufacturing.

Overall, Maryland has a high level of business tax burden. According to the national Tax Foundation's 2022 State Business Tax Climate Index, Maryland was ranked 46th nationally and behind all of the State's regional competitors except Washington DC (48th). Maryland's ranking has fallen from 42nd nationally in 2017 and 2012 – so Maryland's overall competitiveness in terms of business tax rankings has fallen. In terms of regional comparisons, Delaware was ranked 16th, West Virginia 21st, Virginia 25th and Pennsylvania 29th. According to the Tax Foundation, Maryland was ranked: 33rd in Corporate Income Taxes; 46th in Individual Income Taxes; 26th in Sales Taxes; 43rd in Property Taxes; and 46th in Unemployment Insurance Taxes. However, it is important to note the while Maryland's overall tax burden is high, favorable apportionment formulas, generous property tax abatement, low income, unemployment insurance, and sales tax burdens make

Maryland competitive for both capital- and labor-intensive manufacturing – with Maryland ranked: 8th nationally in terms of tax burden on a mature capital intensive manufacturer; 5th in terms of tax burden on a new capital intensive manufacturer; 13th in terms of tax burden on a mature labor intensive manufacturer; and 22nd in terms of tax burden on a new labor intensive manufacturer (Figure 5).

Figure 5: Effective State Tax Rates and National Rankings by Type of Firm for Maryland



Source: Tax Foundation - Location Matters 2021 The State Tax Costs of Doing Business

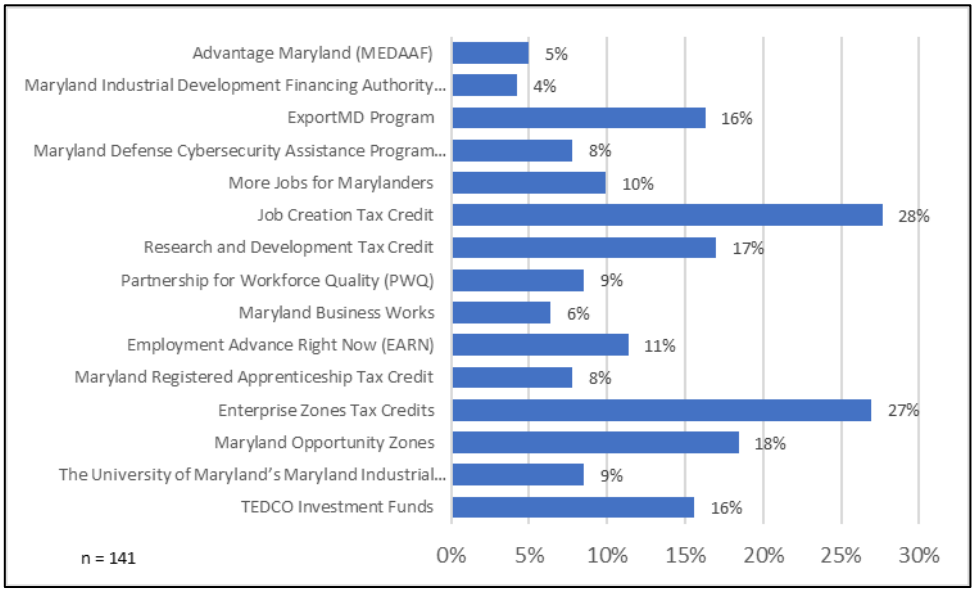
Utilization of Maryland State Incentives

Nationally, there are a large number of business incentives programs. The JFI identified 2,373 state business incentives programs nationally, with Maryland having 83 (the most of any state). Of the 2,373 programs, 63 are specifically targeted to manufacturing; however, most of broad incentive programs are open to and include manufacturing. Interestingly, of the 63 targeted state incentives programs specifically targeted on manufacturing 10 are in Connecticut, a best practice state described above for its manufacturing programs.[16] Maryland offers a wide variety of business tax credits and financial and assistance programs. The Maryland Department of Commerce surveyed manufacturers on their awareness of key state programs and the JFI collected data from the Maryland Departments of Commerce and Labor on manufacturers utilization of key state programs. ***Overall, while manufacturing firms' awareness of key state programs is limited, manufacturers are utilizing the key state programs***.

[16] JFI analysis of data from http://selectusa.stateincentives.org.

Overall Maryland Manufacturers have limited awareness of Maryland State Programs. In the 2021 Maryland Manufacturing Survey, the Maryland Department of Commerce surveyed firms on their awareness of 28 key Maryland business tax credits, financial programs and assistance programs. Overall, a minority of manufacturing firms, were aware of key state programs, ranging from 28% of firms being aware of the Job Creation Tax Credit Program to 4% of firms being aware of Maryland Industrial Development Financing Authority (MIDFA) programs (Figure 6).

Figure 6: Manufacturing Company Awareness of Selected Maryland Business Tax Credits, Financial Programs and Assistance



Maryland Manufacturers are Utilizing Existing State Programs. While a minority of Maryland manufacturing firms are aware of Maryland's key business tax credits and financial and assistance programs, manufacturing firms do utilize many of these programs. The Maryland Department of Commerce and Workgroup identified thirteen key State programs most relevant to the manufacturing sector in presentations to the Workgroup, with nine managed by the Maryland Department of Commerce, and three by the Maryland Department of Labor. These include:

- Six Loan and Grant Programs (Advantage Maryland; Maryland Industrial Development Financing Authority; ExportMD; Maryland Defense Cybersecurity Assistance Program; Supply Chain Resiliency Program; and the MEA's Commercial, Industrial & Agricultural Grant Program);
- Three Tax Credit/Exemption Programs (More Jobs for Marylanders Tax Credit; Job Creation Tax Credit; R&D Tax Credit); and
- Three Workforce Programs.

As presented in Table 11, manufacturing firm participation in the programs where data were available was relatively strong, with manufacturers representing the majority of firms participating in the More Jobs for Marylanders Tax Credit and Partnership for Workforce Quality (PWQ) and

manufacturing firms representing a strong base of firms participating in other programs.[17] ***With strong manufacturing participation in key state programs, increasing manufacturing firm awareness of and participation in existing programs should be a core emphasis of Maryland's manufacturing strategy.***

Table 11: Manufacturing Utilization of Selected Programs, FY2016-21 for Key Financial Programs

Loans and Grants	Department	Notes
Advantage Maryland	Commerce	• 89 Recipients – 34 Manufacturers
Maryland Industrial Development Financing Authority	Commerce	• 8 Recipients – 1 Manufacturer
ExportMD	Commerce	• 199 Recipients – 47 Manufacturers
Maryland Defense Cybersecurity Assistance Program	Commerce	
Supply Chain Resiliency Program	Commerce	
Tax Credits/Exemptions	**Department**	**Notes**
More Jobs for Marylanders Tax	Commerce	• 29 Recipients – 29 Manufacturers
Job Creation Tax Credit	Commerce	• 81 Recipients – 23 Manufacturers
R&D Tax Credit	Commerce	• 1,892 Recipients – 599 Manufacturers
Workforce Training	**Department**	**Notes**
Partnership for Workforce Quality (PWQ)	Commerce	• 97 Recipients – 63 Manufacturers • 2,493 Trainees – 1,336 in Manufacturers
Maryland Business Works	Labor	• $500k – 4 Programs
EARN	Labor	• 64 Active SIPs – 9 Manufacturing Specific and 3 in Biotechnology and 17 in Cyber/IT • 4,761 Participants – 1,979 Credentials Awarded – 2,843 Gained Skills
Maryland Apprenticeship and Training Program		
Registered Apprenticeship Programs	Labor	• 258 Programs – 27 Manufacturing Specific • 102 Manufacturers
Youth Apprenticeship Programs	Labor	• 260 Employers – 34 Manufacturers

Source: JFI Analysis of MD Commerce and MD Labor Data

[17] In addition to the thirteen key loan/grant, tax credit/exemption and workforce programs described above the Maryland Energy Administration offers a number of programs, most importantly the Commercial, Industrial and Agricultural Energy Efficiency Program; the Jane E. Lawton Loan Program; the Combined Heat and Power Program; and the Offshore Wind Business Development Program that assist the Maryland manufacturing industry. Data were unavailable on the number of manufacturing firms utilizing these programs.

Manufacturing Workforce Development Demand, Supply and Gaps Analysis

In order to inform the Workgroup discussions on the three specific focus areas related to workforce development, the JFI conducted a workforce development demand, supply and gaps analysis for the manufacturing sector using data from Lightcast and various federal and state data sources.

Maryland Manufacturing Workforce Demand Analysis

The first step in conducting an industry workforce development study is to assess the levels of occupational workforce workforce demand in the areas of employment trends, job postings and job openings.

Manufacturing Employment By Occupation, Education and Skills

Manufacturing 4.0 is already changing the face of Maryland manufacturing and the sector is projected to experience growth across all skills levels over the next ten years. The technological changes embodied in Manufacturing 4.0 are already changing manufacturing in Maryland. Between 2016 and 2021, nearly all of the job gains in the Maryland manufacturing sector were higher skill, more technologically advanced jobs, and the number of production and middle skill jobs actually fell during this period. These declines in middle skill and production worker employment occurred despite 14 % growth in real manufacturing output, with real output per manufacturing worker increasing. The Maryland manufacturing sector is projected to continue to grow over the next ten years as a result of re-shoring production to domestic locations, with the sector projected to create both higher skilled professional as well as middle skill production jobs in Maryland.

The JFI first analyzed patterns of Maryland manufacturing employment (described above) by level summary level of occupation (2 digit SOC) and then analyzed patterns of occupational employment by required educational and skills level. Based on the educational and job training requirements of these occupations, employment was further divided into ***high***, ***middle*** and ***lower*** skilled occupations by the JFI. There is no generally accepted methodology for defining jobs by skills level. For this analysis, the JFI developed an estimate of High, Middle and Low Skill jobs by analyzing patterns of detailed SOC employment based on required occupational educational and on-the-job training requirements based on the following criteria:

- ***High Skill*** jobs require a Bachelor's Degree or above;
- ***Middle Skill*** jobs include jobs that require more than a High School Diploma but less than a Bachelor's Degree and jobs requiring a High School Diploma or Less but also requiring Moderate or Long-term On-the-Job (OTJ) Training or an Apprenticeship; and
- ***Low Skill*** jobs include requiring a High School Diploma or Less and either Short-term or no On-the-Job (OTJ) Training.

The key findings of these analyses are as follows:

- The transition to the higher technologically intensive job requirements of the MIT *Work of the Future* report and by the adoption of Manufacturing 4.0 described above are evident in changes in manufacturing employment and the occupational level. As presented in Figure 7 and Table 12, the strong growth in Maryland manufacturing employment over the past five years (2016-21) was driven nearly entirely by growth in technologically intensive management, business, IT, engineering, sciences and related professional occupations, and the employment of production, transportation, and materials moving occupations actually fell despite strong sector growth.
- However, as a result of expected national manufacturing employment growth driven by both re-shoring production from overseas and growth in technologically advanced product manufacturing, Maryland is projected to experience strong growth in manufacturing employment over the next 10 years and is expected to reverse this trend, with the manufacturing sector projected to gain 6,015 Professional and Technical jobs and 5,766 of Production, Transportation, and Materials Moving jobs through 2031. ***Given current shortages, finding these workers may be difficult***.
- Job growth over the past five years has favored high skill Occupations (requiring a Bachelor's and above; however, the manufacturing sector is projected to gain 6,144 middle skill jobs (jobs requiring significant on the job training, apprenticeship training, or an associate's degree/some college over the next ten years -Figure 8 and Table 13);
    - The manufacturing sectors employment of workers with a Bachelor's Degree or above is projected to grow by 18% through 2031, with even stronger growth for workers with advanced (Master's or Doctorate) degrees;
    - Middle skill jobs are projected to increase by 13% and 6,144 through 2031.

Figure 7: Manufacturing Change in Employment By Summary Occupation

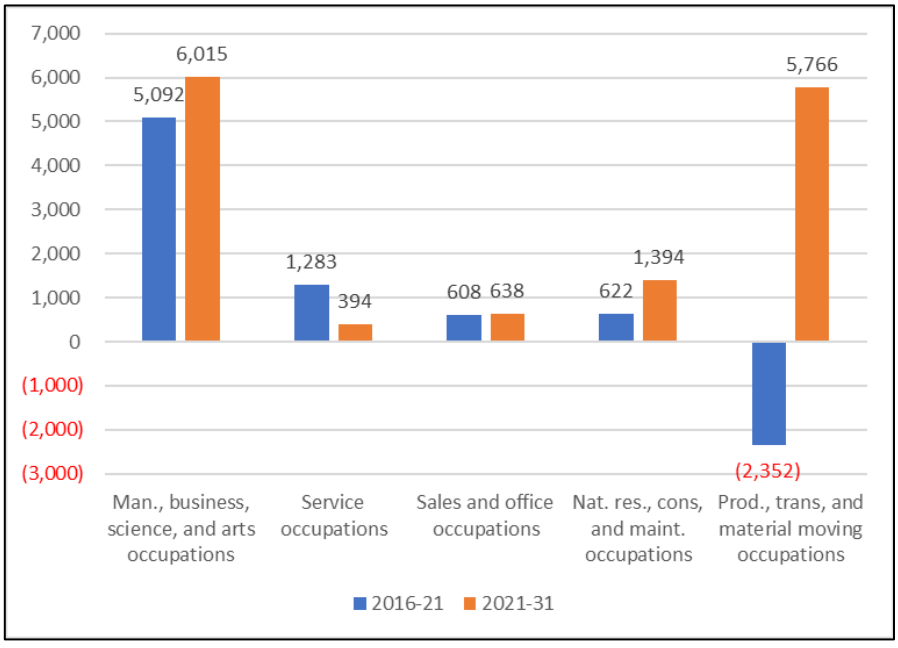


Figure 8: Manufacturing Change in Employment By Skill Level

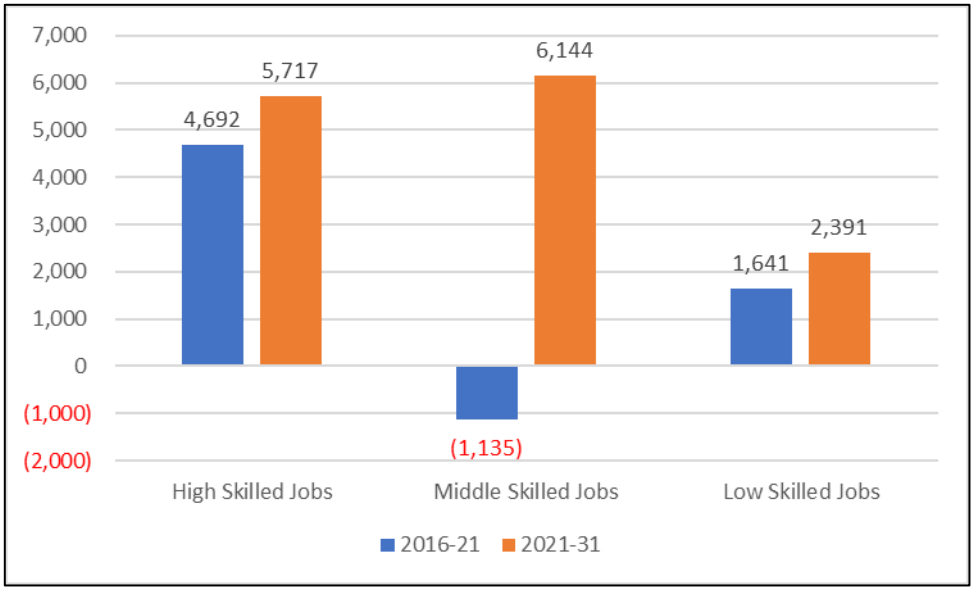


Table 12: Manufacturing Sector Employment and Change, by Summary Occupation - 2016, 2021 and 2031

Occupation	Employment			Change 2016-21		Change 2021-31	
	2016	2021	2031	#	%	#	%
Total	103,662	108,883	123,091	5,222	5%	14,208	13%
Management Occupations	7,894	8,694	10,000	800	10%	1,306	15%
Business and Financial Operations Occupations	5,196	6,720	7,825	1,525	29%	1,104	16%
Computer and Mathematical Occupations	4,008	5,152	6,148	1,144	29%	996	19%
Architecture and Engineering Occupations	8,507	9,319	11,164	812	10%	1,845	20%
Life, Physical, and Social Science Occupations	2,642	3,195	3,872	553	21%	677	21%
Community and Social Service Occupations	0	0	0	n.m.	n.m.	n.m.	n.m.
Legal Occupations	56	58	75	2	3%	17	30%
Educational Instruction and Library Occupations	0	0	<10	n.a.	n.a.	n.m.	n.m.
Arts, Design, Entertainment, Sports, and Media Occupations	944	1,159	1,197	214	23%	38	3%
Healthcare Practitioners and Technical Occupations	66	109	139	43	65%	31	28%
Healthcare Support Occupations	<10	27	30	n.a.	n.a.	3	12%
Protective Service Occupations	115	99	114	(16)	(14%)	14	14%

Occupation	Employment 2016	Employment 2021	Employment 2031	Change 2016-21 #	Change 2016-21 %	Change 2021-31 #	Change 2021-31 %
Food Preparation and Serving Related Occupations	625	1,820	2,098	1,195	191%	278	15%
Building and Grounds Cleaning and Maintenance Occupations	546	607	706	61	11%	99	16%
Personal Care and Service Occupations	16	<10	<10	n.m.	n.m.	n.m.	n.m.
Sales and Related Occupations	4,018	4,561	4,991	543	14%	431	9%
Office and Administrative Support Occupations	10,359	10,425	10,633	66	1%	208	2%
Farming, Fishing, and Forestry Occupations	228	440	476	212	93%	36	8%
Construction and Extraction Occupations	1,165	1,223	1,433	58	5%	210	17%
Installation, Maintenance, and Repair Occupations	4,793	5,145	6,293	352	7%	1,147	22%
Production Occupations	42,687	40,999	45,507	(1,688)	(4%)	4,508	11%
Transportation and Material Moving Occupations	9,796	9,132	10,390	(664)	(7%)	1,258	14%
Military-only occupations	0	0	0	n.m.	n.m.	n.m.	n.m.
Unclassified Occupation	0	0	0	n.m.	n.m.	n.m.	n.m.

Source: JFI analysis of Lightcast Data

Table 13: Manufacturing Sector Employment and Change, By Education Requirements, Selected OTJ Training Requirements, and Skill Level - 2016, 2021 and 2031

Education/Training/Skill Level	Employment 2016	Employment 2021	Employment 2026	Change 2016-21 #	Change 2016-21 %	Change 2021-31 #	Change 2021-31 %
Total[1]	103,209	108,407	122,660	5,198	5%	14,252	13%
High Skill Jobs[2]	26,648	31,340	37,057	4,692	18%	5,717	18%
Middle Skill Jobs[3]	49,862	48,727	54,871	(1,135)	(2%)	6,144	13%
Low Skill Jobs[4]	26,700	28,341	30,732	1,641	6%	2,391	8%
Total	103,209	108,407	122,660	5,198	14,252	14,252	13%
Not Applicable	0	0	0	n.m.	n.m.	n.m.	n.m.
No formal educational credential	12,132	13,803	15,433	1,671	1,630	1,630	12%
No OTJ Training Requirement	0	0	0	n.m.	n.m.	n.m.	n.m.
Short-term on-the-job training	9,889	11,603	12,975	1,713	1,372	1,372	12%
Moderate-term on-the-job training	1,300	1,558	1,709	258	152	152	10%

Education/Training/Skill Level	Employment 2016	Employment 2021	Employment 2026	Change 2016-21 #	Change 2016-21 %	Change 2021-31 #	Change 2021-31 %
Long-term on-the-job training	942	643	748	(300)	106	106	16%
High school diploma or equivalent	57,418	56,639	62,843	(778)	6,204	6,204	11%
No OTJ Training Requirement	6,692	6,544	7,324	(147)	780	780	12%
Short-term on-the-job training	10,118	10,194	10,432	76	239	239	2%
Moderate-term on-the-job training	35,515	35,087	38,977	(428)	3,890	3,890	11%
Long-term on-the-job training	4,232	4,012	5,157	(220)	1,145	1,145	29%
Apprenticeship	861	803	952	(58)	150	150	19%
Postsecondary non-degree award	2,750	2,280	2,522	(470)	242	242	11%
Some college, no degree	1,211	1,200	1,262	(12)	63	63	5%
Associate's degree	3,050	3,145	3,542	95	397	397	13%
Bachelor's degree	26,108	30,685	36,242	4,576	5,558	5,558	18%
Master's degree	113	100	135	(13)	34	34	34%
Doctoral or professional degree	426	555	680	129	125	125	23%

(1) Does not sum to total jobs because of unallocated employment and for Occupations for which data are not available.

(2) Occupations requiring a Bachelors or Above.

(3) Occupations requiring more than a High School Diploma but less than a Bachelors Degree and Jobs requiring a High School Diploma or Less but also requiring Moderate or Long-term OTJ Training or an Apprenticeship

(4) Occupations requiring a High School Diploma or Less.

Source: JFI analysis of Lightcast Data

Maryland Job Postings and Openings

The Maryland manufacturing sector needs workers. In order to assess the employment and occupational demands or the manufacturing sector, it is also important to analyze current levels of job openings and postings in addition to historical and projected changes in employment. The JFI analyzed data from both the Maryland Department of Labor's Maryland Workforce Exchange and Lightcast. Based on data from the Maryland Workforce Exchange, the Maryland manufacturing sector is experiencing a strong level of workforce demand as measured by job openings[18]. As of August 24, 2022, the manufacturing sector accounted for a total of 14,052 of all job openings in Maryland, or 8% of total job openings. Because manufacturing accounts for only 4% of Maryland employment, this high share of openings – more than twice the sector's share of employment, is indicative of the strong demand for labor in the industry (Table 14). Using Lightcast data on total job postings, manufacturing job postings of 14,153 in June of 2022 are well above pre-pandemic levels and since the pandemic, the recovery in manufacturing job postings has outpaced the overall Maryland economy. In contrast, job openings in the professional services sector, the key driver of the Maryland economy, remain well below pre-pandemic levels (Figure 9).

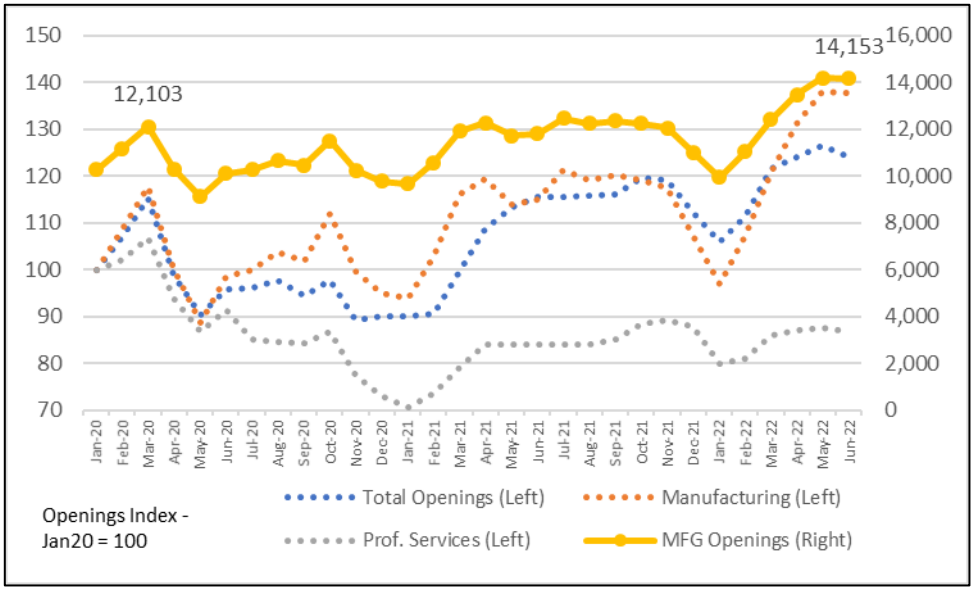
[18] The MWE defines job openings as job openings on line. With the Lightcast data (below) these are called job openings and differ from

Table 14: Maryland Job Openings, August 24, 2022 (Maryland Workforce Exchange)

Industry	Job Openings	% of Total
Total Postings	**175,004**	**100%**
Health Care and Social Assistance	35,284	20%
Professional, Scientific, and Technical Services	27,397	16%
Manufacturing	14,052	8%
Retail Trade	10,156	6%
Educational Services	9,796	6%
Accommodation and Food Services	6,224	4%
Administrative and Support and Waste	4,425	3%
Wholesale Trade	3,138	2%
Other Services (except Public Administration)	2,757	2%
Finance and Insurance	2,603	1%
Construction	2,448	1%
Public Administration	2,396	1%
Information	1,990	1%
Transportation and Warehousing	1,544	1%
Real Estate and Rental and Leasing	1,390	1%
Arts, Entertainment, and Recreation	1,153	1%
Management of Companies and Enterprises	369	0%
Utilities	269	0%
Agriculture, Forestry, Fishing and Hunting	187	0%
Government	132	0%
Mining, Quarrying, and Oil and Gas Extraction	111	0%
Local Government, Exc. Education & Hosp.	10	0%
Unclassified establishments	47,173	27%

Source: MDOL Maryland Workforce Exchange

Figure 9: Job Postings for Maryland By Selected Sector



Manufacturing Specialized Skills Requirements

The Lightcast data on job postings also allows for analyses of data on the specific skills requirements of the online job postings data, with it possible to analyze skills requirements by occupation and other variables. The JFI analyzed the in-demand skills for manufacturing job postings over the first six months of 2022 both for the total manufacturing sector (all manufacturing job postings) as well as for three summary occupations: Professional Occupations (SOC 11-19); Production Occupations (SCO 51); and Transportation and Materials Moving Occupations (SOC 52); which combined account for 73% of all jobs in the manufacturing sector. Based on this analysis:

- The impacts of Manufacturing 4.0 on the skills requirements for the manufacturing sector are clear, information technology dominate the overall skills requirements of the sectors job postings (8 of the top 20 specialized skills) as do automation, process improvement and related managerial skills;
- Similarly, the most in-demand skills for Professional Occupations jobs openings in manufacturing are focused on information technologies, automation and managerial skills (Table 15a); and
- The most in-demand skills for manufacturing job postings for Production Workers remain focused on traditional production oriented skills (Table 15b).

Table 15a: Selected Skills for 2022(January-June) Manufacturing Job Postings, By Selected Occupation

Skills Mentioned in Job Postings for All Occupations in Manufacturing			Skills Mentioned in Job Postings for Professional Occupations in Manufacturing(e.g., management, scientists, programmers)		
Skill	Number of Postings Mentioning This Skill	% of Postings Mentioning This Skill	Skill	Number of Postings Mentioning This Skill	% of Postings Mentioning This Skill
Pharmaceuticals	3,182	8%	Computer Science	3,030	14%
Computer Science	3,179	8%	Systems Engineering	2,625	12%
Marketing	3,067	8%	Agile Methodology	2,487	11%
Auditing	2,959	8%	Pharmaceuticals	2,435	11%
Systems Engineering	2,736	7%	Auditing	2,165	10%
Agile Methodology	2,733	7%	Data Analysis	2,100	10%
Good Manufacturing Practices	2,546	7%	Python (Programming Language)	2,066	9%
New Product Development	2,481	7%	Software Engineering	2,045	9%
Data Analysis	2,474	7%	Marketing	1,987	9%
SAP Applications	2,396	6%	New Product Development	1,974	9%
Warehousing	2,331	6%	Automation	1,878	9%
Automation	2,260	6%	Software Development	1,850	8%
Process Improvement	2,211	6%	Project Management	1,766	8%
Python (Programming Language)	2,131	6%	Process Improvement	1,668	8%
Corrective And Preventive Action (CAPA)	2,111	6%	Linux	1,650	7%
Software Engineering	2,103	6%	Finance	1,620	7%
Finance	2,074	5%	SAP Applications	1,605	7%
Supply Chain	2,018	5%	Corrective And Preventive Action (CAPA)	1,585	7%
Selling Techniques	1,968	5%	Good Manufacturing Practices	1,515	7%
Project Management	1,959	5%	Supply Chain	1,507	7%

Source: JFI Analysis of Lightcast Data

Table 15b: Selected Skills for 2022 (January-June) Manufacturing Job Postings, By Selected Occupation

Skills Mentioned in Job Postings for Production Occupations in Manufacturing			Skills Mentioned in Job Postings for Transportation and Materials Moving Occupations in Manufacturing		
Skill	Number of Postings Mentioning This Skill	% of Postings Mentioning This Skill	Skill	Number of Postings Mentioning This Skill	% of Postings Mentioning This Skill
Good Manufacturing Practices	432	20%	Warehousing	827	44%
Machinery	272	12%	Forklift Truck	480	25%
Machine Operation	261	12%	Palletizing	327	17%
Housekeeping	224	10%	Pallet Jacks	248	13%
Standard Operating Procedure	217	10%	Merchandising	225	12%
Corrective And Preventive Action (CAPA)	192	9%	Forklift Operation	211	11%
Warehousing	179	8%	Housekeeping	191	10%
Hand Tools	176	8%	Material Handling Equipment	177	9%
Machining	173	8%	Inventory Control	145	8%
Micrometer	167	8%	Invoicing	145	8%
Auditing	164	7%	Cycle Counting	144	8%
Manufacturing Processes	163	7%	Customer Support	138	7%
Pharmaceuticals	156	7%	Truck Driving	134	7%
Food Safety And Sanitation	145	7%	Shipping And Receiving	131	7%
Production Line	145	7%	SAP Applications	127	7%
Forklift Truck	125	6%	Pre-Trip And Post-Trip Vehicle Inspections	125	7%
Tooling	122	6%	Machinery	121	6%
Milling	116	5%	Inventory Management	119	6%
Biology	115	5%	Selling Techniques	118	6%
SAP Applications	108	5%	Good Manufacturing Practices	98	5%

Source: JFI Analysis of Lightcast Data

Maryland Manufacturing Job Openings

A different way to look at workforce and occupational demand for the manufacturing sector is to look at the ***estimated level of annual job openings***. According to the U.S. Bureau of Labor Statistics, occupational openings are the projected number of openings (positions) for workers entering the occupation. The openings are defined as the sum of net occupational employment change and occupational separations. Workers who change jobs within an occupation do not generate openings since there is no net change in openings from this movement.[19] Total openings is the combination of occupational job growth (new jobs created by industry growth) plus replacement demand or jobs that will need to be filled by new hires due to existing workers leaving the occupation. Using data from Lightcast the JFI estimated that the Maryland manufacturing sector will have a total of 12,428 estimated job openings each year over the next ten years, 4% of the total of 331,804 annual job openings in Maryland, with:

- 2,757 annual openings in Professional Services occupations;
- 4,996 annual opening in Production Occupations;
- 1,253 annual openings in Transportation and Material Moving Occupations; and
- 1,151 annual openings in Office and Administrative Support Occupations.

Table 15: Employment and Estimated Annual Average 10 Year Openings - Maryland Total and Manufacturing

SOC	Description	Total	Manufacturing	% of Total
Total		**331,804**	**12,428**	4%
11-0000	Management Occupations	17,888	789	4%
13-0000	Business and Financial Operations Occupations	20,490	686	3%
15-0000	Computer and Mathematical Occupations	13,401	462	3%
17-0000	Architecture and Engineering Occupations	4,928	821	17%
19-0000	Life, Physical, and Social Science Occupations	5,131	362	7%
21-0000	Community and Social Service Occupations	6,701	0	0%
23-0000	Legal Occupations	1,849	5	0%
25-0000	Educational Instruction and Library	18,391	0	0%
27-0000	Arts, Design, Entertainment, Sports, and Media	4,046	105	3%
29-0000	Healthcare Practitioners and Technical	12,040	7	0%
31-0000	Healthcare Support Occupations	15,293	2	0%
33-0000	Protective Service Occupations	9,920	13	0%
35-0000	Food Preparation and Serving Related	37,785	342	1%
37-0000	Building and Grounds Cleaning and Maintenance	12,620	89	1%
39-0000	Personal Care and Service Occupations	11,189	0	0%
41-0000	Sales and Related Occupations	32,856	574	2%
43-0000	Office and Administrative Support Occupations	37,956	1,151	3%
45-0000	Farming, Fishing, and Forestry Occupations	1,507	69	5%
47-0000	Construction and Extraction Occupations	12,386	133	1%
49-0000	Installation, Maintenance, and Repair	11,243	570	5%
51-0000	Production Occupations	9,672	4,996	52%

[19] https://www.bls.gov/emp/documentation/definitions.htm

SOC	Description	Total	Manufacturing	% of Total
53-0000	Transportation and Material Moving	31,359	1,253	4%
55-0000	Military-only occupations	3,152	0	0%

Source: JFI Analysis of Lightcast Data

Using this Lightcast data, the JFI analyzed patterns of occupational demand by summary occupation, education level, and skills, with the following results:

- Annual job openings in the manufacturing sector are concentrated in ***high skill*** Management, Business Sciences and Arts Occupations (3,236 openings and 26% of all manufacturing openings and mostly ***middle skill*** Production (4,996 openings and 40%) and Transportation and materials Moving Occupations (1,253 openings and 10%). Combined these three occupational groupings account for more than three quarters of manufacturing sector job openings (Figure 9);
- Most manufacturing job openings do not require a college education, with 8,736 job openings, 70% of the total number of openings requiring either a high school diploma or having no formal educational requirement (Figure 10);
- While most manufacturing job openings do not require more than a high school degree ***they are not low skill jobs***, with most job openings 5,800 (47%) classified as ***middle skill*** jobs requiring either significant on the job training, an apprenticeship, or an associate's degree/some college (Figure 11).

Figure 9: Estimated Annual Manufacturing Openings, By Summary Occupation Level

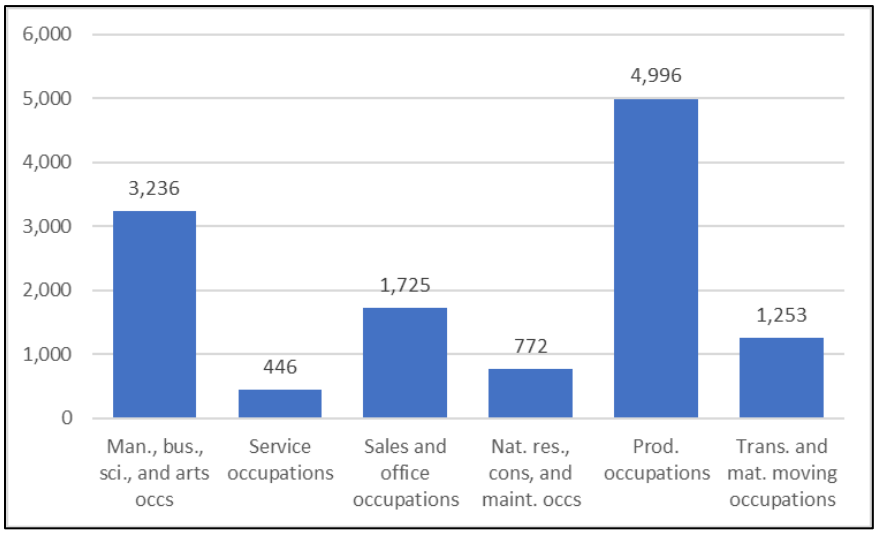


Figure 10: Estimated Annual Manufacturing Openings, By Minimum Educational Requirements

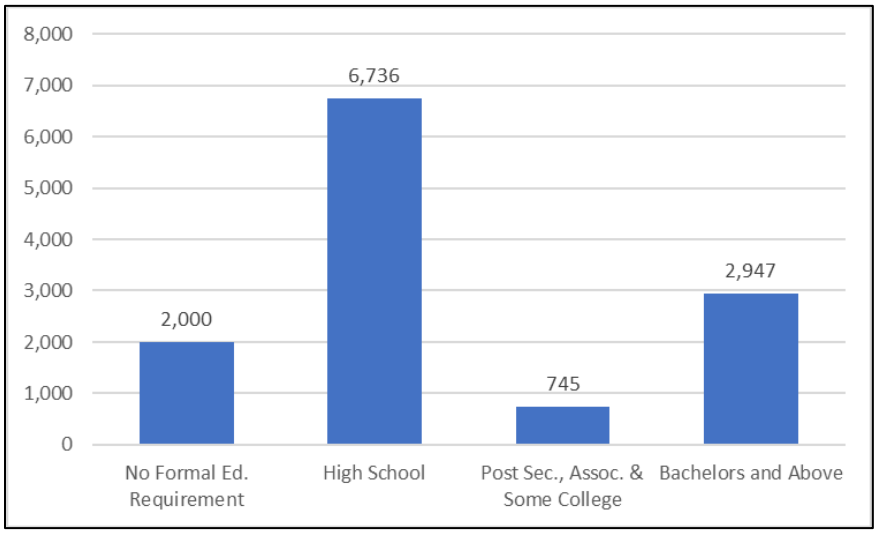
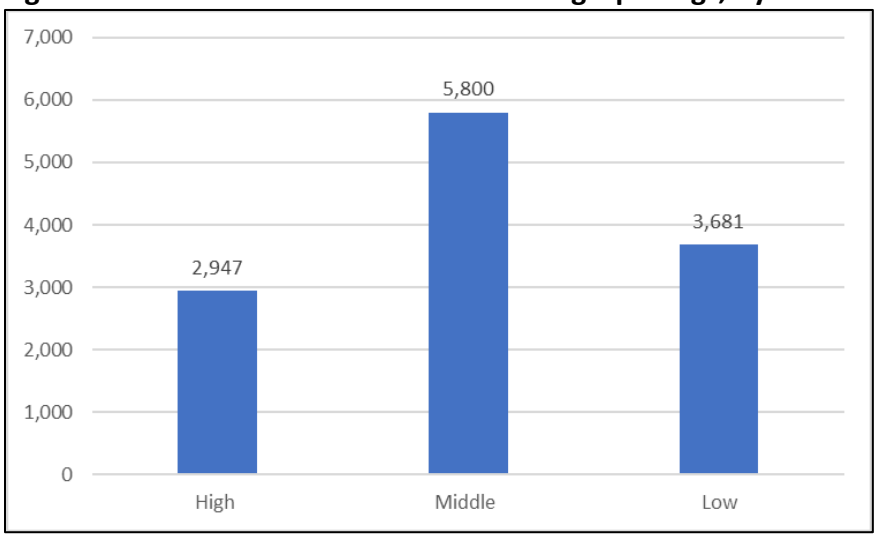


Figure 11: Estimated Annual Manufacturing Openings, By Skill Level



Maryland Manufacturing Workforce Supply Analysis

In order to assess the capacity of Maryland's existing resident workforce and workforce development system/talent pipeline to meet the needs of the manufacturing sector, the JFI also analyzed both the composition of the Maryland workforce and the supply of talent in terms of graduates/completers from key education and training providers.

Maryland's Resident Workforce

The JFI analyzed the composition of the Maryland resident workforce using Occupational Location Quotients (LQ). As described above, a LQ measures the composition of the Maryland workforce as compared to the national average, with a LQ of 1 equaling the national average.

Maryland has a high concentration (LQ above 1) of workers in the Management, Business and financial, Computer and mathematical occupations, Architecture and engineering and Life, physical, and social science occupations but a low concentration of workers in Production occupations (LQ .49 – signifying a concentration of workers less than half the national average (Table 17)

Table 17: Maryland Resident Workforce

Description	Resident Workers	% of Total	Occ. LQ
Total	**3,098,870**	**100%**	**1.00**
Management occupations	369,280	12%	1.11
Business and financial operations occupations	213,589	7%	1.28
Computer and mathematical occupations	181,556	6%	1.78
Architecture and engineering occupations	69,218	2%	1.08
Life, physical, and social science occupations	67,976	2%	2.09
Community and social service occupations	59,721	2%	1.07
Legal occupations	55,141	2%	1.57
Educational instruction, and library occupations	206,917	7%	1.08
Arts, design, entertainment, sports, and media occupations	69,843	2%	1.10
Healthcare practitioners and technical occupations	194,896	6%	1.02
Healthcare support occupations	85,638	3%	0.82
Protective service occupations	90,332	3%	1.34
Food preparation and serving related occupations	157,338	5%	0.89
Building and grounds cleaning and maintenance occupations	111,614	4%	0.97
Personal care and service occupations	87,325	3%	1.02
Sales and related occupations	245,820	8%	0.81
Office and administrative support occupations	309,648	10%	0.94
Farming, fishing, and forestry occupations	5,395	0%	0.28
Construction and extraction occupations	151,103	5%	0.95
Installation, maintenance, and repair occupations	85,254	3%	0.90
Production occupations	85,569	3%	0.49
Transportation occupations	115,772	4%	0.95
Material moving occupations	79,925	3%	0.70

Source: U.S. Bureau of the Census - ACS

Maryland's Manufacturing Workforce

The JFI also analyzed the demographic composition of the Maryland manufacturing workforce using data from the U.S. Bureau of the Census American Community Survey.[20] Based on this analysis, the Maryland manufacturing workforce is:

- Overwhelmingly male (68% versus 50% for non-manufacturing workers)
- Diverse but predominately (68%) white;
- Less educated with 39% of manufacturing workers having a high school diploma or less compared to 30% of non-manufacturing workers;
- Older, with 30% of manufacturing workers older than 55 compared to 25% of non-manufacturing workers; and
- Employed Across a Spectrum of Occupations with both a high concentration of workers in higher skilled Management, Business, and Financial and Computer, Engineering, and Science Occupations (40%) and much higher share of workers in production occupations (28% - Table 18).

Table 18: Workforce Demographic Characteristics Manufacturing and Non-Manufacturing – Demographics

Item	Manufacturing	Non-Manufacturing
Demographics		
Male	68%	50%
Female	32%	50%
White alone	68%	55%
Black or African American alone	21%	30%
Hispanic	7%	11%
Average Wage and Salary Income	$81,773	$67,382
Educational Attainment		
Less Than High School	6%	8%
High School Graduate	33%	22%
Some College	16%	19%
Associate Degree	6%	7%
Bachelor's Degree	24%	24%
Graduate or Professional Degree	15%	20%
Age		
<24	7%	11%
25-34	18%	21%
35-54	45%	42%
55+	30%	25%
Occupational Employment		

[20] Because of the Covid Pandemic the 2020 ACS was not released with full data and the data analyzed were for 2019.

Item	Manufacturing	Non-Manufacturing
Management, Business, and Financial Occupations	23%	19%
Computer, Engineering, and Science Occupations	17%	10%
Education, Legal, Community Service, Arts, and Media Occupations	2%	13%
Healthcare Practitioners and Technical Occupations	0%	7%
Healthcare Support Occupations	0%	3%
Service Occupations	2%	15%
Sales and Related Occupations	6%	8%
Office and Administrative Support Occupations	9%	10%
Farming, Fishing, and Forestry Occupations	0%	0%
Construction and Extraction Occupations	1%	5%
Installation, Maintenance, and Repair Occupations	4%	3%
Production Occupations	28%	2%
Transportation and Material Moving Occupations	8%	6%

Source: U.S. Bureau of the Census - ACS PUMS

The three key implications of this analysis of Maryland's resident workforce are that:

1. ***Because Maryland has a low concentration of resident manufacturing/production workers and the manufacturing workforce is aging, creating a pipeline of trained and skilled manufacturing to meet the projected workforce needs of the sector will be critical;***
2. ***Because the Maryland manufacturing workforce is less diverse than the non-manufacturing workforce, opportunities to attract women, African Americans and Hispanics into the industry is both critical and an opportunity to meet future industry workforce needs; and***
3. ***As a result, expanding Maryland's training infrastructure, especially for production and transportation and materials moving occupations, which are already in short supply, will be even more important.***

Maryland's Manufacturing Talent Pipeline

As discussed above, investing in Maryland's workforce training infrastructure to meet the projected workforce needs of the manufacturing sector will be critical to support both the current needs and projected growth of the industry. In order to assess how Maryland's current workforce development system and talent pipeline is meeting the needs of the manufacturing sector, the JFI analyzed patterns of enrollment and degree/completions in key training programs using state and Lightcast data. The key results of this analysis are as follows:

- Maryland has only limited Career and Technical Education (CTE) enrollment in key manufacturing related programs.
    - Only 10% of high school CTE and 3% of Community College CTE enrollment is in Manufacturing, Engineering and Technology (MET) programs;
    - Based on Workgroup discussions, only a small number of these students are in manufacturing specific programs;
    - There are lower levels of African American and Hispanic enrollment in MET CTE programs;
    - There is a higher level of CTE enrollment (19% in High schools and 10% in Community Colleges) in Manufacturing 4.0 enabling Information Technology (IT) programs (Table 19);
- Maryland Community Colleges play an important role in Maryland's workforce development system with 38,052 Students enrolled in 175 licensure and certification courses; 59,557 students representing over 600 business, associations, and agencies participated in contract training in order to gain the technical or essential skills needed for continued success in the workplace; and 27,561 students enrolled in basic skills and literacy courses. Despite this important role, Community Colleges have only limited generation of certificates for manufacturing careers, according to the Maryland Community Colleges Workforce Training Reports Fiscal Year 2020 report only a small number of community college certificates were in manufacturing related programs (Table 20);
- Analyzing Lightcast data on degree completions from Maryland educational program, the State's workforce development system:
    - Generates a large number of graduates/completers in key manufacturing related Computer and Information Sciences and Support Services programs, 9,962 degrees and certificates; Engineering programs, 4,364; Biological and Biomedical Sciences programs, 3,490, and Business, Management, Marketing, and Related Support Services programs, 14,806 (Table 21); but
    - Generates a far smaller number of graduates/completers in key manufacturing related Science Technologies/ Technicians programs, 155 degrees and certificates; Precision Production, 40; and Transportation and Materials Moving programs, 505 (Table 22).

Table 19: CTE Participant Enrollment

Program	High School # Enrolled	High School % of Total	Community Colleges # Enrolled	Community Colleges % of Total
Total	**122,519**	100%	**48,588**	100%
Information Technology (IT)	23,301	19%	4,641	10%
Human Resource Services (HRS)	22,300	18%	6,802	14%
Business Management and Finance (BMF)	16,981	14%	9,841	20%
Manufacturing, Engineering, and Technology (MET)	**12,176**	**10%**	**1,421**	**3%**
Consumer Services, Hospitality, and Tourism (CSHT)	11,806	10%	1,440	3%
Health and Biosciences (HB)	10,618	9%	18,941	39%
Career Research and Development (CRD)	9,128	7%	15	0%
Construction and Development (CD)	5,958	5%	1,361	3%
Environmental, Agricultural, and Natural Resources (EANR)	3,822	3%	589	1%
Arts, Media, and Communication (AMC)	3,708	3%	2,674	6%
Transportation Technologies (TT)	2,721	2%	863	2%

Source: https://www.mdctedata.org/dashboards/enrollment.php

Table 20: Maryland Workforce Training Certificate Programs by Industry and Program Classification

Industry	Total Completions	Mfg. Specific Completions
Total	**11,470**	**160**
Health Care	3,075	
Trades, Communications and Manufacturing	**1,490**	**121**
Business and Professional	1,397	
Information Technology	**1,172**	**39**
Public Safety	999	
Education	907	
Culinary, Entertainment and Personal Services	927	
Transportation	**723**	
Other	415	

Recreational and Fitness Professionals	127
Animal and Plant Services	238

Source: Maryland Workforce Training Certificate Programs by Industry and Program Classification with Completers from MCCACET Report 2020-2

Table 21: Certificate and Degree Generation in Selected Instructional Fields - Computer, Engineering, Life Sciences and Business Fields

Program	Total Degrees and Certificates	Certificates	Associates Degree's	Bachelor's Degrees	Advanced Degrees
Total	**32,622**	**2,279**	**3,475**	**16,104**	**10,764**
Computer and Information Sciences and Support Services	9,962	948	980	5,356	2,678
Engineering	4,364	85	331	2,326	1,622
Biological and Biomedical Sciences	3,490	55	12	2,298	1,125
Business, Management, Marketing, and Related Support Services	14,806	1,191	2,152	6,124	5,339

Source: Lightcast

Table 22: Certificate and Degree Generation in Selected Instructional Fields – Science Technicians, Production and Transportation/Materials Moving Fields

Program	Total Degrees and Certificates	Certificates	Associates Degree's	Bachelor's Degrees	Advanced Degrees
Total	**700**	**527**	**154**	**16**	**3**
Science Technologies/ Technicians	155	27	128	0	0
Precision Production	40	40	0	0	0
Transportation and Materials Moving	505	460	26	16	3

Source: Lightcast

Maryland Manufacturing Workforce Supply, Demand and Gap Analysis

There is a strong level of alignment between Maryland's resident workforce and talent pipeline and the workforce needs of the manufacturing sector for higher skilled professional occupations but significant gaps exist for middle skill production workers. The final step in assessing the alignment of Maryland's workforce development system to the needs of the manufacturing sector is to assess how the supply of labor in the form of Maryland's resident workforce and talent pipeline aligns with the manufacturing industry's demand for labor. As presented in Figure 12, Maryland has a large number of resident workers in higher skilled Management, business and financial occupations, and Computer, engineering and science occupations, but a very low share of resident workforce in high manufacturing sector demand Production occupations. Similarly, as presented in Figure 13, Maryland colleges, universities,

community colleges, and related education and training providers provide a strong pipeline of talent in Management, business and financial occupations, Computer and mathematical occupations, and Architecture and engineering occupations, with degree and certificate generation far in excess of annual occupational demand from the manufacturing sector. However, degree and certificate generation in areas related to both Production occupations and Transportation and materials moving occupations falls far short of annual occupational demand from the manufacturing sector.

Figure 12: Share of Maryland Resident Workforce and Manufacturing Jobs, By Selected Occupation

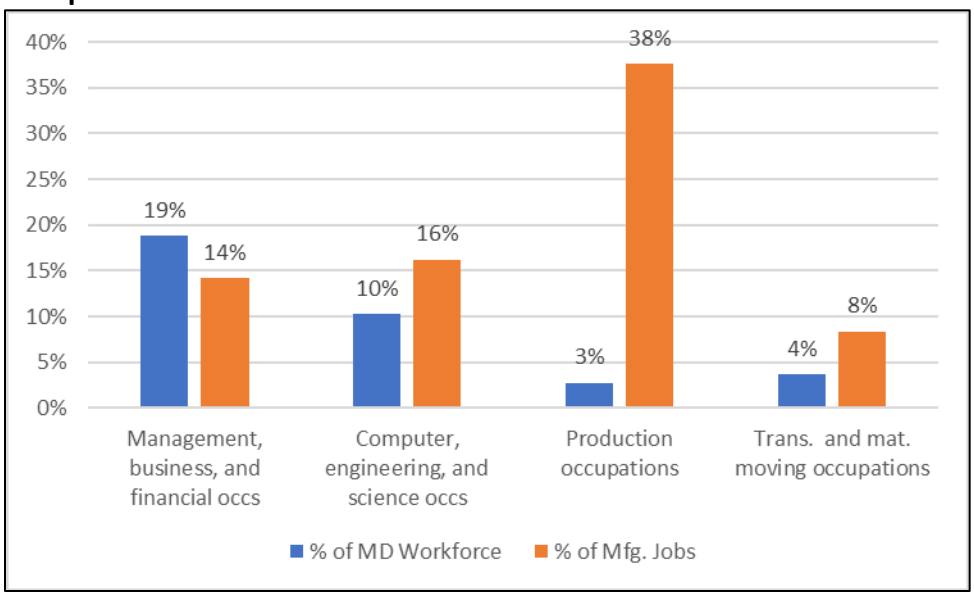
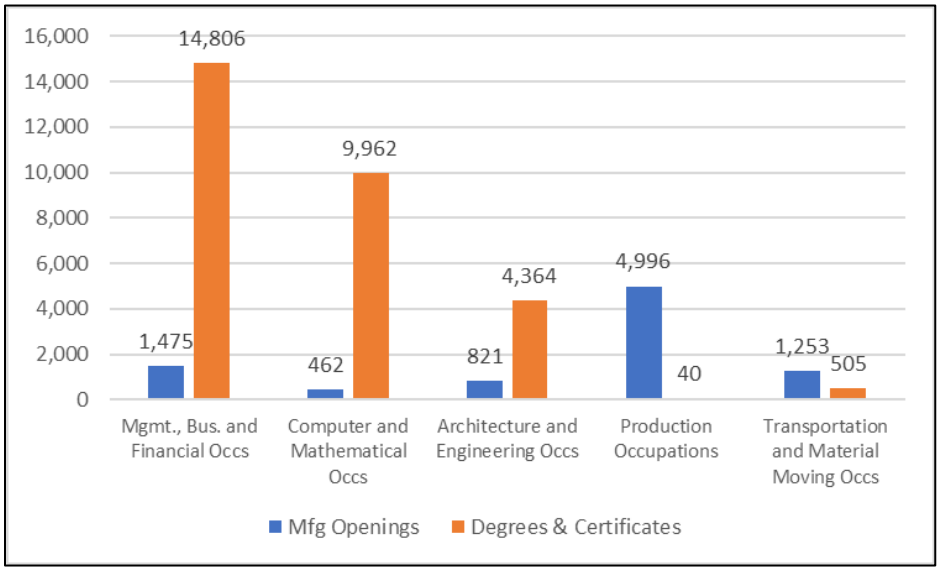


Figure 13: Maryland Workforce System Degree and Certificate Generation Compared to Manufacturing Sector Job Opening, By Selected Occupation



Selected National Manufacturing Workforce Development Program Examples

As described above and discussed in the Workgroup meetings, the Maryland manufacturing sector has significant unmet workforce development needs. The manufacturing sector is projected to create over 14,000 net new jobs over the next ten years and will need fill more than 12,000 openings each year. The Maryland manufacturing sector is already facing significant difficulty in finding a sufficient number of sufficiently educated, skilled and trained workers to meet current labor market demand. The industry is already facing a shortage of workers across nearly all levels of occupational needs, from engineers, to production workers, to transportation and logistics workers. These workforce shortages are only expected to get worse as the technological requirements for the workforce continue to change, driven by Manufacturing 4.0 and other technology changes. In order to identify potential solutions to both current and expected workforce shortages, the Working Group requested that the JFI identify national programs put in place in other states and regions to meet the current and changing needs of Maryland's vital and growing manufacturing sector.[21]

Increase the Pipeline of High School Students Interested in Manufacturing

Many Americans do not have have a positive impression of manufacturing jobs, especially in a State like Maryland with a highly educated population and a public education system focused on preparing students for college. This is changing, according to the Manufacturing Institute and Deloitte, *Competing for talent: Recasting perceptions of manufacturing: Manufacturers continue to bridge the perception gap and enhance the workforce experience* report, the %age of respondents in a national survey who believe that US manufacturing jobs are creative, innovative, and employ problem-solving skills has increased from 39% in 2017 to 64% in 2022 and the percentage of respondents who are likely to encourage their child (or other youth) to pursue a career in manufacturing increased from 27% to 40%.[22]

One successful program identified by the JFI is the **Alliance for Working Together** (AWT). AWT was started in 2002 as a small, informal group of manufacturers, who met to discuss topics of interest and best practices among local manufacturers. Finding skilled workers was quickly identified as one of the top challenges for our manufacturers. Promoting rewarding careers in manufacturing became the core mission of the organization. In 2012, the AWT Foundation became a 501-(c)3 non-profit. Since then, the AWT Foundation now has 500+ manufacturing company, community organization, and school members. Selected programs include:

- Transformation Training Center - $3 Million 12,500 sq. ft. Training Facility that will offer programs for K-12 students, pre-apprenticeships for high school students, and apprenticeships for the unemployed and the employed.

[21] For an excellent summary of manufacturing sector education and training issues see - Benchmarking Advanced Manufacturing Education: A study from the MassBridge Workforce Education Program – parts of which are summarized here. The link to the report is as follows https://mitili.mit.edu/research/advanced-manufacturing-workforce-education-program-benchmarking-study.

[22] https://www2.deloitte.com/us/en/pages/manufacturing/articles/public-perception-of-the-manufacturing-industry.html.

- The Summer Manufacturing Institute is a collection of two week-long day camps. Each camp connects Science, Technology, Engineering, and Mathematics (STEM) concepts to local careers throughout Lake and Geauga Counties. Campers complete hands-on, STEM projects to showcase to parents and local businesses.
- Apprenticeships - AWT Foundation has placed more than 1,000+ students into manufacturing careers.
    - Exposed over 300 5th and 6th grade students to manufacturing careers in local communities.
    - Facilitated over 1,200 student, teacher, and parent tours of manufacturing facilities.
    - Trained 288 apprentices in the Northeast Ohio region.

Manufacturing Training in Community Colleges

Community Colleges play a critical role in the workforce development system serving as both a source of educated, skilled and trained workers through certificate and degree programs and playing a vitally important role in providing specialized training and opportunities for upgrading the skills of both residents and incumbent workers. Three successful (of many) community college manufacturing training efforts identified by the JFI include:

- **Trident Technical College** in Charleston, South Carolina links high schools, a community college and area companies. The program begins in a student's junior year with morning courses in high school that emphasize science and math, technical courses in the early afternoon at the community college, and part-time work at an area company in later afternoons during the school year and full time work during summers and holidays. Wages generally start at around ten dollars an hour and increase as apprentices build experience. Apprenticeships like this shift students out of a high school environment and into a more mature context, studying with adults at the community college and working with adults at their companies.
- **Ohio TechNet** launched in 2014 as the result of a $15 million Trade Adjustment Assistance Community College and Career Training (TAACCCT) grant made to Lorain County Community College on behalf of a statewide consortium of 18 community colleges and one university. This consortium works closely with multiple government agencies, workforce and community partners. Ohio TechNet is helping to transform the way in which higher education works with employers to better align training and education with manufacturing workforce needs in Ohio. Ohio TechNet partners are modeling or replicating innovative strategies that accelerate the readiness for workers who are in transition to fill in-demand, skilled jobs in advanced manufacturing. To meet state goals and industry needs, the colleges will focus on training in the high-need areas of Welding, CNC/Machining, Industrial Maintenance, Digital Fabrication/Industrial Automation, and Occupational Safety.
- **Ivy Technical Community College System** (Ivy Tech) has career focused programs in Healthcare, IT, Business and Advanced Manufacturing. The Advanced Manufacturing degrees provide a well-rounded plan of study that prepares students for a broad range

of technical positions within business and manufacturing. They offer elective focus areas in: manufacturing design, production technology, mechatronics, digital and systems integration, mechanical, electrical, and manufacturing operations. Ivy Tech has also used modules from the IGNITE curriculum, developed by LIFT and two other manufacturing institutes. As a leading manufacturing state, Ivy Tech has manufacturing labs with equipment at 22 campuses.

One barrier to community college manufacturing education and training is the cost and availability of advanced manufacturing training equipment for students to train on. According to the MassBridge Benchmarking Advanced Manufacturing Education: A study from the 2021 MassBridge Workforce Education Program report, "Community colleges experience challenges in providing manufacturing students with enough hands-on time with up-to-date machinery. Currently available equipment may be non-standard, sometimes outdated or under-maintained. In other cases, it can be under-utilized because it is dedicated to specific programs and not shared." Connecticut has addressed this need by establishing four $25 million advanced manufacturing technology equipment centers at four community colleges.

Curriculum Development

Training workers for manufacturing also requires the development of curriculum to guide training programs. Workers need the hands-on, transferable skills industry needs required by manufacturers. Curriculum development works best when developed in cooperation with the employer community. There are several national efforts to develop a scalable manufacturing curriculum, with two successful programs including:

- **IGNITE: Mastering Manufacturing** - IGNITE is a foundational skill development program designed to stimulate student interest in today's Advanced Manufacturing / Industry 4.0 careers. Students learn about the many careers and experience them firsthand by performing tasks with hands-on Industry 4.0 / IIoT technology and virtual environments. IGNITE: Mastering Manufacturing was developed in collaboration with three Manufacturing USA Institutes (LIFT, America Makes, and MxD) to ensure that students interested in a rewarding career in modern industry can make an immediate contribution in the workplace.
- **MassBridge** -- In 2020, the Commonwealth of Massachusetts was awarded a $3.2 million grant from the U.S. Department of Defense's Manufacturing Technology Program (DoD ManTech) for a manufacturing technician training program that will serve as a national model. This effort, named MassBridge, is being led by the Massachusetts Center for Advanced Manufacturing along with a team of experts from MIT, industry, community colleges, vocational high schools, and federal and state agencies. The goal of the MassBridge project is to develop and test a well-connected, state-based training and career pathway model - a "Bridge" for technicians that spans the gaps between the Commonwealth of Massachusetts' state-wide advanced manufacturing programs and the needs of the Manufacturing USA Institutes. The curriculum will be deployed through vocational and academic high schools and community colleges across Massachusetts,

with connectivity to supporting universities (for those workers who want to continue their education) to pull students along a pathway toward careers in Manufacturing USA technologies.

Underrepresented Populations/Returning Citizens

As described above, the Maryland manufacturing workforce is mostly male, white and older than the non-manufacturing workforce. Increasing the diversity of workers in the manufacturing sector is a key potential strategy for meeting the workforce needs of the manufacturing community. One identified best practice in this area is the **ACCESS to Manufacturing Careers** program in Northeast Ohio. This program is targeted on attracting underrepresented populations, including ex-offenders, into manufacturing. It targets ready, motivated individuals who want to get into entry-level jobs in manufacturing that start them on a path of learning, advancement, raises, and a great career! In this four-week program, students learn both job readiness skills and technical competencies that are desired by the 20+ companies involved. Key program elements are as follows:

1. 4 week training
    - Technical training
    - Soft Skill/Work Readiness training
    - Employer-led classes, presentations, etc.
    - OJT check-list skills validation
    - Starting Wages $13.5
2. Built on Employer Engagement
    - Identify open positions
    - Agree on minimum wage range
    - Commit to common hiring process
    - Commit to hiring timeline
    - Participate in Interview Day
    - Lend staff to create lesson plans, material, teach classes, create virtual plant tours, do company showcases
    - Attend periodic update meetings
3. Employer-Led and Philanthropically Funded

Integrated Manufacturing Workforce Development Training and Certificate Planning and Implementation

Overall, workforce development systems work best when developed in an integrated fashion between the workforce development system and the employer community. One national example of integrated of manufacturing workforce education with the business community and state MEP program is the **Florida Advanced Technology Education (FLATE)**. FLATE is a National Science Foundation Center of Excellence in high-technology manufacturing. It provides manufacturing and advanced technical education, best practices and resources supporting the high performance skilled workforce for Florida's manufacturing sectors. FLATE provides industry partnerships, workforce opportunity, and educational synergy throughout the state of

Florida by connecting industry and workforce needs to targeted educational endeavors at many community and state colleges across Florida. FLATE includes:

- Network of community colleges; CareerSource Florida; workforce investment boards and the Florida MEP;
- Created an industry defined/endorsed Engineering Technology (ET) AS/AAS Degree programs approved by FLDOE;
- Built 31 curriculum frameworks for 20 certificates and 11 specializations of the degree
- Grew the ET AS degree program from 3 to 24 of the 28 Florida colleges since 2007.
- Submitted three articulated high school frameworks to FLDOE, which is now offered to 510 schools
- Since 2007, tracked ET AS degree student enrollment in Florida has grown from 9 To 2,027 students in 2018-19
- Awarded over $220,000 to ET degree awarding college partners for laboratory upgrades
- Leveraged by partners to obtain over $80 million in state and local funding

Summary, Conclusion and Recommendations

The manufacturing sector is a core and growing driver of the Maryland economy. Technological changes (Work of the Future and Manufacturing 4.0) are reshaping the competitive structure of the sector and have the potential to support a *manufacturing renaissance* nationally and in Maryland. Manufacturers in Maryland and across the nation are already facing a shortage of skilled workers that is being amplified by technological changes that are increasing the skills requirements of manufacturing jobs. The current and projected job growth and employment needs of the Maryland manufacturing sector are not being fully met by Maryland's successful workforce development system. Other states are rising to these challenges through innovative, well-funded efforts to support technology/Manufacturing 4.0 investments and increase the talent pipeline for high wage, good jobs in manufacturing. Based on the JFI's research, review of national best practices, and work with the Workgroup, Maryland should consider targeted investments in supporting the growth of manufacturing in Maryland, including the following:

1. **Create a Manufacturing Roadmap/Strategic Plan to Identify and Meet the Needs of the Manufacturing Sector**. The work of this legislatively mandated Workgroup and The Maryland MEP's *The Future is Now, Realizing the Promise of Industry 4.0: A Strategic Plan to Ensure a Competitive Future for Manufacturing in Maryland* report is the beginning of this process, but best practice states have engaged in more thorough, industry-led, and comprehensive assessments. With the coming election and change in administrations, this is a good time to initiate a comprehensive plan to grow manufacturing in Maryland.
2. **Expand Support for Manufacturing 4.0 Investments.** Maryland's $1 million Maryland Manufacturing 4.0 Grant Program is a step in the right direction but is well below the levels of investment support put in place by best practice states. In addition to this investment support, Maryland needs to expand the support infrastructure for Maryland manufacturers to make needed Manufacturing 4.0 investments, including:

- Expanding technical assistance through the Maryland MEP to support Manufacturing 4.0 investments; and
- Invest in and support a Maryland Manufacturing 4.0 Tech Demonstration and Training Lab.

3. **Deploy Targeted Investments in Manufacturing Focused Workforce Development**. Maryland's extensive workforce development system is not well aligned to meet the employment needs of Maryland's manufacturing sector, especially for the skilled production workers currently in short supply. More can be done to provide Maryland residents with the education, skill, and training for well paying jobs in manufacturing, including:
    - Maryland is making significant investments in expanding its CTE programs under the Kirwan Commission plan, and in expanding its apprenticeship programs. Including targeted efforts to meet the needs of manufacturing sector in these investments is an immediate opportunity to deploy existing resources to meet manufacturing sector needs. These efforts can also be specifically targeted to increase the pipeline of underrepresented populations for the sector;
    - Expanding the pipeline of manufacturing workers through the State's extensive and successful community college training system through the development of cooperatively developed, industry supported curriculum, certificate and training programs; and
    - Maryland lacks a university manufacturing engineering program. The state should examine the development of a program, linked to key manufacturing sectors within one of its university engineering programs. This would increase both research and technical support and provide skilled engineers for the manufacturing sector.
4. **Explore the Development of an Advanced Manufacturing Center**, such as those in Connecticut and Massachusetts, to better align the research and technical capabilities of Maryland leading higher education resources to support the technology needs of Maryland's advanced manufacturing industries.

Appendix B – The Future is Now, Realizing the Promise of Industry 4.0

The Maryland Manufacturing Extension Partnership (MD MEP) commissioned a report titled "The Future is Now, Realizing the Promise of Industry 4.0: A Strategic Plan to Ensure a Competitive Future for Manufacturing in Maryland." This report was used as supplemental information for the Transforming Manufacturing in a Digital Economy Workgroup, and is referenced throughout this report. It is attached as a separate document for background information.

The Future is Now, Realizing the Promise of Industry 4.0:

A Strategic Plan to Ensure a Competitive Future for Manufacturing in Maryland

For more information on this report please contact its authors with TEConomy Partners:
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EXECUTIVE SUMMARY

Manufacturing in Maryland is an often-overlooked sector contributing to Maryland's leading advanced industrial base. While manufacturing is not as highly concentrated in Maryland as in other states, the industry is a foundational pillar of the state's economy that consistently generates high-paying, family-sustaining jobs, drives wealth generation and economic growth through intensive exports, and adds high value through innovative product development. State manufacturers serve diverse global markets in food and agribusiness, protect the nation and serve strategic interests in aerospace and defense systems, improve quality of life in biopharmaceutical and vaccine production, and build homes by delivering high-quality wood products. These are just some of the areas in which more than one hundred thousand Marylanders contribute their skills and expertise each day across each region in the state.

For Maryland manufacturing to remain competitive and continue to drive outsized economic and innovation returns for the state and its residents, the industry must be prepared to embrace a digital future. Manufacturers globally are both preparing for and already implementing a digital transformation toward "smart" manufacturing that will have vast implications for industry competitiveness. This transformation is so significant that some have heralded its arrival as the Fourth Industrial Revolution, or "Industry 4.0." While the earlier Industry 3.0 leveraged the digital revolution of the late 20th century to embed computers and robotics into single processes or machines, Industry 4.0 is utilizing a new wave of technologies to fully automate processes and decision-making across the production life cycle.

Maryland's Manufacturing Industry Represents:

- 109,000 jobs across all regions with avg. wages of nearly $84,000
- 4,170 business establishments
- $27.6 Billion in GSP
- $9.1 Billion in employee compensation
- $39.8 Billion in annual exports
- 7 diverse clusters, markets served
- Major innovation driver: accounts for 10% of GSP but 75% of industrial R&D

Source: TEConomy Partners' analysis of Emsi, 2021.2 data sets.

As one would expect from such transformational technology, Industry 4.0 has significant implications for all facets of the manufacturing ecosystem, including innovation, supply chains, infrastructure, the workforce, and even customer engagement—implications that will have tremendous impacts on state and regional competitiveness. Recognizing the stakes, the Maryland Manufacturing Extension Partnership, or MD MEP, has commissioned this strategic plan to guide and advance both the near- and longer-term competitiveness and growth of Maryland manufacturing against this backdrop of intensive digitization.

SETTING THE CONTEXT:
AN IMPACTFUL INDUSTRY FOR MARYLAND HAS STABILIZED, BUT COMPETITIVE CHALLENGES REMAIN

Manufacturing in Maryland contributes nearly $28 billion to the state's Gross State Product (GSP) and comprises a highly diverse subset of industry clusters. The clusters illustrate the breadth of products manufactured across the state and the varied global markets served, including:

- **Aerospace & Defense Systems**
- **Food & Beverage**
- **Life Sciences**
- **Polymers & Related Products**
- **Precision Manufacturing**
- **Printing & Packaging**
- **Wood Products**

Manufacturing is active across each of Maryland's four geographic regions. Its footprint, like the state's population, is largest in Central Maryland (57% of all jobs) but extends outward in all directions. Although Eastern and Western Maryland have lower employment levels, manufacturing represents a somewhat greater share and importance to their overall economies, as illustrated by employment concentrations closer to national averages (location quotients closer to 1.0). Each region contributes its own unique companies, innovations, and key products to the markets it serves.

While manufacturing is an important economic driver across the state, manufacturing is less concentrated in Maryland relative to the national average. But what Maryland may lack in the overall size or concentration of its manufacturing base relative to other states, it makes up for by punching above its weight in terms of worker productivity and industrial research and development.

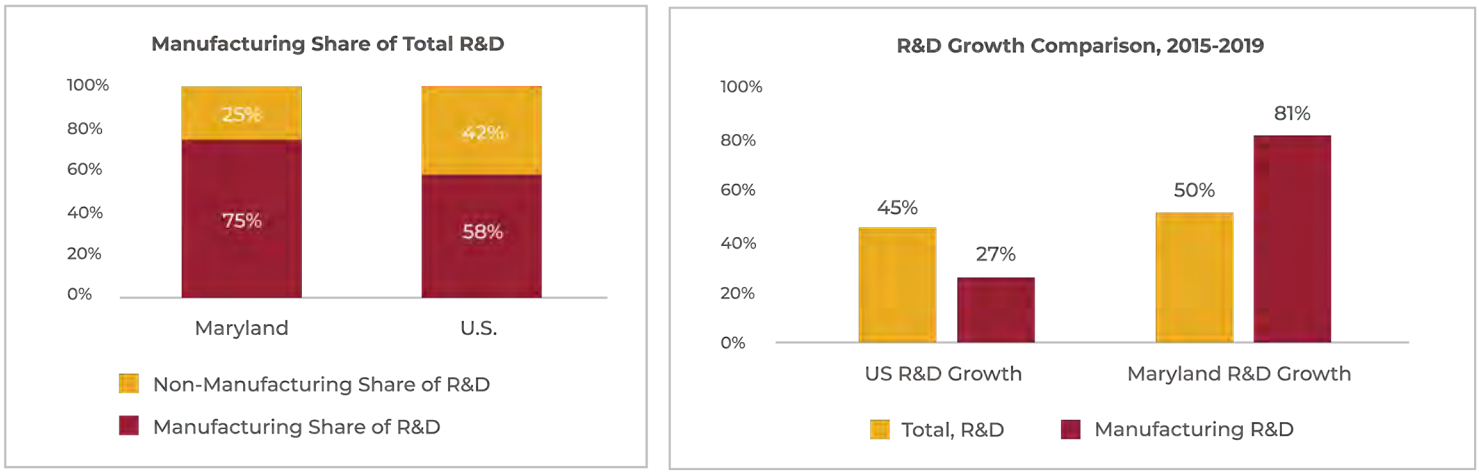
On average, Maryland manufacturing workers produced more than $250,000 in value-added activity per worker in 2020. High value-added per worker is a measure of productivity in manufacturing, along with enhanced quality and features of products being produced, and therefore is highly dependent on the successful deployment of technology. In recent years, Maryland has not only surpassed the level of productivity seen nationally (nearly $191,000), but has grown at a faster rate than the nation. This is further evident in manufacturing accounting for 10% of GSP in Maryland while utilizing just 5% of the state's labor force. Across Maryland's diverse manufacturing base, all of its clusters, with the exception of printing and packaging, have average productivity levels exceeding the national average. So, while Maryland is undersized in manufacturing employment, it stands out in manufacturing productivity across its diverse industry base.

At $3.2 billion, Maryland manufacturers account for three-quarters of the state's annual total industrial R&D expenditures, led by the life sciences and aerospace and defense clusters. Industrial R&D investment is one key metric of innovation activity and often provides an additional glimpse at Industry 4.0 potential, as innovative firms are much more likely to adopt or consider digital automation solutions.

Maryland Manufacturing plays an outsized role as an innovation engine for the state—the sector represents 10% of GSP but accounts for 75% of industrial research and development ($3.2 Billion).

As shown in Figure ES-1, Maryland's industry R&D base found in manufacturing is both a higher share than the national average and is also growing much faster than the national average.

Figures ES-1: Manufacturing Share of Total Industrial R&D and Recent Growth, Maryland and U.S., 2019



Source: TEConomy analysis of National Science Foundation, Business R&D Survey data, 2015 & 2019 (most recent year available).

In the academic R&D space, Maryland represents a leading state in science and engineering R&D, and many of these activities are concentrated in key fields relevant for Industry 4.0. In fields most closely relevant for Industry 4.0 solutions development, Maryland's $1.32 billion in 2020 R&D expenditures is highly concentrated and "specialized"—representing 28% of University R&D in Maryland compared to 11% across the nation overall.[1] R&D activities in these fields are growing as well and outpacing the nation since 2015. Maryland universities represent an important and leading source of both innovation and talent development relevant for Industry 4.0 adoption, and collaborations and partnerships with Maryland's manufacturing community are critical for seizing a competitive edge.

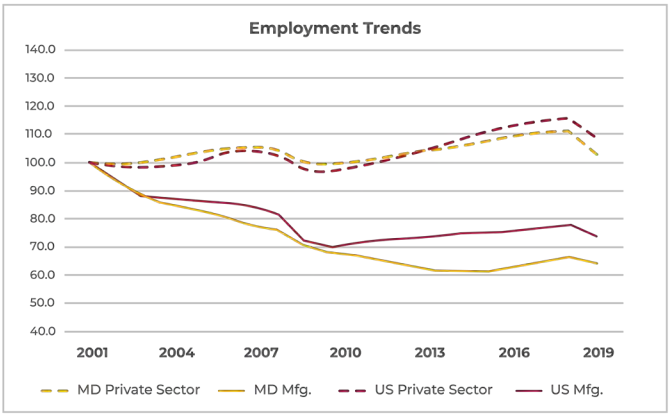
Maryland's ability to compete based on higher productivity and industry R&D is generating positive results in recent years, and offsets the state's higher costs of doing business in manufacturing:

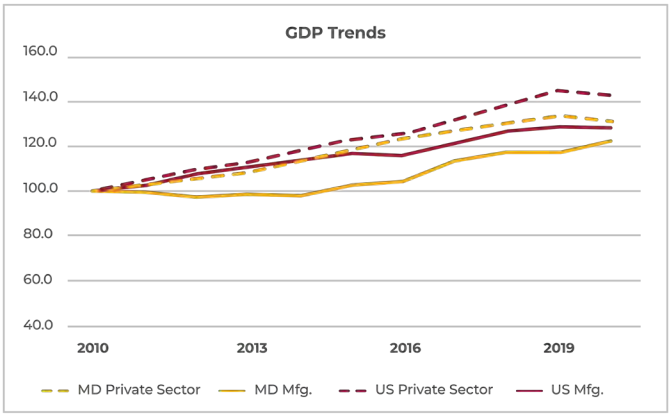
- **Maryland has slightly outpaced U.S. manufacturing employment and GDP growth since 2015, but this recent trend is a stabilization of the industry following years of steeper employment declines and lagging output growth for the state** (see Figure ES-2). Over the last two decades, Maryland manufacturing has struggled with lagging GSP growth and steady, rapid declines in its employment base. While industry employment has stabilized and GSP growth has increased its pace in recent years, the industry has clearly faced longer-term competitiveness challenges and contraction—a key context as to why Industry 4.0 adoption will matter for state competitiveness.

- **This growth in manufacturing is found broadly across the state's diverse manufacturing base.** Five of the seven manufacturing industry clusters found in Maryland have grown in employment since 2015, and four of those five experienced double-digit growth rates despite the inclusion of the challenging 2020 COVID-19 year.

[1]Relevant fields identified by TEConomy include electrical, electronic, and communications engineering; computer and information sciences; mechanical engineering; mathematics and statistics; and industrial and manufacturing engineering.

Figures ES-2: Maryland Manufacturing has Seen Long-Term Competitiveness Challenges that it has Recently Reversed—Manufacturing Employment & GSP Average Annual Growth Trends, 2001-20, 2010-20





Source: TEConomy Partners' analysis of Emsi Q2 2021 data set.

Maryland manufacturing has effectively stabilized in recent years, but its longer-term competitive challenges cannot be ignored. The state industry has seen many years of declining employment and lagging output growth. And for a state sector that competes on its productivity and innovation edge, the current and impending digitization wave in the form of Industry 4.0 must be a key pillar and focus for the industry to effectively compete into the future.

HOW IS MARYLAND POSITIONED FOR INDUSTRY/MANUFACTURING 4.0?

Industry 4.0 has significant implications for Maryland's competitive advantages in productivity and innovative product development. The essence of Industry 4.0 is a transformational change in the manufacturing production process, as well as in product design and development, through the digitization of manufacturing activities. Maryland cannot afford to fall behind or be excluded from the national leaders in Industry 4.0, as it risks the state's competitive edge in sustaining growth in manufacturing across its diverse base.

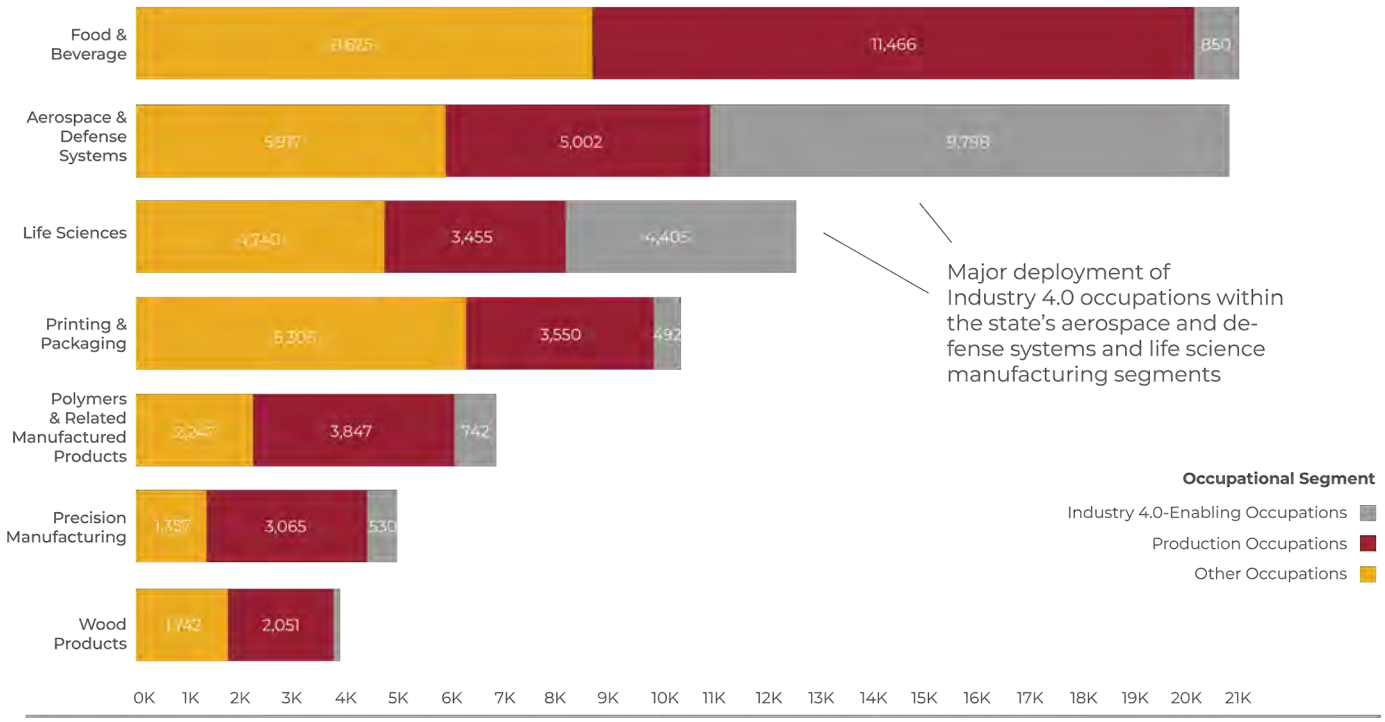
A series of quantitative analyses, combined with situational interviews and group discussions with manufacturing leaders and other industry stakeholders, finds that Maryland has assets to leverage in adopting Industry 4.0 technologies; however, like other manufacturing ecosystems, it faces significant challenges and barriers.

Maryland's manufacturing workforce is particularly concentrated in what can be referred to as an *Industry 4.0-enabling* workforce—a set of occupational groups and roles spanning computer and data sciences to engineers and technicians critical for assessing, designing, implementing, and deploying digital technologies and resulting data streams for smart automation. **Maryland's Industry 4.0-enabling occupational employment share of its overall manufacturing industry is significantly higher than that of the nation's—21% of the sector's workforce versus 13% of the nation's.** Although this represents a smaller share of manufacturing relative to the industry's large production workforce, these one-in-five workers have grown their share of the industry's workforce at roughly twice the rate of the nation's since 2015.

Not all manufacturing clusters, however, are well-positioned with respect to this critical workforce—among the seven, two stand well above their counterparts, both in Maryland and nationally, in their concentration and deployment of Industry 4.0-enabling talent: 1) aerospace and defense systems and 2) life sciences (Figure ES-3). Aerospace and defense systems is reliant on engineering talent (37% of Industry 4.0-related employment) but is still driven by a well-distributed mix of additional Industry 4.0-enabling occupations, ranging from computing and IT to business analytics. Life sciences, on the other hand, leverages a large scientific workforce (38% of Industry 4.0-related employment) and represents a unique context, as most manufacturing industries have lower concentrations of scientific occupations relative to traditional engineering.

Maryland has an overall competitive advantage in its enabling talent situation—but is it a tale of two "tiers," with aerospace and defense and life sciences well-positioned to adopt and integrate Industry 4.0, while other clusters struggle? Although not all sectors can expect the same level of adoption, it will be important to "lift all boats" among clusters when considering strategic interventions and support.

Figure ES-3: Industry 4.0-Enabling Occupational Employment within Maryland's Manufacturing Clusters, 2020



Maryland Employment in Manufacturing Industries, 2020

Source: TEConomy analysis of industry staffing patterns data from Emsi (Emsi Release 2021.2).

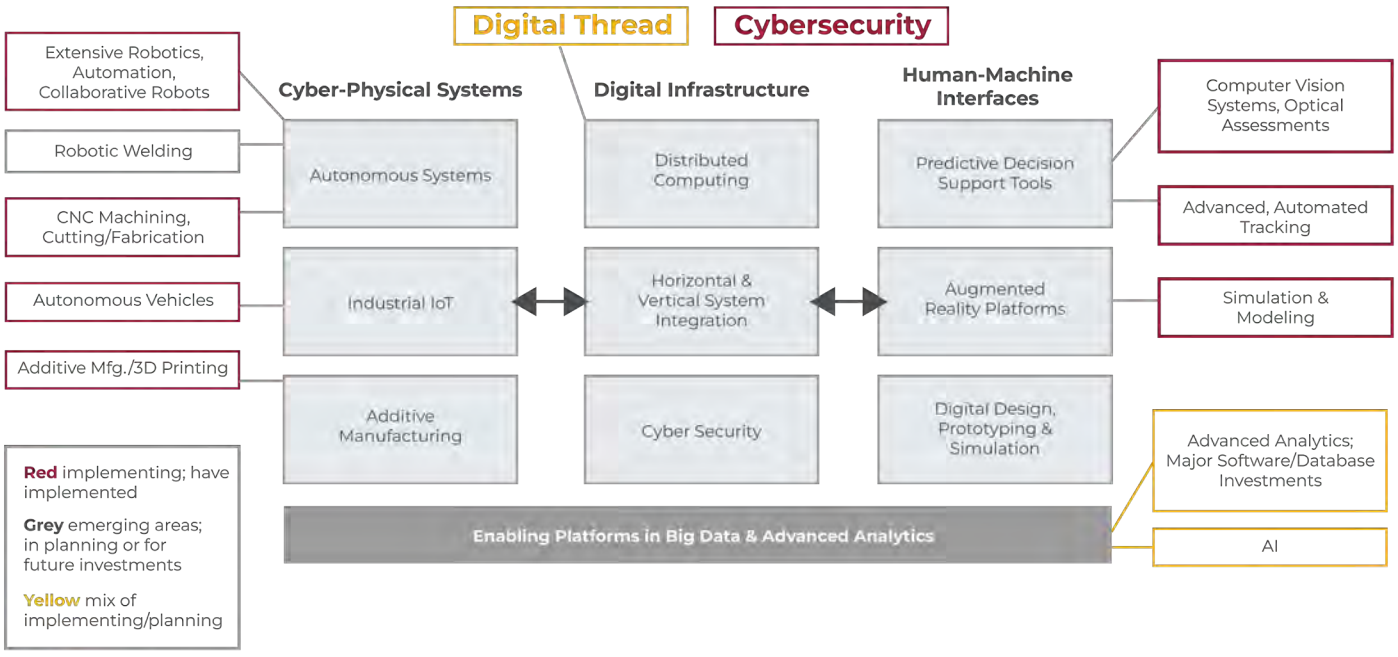
The challenge for Maryland will be the inevitable strain on the supply of this skilled workforce critical for Manufacturing 4.0 adoption. Manufacturers face an especially competitive and challenging workforce landscape in attracting and retaining Industry 4.0-enabling jobs due to the combined challenges of limited supply; high demand from, and competition with, other tech-driven industries for talent; and relatively large cohorts of existing workers likely to require "up-skilling."

The Situation for Industry 4.0 Technology Adoption/Integration in Maryland: Primarily Discrete Implementation, Companies Point to Several Consistent Challenges, Barriers

Maryland manufacturing leaders are adopting and integrating numerous technologies and capabilities squarely in the digital automation and Industry 4.0 context; however, this adoption, particularly among small- and mid-sized manufacturers or enterprises (SME) manufacturers, is most often discrete and not more broadly integrated to realize the full capabilities and data-driven insights of a 4.0 environment. Interviews indicate a generally low adoption rate of integrated industry automation and 4.0 technologies and suggest that Maryland is lagging behind as a state. Maryland manufacturing SMEs today typically use discrete individual technologies (e.g., a 3D printer, virtual reality simulation, robotic welding equipment) but are not yet implementing multi-technology, digitally integrated systems that harness the full potential of Industry 4.0 advances and data-driven insights.

Figure ES-4 maps the types of Industry 4.0 technologies being adopted in Maryland today and in the near future. It is important to note that these technologies are pulled from interviews with state manufacturers, and therefore are not an exhaustive survey or inventory of Maryland manufacturing. The technologies and capabilities mapped to the outer edges of Figure 4 were assigned a color based on the implementation status described by the companies interviewed.

Figure ES-4: Types of Industry 4.0 Technologies Being Adopted/Integrated in Maryland Today and in Near-Future (Based on Maryland Manufacturing Interviews, Not an Exhaustive Inventory)



Source: TEConomy Partners, LLC.

Common Barriers & Challenges to Industry 4.0 Technology Adoption

At the crux of this strategic planning effort, and one of its primary objectives, is assisting Maryland manufacturers in addressing major challenges and barriers to increased technology adoption—effectively answering, how do we help to "de-risk" technology adoption, particularly for SME manufacturers? It is therefore important to consider the consistent themes raised regarding these barriers (Figure ES-5):

Maryland SME manufacturers have few resources to leverage to start the Industry 4.0 journey. Companies interviewed cited a general lack of resources and expertise to help them know where to start and what is most appropriate for their firm. A major theme in these discussions centered around firms' interest in and need to test, pilot, and demonstrate 4.0-related technologies before making individual investments or trying to implement digital solutions at scale.

The significant costs associated with digital technology investments and their integration with legacy IT systems represents another major hurdle, particularly for SMEs, but also for large manufacturers. And although pricing a particular piece of equipment or software package may be relatively easy, more challenging for firms working to understand the big picture is understanding the return on that investment. A key resource for manufacturers currently lacking in Maryland is a database or repository of Industry 4.0 "use cases"—real-world examples and experiences of manufacturers that are implementing technologies and driving them to scale—to help their counterparts understand the ROI and payback on digital investments.

Implementing Industry 4.0 technologies has major implications for the industry's workforce, both in terms of incumbents and new hires. Maryland manufacturers are experiencing a broad-based need for employees with enhanced digital skills, as well as for additional IT specialists, data scientists, and professional engineers, technicians, and scientists who have hybrid expertise. This hybrid expertise takes the form of mechanical engineers who are, as one manufacturer emphasized, "both mechanically and tech competent," such as industrial engineers with some data sciences knowledge and expertise. Thus, there are needs for both education and training resources to upskill the existing manufacturing workforce that are flexible and very focused, while continuing to generate the core talent that maps to "enabling" roles.

Enabling 4.0 tech adoption by addressing foundational technologies and technology infrastructure for interoperability and systems integration. A dynamic Industry 4.0 operating environment is not simply "plug and play;" it requires addressing the integration of new machinery and services into existing operations. Often, manufacturers face the challenge of integrating new smart solutions in an environment where numerous legacy software systems and hardware components must now communicate with each other, send data, and connect with cloud-based services.

Figure ES-5: Major Barriers Identified by Maryland Manufacturers to Adopting Industry 4.0 Technologies

RECOMMENDED STRATEGIES AND ACTIONS TO ENSURE A COMPETITIVE FUTURE FOR MARYLAND MANUFACTURING

The key findings from this effort, including those from both the baseline quantitative and situational analyses, point to four strategic priorities on which to organize and focus the recommended strategies and actions of the Plan. These include:

1. **Establishing resources for starting the Industry 4.0 journey for Maryland manufacturers.**
2. **Addressing the barriers and challenges to Industry 4.0 technology adoption and integration.**
3. **Strengthening intra-state supply chain connections.**
4. **Seizing emerging manufacturing industry and market opportunities.**

Combined, these strategic priorities are aligned with the overall project goals and objectives and draw from the key findings. A set of recommended strategies and actions are aligned with each priority area for the state and its manufacturing leaders and stakeholders to consider, and are summarized in Figure ES-6.

Figure ES-6: Summary of Recommended Strategies and Actions to Ensure a Competitive Future for Maryland Manufacturing

1. Establishing resources for starting the Industry 4.0 journey for Maryland manufacturers.

Action 1.1: Offer Manufacturing 4.0-specific assessments and facilitation for Maryland SMEs.

Action 1.2: Invest in and support a Maryland Manufacturing 4.0 Tech Demonstration and Training Lab primarily targeted toward SMEs.

Action 1.3: Catalogue and showcase "Use Cases" in communicating the ROI and the journey for other manufacturers that have successfully implemented Industry 4.0 technologies and to assist in making the business case for investments.

Action 1.4: Provide assessment and informational resources for systems integration and addressing interoperability challenges.

Action 1.5: Implement regular survey efforts to gauge progress on Industry 4.0 adoption among Maryland SMEs.

2. Addressing the barriers and challenges to Industry 4.0 technology adoption and integration.

Action 2.1: Develop and deploy a state incentives program—The Maryland Manufacturing Innovation Fund — to de-risk and address cost challenges for SMEs to invest in digital, Manufacturing 4.0 Technologies.

Action 2.2: Build awareness among Maryland manufacturers of existing state incentives and programs, particularly those which are applicable to Industry 4.0 investments and workforce and talent development.

Action 2.3: Advance broad-based assistance and strategic partnerships in addressing cybersecurity threats to manufacturers.

Action 2.4: Support both upskilling and broad-based training of Maryland's Manufacturing workforce — both among incumbent workers and across the education pipeline—at an appropriate scale for impending rise of Industry 4.0.

3. Strengthening intra-state supply chain connections.

Action 3.1: Develop Maryland supply chain mapping and directory resources for targeted manufacturing clusters.

Action 3.2: Incent, promote in-state supply chain connections, sourcing, purchasing

Action 3.3: Proactively pursue potential "reshoring" opportunities in targeted industries.

4. Seizing emerging manufacturing industry and market opportunities.

Action 4.1: Increase engagement between MD MEP and the Maryland life sciences cluster leveraging strategic partnerships and collaborations with life sciences-focused state organizations and strategic life sciences assets.

Action 4.2: Identify and seize Federal procurement opportunities for Maryland manufacturers.

It is envisioned that MD MEP will play a lead role in many of these strategic interventions, but effective partnerships are vital for implementation, as many recommendations require collaboration with state government agencies (e.g., Departments of Commerce and Labor), Maryland research universities and community colleges, industry associations, and others across the ecosystem.

What was once considered futuristic digital transformation is now very much in the forefront for global manufacturing competitiveness. For Maryland manufacturers considering Industry 4.0 solutions—the future is now.

INTRODUCTION: A FOUNDATION OF MARYLAND'S ECONOMY PREPARES FOR DIGITAL TRANSFORMATION

Maryland's economic and innovation reputation in areas such as IT and cyber, leading-edge life sciences research, and its extensive federal government complex typically overshadow its rich history in, and the outsized innovation contributions from, manufacturing. Manufacturing in Maryland is an often-overlooked sector contributing to Maryland's leading advanced industrial base. While it is true that manufacturing is not highly concentrated in Maryland as in other states, what is often missed is that manufacturing in Maryland has long represented a foundational pillar and significant contributor to the state economy in the form of high-paying, family-sustaining jobs, wealth generation and economic growth through exports and innovative product development. State manufacturers serve global markets in food and agribusiness, protect the nation and serve strategic interests in aerospace and defense systems, improve quality of life in biopharmaceutical and vaccine production, and build homes by delivering high-quality wood products. These are just some of the areas in which more than one hundred thousand Marylanders contribute their skills and expertise each day across each region of the state.

As the leading champion for state manufacturers, the Maryland Manufacturing Extension Partnership, or MD MEP, understands these contributions and the strategic importance of the sector and works every day to ensure its competitiveness. MD MEP, which is part of the national network of state MEP programs, is primarily focused on serving small- and mid-sized manufacturers or enterprises (SMEs, defined as having 500 or fewer employees) across all subsectors and markets of the industry. The organization carries out this mission through an array of programs and services designed to enhance the efficiency and profitability of manufacturing operations and ultimately to create jobs and growth opportunities for Maryland. MD MEP considers the broader ecosystem in which its constituent companies operate, as well as their needs that span workforce and talent, technology and innovation, supply chain solutions, continuous process improvements, and overall market growth strategies.

MD MEP Drives Significant Impacts for Maryland Manufacturers

As a result of its engagements with state manufacturers, MD MEP clients report the following impacts since 2013:

- $954M of economic impacts including new sales, savings, and investments
- More than 6,400 jobs created or retained

Source: Maryland MEP.

MD MEP has contributed to and seen encouraging signs of turnaround in Maryland manufacturing in recent years, with strong job and output growth that has outpaced the nation. The industry continues to punch above its weight in productivity and innovation activity, as manufacturing contributes 10% to state GSP and accounts for 75% of its total industrial research and development, while only employing 5% of the state's workforce. But there have been longer-term competitiveness challenges as Maryland has for many years lagged its counterparts nationally in employment and output growth and, like those counterparts, is experiencing a new dynamic of painful labor and supply chain shocks during the COVID-19 pandemic.

Looking forward, a significant transformational change is rapidly unfolding across manufacturing that poses both opportunities and challenges for the long-term competitiveness of Maryland's manufacturing sector. The transformation involves the intensive digitization of manufacturing operations, often referred to as Industry 4.0. The capabilities of Industry 4.0 technologies represent a paradigm shift so significant industry experts have referred to it as the arrival of the "Fourth Industrial Revolution." While "Industry 3.0" leveraged the "digital revolution" of the late 20th century to embed computers and robotics into single processes or machines, Industry 4.0 is utilizing a new wave of technologies to fully automate processes and decision-making across the production life cycle.

Digital industrial technology is transforming the modern global manufacturing sector, with major implications for industry competitiveness. As one would expect from such transformational technology, Industry 4.0 has significant implications for all facets of the manufacturing ecosystem including innovation, supply chains, infrastructure, the workforce, and even customer engagement—implications that will have tremendous impacts on state and regional competitiveness within advanced manufacturing clusters.

MD MEP engaged TEConomy Partners, LLC (TEConomy) to develop a Strategic Plan for manufacturing to guide and advance both near- and longer-term competitiveness and growth of Maryland manufacturing that leverage the promise of Industry 4.0 technologies. The organization seeks to inform the state and its industrial leaders and varied stakeholders, as well as its own operations and strategy with the following identified as primary goals and objectives:

- Advance the use and adoption of, and readiness for new and emerging advanced manufacturing and automation technologies, including and primarily those associated with Industry 4.0 among Maryland manufacturers.

- Identify one to two industry and/or market "verticals" associated with supply chain strengths and aligned with strong growth opportunities for Maryland manufacturers for targeting into the future, including for strategic "reshoring" opportunities.

The Plan is organized into four sections: 1) a baseline assessment of the economic trends and positioning of Maryland's manufacturing sector to set the context; 2) an overview of Industry 4.0 technologies and their role in transforming modern manufacturing and how Maryland is positioned to seize the opportunity; 3) a situational assessment that brings forth the voice of industry and drives toward strategic priorities for the sector; and finally, 4) a set of strategic recommendations and specific actions for MD MEP, its stakeholders, and partner organizations to consider for maintaining manufacturing competitiveness into the future.

This strategic planning effort has been overseen and guided by a diverse representation of manufacturing leaders and broader stakeholders participating as part of the project Advisory Committee and prioritizing the voice of industry via one-on-one interviews and group discussions.
Industry or Manufacturing 4.0 (which will be used interchangeably in this report) have primarily been viewed as an aspirational future of "smart" manufacturing, but that future is here, that future is now for Maryland and its competitors across the globe.

I. A BASELINE ASSESSMENT FOR MARYLAND MANUFACTURING: SETTING THE CONTEXT OF THE INDUSTRY'S POSITION, PERFORMANCE, & MAJOR CLUSTERS AND THE NEED FOR INDUSTRY 4.0 ADOPTION TO MAINTAIN COMPETITIVENESS

At the outset, it is important to provide a quantitative "baseline" analysis to set the context of the overall structure, composition, competitive position, and unique existing and emerging strengths of the manufacturing industry in Maryland as we begin to consider the implications of Industry 4.0. This baseline analysis highlights the overall importance to Maryland's economy of its manufacturing industry as a major economic driver that stands out as an outsized leader in statewide productivity and high-value innovation, but also illuminates competitive challenges that must be addressed by adopting transformative technology in the form of Industry 4.0.

MANUFACTURING INDUSTRY ECONOMIC ANALYSIS FINDS AN IMPACTFUL GROWTH SECTOR BUT LONGER-TERM COMPETITIVENESS CHALLENGES

As shown in Figure 1, every day more than 109,000 Marylanders report to more than 4,000 individual manufacturing establishments spanning all regions of the state to produce an impressive array of products and serving diverse global markets. This activity combines to contribute nearly $28 billion to Maryland's GSP—strong value-adding activity reflected by just over $9 billion in total compensation paid to the industry's workforce.

Figure 1: Summary Economic Metrics for Maryland Manufacturing, 2020

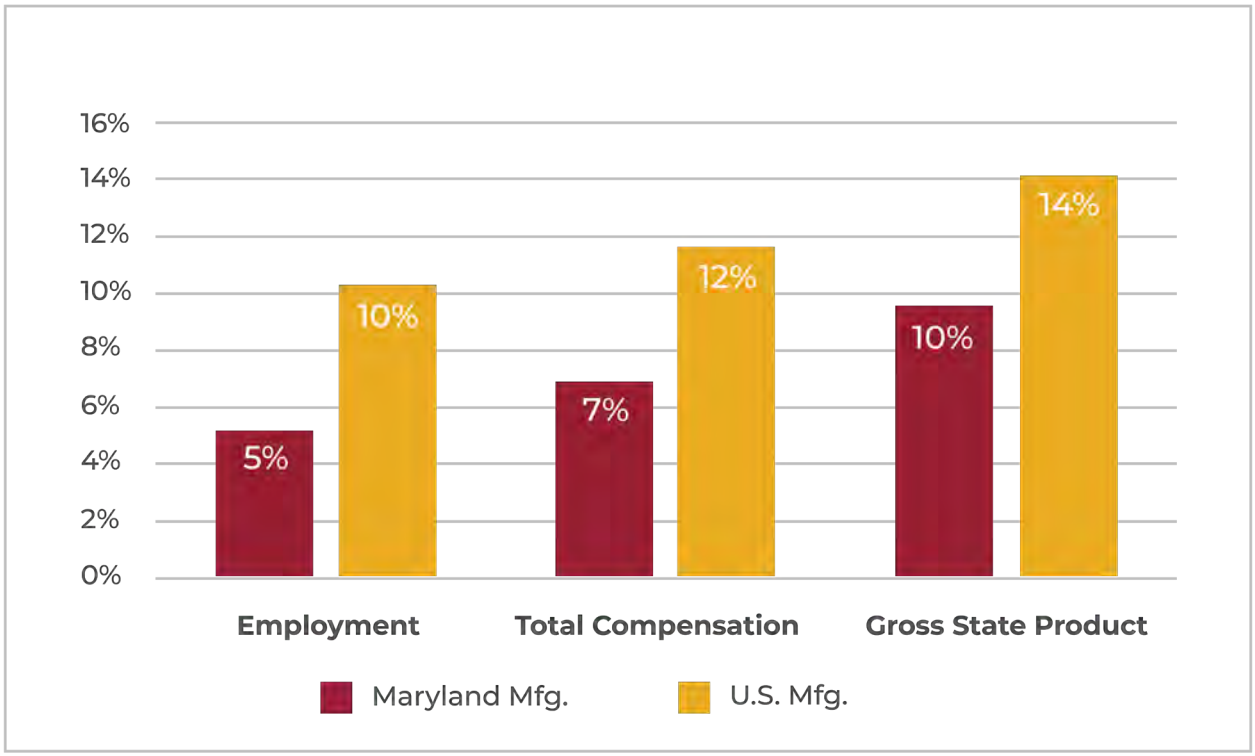
Maryland's Manufacturing Industry Represents:

Source: TEConomy Partners' analysis of Emsi Q2 2021 data set.

While it's an important economic driver in the state, manufacturing is less concentrated in Maryland relative to the national average. This under-concentration is evident across three top-line metrics where Maryland's share of economic activity attributable to manufacturing stands below those seen nationally, specifically with respect to employment, total compensation, and GSP (Figure 2). Manufacturing accounts for 5% of all private sector jobs in Maryland, compared to 10% of jobs nationally, translating into an industry location quotient (LQ) for Maryland of 0.52.[2] This occurs in Maryland, in part, due to the outsized service economy driven by the federal, contracting, and related industrial complex in Central Maryland that leads to dampening the contributions of manufacturing as a share of overall economic activity in the state.

[2] Location quotients (LQs) are a standard measure of the concentration of a particular industry in a state or region relative to the nation. The LQ is the share of total state or regional employment in the particular industry divided by the share of total industry employment in the nation. An LQ greater than 1.0 for a particular industry indicates that the region has a greater relative concentration, whereas an LQ less than 1.0 signifies a relative underrepresentation. An LQ greater than 1.20 denotes employment concentration significantly above the national average. In this analysis, regional specializations are defined by LQs of 1.20 or greater.

Figure 2: Maryland Manufacturing's Share of Key Top-Line Economic Indicators vs. US, 2020

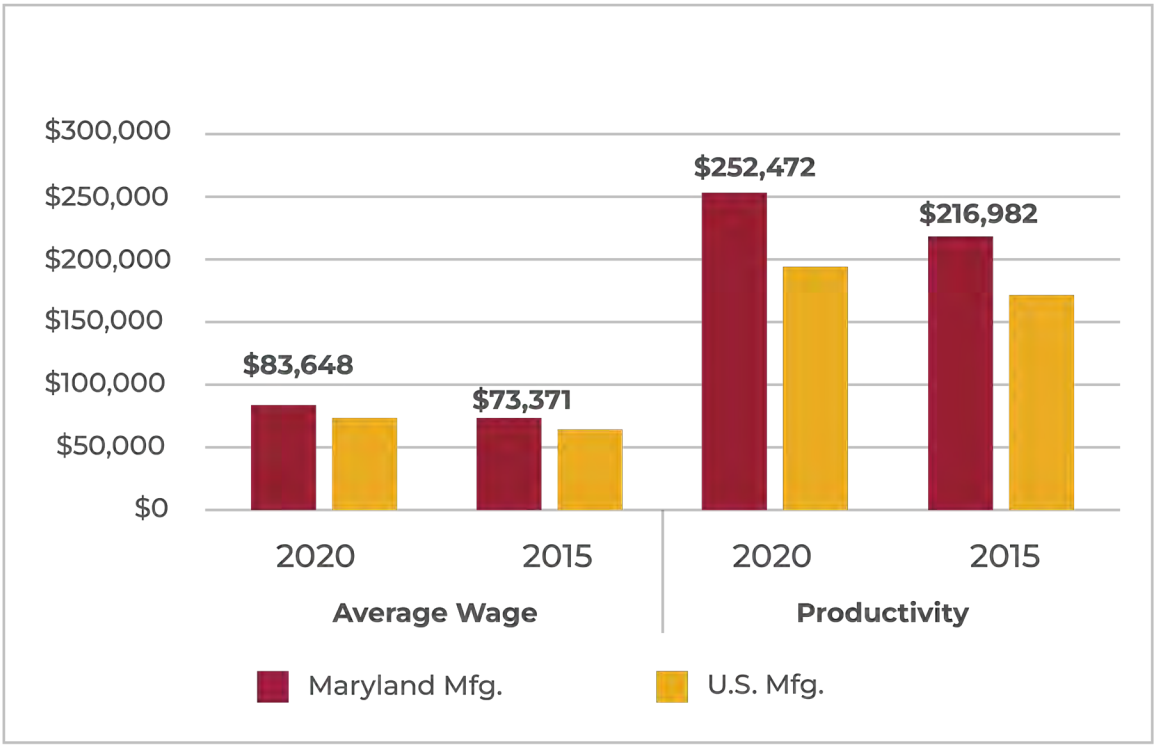


Source: TEConomy Partners' analysis of Emsi Q2 2021 data set.

What Maryland may lack in the overall size or concentration of its manufacturing base relative to other states, it makes up for by punching above its weight in terms of value-adding activity that measures worker productivity. On average, Maryland manufacturing workers produced more than $250,000 in value-added activity per worker in 2020—the key measure of workforce productivity in manufacturing (see Figure 3). In recent years this figure has not only surpassed the level seen nationally (nearly $191,000), but it has grown at a faster rate than the nation. This is further evident in manufacturing accounting for 10% of GSP in Maryland while utilizing just 5% of the state's labor force.

Strong productivity enables Maryland manufacturing industries to pay higher overall wages and remain competitive. Maryland manufacturing workers earn more than both their counterparts nationally and relative to the overall private sector worker in the state. In 2020, manufacturing wages averaged nearly $84,000 in Maryland, compared to $71,000 nationally and $64,000 for the overall Maryland private sector. This situation is obviously beneficial to workers but drives concerns among manufacturers about high labor costs, a concern addressed in the situational assessment to follow.

Figure 3: Maryland Manufacturing's Average Wages and Productivity vs. US, 2020



Source: TEConomy Partners' analysis of Emsi Q2 2021 data set.

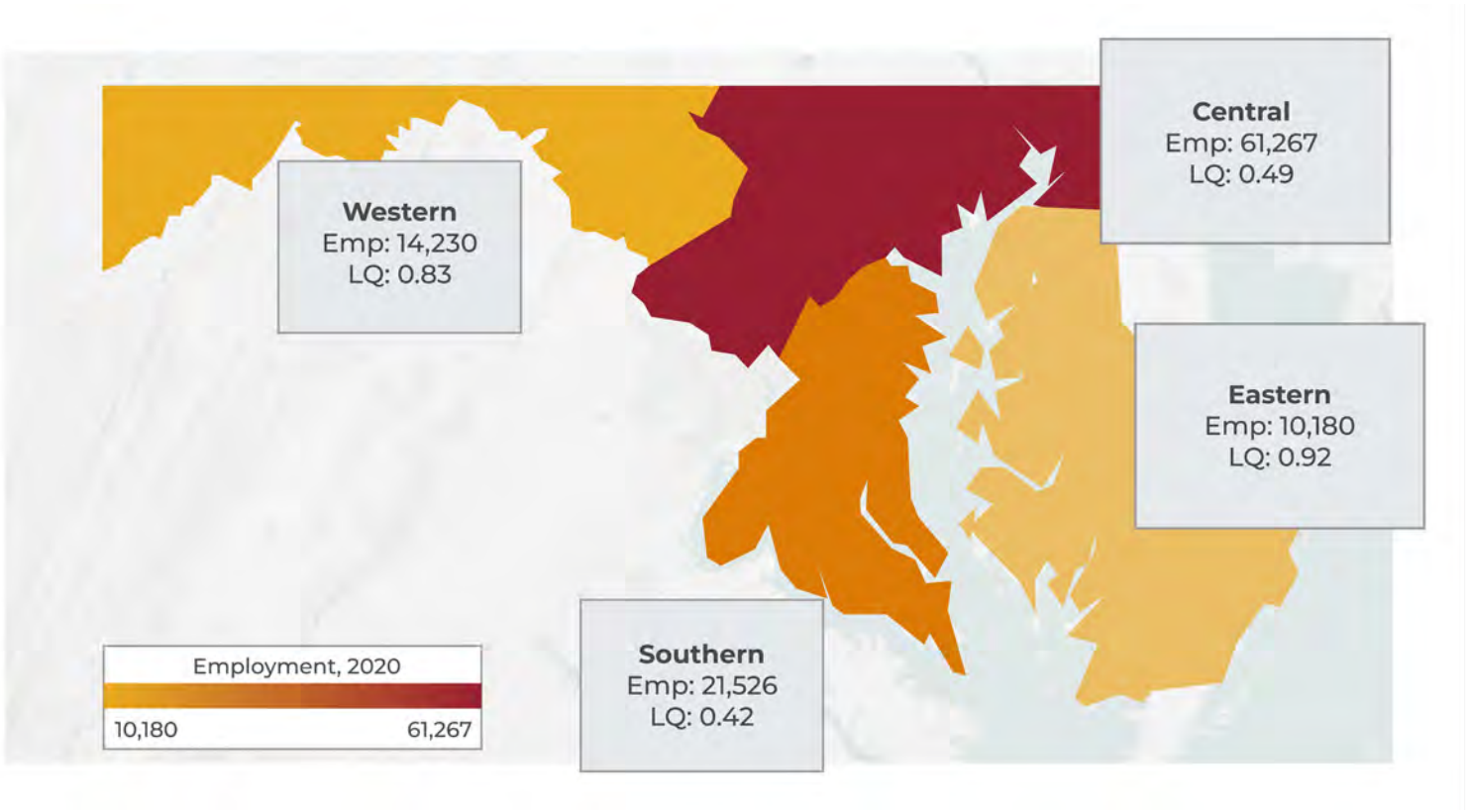
Manufacturing's outsized productivity and importance to the state's economy relative to other industries is illustrated in the context of its role as a "traded" industry, one that exports its products outside of the state, thereby generating net new wealth for Maryland.[3] In 2020, the value of exports generated by state manufacturers reached $39.8 billion.

Manufacturing is active across each of Maryland's four major regions. Its footprint, like the state's population, is largest in Central Maryland (57% of all jobs) but extends outward in all directions (Figure 4). While Eastern and Western Maryland have lower employment levels, manufacturing represents a somewhat greater share and importance to their overall economies, as illustrated by employment concentrations closer to national averages (location quotients closer to 1.0). Each region contributes its own unique companies, innovations, and key products to the markets it serves.

In 2020, the sales value of exports generated by Maryland manufacturers reached $39.8 billion.

[3]As opposed to a "local" or "non-traded" industry that primarily serves local residents and therefore does not generate new wealth for a region, state, or nation. Examples of local or locally traded industries include education, utilities, and most healthcare services.

Figure 4: Manufacturing Employment in Maryland by Region, 2020



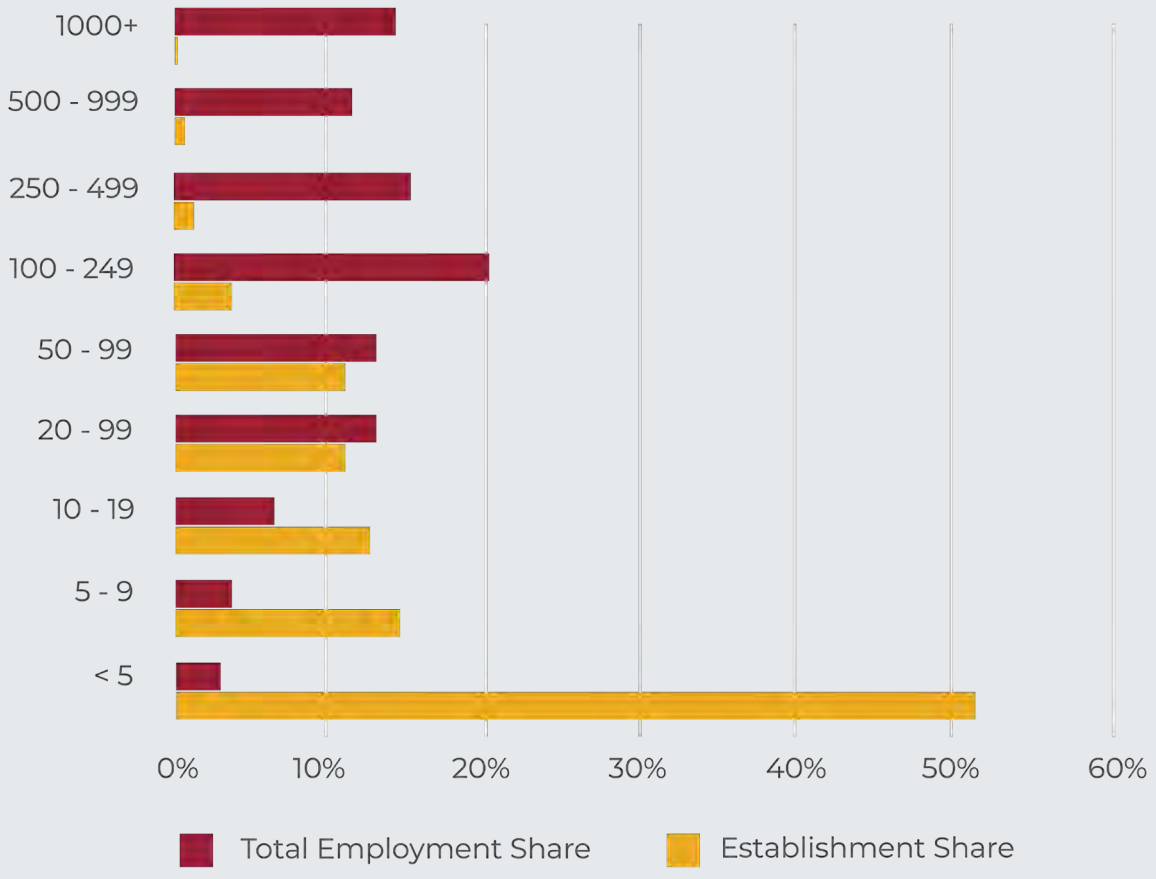
Note: LQ = Location Quotient.

Source: BLS, QCEW data via Emsi (Datarun 21.2); TEConomy analysis.

THE IMPORTANCE OF SMALL- AND MID-SIZED ENTERPRISES (SMEs) IN MARYLAND'S MANUFACTURING SECTOR

Although large manufacturers (those with 500 or more employees) with household names are front of mind for consumers and state residents, more than half of manufacturing firms in Maryland have fewer than five employees and the largest employment totals for firms lie within the 100-249 employee band. Recognizing the important role these firms play within the state and nation's manufacturing ecosystem as local and often rural employers and key suppliers, and the limited resources these firms have, the National Institute of Standards and Technology (NIST) has ensured the MEP Network is focused on primarily serving SMEs. This is not to diminish at all the importance of large manufacturers as significant employers, major exporters, and drivers of demand for SMEs along critical supply chains.

Size Distribution of Maryland's Manufacturing Establishments and Employment, 2020



Source: TEConomy estimates and analysis of U.S. BLS QCEW Employment Size Distribution Data Set, Q1-2020.

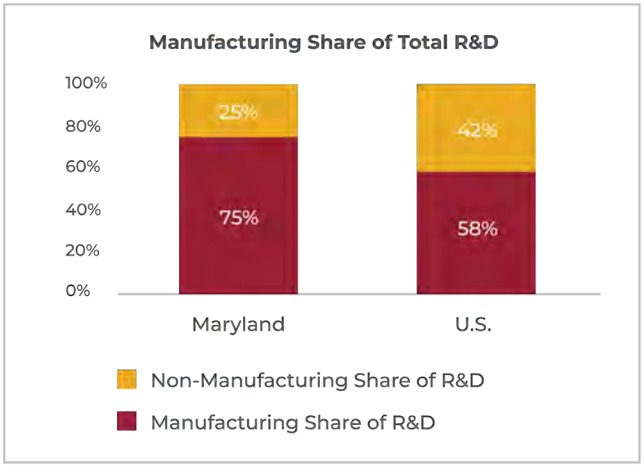
Industrial R&D: Manufacturing is the Predominant Driver for Maryland

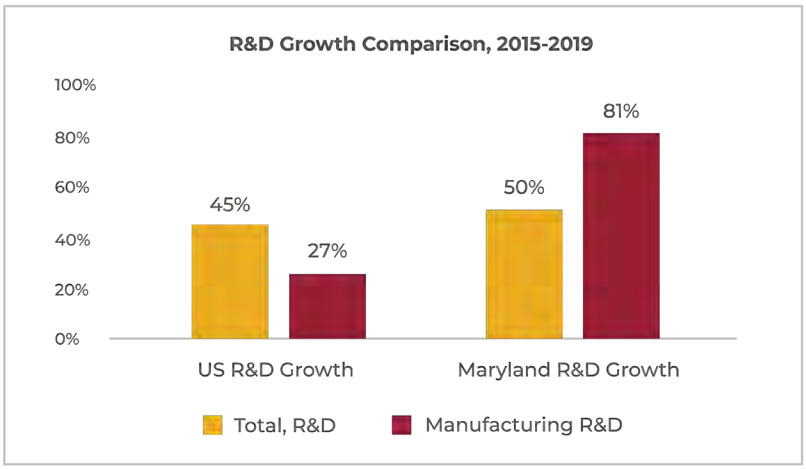
Industrial R&D investment is one key metric of innovation activity and often provides an additional glimpse at Industry 4.0 potential, as innovative firms are much more likely to adopt or consider digital automation solutions. Maryland manufacturers account for three-quarters of the state's total industrial R&D expenditures. While industry R&D survey data have an unfortunate time lag, Maryland manufacturing R&D reached $3.2 billion in 2019. This figure, as well as overall industrial R&D, has grown substantially above US averages since 2015 (Figure 5).

Maryland Manufacturing plays an outsized role as an innovation engine for the state—the sector represents 10% of GSP but accounts for 75% of industrial research and development ($3.2 Billion).

Industrial R&D is most concentrated within large firms, and this is the case in Maryland; however, while 74% of Maryland's total industrial R&D (manufacturing and non-manufacturing combined) occurs in firms with 500 or more employees, this figure is significantly lower than the 87% at the national level. This is good news for Maryland manufacturing, as it signals a strong innovation stance for SMEs and potential for enhanced, innovation-driven growth in a Manufacturing 4.0 environment.

Figure 5: Manufacturing Share of Total Industrial R&D and Recent Growth, Maryland, and U.S., 2019





Source: TEConomy analysis of National Science Foundation, Business R&D Survey data, 2015 & 2019 (most recent year available).

Industrial R&D spans the manufacturing cluster context in Maryland, predictably dominated by the life sciences and aerospace and defense systems. A summary of R&D expenditures, growth and focus areas finds:

Life Sciences Manufacturing

- Reached $1.98 billion in 2019, accounting for 62% of state's manufacturing R&D (47% of Maryland's total industrial R&D)
- Recent (2015-2019) growth dramatically outpaced US (220% to 53%)
- Most of the R&D occurs within pharmaceutical manufacturing ($1.77 billion; 89% of industry cluster total)

Aerospace & Defense Systems Manufacturing

- Reached $550 million in 2019 (down from $760 million in 2018), accounting for 17% of state's manufacturing R&D (compared to 22% nationally)
- Overall cluster R&D levels declined in the recent period (2015-2019), similar to the US overall (-6% to -8%)
- Most of the R&D occurs within aerospace manufacturing ($338 million; 61% of industry cluster total, but down from $520 million in 2018)

Machinery Manufacturing (broad with components captured in other Maryland clusters)

- Reached $182 million in 2019, accounting for 6% of state's manufacturing R&D (slightly above US average)
- Industry R&D levels grew in recent period (2015-2019) exceeding US growth (17% compared to 11% in US)

Polymers & Related Manufactured Products

- Reached $117 million in 2019, accounting for 4% of state's manufacturing R&D (compared to 2% US average)
- Cluster R&D levels declined in recent period (2015-2019) compared to a growth in the US overall (-22% to 4%)

Food Manufacturing

- Reached $50 million in 2019 (down from $58 million in 2018), accounting for 2% of state's manufacturing R&D (similar to US average)
- Cluster R&D levels grew slightly in recent period (2015-2019) compared to a decline in the US overall (4% to -15%)

Academic R&D: Maryland's Research Universities Represent a Key Asset, Potential Partner in Industry 4.0 Solutions Development

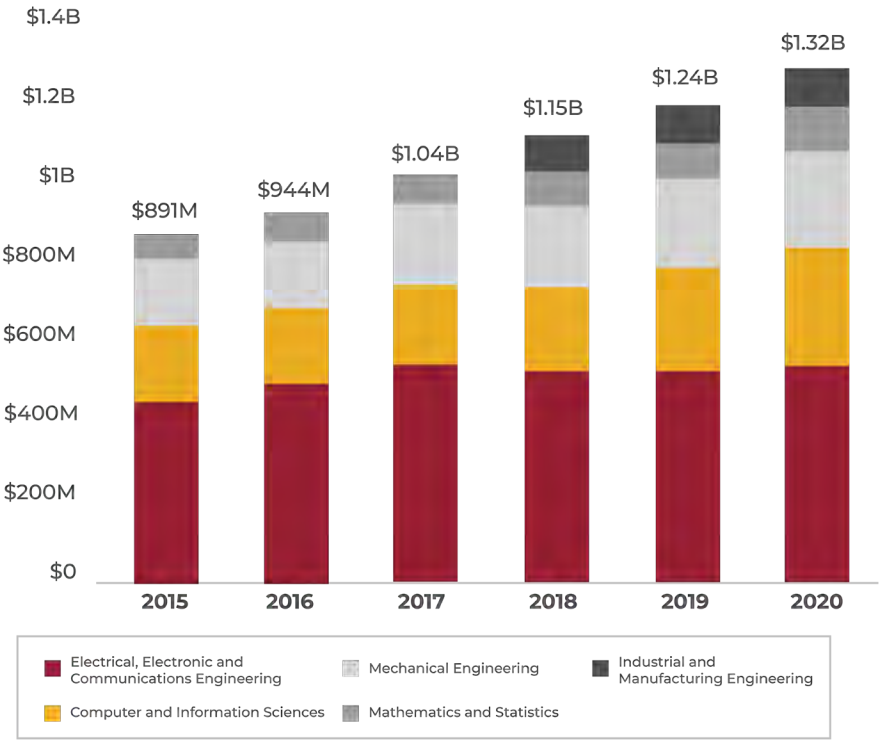
Maryland has a strong reputation in postsecondary education and R&D, and deservedly so as the state ranks fourth among all states in its annual level of science and engineering research expenditures.[4] Maryland is incredibly concentrated in science and engineering or "S&E" R&D as a small state positioned behind only California, New York, and Texas nationally. Led by nation-leading research institutions in Johns Hopkins University and the University of Maryland, College Park and Baltimore County, Maryland institutions conducted nearly $4.7 billion in S&E-related R&D in 2020 alone.

[4] Based on analysis of National Science Foundation (NSF), Higher Education R&D Survey, 2020.

In fields most closely relevant for Industry 4.0 solutions development, Maryland's $1.32 billion in 2020 R&D expenditures is highly concentrated and "specialized"—representing 28% of University R&D in Maryland compared to 11% across the United States. R&D activities in these fields are growing as well and outpacing the nation since 2015 (Figures 6 and 7).

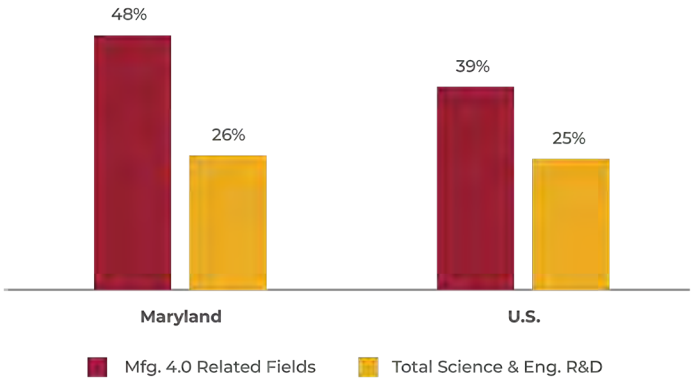
Maryland universities represent an important and leading source of both innovation and talent development relevant for Industry 4.0 adoption, and collaborations and partnerships with Maryland's manufacturing community are critical for seizing a competitive edge.

Figure 6: Maryland University R&D Expenditures in Mfg. 4.0-related Fields, 2015-2020



Source: TEConomy analysis of National Science Foundation, Higher Education R&D Surveys, 2015-2020.

Figure 7: Growth Trend in University R&D, Maryland vs. US, 2015-2020

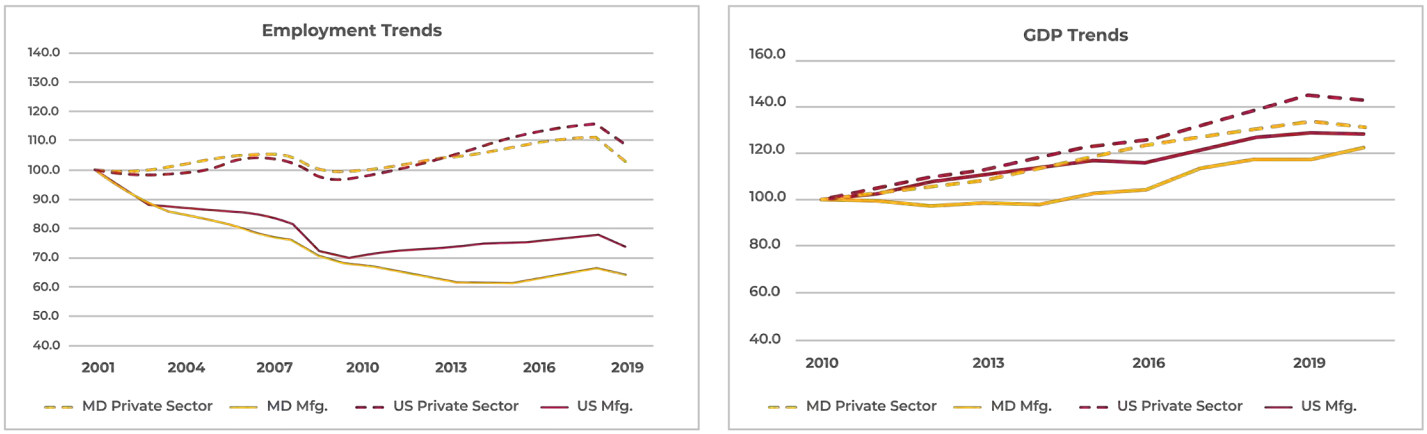


Source: TEConomy analysis of National Science Foundation, Higher Education R&D Survey.

Longer-Term Competitiveness Challenges for Manufacturing

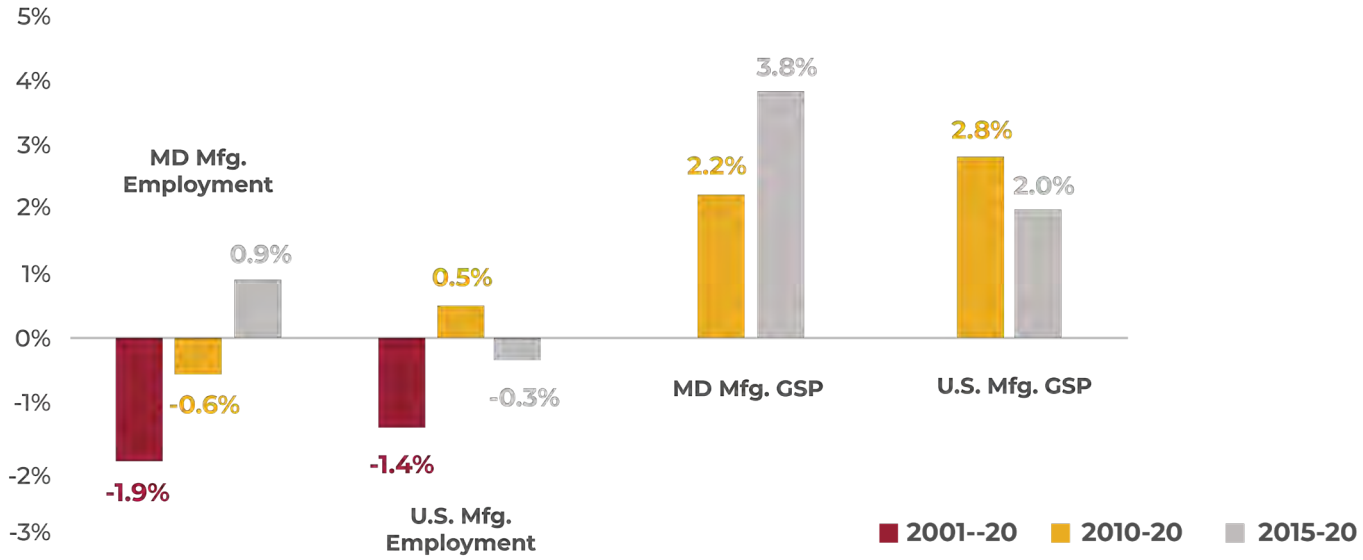
As a consequence of Maryland's higher productivity and R&D in manufacturing, the state has outpaced US manufacturing employment and GDP growth since 2015, but this recent trend is a stabilization of the industry following years of steeper employment declines and lagging output growth for the state (see Figures 8 and 9). Over the last two decades, Maryland manufacturing has struggled with lagging GSP growth and steady, rapid declines in its employment base. While industry employment has stabilized and GSP growth has increased its pace in recent years, the industry has clearly faced longer-term competitiveness challenges and contraction—a key context as to why Industry 4.0 adoption will matter for state competitiveness.

Figure 8: Maryland Manufacturing has Seen Long-Term Competitiveness Challenges That it has Recently Reversed—Manufacturing Employment & GSP Average Annual Growth Trends, 2001-20, 2010-20



Source: TEConomy Partners' analysis of Emsi Q2 2021 data set.

Figure 9: Maryland Manufacturing has Seen Long-Term Competitiveness Challenges That it has Recently Reversed—Manufacturing Employment & GSP Average Annual Growth Trends, 2001-20



Manufacturing is a diversified industry in Maryland with the baseline analysis identifying seven distinct and varied clusters. The clusters illustrate the breadth of products manufactured across the state and numerous global markets served—from cutting-edge aerospace navigation and defense systems to vaccines and cell therapies for cancer patients, to seafood and spices, Maryland manufacturing is truly diverse. Table 1 lists the seven clusters, their key sub-clusters, and examples of the Maryland companies within each. Summary employment metrics and the geographic distribution of each cluster is included in Appendix A to this report.

Table 1: Maryland Manufacturing Industry Clusters–Key Subsectors and Example Companies

Manufacturing Cluster	Key Sub-Clusters (% of Jobs)	Examples of MD Companies
Aerospace & Defense Systems	Navigation, Guidance, & Security Instrumentation (61%) Aerospace (15%) Communications Equipment (14%)	Northrup Grumman Systems Corporation, Lockheed Martin, Raytheon, Boeing, L3Harris, Textron Systems (AAI Corporation), Advanced Thermal Batteries
Food & Beverage	Food (82%) & Beverage (18%) Manufacturing	Perdue Farms, McCormick & Company, Smithfield Foods, Synutra International, Northeast Foods, Ingredion, Inc., Fuchs North America, Eight O'Clock Coffee
Life Sciences	Pharmaceuticals (76%) Medical Devices & Equipment (24%)	Celegene, Orgenesis, AstraZeneca (Medimmune), Emergent Biosolutions, Kite Pharma, Meridian Medical Technologies, Trinity Sterile, Inc., Action Products, Inc.
Polymers & Related Products	Plastic & Rubber Products (75%) Adhesives, Coatings & Paint (25%)	W. L. Gore & Associates, Inc., Berry Plastics, Fawn Industries, Wm. T. Burnett & Co., Tenax Corporation
Precision Manufacturing	Precision Metalworking (55%)	Dixon Valve & Coupling Company; Cambridge International (Rexnord), Kenlee Precision Corporation, Danko Arlington, The Bechdon Company, Inc.; Raloid Corporation
Printing & Packaging	Printing (66%)	Plastipak, Altium Packaging, Spartech, Phoenix Color, Atlas Container Corporation, CCL Label, WebbMason Marketing
Wood Products	Lumber & Building Products (53%)	Shelter Systems, Washington Woodworking, The Taney Corporation, Beachley Furniture Company, Helmut Guenschel, Inc.

Source: TEConomy Partners, LLC.

The employment size, concentration, and recent hiring trend of each cluster is shown in Table 2 and Figure 10. The bubble chart provides a snapshot of the varied size of each cluster (size of each bubble), with food and beverage manufacturing and aerospace and defense systems the two largest clusters approaching 21,000 jobs each. What stands out in recent years is the strong employment growth across a majority of the clusters, with five of seven growing since 2015 and four of those five seeing double-digit growth rates despite the inclusion of the 2020 COVID year.

Like the overall manufacturing industry in Maryland, nearly all of the clusters are under-concentrated in the state relative to national averages. The exception is life sciences, where Maryland has a 6% greater concentration of jobs relative to the United States (LQ of 1.06), a strong concentration though one that is not yet considered to be "specialized" (LQ of 1.2 or greater). The strong growth and under-concentration of the clusters place many of them firmly in the "emerging" category from an industry targeting perspective.

Table 2: Employment Size, Concentration, and Growth Metrics for Maryland Manufacturing Clusters, 2020

Maryland Manufacturing Industry	Employment		
	Totals, 2020	Change, 2015-2020	Concentration (LQ)
Food & Beverage	20,908	17%	0.64
Aerospace Defense Systems	20,740	17%	0.95
Life Sciences	12,604	29%	1.06
Printing & Packaging	10,354	-10%	0.72
Polymers & Related Mfd. Products	6,826	5%	0.53
Precision Manufacturing	4,944	0%	0.28
Wood Products	3,870	12%	0.44

Source: TEConomy analysis of enhanced US Bureau of Labor Statistics CEW data (from Emsi, Datarun 2021.2)

Figure 10: Employment Size, Concentration, and Growth Metrics for Maryland Manufacturing Clusters, 2020

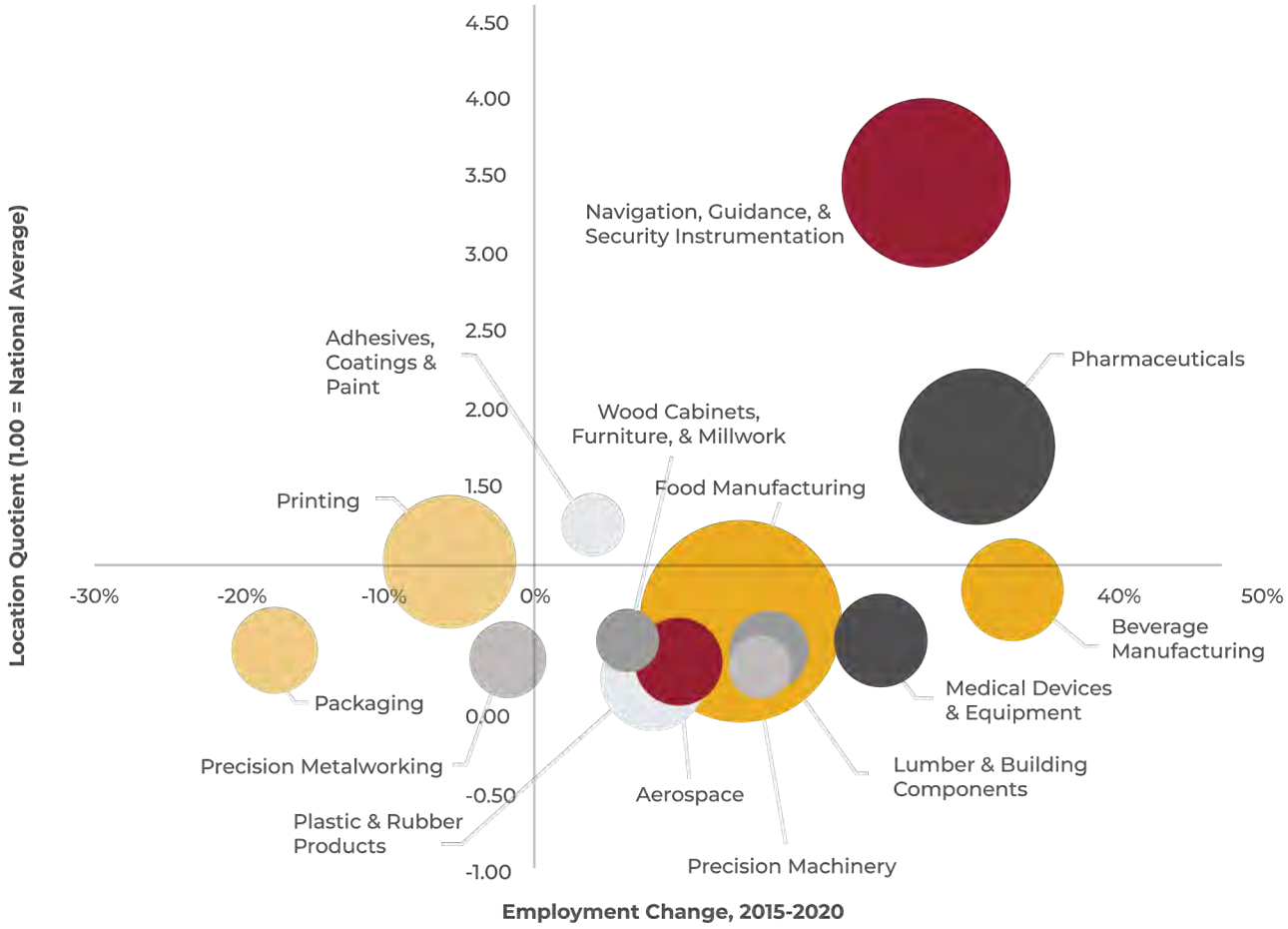
Source: TEConomy analysis of enhanced US Bureau of Labor Statistics CEW data (from Emsi, Datarun 2021.2)

Five of the Maryland manufacturing clusters have outpaced their national counterparts in job growth since 2015. All but printing and packaging and polymers and related products have seen stronger net hiring in the 5-year period compared to the national average.

Narrowing the lens and drilling down on the major subclusters driving the overall trends finds three that can be considered current strengths for Maryland—navigation, guidance, and security instrumentation (within aerospace and defense systems); pharmaceutical manufacturing (life sciences); and adhesives, coatings, and paint (polymers and related, see Figure 11). Each of these has a "specialized" concentration of jobs in Maryland relative to the national average and has grown its base since 2015. The rapid growth of the instrumentation and pharmaceuticals sub-clusters is especially impressive given the large size of their existing employment base.
Likewise, food manufacturing has hired at a rapid clip (up 14%) despite its sizable base representing the largest individual sub-cluster.

Even at a quick glance, the color-coded bubbles tell the story at the cluster level with strong recent hiring in life sciences and in food and beverages, aerospace and defense systems, and wood products. Precision manufacturing has seen mixed performance, with net new hires in precision machinery offset by job declines in precision metalworking. The net job losses in printing and packaging have been across both major components.

Figure 11: Employment Size, Concentration, and Growth Metrics for Maryland Manufacturing Clusters, 2020

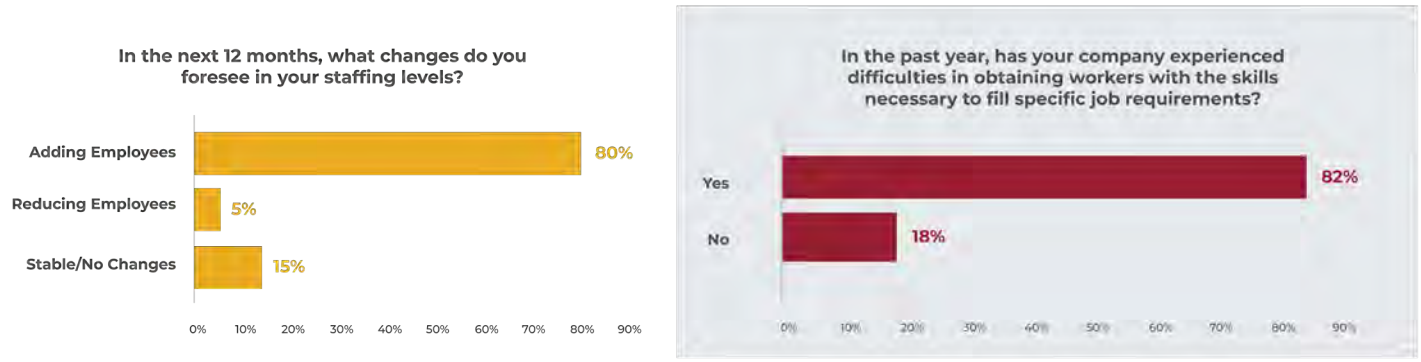


Source: TEConomy analysis of enhanced US Bureau of Labor Statistics CEW data (from Emsi, Datarun 2021.2)

Reflecting the strong employment growth of the seven clusters, nearly all of Maryland's subclusters have outpaced job growth nationally (see Appendix A). Based on a 2021 Maryland Department of Commerce survey, this strong overall hiring stance is expected to continue in Maryland in the near term, with 80% of manufacturers reporting plans to add employees in the next 12 months (Figure 12).[5] As will be discussed in the next section of the report, the most common and most challenging issue facing Maryland manufacturers today is around identifying and hiring new talent and workforce—and a key question will be, can state manufacturers continue to hire their way to sustained growth?

[5] The Maryland Department of Commerce surveyed 228 state manufacturers in Summer 2021 on an array of topics regarding their current situation and outlook for the future. Selected results are used to inform this study and are included in different sections of the report. Sample sizes responding to each question vary and are noted for each figure used in this report.

Figure 12: Hiring Outlook for and Challenges Faced by Maryland Manufacturers, 2021



Note: for these questions, the sample sizes were 130 for staffing outlook and 131 for difficulty in hiring.
Source: Maryland Dept. of Commerce, 2021 Maryland Manufacturing Survey.

IMPLICATIONS AND INITIAL INSIGHTS FOR INDUSTRY 4.0 ADOPTION

The baseline analysis poses two significant realities around the importance of Maryland manufacturing adopting Industry 4.0:

- Maryland manufacturing has effectively stabilized in recent years, but its longer-term competitive challenges cannot be ignored. The state industry has seen decades of declining employment and lagging output growth, and Maryland's ability to master Industry 4.0 capabilities may provide an opportunity for sustaining long-term growth.
- At the same time, Industry 4.0 poses significant challenges to Maryland maintaining its existing competitive advantages in productivity and innovative product development. The essence of Industry 4.0 is a transformational change in manufacturing production process and product design and development through the digitization of manufacturing activities. Maryland cannot afford to fall behind or even not be among the national leaders in Industry 4.0 because it risks the state's competitive edge in manufacturing across its diverse base.

Other challenges and threats identified by the baseline assessment include:

- While above-average industry wages reflect strong value-adding activities and benefit workers, they represent a competitiveness challenge for manufacturers trying to compete for talent, a dynamic that will be raised in the situational assessment from discussions with employers.
- Maryland's under-concentrated manufacturing base remains a challenge to retaining, recruiting, and attracting both new firms and talent in the industry looking for career opportunities, supply chain and talent connections.

But opportunities also emerge from the baseline industry assessment, namely that growth opportunities are abundant across the state's manufacturing clusters based on recent trends. The next section of the report will describe Industry 4.0 in greater detail and frame how Maryland is positioned both currently and into the future for technology adoption and integration.

II. WHAT IS INDUSTRY/MANUFACTURING 4.0 AND HOW IS MARYLAND POSITIONED TO SEIZE THE OPPORTUNITY?

A DIGITAL TRANSFORMATION IN MANUFACTURING ENABLING GAME-CHANGING OUTCOMES

Many manufacturers with long-standing industry experience will note that digital technologies in manufacturing are not a new phenomenon, as manufacturers have long made use of robotics and other automation tools and technologies since the 1980s. What has shifted in recent years, as technology development has progressed, is a transformational evolution away from a number of formerly disparate tools and applications used in isolation toward the ability to interconnect in a "smart" manufacturing environment. Today's smart manufacturing, or Industry 4.0 environment, draws from a host of technologies enabling data collection and analysis and real-time communication across and between machines.

The Origins, Terminology of "Industry 4.0"

Originally rooted in Germany's national strategy for adoption of smart manufacturing systems, the term Industry 4.0 (or "Industrie" 4.0, often used interchangeably with the term Manufacturing 4.0 as done in this report) is now widely used to refer to the portfolio of technologies, capabilities, and services that manufacturers are using to shift traditionally labor-intensive production enterprises towards digital and automated operations models.

Industry 4.0 technologies are thus driving bottom-line outcomes for manufacturers in terms of increased productivity and efficiencies, faster and more flexible production, and, ultimately, higher quality goods at lower costs. These highly desirable outcomes are enabled by an expansive portfolio of new technologies, capabilities, and services, with several key goals in transitioning operations to Industry 4.0 models shown in Figure 13.[6]

Figure 13: Goals in Transitioning Manufacturing Operations to Industry 4.0 Models

Interconnectivity
Generation of Big Data, Machine-to-machine and machine-to-human communication

Decision Support
Use of analytics for predictive action and autonomous decision making

Customization & Flexibility
Ability to create highly tailored production runs with minimal downtime and waste

Decentralization
Outsource low level tasks and decision-making to machines and increase modular capabilities of production assets

Source: adapted from "Design Principles for Industrie 4.0 Scenarios, 2016."

There are varied concepts and depictions of the range of Industry 4.0 technologies, but framing them using key groupings is more appropriate for understanding the modern industrial setting and full context of their applications. Three key categories of technologies most commonly come together to enable an integrated Industry 4.0 operating environment:

[6] Mario Hermann, Tobias Pentek and Boris Otto, "Design Principles for Industrie 4.0 Scenarios," 2016 49th Hawaii International Conference on System Sciences (HICSS), 2016, pp. 3928-3937, doi: 10.1109/HICSS.2016.488.

Foundational technologies for Industry 4.0 form the backbone of infrastructure that workers and other technologies leverage to gather and access digital information within manufacturing operations.

- Key examples include the back-end data storage and cloud computing technologies that make up the information technology stack of manufacturing; connectivity infrastructure such as wireless networks and high-speed broadband as well as cybersecurity systems; and sensing and monitoring hardware that makes up the Industrial Internet of Things (IIoT).

Enabled technologies for Industry 4.0 leverage and are largely dependent on the foundational technologies that enable the gathering and transfer of digital information. Many of these technologies represent recent or emerging applications that have become more prevalent as a result of manufacturing's ongoing digitization.

- Examples include advanced robotics and autonomous systems, additive manufacturing, augmented and virtual reality, digital design and prototyping capabilities, and other cyber-physical systems.

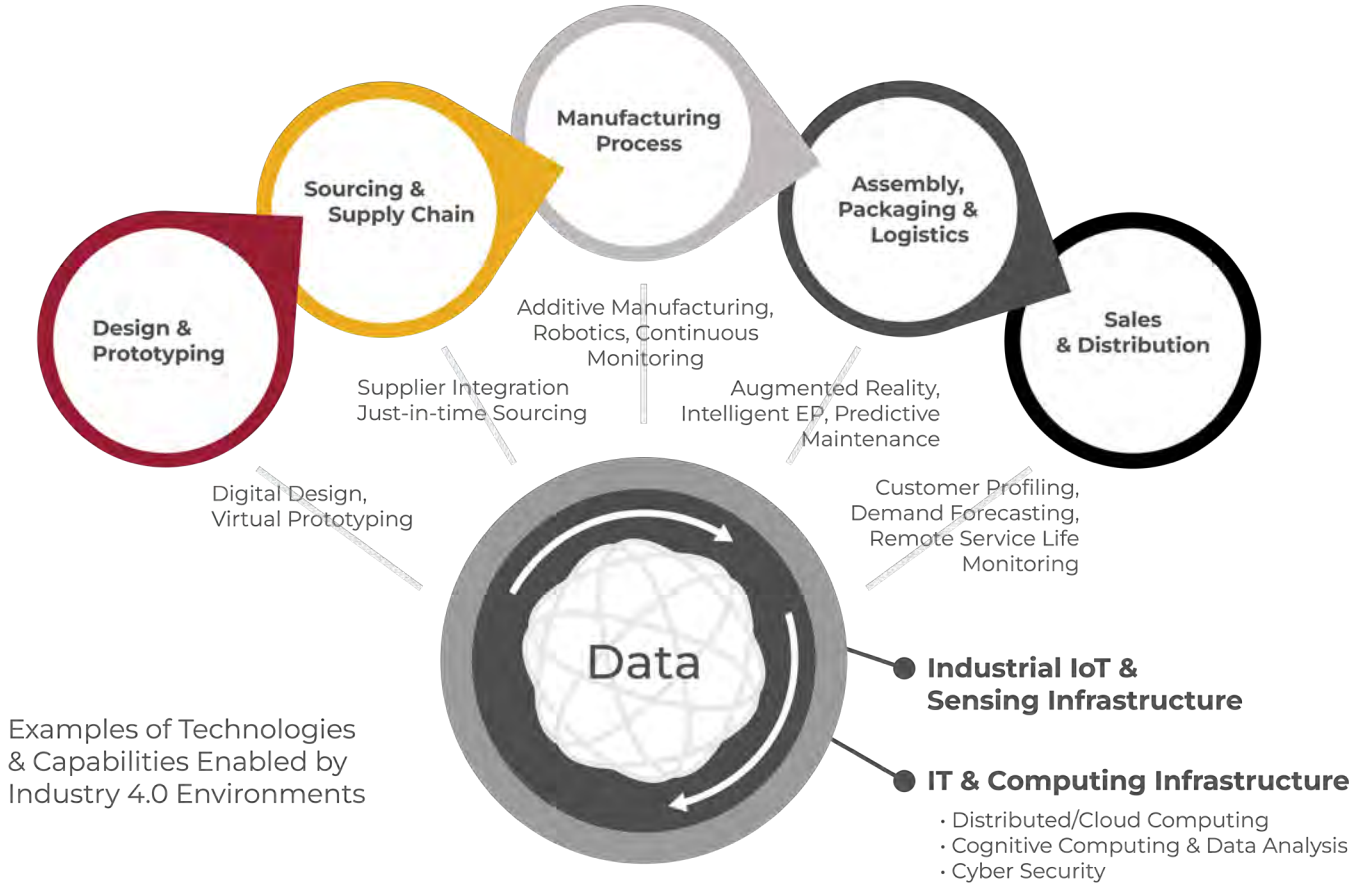
Downstream Industry 4.0 capabilities and services that leverage both of the technology types described above to produce new value-added capabilities for manufacturers, but are not novel technologies in and of themselves.

- Examples include intelligent Enterprise Resource Planning (ERP) systems that automate and streamline workflows, horizontal and vertical integration with supply chains, predictive decision support tools for maintenance and monitoring, and simulation tools that can "virtualize" production operations for testing.

As will be shown in the situational assessment, Maryland manufacturers are leveraging most all of these discrete individual technologies, though the degree to which they are optimized as a truly integrated system varies considerably and is generally limited based on discussions held with selected manufacturers.

The ultimate goal of an integrated and optimized Industry 4.0-enabled production environment is to leverage the ability to gather, store, manipulate, and fully utilize data generated from manufacturing operations to generate actionable insights. This is an aspirational goal to realize the concept of a "smart" or "intelligent" factory or plant at scale, where a broad suite of 4.0 technologies is deployed to create a positive feedback cycle that allows a manufacturer to be highly adaptive and flexible in real time. For corporate leaders in Industry 4.0 adoption, this capability creates a highly advantageous, uneven playing field against competitors operating in legacy production environments. An illustration of this smart manufacturing model and the insights leveraged through continuous feedback cycles is shown in Figure 14.

Figure 14: A Fully Integrated Industry 4.0 Environment and the Role of Data-Driven Feedback Cycles



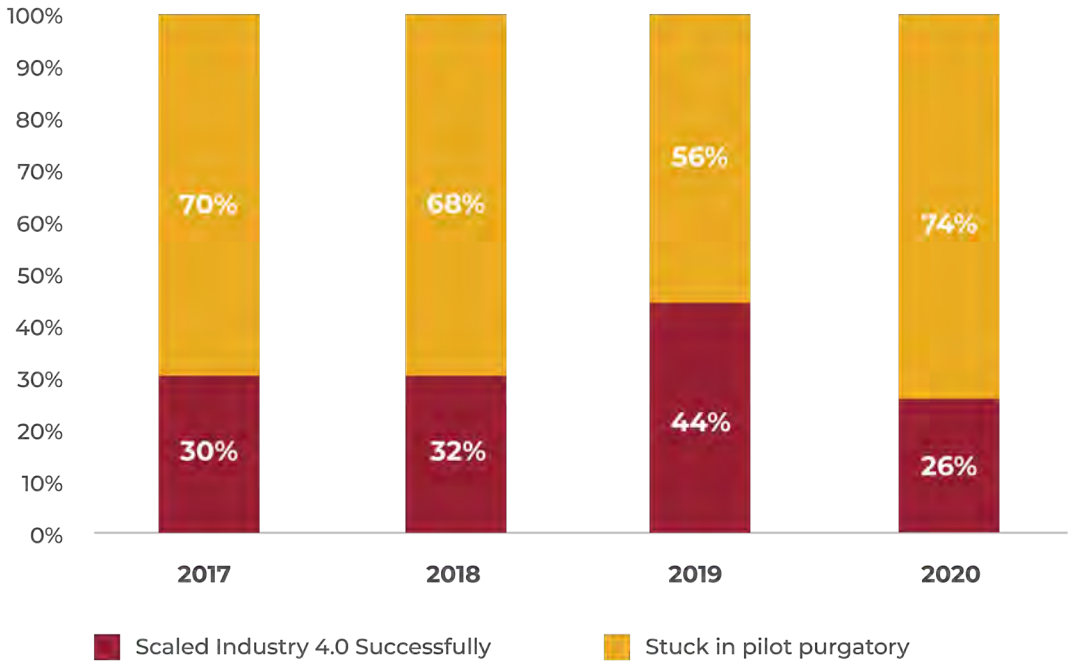
Source: TEConomy Partners, LLC.

GAUGING GLOBAL ADOPTION TODAY AND THE OUTLOOK FOR THE FUTURE

McKinsey & Company has tracked Industry 4.0 adoption in global surveys of manufacturing executives and the degree to which companies are achieving the type of scale and optimization described above along a maturity scale. Response summaries from their latest four surveys are shown in Figure 15.[7] And while the share reporting that they had successfully scaled Industry 4.0 was down considerably in 2020, they report two likely causes—one, the bar for successful scaling has risen amid real tests during crises caused by COVID-19; and two, "battle testing" platforms during a pandemic may have revealed implementation once thought to have reached scale not yet fully realized. Regardless, the surveys continue to show a significant share of firms investing in Industry 4.0 and a rising share prior to 2020.

[7] McKinsey & Company. (2021, January). "COVID-19: An Inflection Point for Industry 4.0."

Figure 15: Manufacturing Survey Respondents Reporting Successfully Scaling Industry 4.0 (Shares)



Source: McKinsey & Company.

The general upward growth pattern of adoption at scale of Industry 4.0 technologies is reinforced by a recent survey conducted by SME and Plataine in 2020 that found major acceleration in recent years—with 84% of global manufacturing respondents currently implementing digital strategies compared to only 27% in 2018.[8] While not the threshold of "successfully scaling," this finding clearly illustrates the growing adoption among manufacturers. The Industry 4.0 opportunity has grown to significant market size—the International Society of Automation recently reporting the global Industry 4.0 market was valued at $81.7 billion in 2020, with a projected compound annual growth rate (CAGR) of 20% through 2027.[9]

[8] SME & Plataine, Trends in Global Digital Manufacturing Survey, 2020.

[9] International Society of Automation, "Rising Demand for Industry 4.0 Due to Adoption of Artificial Intelligence in Manufacturing Sector," September 2021

COVID-19 PANDEMIC HAS ACCELERATED URGENCY ON RESILIENT OPERATIONS ENABLED BY INDUSTRY 4.0 SOLUTIONS

Prior to the pandemic there was plenty of momentum behind transformative Industry 4.0 technology adoption, but the trend is accelerating based on the challenges arising from COVID-19. McKinsey & Company, in a recent survey of global manufacturers, finds manufacturing leaders calling on Industry 4.0 solutions to address critical supply chain and workforce challenges seen in the depths of the pandemic—39% implemented a "nerve center" approach to "increase end-to-end supply-chain transparency," and about one quarter were fast-tracking automation initiatives to respond to worker shortages.[1]

Further, McKinsey & Company has found:
"Recent evidence shows that the move towards digital transformation is gaining momentum across virtually all sectors. In fact, in a survey of more than 400 global manufacturing companies, 94 percent of respondents indicated that Industry 4.0 helped them to keep their operations running during the crisis, and 56 percent said the digital transformation they undertook was essential to their pandemic responses. Conversely, for those companies that hadn't scaled—or even begun—their digital transformation, the past year has served as a serious wake-up call to review operational strategies and refocus on Industry 4.0 capabilities." [2]

[1] See: https://www.mckinsey.com/business-functions/operations/our-insights/industry-40-reimagining-manufacturing-operations-after-covid-19

[2] See: https://www.mckinsey.com/business-functions/operations/our-insights/operations-blog/industry-40-adoption-with-the-right-focus

Table 3 considers each of Maryland's seven manufacturing clusters and likely or potential areas of importance in terms of Industry 4.0 technologies and applications.

Table 3: Examples of Key Potential Manufacturing 4.0 Technologies and Applications for Maryland's Manufacturing Clusters

MD Manufacturing Cluster	Examples of Potential Manufacturing 4.0 Technologies of Importance
Aerospace & Defense Systems	• Digital twin and simulation modeling for aircraft and defense platforms for use in digital design and evaluating interoperability challenges for systems integrators • Real-time monitoring of field usage, maintenance, and wear of manufactured parts/systems to enable JIT manufacturing of replacements and adaptive design improvements – relies on embedded instrumentation within products/systems to provide data • Additive manufacturing for customized production runs, usage of novel hybrid feedstock materials • Digital supply chain management for seamless integration into trusted/verified supplier networks • Dedicated cybersecurity operations centers (CSOC) for continuous threat monitoring that addresses security requirements of customers (particularly federal government)

MD Manufacturing Cluster	Examples of Potential Manufacturing 4.0 Technologies of Importance
Food & Beverage	• Data lakes/repositories capturing production, storage, and transportation environment data throughout processing to enable downstream applications • Predictive AI and ML modeling applications that leverage environmental, ingredient, and processing variables across the product journey from initial harvest and processing to packaging in order to optimize product quality and cost savings • Digital traceability, enabled by technologies like distributed ledger systems, that use decentralized metadata tracking to quickly address traceability issues such as food safety • IoT-enabled industrial food and beverage production equipment, e.g., filling and depositor machines that integrate improved sensors for monitoring product quality and local connectivity for sharing data
Life Sciences	• Bioinformatics and materials informatics tools for optimizing production processes and enabling adaptive manufacturing models for precision medicine (with smaller lot sizes, potentially as small as single patient) • Continuous manufacturing approaches (continuous mixing, blending, coatings, etc.) that leverage end-to-end (E2E) systems as opposed to batch runs to optimize run times and automate therapeutics production within flexible, modular production cells • Bioprocessing automation enabled through standardized communications protocols, supervisory control systems, and combinations of linked, modular processing equipment such as bioreactors • 3D printing and novel biomaterials for highly personalized medical device production • Digital integration of laboratory information management systems, clinical deployment data, and supply chain information (i.e., cold chain) for use in regulatory compliance systems and software (Quality 4.0 for life sciences)
Polymers & Related Products	• Digital supply chain integration of upstream materials suppliers as well as customer design tools for highly customized production runs – scaled production of individualized parts • Feedstock materials production for additive manufacturing applications (3D printing), and eventual implementation of 4D printing • IIoT-enabled processing machinery and quality management systems to ensure consistent operating conditions and product output
Precision Manufacturing	• Robotic production cells for use in precision tasks, e.g., robotic welding. • Metal printing technologies for advanced designs (e.g., metal powder bed fusion). • Advanced CNC machinery employing technologies such as laser cutting, tactile manipulation, imaging sensors, etc. that work in conjunction with electronic design automation software. • Materials use life simulation (e.g., stress and wear patterns).
Printing & Packaging	• Packaging automation systems (e.g., automated palleting, labeling, etc.) and industrial automated ground vehicle (AGV)/autonomous mobile robot (AMR) systems • Hybrid packaging machinery (e.g., corrugation plus RPET) for improved packing options • New location and localization systems for real-time tracking of packaging and incorporation of embedded tracking/tracing media withing packaging • "Smart" packaging materials that react to environmental stimuli such as temperature or acceleration • Cyber-physical security solutions to enable secure logistics facilities and distribution
Wood Products	• Adaptive response for wood processing machinery (e.g., dynamic cutting speed in sawmill machinery based on wood properties) • Computer vision applications for analyzing wood characteristics (e.g., defect detection, log shape, board dimensions) • AI/ML applications for wood quality characterization defect prediction • Computer-aided design (CAD) for Mass Timber applications

With this framing context in hand, the assessment now turns to Maryland manufacturing and how it is positioned to adopt and integrate Industry 4.0.

MARYLAND'S MANUFACTURING 4.0-ENABLING WORKFORCE: A COMPETITIVE ADVANTAGE, BUT POTENTIALLY A TALE OF TWO TIERS?

To implement and realize the potential of Industry 4.0 technologies and fully leverage the capabilities of an integrated digital transformation, manufacturers must have the right mix of skilled talent across the organization. A workforce and talent analysis uses several data sets and approaches for understanding the current employment situation and demand dynamics for Maryland manufacturers, including industry "staffing patterns" of occupational employment across the state sector, as well as recent job postings of Maryland manufacturers. The analyses yield insights into Maryland's current situation and to inform strategy development.

TEConomy has developed a concept of an "Industry 4.0-enabling" workforce spanning a broad spectrum of key roles and occupations that range from computer and data sciences to business services. Individuals employed in these roles represent those assessing, designing, implementing, and deploying digital technologies and resulting data streams for smart automation. Using federal occupational classifications, job types have been categorized related to manufacturing operations into production-related occupations that represent traditional labor-intensive manufacturing functions and operations versus Industry 4.0-enabling occupations that develop, deploy, and/or support the digitization and automation applications that are most closely related to the concepts of Manufacturing 4.0. These occupational segments and some illustrative examples are presented in Table 4.

Table 4: Industry/Manufacturing 4.0-Enabling Occupational Segments and Example Occupations

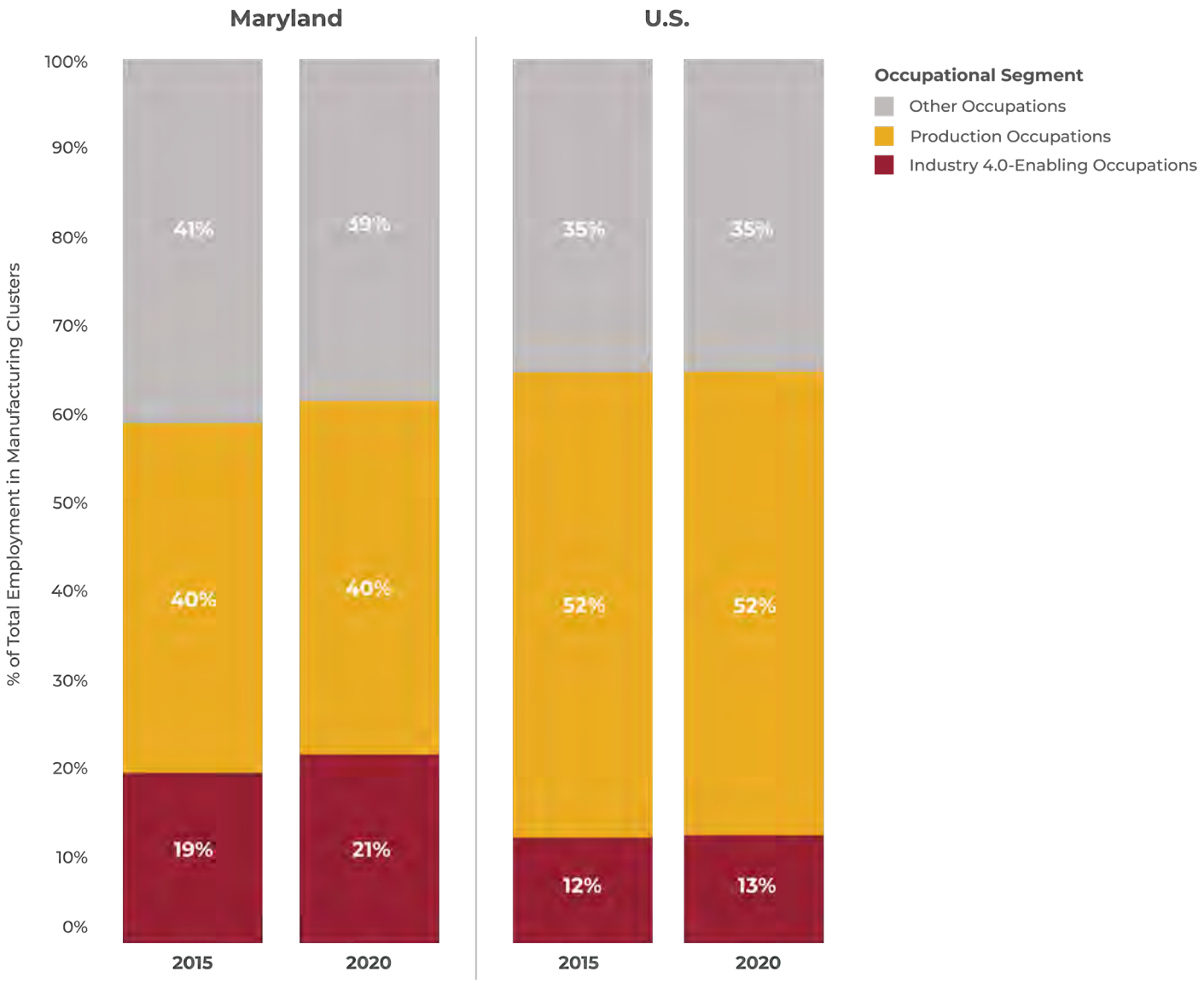
Industry 4.0-Enabling Occupational Segments	Example Occupations in Segment
Business Analytics	Management Analysts, Market Research Analysts
Computer Hardware & Networking	Information Security Analysts, Network and Computer Systems Administrators
Computer Software	Software Developers, Applications, Computer Programmers
Digital Systems	Computer Systems Analysts, Database Administrators
Engineering Technicians	Aerospace Engineering and Operations Technicians, Industrial Engineering Technicians
Engineers	Mechanical Engineers, Industrial Engineers
Modeling & Data Science	Statisticians, Mathematicians
Operations & Logistics	Logisticians, Operations Research Analysts
Scientific Technicians	Chemical Technicians, Ag and Food Science Technicians
Scientists	Chemists, Materials Scientists

Source: TEConomy Partners, LLC.

Maryland's Industry 4.0-enabling occupational employment share of its overall manufacturing industry is significantly higher than that of the nation's—21% of the sector's workforce versus 13% for the nation (Figure 16). While a smaller share of manufacturing relative to the industry's large production workforce, these one-in-five workers total nearly 17,000 and have grown their share of the industry's workforce at roughly twice the rate as the nation since 2015. Maryland also has a higher share than the United States of other types of non-production occupations such as business support and sales.

While less concentrated as a proportion of the state's manufacturing workforce relative to the nation, production workforces will still play a key role in supporting manufacturing operations. With targeted retraining and reskilling efforts, these roles can successfully transition to new occupational segments over time in an Industry 4.0 environment.

Figure 16: Industry 4.0-Enabling Occupational Employment in the Maryland and US Manufacturing Sector, 2015 and 2020



Source: TEConomy analysis of industry staffing patterns data from Emsi (Emsi Release 2021.2).

Among the enabling occupational workforce the role of engineers across manufacturing stands out as the largest individual segment, but Maryland's manufacturing industries still have a less engineering-intensive profile than the United States overall (Figure 17). This is true for engineering technicians as well. Trend data and job postings, however, find a major hiring push for engineers among manufacturers—the sector has increased its employment of engineers by 22% since 2015, compared to 10% growth within the industry nationally.[10] Engineers are tied with computer software professionals as having the largest share of job postings among the "enabling" workforce—nearly 10% of manufacturing job postings over the last 3.5 years are for engineers.

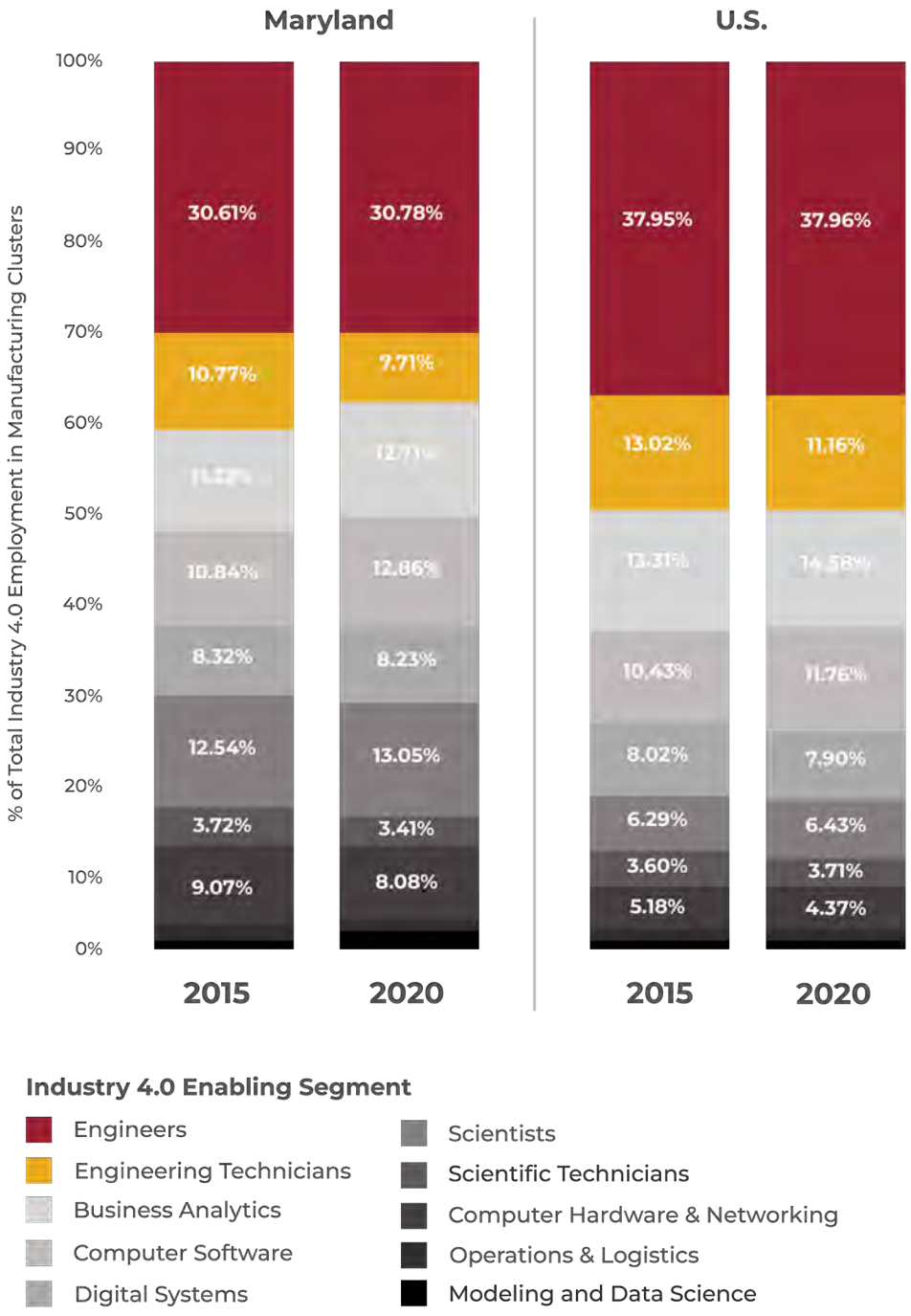
Where Maryland manufacturing does stand out today is in its significantly higher deployment of computer software, hardware, and networking occupations. Along with engineering, the demand for software talent is especially high, with Maryland manufacturers increasing their software workforce by 44% since 2015 compared to a 24% increase nationally. One in ten manufacturing industry job postings is for software professionals in Maryland compared to just 5% nationally.

Maryland also stands out in its scientific workforce, reflecting the concentration and growth of jobs in life sciences manufacturing. The life sciences are among the most R&D- and innovation-intensive sectors globally and employ a very scientific and STEM-intensive workforce. Maryland manufacturers are not standing still, hiring scientists at a rapid rate since 2015 (up 26% in Maryland vs. 12% nationally).

Although it stands at a small base today, a critical and rapidly growing 4.0-enabling segment of the manufacturing workforce is in modeling and data science positions—those spanning math, statistics, and advanced analytics and crucial for making actionable the intelligence generated out of massive data streams in a highly digitized operating environment. These professionals make up a small share of the industry's workforce, but hiring has been on a tear with Maryland manufacturers increasing their data sciences workforce by 74% versus 19% growth nationally.

[10] For growth trend comparisons vs. the U.S. in Industry 4.0-enabling occupational groupings, see Appendix B.

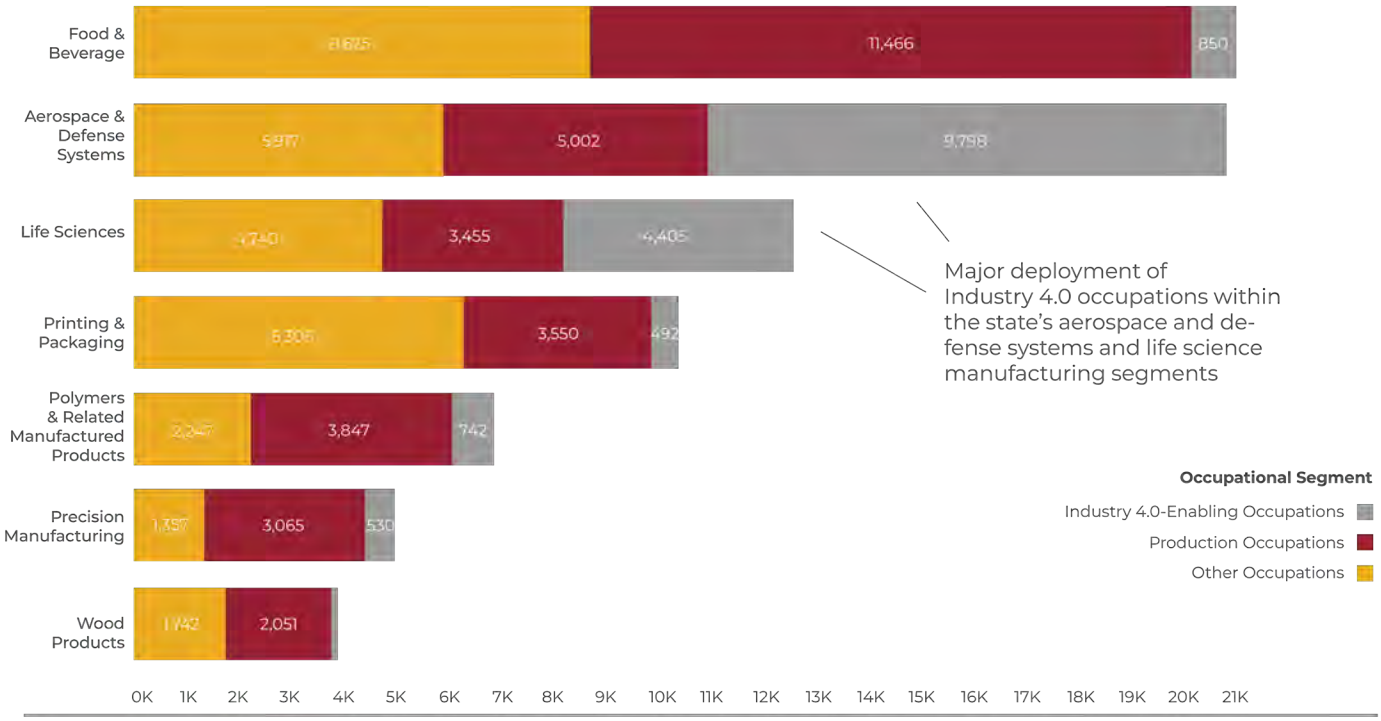
Figure 17: Detailed Industry 4.0-Enabling Occupational Employment in the Maryland and US Manufacturing Sector, 2015 and 2020



Source: TEConomy analysis of industry staffing patterns data from Emsi (Emsi Release 2021.2)

Among the seven manufacturing clusters, two stand well above their counterparts both in Maryland and nationally in their concentration and deployment of Industry 4.0-enabling talent—aerospace and defense systems and life sciences (Figures 18 and 19). Aerospace and defense systems is reliant on engineering talent (37% of Industry 4.0-related employment) but is still driven by a well-distributed mix of additional Industry 4.0-enabling occupations ranging from computing and IT to business analytics. Life sciences, on the other hand, leverages a large scientific workforce (38% of Industry 4.0-related employment) and represents a unique context, as most manufacturing industries have lower concentrations of scientific occupations relative to traditional engineering.

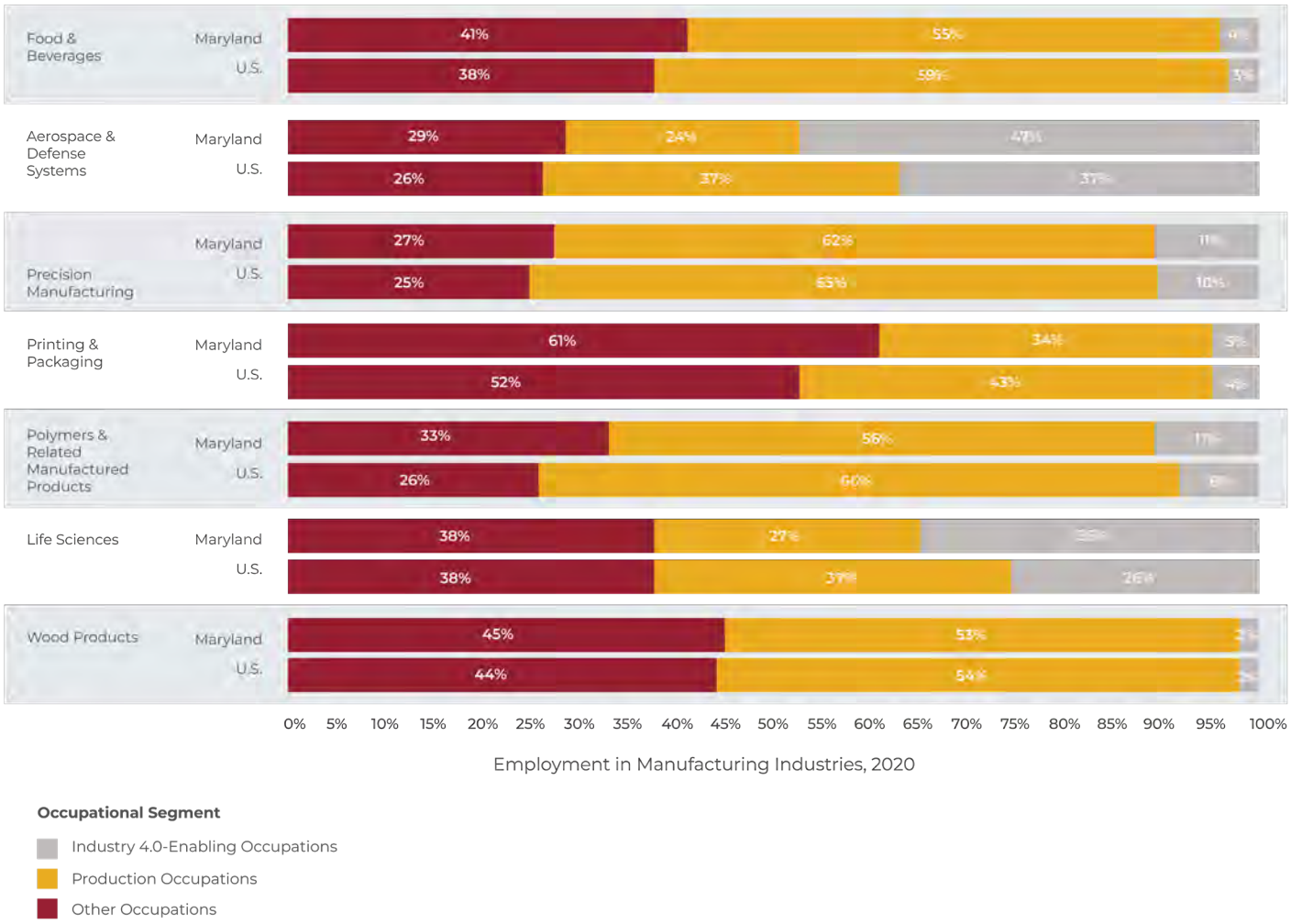
Figure 18: Industry 4.0-Enabling Occupational Employment within Maryland's Manufacturing Clusters, 2020



Maryland Employment in Manufacturing Industries, 2020

Source: TEConomy analysis of industry staffing patterns data from Emsi (Emsi Release 2021.2).

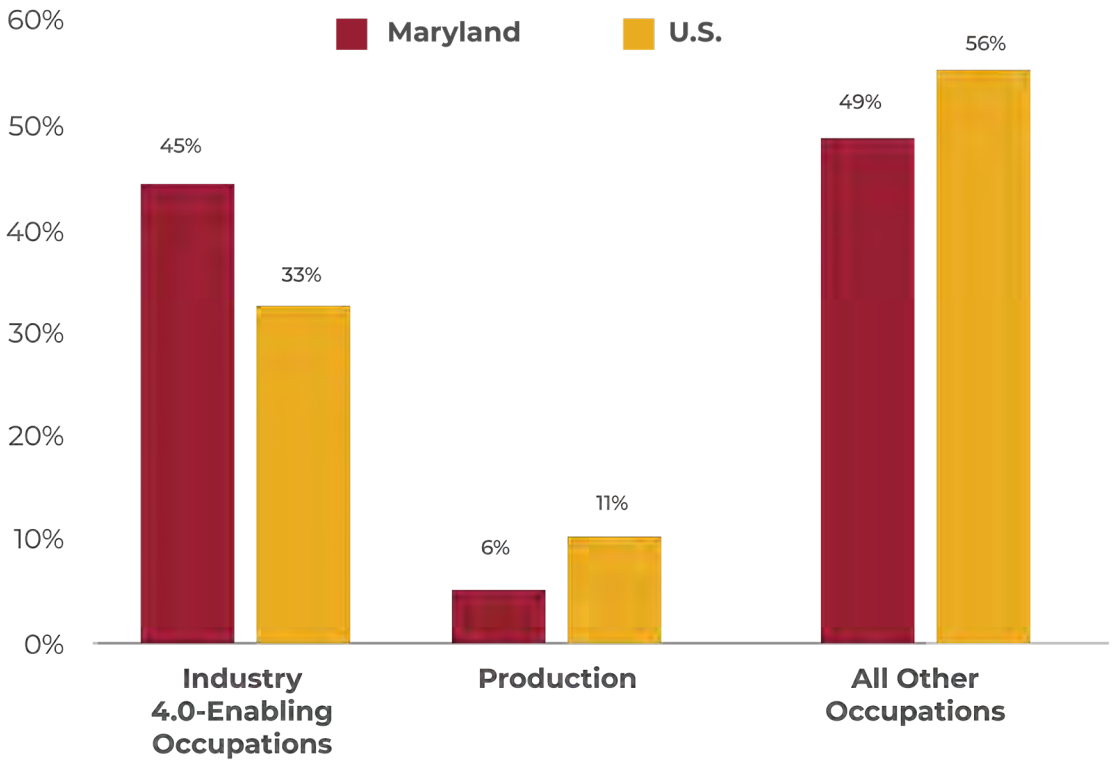
Figure 19: Industry 4.0-Enabling Occupational Employment in Maryland's Manufacturing Clusters, 2020



Source: TEConomy analysis of industry staffing patterns data from Emsi (Emsi Release 2021.2).

Maryland manufacturing is clearly ramping up hiring in these key enabling fields—nearly every manufacturing cluster experienced growth in Industry 4.0-enabling workforce in Maryland that outpaced US growth except for printing and packaging.[11] These professions are dominating industry job postings—while Industry 4.0-enabling occupations make up 21% of the manufacturing workforce, they comprise 45% of industry job postings the last 3.5 years (Figure 20).

Figure 20: Share of Maryland Manufacturing Job Postings by Major Occupational Group, 2018–July 2021



Source: TEConomy Partners' analysis of Emsi, JPA Database, Q3 2021.

Industry 4.0-enabling professions are dominating Maryland manufacturing job postings—while these occupations make up 21% of the manufacturing workforce, they comprise 45% of industry job postings the last 3.5 years.

[11] Ibid.

The challenge for Maryland will be the inevitable strain on the supply of this skilled workforce critical for Manufacturing 4.0 adoption. Manufacturers face an especially competitive and challenging workforce landscape in attracting and retaining Industry 4.0-enabling jobs due to the combined challenges of limited supply, high demand from and competition with other tech-driven industries for talent, and relatively large cohorts of existing workers that are likely to require "up-skilling."

Maryland has an overall competitive advantage in its enabling talent situation—but is it a tale of two "tiers," with aerospace and defense and life sciences well-positioned to adopt and integrate Industry 4.0 while other clusters struggle? Although not all sectors can expect the same level of adoption, it will be important to "lift all boats" among clusters when considering strategic interventions and support.

INNOVATION SCAN: PATENT ACTIVITIES

An additional perspective on manufacturing innovation comes through trend and other analysis of intellectual property (IP) generation in the form of patent awards to firms with in-state manufacturing operations. The level of patenting tied to these "assignees" indicates the types of innovative products and processes that will potentially require new Industry 4.0 solutions and services. It also allows for a scan of potential technologies and tools developed as specific Industry 4.0 solutions.

A total of 21,650 patent award and application records were assigned to Maryland individuals and organizations over the 2015 to 2020 period. To identify key manufacturing-related assignees with in-state manufacturing plants or other production-associated sites, we focused on those entities with 10 or more patents over the time period. **This analysis identified at least 4,955, or nearly one in four, Maryland-assigned patent records that are associated with leading manufacturing companies.**

Companies with Maryland manufacturing locations are generating IP across a diversity of industry verticals—more than 70 corporate assignees had at least 10 patents from 2015 through 2020. Table 5 shows those companies with more than 40 assigned applications and awards and Table 6 shows the technology and market focuses that span defense systems sensing, networking hardware, specialty compounds (high performance materials, cosmetics, etc.), biopharmaceuticals, and medical devices.

What the patent analysis has not uncovered is a focus of firms on developing and deploying Industry 4.0-specific technologies, tools, and applications—though admittedly, when developed in-house for production process applications these digital technologies and trade secrets are often not patented. The strategic focus, therefore, is largely on promoting adoption and deployment among Maryland firms rather than a strategy to serve the globe from a solutions development perspective.

Table 5: Patenting by Leading Maryland Manufacturers: Key Companies, 2015-2020

Primary Patent Assignee	MD-Assigned Applications	MD-Assigned Awards	Total MD-Assigned Apps & Awards
Lockheed Martin Corporation	204	1,026	1,230
Ciena Corporation	119	613	732
Hughes Network Systems	75	325	400
Under Armour Inc	149	177	326
Northrop Grumman Systems Corporation	39	181	220
MedImmune	106	72	178
Senseonics Incorporated	58	49	107
MesoScale Technologies	52	44	96
Infinera Corporation	18	72	90
Macrogenics Inc.	38	48	86
Noxell Corporation	28	53	81
WR Grace & Co-Conn	21	55	76
United Therapeutics Corporation	26	46	72
Black & Decker Inc.	1	62	63
Evapco Inc.	27	26	53
Supernus Pharmaceuticals Inc.	18	32	50
Vorbeck Materials Corp	23	25	48
Qiagen Sciences	21	23	44

Source: TEConomy analysis of Clarivate Analytics' Derwent Innovation patent analysis database.

From a patent perspective, the broadly defined aerospace and defense industry cluster captures a significant portion of Maryland's industry patent portfolio, with four of the top five manufacturers(i.e., Lockheed, Ciena, Hughes, and Northrop Grumman), from that cluster accounting for 52% of all manufacturing company patents.

Technology classifications on patent records can be leveraged to assess the types of innovative products and processes local companies are investing in and to understand forward-looking implications for Industry 4.0 deployment. Leading technology areas associated with manufacturing companies in the state include:

- Optoelectronic systems and related communication components
- Diagnostic medical devices
- Biologic therapeutics and biomarker detection technologies (assays, etc.)
- Networking systems and hardware

Table 6: Patenting by Leading Maryland Manufacturers: Key Technology Areas, 2015-20

Technology Area	MD-Assigned Applications	MD-Assigned Awards	Total MD-Assigned Apps & Awards
Optical communications transmitters	21	175	196
Immunoglobulins [IGs], e.g. monoclonal or polyclonal antibodies	99	92	191
Radio transmission systems	26	122	148
Diagnostic medical devices	64	48	112
Biopharmaceuticals	43	48	91
Optical multiplex systems	16	69	85
Diagnostic biomarker detection and sample analysis	50	33	83
Therapeutic antigens and antibodies	29	52	81
Networking: Arrangements for maintenance or administration or management of packet switching networks	18	60	78
Measuring or testing processes involving enzymes, nucleic acids, or microorganisms	26	48	74
Magnetic sensing systems	24	47	71
Networking: Routing or path finding of packets in data switching networks	13	53	66
Selecting arrangements for multiplex systems	4	52	56
Cosmetics or similar toilet preparations	23	30	53
Traffic regulation in packet switching networks	12	40	52
Optical hardware elements and couplings	10	41	51
Arrangements for monitoring or testing packet switching networks	6	40	46
Constructional details common to different types of electric apparatus	4	38	42
Mutation or genetic engineering; DNA or RNA concerning genetic engineering, vectors, e.g. plasmids, or their isolation, preparation or purification; Use of hosts therefor	22	18	40
Methods or arrangements for reading or recognizing printed or written characters or for recognizing patterns, e.g. fingerprints	8	31	39
Therapeutic biobank products (e.g. bone marrow, lymphocytes, etc.)	22	17	39
Fuel cells; Manufacture thereof	7	29	36
Networking: Error correction and signals processing	4	32	36
Apparel: Soles; Sole and heel units	10	25	35
Network-specific arrangements or communication protocols supporting networked applications	6	28	34
Peptides having more than 20 amino acids; Gastrins; Somatostatins; Melanotropins	13	21	34
Apparel: Uppers; Boot legs; Stiffeners; Other single parts of footwear	21	13	34
Information retrieval; Database structures therefor; File system structures therefor	9	24	33
Network architectures or network communication protocols for network security	9	22	31

Source: TEConomy analysis of Clarivate Analytics' Derwent Innovation patent analysis database.

INFORMING THE "SITUATIONAL" ASSESSMENT FOR MARYLAND MANUFACTURING: THE VOICE OF INDUSTRY AND OTHER INTELLIGENCE AND INPUT GATHERED

Quantitative analyses of the baseline industry, workforce, innovation, and other data sources provide useful insights regarding the competitive positioning of Maryland manufacturing, but without the voice of industry and manufacturing ecosystem stakeholders, many of the findings are incomplete or lack underlying context. At the direction of MD MEP, the project team conducted a series of nearly 20 one-on-one interviews with manufacturing leaders across the seven clusters and regions of the state, as well as interviews with ecosystem leaders and key staff from the state's Departments of Commerce and Labor, and MD MEP.

To align with the project goals and objectives, industry interviews focused on the following topics and themes:

- The company's business needs and requirements to stay competitive in an increasingly "smart" Manufacturing 4.0 environment, including challenges or barriers to compete and to grow.
- Manufacturing supply chain dynamics, strengths, and opportunities in Maryland.
- The company's experience, if applicable, in partnering with MD MEP and/or Maryland's colleges and universities for workforce or leadership training, technology and cyber assistance, R&D, or other areas.
- Utilization of and recommendations for incentives, programs and funding including MD MEP programming, State-offered incentive programs and policies, and supportive infrastructure for manufacturing.

When combined with the following resources and additional intelligence, this input and the voice of industry forms a foundation for better understanding the situation for manufacturers regarding investing in Industry 4.0 technologies and related needs and challenges. The additional intelligence was drawn from:

- The preceding baseline quantitative assessment of MD manufacturing industry and ecosystem;
- The Department of Commerce 2021 survey of more than 200 Maryland manufacturers;
- Annual Reports from Maryland DoC and DoL economic development programs/incentives; and
- MD MEP projects/engagements since 2015 as reported to NIST.

The project and its interim work products, key findings, and conclusions have further benefitted from the regular guidance and input provided by the project Advisory Committee, consisting of a blend of manufacturing leaders representing industry, state government, MD MEP, and the national NIST organization. In addition, project leadership met with and presented preliminary findings to Maryland's Transforming Manufacturing Workgroup, a group of more than two dozen manufacturing leaders, state government leaders, legislators, university representatives, and other key stakeholders. Both the Advisory Committee and Transforming Manufacturing Workgroup have provided valuable feedback that largely confirmed key findings but also suggested helpful input and refinements, essentially serving as well-designed focus groups for the course of this project.

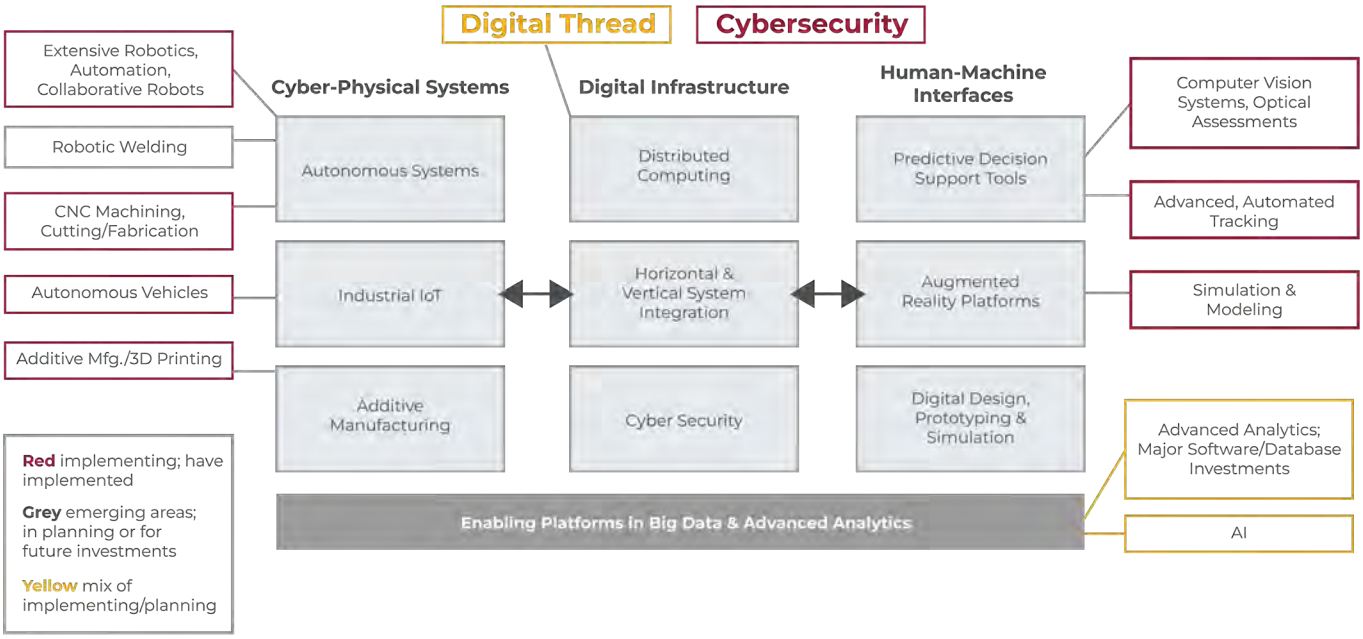
THE SITUATION FOR INDUSTRY 4.0 TECHNOLOGY ADOPTION/ INTEGRATION IN MARYLAND: PRIMARILY DISCRETE IMPLEMENTATION, COMPANIES POINT TO SEVERAL CONSISTENT CHALLENGES, BARRIERS TO TECH ADOPTION

Maryland manufacturing leaders are adopting and integrating numerous technologies and capabilities squarely in the digital automation and Industry 4.0 context; however, this adoption, particularly among SME manufacturers, is most often discrete and not broadly integrated to realize the full capabilities and data-driven insights of a 4.0 environment. Interviews indicate a generally low adoption rate of integrated industry automation and 4.0 technologies, and that Maryland is lagging behind as a state. Maryland manufacturing SME's today typically use primarily discrete individual technologies (e.g., a 3D printer, virtual reality simulation, robotic welding equipment) but are not yet implementing multi-technology, digitally integrated systems that harness the full potential of Industry 4.0 advances and data-driven insights.

Figure 21 maps the types of Industry 4.0 technologies being adopted today and in the near future. It is important to note that these are based on the set of interviews conducted, and are not an exhaustive survey or inventory of Maryland manufacturing.

Figure 21: Types of Industry 4.0 Technologies Being Adopted/Integrated in Maryland Today and in Near-Future

(Based on Maryland manufacturing interviews, not an exhaustive inventory)



Source: TEConomy Partners, LLC.

The technologies and capabilities mapped to the outer edges of Figure 21 were assigned a color-coding based on the implementation status described by the companies interviewed. Most of the technologies with a red outlined box are relatively well-developed and accessible for "plug and play" today. Others, such as those in yellow outline, represent more advanced, higher-order capabilities that lean toward harnessing AI and advanced analytics for predictive modeling and maintenance, automated communication and planning with suppliers (such as requiring and leveraging both internal and external data streams), and customizing production runs.

Several forces are driving the integration and adoption of Industry 4.0 technologies (Figure 22). The most consistent challenge reported by employers, and the most-cited driver for adopting automation technologies, is a lack of qualified workers to fill vacancies—a situation exacerbated by retirements that accelerated amid the COVID-19 pandemic, an aging workforce, and broader competition for the skilled manufacturing workforce (e.g., with tech companies like Amazon). These talent gaps and shortages are a major driver of Industry 4.0 and other automation solutions. Acute shortages reported by several manufacturers span both traditional roles in operations such as welders and industrial maintenance, but also areas critical for advanced automation and Industry 4.0-enabling roles, such as automation mechanics. A key question is: Can the rate at which manufacturers have been posting jobs for and hiring high-skilled IT and engineering talent continue?

As a backdrop to sourcing and retaining talent, manufacturers report Maryland's already high and rising labor costs represent an additional pain point for hiring. Manufacturers often "poach" the workforce of competitors, for example, by offering slightly higher wages to high-demand, translatable skilled trades such as welding or industrial maintenance. But increasingly, given the new labor market dynamics of the COVID and post-COVID years, they cite competition against rising wages paid in fast food and other industry competition they previously had not had to consider. The competition for the existing and potential manufacturing workforce is stiff and more often is out of employers' hands.

A longer-term existing challenge, and one that is not unique to Maryland, are the negative perceptions of manufacturing careers in the minds of students and young workers and professionals. MD MEP and others are working to counter these perceptions with programming such as the "Faces of Maryland Manufacturing" which promotes awareness of the breadth of exciting opportunities in a modern production environment.

While overall talent and key skill shortages present a major challenge to Maryland manufacturers today, interviews suggest it is a major driver of Industry 4.0 technology investment. Companies increasingly recognize that in today's constrained talent pool, they cannot hire their way to increased productivity and output.

THE ONGOING (AND WIDENING) SKILLS GAP IN U.S. MANUFACTURING

Maryland manufacturers are not alone in their workforce challenges—the industry as a whole is experiencing serious difficulty in finding the right talent and filling open positions. In recent years, Deloitte and The Manufacturing Institute have surveyed manufacturers to understand and project national skills gaps and other labor force dynamics within and across the industry.[1]

Their latest survey of more than 800 U.S. manufacturers found:

- The skills gap in U.S. manufacturing is expected to leave 2.1 million jobs unfilled by 2030.
- This potential gap could result in a $1 trillion economic impact (cost) to the nation's economy.
- 77% of companies surveyed expect ongoing difficulties in attracting and retaining workers through 2021 and beyond.
- Finding talent is 36% harder than it was in 2018.

Manufacturers increasingly have difficulty hiring middle-skilled workers, including CNC machinists, welders, and maintenance technicians—all areas identified by Deloitte, as well as in interviews with Maryland manufacturers.

The study recognizes the implications for Industry 4.0 that are likely to exacerbate the existing challenges:

"As digital transformation in the manufacturing industry continues to develop, the skills needed to do the jobs in the smart factory will likely be different than skills used today. But today's manufacturing workforce doesn't possess many of these skills."

[1]Deloitte and The Manufacturing Institute. "Creating pathways for tomorrow's workforce today: Beyond reskilling in manufacturing." May 2021.

Figure 22: What's driving the integration of automation, Industry 4.0 technologies among Maryland manufacturers?

Labor & Talent Shortages

COVID-Related waves of retirements; aging workforce; high and increasing wages

Focus on Productivity & Quality Enhancements

Increasing output, precision, accuracy in design, production

Systems Integration

Addressing legacy IT systems as a pre-requisite to leveraging data, "predictive" capabilities

Declining Cost Curves

Declining cost curves (on some tech) leads to affordability and increasing ROI

Source: TEConomy Partners, LLC based on project interviews and discussions.

Common Barriers & Challenges to Industry 4.0 Technology Adoption

At the crux of this project and its primary objectives is assisting Maryland manufacturers in addressing major challenges and barriers to increased technology adoption. Essentially, we want to answer: How do we help to "de-risk" technology adoption, particularly for SME manufacturers? It is therefore important to consider the consistent themes raised regarding these barriers (summarized in Figure 23).

Maryland SME manufacturers have few resources to start the Industry 4.0 journey. Companies interviewed cited a general lack of resources and expertise to simply know where to start and what is appropriate for their firm. A major theme in these discussions centered around firms' interest in and needs to test, pilot, and demonstrate 4.0-related technologies before making individual investments or trying to implement digital solutions at scale. As one manufacturing CEO remarked regarding digital automation investments under consideration: "To see this type of [automation] technology demonstrated I have to leave the state, as Maryland companies only see a competitor." Other states through MEP or other organizations and nations, such as Germany and Japan, have put in place extensive resources accessible to all manufacturers to test, pilot, and demonstrate technologies—some of which will be highlighted in the following section.

The significant costs associated with digital technology investments and their integration with legacy IT systems represents another major hurdle, particularly for SMEs, but also for large manufacturers. And while pricing a particular piece of equipment or software package may be relatively easy, what's more challenging for firms is understanding the return on that investment. A key resource for manufacturers currently lacking in Maryland is a database or repository of Industry 4.0 "use cases"—real-world examples and experiences of manufacturers implementing technologies and driving them to scale—to help their counterparts understand the ROI and payback on digital investments. Just one example was illustrated in discussions with a Maryland manufacturer who had recently implemented a new robotic solution, representing a $200,000 expense. The new automation equipment allowed her firm to enter a new product line/market, and in two years it had paid for itself in the value of new sales.

Implementing Industry 4.0 technologies has major implications for the industry's workforce, both in terms of incumbents and new hires. There is a broad-based need for enhanced digital skills, additional IT specialists, data scientists, and professional engineers, technicians, and scientists who have hybrid expertise. This hybrid expertise takes the form of mechanical engineers with embedded electronics or systems skills. For example, one manufacturer emphasized the need for employees who were "both mechanically and tech competent," such as an industrial engineer with some data sciences knowledge and expertise. Thus, there are needs for education and training resources to upskill the existing manufacturing workforce that are flexible and very focused, while continuing to generate the core talent that maps to "enabling" roles.

Enabling 4.0 tech adoption by addressing foundational technologies and technology infrastructure for interoperability and systems integration. A dynamic Industry 4.0 operating environment is not simply "plug and play" but requires addressing the integration of new machinery and services into existing operations. Often, manufacturers face the challenge of integrating new smart solutions in an environment where numerous legacy software systems and hardware components must now communicate with each other, send data, and connect with cloud-based services.

These barriers and challenges raised by Maryland manufacturers are largely in-line with those seen in global manufacturing surveys. Responses from McKinsey & Company's pre-pandemic (2019) global survey of manufacturing leaders identified the following as the three leading challenges facing companies in implementing Industry 4.0 solutions:[12]

- Lack of people, skills, and knowledge (38%)
- Datasecurity concerns (32%)
- Lack of funding (30%)

In 2020, the COVID-19 pandemic shifted these to a degree, with lack of funding because of the pandemic, limited understanding of the technology and vendor landscape, and lack of people/skills/knowledge making up a nearly equal share of the top challenges.

12 | McKinsey & Company, "COVID-19: An Inflection Point for Industry 4.0," January 15, 2021.

Figure 23: Major Barriers Identified by Maryland Manufacturers to Adopting Industry 4.0 Technologies

MD MEP is engaged in developing and delivering relevant Industry 4.0-related programs and services for Maryland manufacturers; but in examining project focus, and through discussions with manufacturing leaders, there is a recognized need for MD MEP to reach a greater scope, scale, and intensity of these services, and to add capacity to guide companies on this journey. Today, MD MEP is delivering:

- Tech-focused projects with specific companies related to robotics adoption and installation, automation support, and physical-to-digital conversions
- Advanced manufacturing training and fiscal support for Industry 4.0 training opportunities identified by manufacturers
- Cybersecurity assessment and mitigation with a defense-related focus
- Supply chain resiliency projects with a focus on reducing risk and improving outcomes across the organizational supply chain
- Career awareness through its “Make It In Maryland” programming
- Networking, innovation events (e.g., the Maryland Manufacturing Innovation Conference)

Manufacturing leaders are expressing support for enhanced capacity in strategic planning services and facilitation with respect to Industry 4.0 implementation.

ADDITIONAL EMERGING MARKET AND ENGAGEMENT OPPORTUNITIES IDENTIFIED FOR THE MARYLAND MANUFACTURING STRATEGIC PLAN

In addition to and beyond the Industry 4.0 context, the baseline quantitative and other analyses, as well as the situational assessment, raise several opportunities important to future manufacturing growth and competitiveness, as well as to the role and strategic focus of MD MEP going forward. These opportunities further inform the strategic priorities for Maryland manufacturing and the recommendations that follow.

- **Despite its legacy and strong roots in Maryland, the life sciences cluster represents a continued "emerging" opportunity for economic development as a high-growth sector and for deeper engagement by the manufacturing community and associated resources (namely, MD MEP), including with adopting Industry 4.0 technologies.** Beyond its recent strong growth in biopharmaceutical and medical device manufacturing, Maryland's Biotech R&D sector in Maryland is large, highly specialized, and growing—its employment base is up 35% from 2015 and the state LQ is an impressive 2.77. This sector, while technically outside the "manufacturing" realm, represents the opportunity for future Maryland-based biopharmaceutical manufacturing as companies commercialize products and shift to a production mode. The state has an opportunity to engage and root these companies in Maryland for prototype development and small batch runs for clinical trials, but also and most importantly for longer-term production.

- **Maryland is leveraging opportunities for offshore wind farm development to bring steel manufacturing, construction, and other supply chain components to a waterfront manufacturing hub.** With wind farm development proceeding off the coast of Ocean City, US Wind, a subsidiary of Italian energy firm Renexia SpA, is turning an old shipyard at the former Bethlehem Steel mill site at Sparrows Point into an offshore wind construction and manufacturing hub.[13] The site spans 90 acres at Tradepoint Atlantic, a 3,300-acre logistics center in Baltimore County. The steel plant would build the wind turbine towers that are anchored to the ocean floor and look to supply US Wind's local projects, as well as longer-term opportunities across the national wind energy market.

- **Many Maryland manufacturers interviewed are eager to connect with intra-state suppliers.** Conversations revealed that many source commodity inputs from outside the state, both domestically and internationally due to competitive cost differentials, but there are connections on key items. The challenge is a lack of awareness of other firms' offerings.

- **Industry 4.0's emphasis on raising productivity and up-skilling existing workforce creates a misalignment with most economic incentives available to manufacturers.** Like many other states, Maryland emphasizes net new hires as a path to accessing key economic development incentives (e.g., via the More Jobs for Marylanders tax credits). Recognizing that an increasingly automated, digital manufacturing 4.0 environment will result in changes to existing roles and require up-skilling of the incumbent workforce, manufacturing leaders see an opportunity for Maryland to re-frame this emphasis toward productivity as a measure of success. This has implications for state incentive design, including, as one leader framed it, an opportunity for a Maryland "modernization" focused program or initiative.

[13]Lorraine Mirabella, "Wind Farm Developer Plans to Bring Manufacturing Back to Baltimore's Sparrows Point," The Washington Post, August 8, 2021.

COMPETITIVE THREATS TO BE CONSIDERED, ADDRESSED

Just as there are opportunities, there are threats to Maryland manufacturing, often externally generated. Discussions with manufacturing leaders raised several themes that can and should be considered as potential threats to Maryland's manufacturing sector and its competitiveness into the future:

- **Acknowledging the competitive importance and dynamics of Industry 4.0 technologies and capabilities to manufacturing, other states (and many nations) are beginning to re-direct existing incentives and state programs toward tech adoption and integration, or starting up wholly new initiatives.** As will be shown in the following section, these states are mobilizing millions of dollars to prioritize Industry 4.0, and if Maryland does not follow suit, the sector will face additional competitive challenges for its firms and talent base from other states.

- **Cybersecurity threats are real, and in increasingly cyber-physical manufacturing environments, these threats will only increase their potentially devastating impacts.** In both interviews with Maryland manufacturers and conversations with other manufacturing leaders TEConomy interacts with across the country, this is a major issue and a consistent theme that keeps CEOs up at night. Companies interviewed, particularly SMEs, often indicate they fully outsource their cybersecurity countermeasures, but this has not insulated them from a steady assault from bad actors; several cited recent ransomware attacks. These literal threats place Industry 4.0 investments in the crosshairs, and cybersecurity must continue to be a programmatic emphasis of MD MEP and others, particularly in the highly sensitive aerospace and defense systems supply chain.

- **In the Industry 4.0 context, at least a few manufacturing and state leaders recognize the potential threats of uneven adoption of digital manufacturing technologies.** The threat is envisioned as a potential dynamic of a sector characterized by "Haves" versus "Have Nots" that could be seen among:
    - » Large manufacturers and/or OEMs versus SME dynamics;
    - » Different manufacturing clusters (e.g., life sciences and aerospace and defense versus other less tech-driven sectors); and/or
    - » Different generations of manufacturing leaders and their comfort levels and familiarity with tech integration, for example Baby Boomers versus Gen Z.

FOUR STRATEGIC PRIORITIES IDENTIFIED

The key findings from all aspects of this planning effort, including the consistent themes raised across interviews and group discussions, must be considered in designing the recommended strategies and actions in the following section. The baseline quantitative and situational analyses points to four strategic priorities on which to organize and focus the recommended strategies and actions of this plan. These include:

1. Establishing resources for starting the Industry 4.0 journey for Maryland manufacturers.

2. Addressing the barriers and challenges to Industry 4.0 technology adoption and integration.

3. Strengthening intra-state supply chain connections.

4. Seizing emerging manufacturing industry and market opportunities.

Combined, these strategic priorities are aligned with the overall project goals and objectives and draws from the key findings. Each priority area is addressed in the following section, along with associated recommended actions for the state and its manufacturing leaders and stakeholders to consider.

III. RECOMMENDED STRATEGIES AND ACTIONS TO ENSURE A COMPETITIVE FUTURE FOR MARYLAND MANUFACTURING

Key findings from the preceding quantitative and qualitative project components and the situational assessment have raised four strategic priorities for Maryland to maintain a competitive manufacturing sector into the future. The priority areas frame the structure for the recommended actions for Maryland to take to seize upon the opportunities presented by Industry 4.0 adoption and integration, but also to consider "win-win" opportunities for a better-connected intra-state supply chain, as well as emerging growth market opportunities identified.

It is envisioned that MD MEP will play a lead role in many of these strategic interventions, but effective partnerships are vital for implementation as many recommendations require collaboration with state government agencies (e.g., Departments of Commerce and Labor), Maryland research universities and community colleges, industry associations, and others across the ecosystem.

Across each set of recommendations illustrative examples of programs and initiatives from other states, regions, or nations are included to help place these recommendations in an actionable context and to provide examples of best practices. In addition, suggested metrics are proposed to track the progress and outcomes most closely associated with the recommended strategies and actions in Maryland into the future.

Four Strategic Priorities Identified:

1. Establishing resources for starting the Industry 4.0 journey for Maryland manufacturers.
2. Addressing the barriers and challenges to Industry 4.0 technology adoption and integration.
3. Strengthening intra-state supply chain connections.
4. Seizing emerging manufacturing industry and market opportunities.

STRATEGIC PRIORITY 1: ESTABLISHING RESOURCES FOR STARTING THE INDUSTRY 4.0 JOURNEY

A strategic gap for Maryland manufacturers, particularly SMEs, is knowing where or how to start their Industry 4.0 journey. A consistent need has been raised for appropriate resources and expertise to get started. Companies face myriad decisions and options, ranging from which equipment and technologies are most appropriate and impactful for the nature and size of their production runs, to digital and other readiness to adopt; how to access reputable vendors and technology integrators; how to secure their data in a new cyber-physical environment; how to integrate and customize solutions aligned with supply chains; and more. Related to this is a consistent need expressed by Maryland SME manufacturers for a "sandbox" or physical lab for piloting, testing, or demonstrating new digital Manufacturing 4.0 technologies.

"To see this type of [automation] technology demonstrated I have to leave the state as Maryland companies only see a competitor."

Maryland Manufacturing Leader

MD MEP is playing an important role in assisting with tech-focused projects, including robotics adoption and installation, automation support, and the physical-to-digital conversion, but many of these engagements are further "upstream" on implementation rather than conducting upfront Industry 4.0 assessments and strategic planning facilitation with respect to a path to staged implementation. The recommended actions within this strategy envision MD MEP in the lead role in partnership, where appropriate, with state partner organizations.

Other states and nations have already, or are in the process of, mobilizing early-stage 4.0 resources, particularly for manufacturing SMEs whose needs in this earliest phase of adoption are greatest (see text boxes for best practices examples).

The following recommended actions are designed to establish key resources for starting the Industry 4.0 journey for Maryland manufacturers.

Action 1.1: Offer Manufacturing 4.0-specific assessments and facilitation for Maryland SMEs.

- MD MEP should take the lead on this initiative but will need to add capacity and expertise.
- Utilize the NIST-MEP network to understand best practices and lessons learned in one-on-one, in-depth assessment design and implementation of assessments and counseling practices that are designed specifically for SMEs. Several state MEP programs are utilizing these today, including MMTC and Automation Alley in Michigan, CIRAS in Iowa, and MassMEP.
- Actively promote the use of these assessments online but also through regional networking events to ensure strong participation and ability to meet firms where they are today.
- Post-assessment, vet and facilitate connections with reputable technology integrators for actionable follow-on projects by participating companies.

Action 1.2: Invest in and support a Maryland Manufacturing 4.0 Tech Demonstration and Training Lab primarily targeted toward SMEs.

- It is important to establish a physical, collaborative, highly accessible space given the nature of manufacturing engineering challenges.
- Begin with identifying core technology capabilities relevant to a wide array of manufacturers, sectors, and production processes so as to serve a varied "customer" base; these could include augmented reality devices, co-bots, and 3D Scanners.
- A demonstration lab can take various forms—Germany's Mittlestand Digital SME Competence Centers have embedded demonstration and testing labs into their regional sites; the GENEDGE Alliance (Virginia's MEP) has developed a mobile demonstration lab.
- Explore strategic partnerships to fund a Lab or Center to ensure that access is granted to SMEs at no-cost.
- Plan to hold both in-person and virtual networking events at the Lab to promote its services and resources.
- Align applicable technology demonstrations with 4.0 assessments for SMEs to see equipment in action.

Action 1.3: Catalog and showcase "Use Cases" in communicating the ROI and the journey for other manufacturers that have successfully implemented Industry 4.0 technologies and to assist in making the business case for investments.

- Host a digital library and integrate into networking and informational sessions statewide Industry 4.0 "where to begin" events for SMEs.
- Promote peer networking for SMEs to share their experiences, challenges, solutions, and key lessons learned.

Action 1.4: Provide assessment and informational resources for systems integration and addressing interoperability challenges.

- Develop and provide an interoperability assessment and basic informational resources for Maryland SMEs to assist in anticipating and evaluating challenges and potential obstacles to integrating new automation equipment and Industry 4.0-enabled technologies. This will require leveraging subject matter experts (e.g., technology integrators, consultants) but the logical access point, assessment, and information delivery should be through MD MEP and its website.
- Resources should include best practice solutions across key technology layers, including machine-to-machine (M2M) interoperability, authentication and data transfer protocols, and cloud-based services.

Action 1.5: Implement regular survey efforts to gauge progress on Industry 4.0 adoption among Maryland SMEs.

- Design and implement biennial surveys to assess the progress of Maryland manufacturing SMEs on the Industry 4.0 journey, as regular and proper assessment will reveal commonality of needs, challenges, technologies, and other characteristics MD MEP and others should focus on.
- Capture information by key demographics including size of firm, manufacturing cluster, region, growth trajectory.
- Focus questions on manufacturer's ability to access resources and expertise within the state, initial steps on the 4.0 journey, pain points along the way, key equipment or applications utilized, scale and scope of 4.0 integration, etc.

Example programs and illustrative best practices related to these recommendations include:

Iowa: CIRAS' Digital Manufacturing Lab is De-Risking Tech Adoption

- Partnership between Alliant Energy and Iowa State University's Center for Industrial Research and Service (CIRAS) helps business evaluate problems and find opportunities using innovative 4.0 technology
- Provides no-cost access for lab tours, testing & training, assessment, connections with vendors for implementation

CT: Matching Grants for Digital Readiness & Cyber Assessments

- The Smart Industry Readiness Index (SIRI) helps companies assess their readiness for incorporation of Industry 4.0 technology, assess their current capabilities for digital transformation, benchmark their current status in key areas against other like manufacturers, prioritize areas for focus/investment, and provide a roadmap to incorporation.
- **This matching grant program will underwrite up to 50% of the cost** of such an assessment to lower the cost for manufacturers to access such an analysis. **In addition, this program will be used for cybersecurity assessments and roadmaps.**

Germany: Mittelstand Digital SME Competence Centers

- Initiative consisting of 26 competence centers scattered throughout Germany providing information and digitalization support to SMEs free of charge
- Centers provide expert knowledge use cases, and networking
- Centers are focused on technology adoption with demonstration and test environments, model industry 4.0 production lines, access to technology integration services, and mobile solutions labs

To track progress on this strategy into the future, industry stakeholders should measure and track:

- Participation in Industry 4.0 and digital readiness assessments by SMEs
- The share of assessment participants that have proceeded to early-stage adoption of Industry 4.0 technologies
- The share of SMEs that are reaching scale in Industry 4.0 adoption

It is important to implement and utilize surveys and follow-on reporting to track these progress measures.

STRATEGIC PRIORITY 2: ADDRESSING BARRIERS AND CHALLENGES TO INDUSTRY 4.0 TECHNOLOGY ADOPTION, INTEGRATION

The steep costs of digital and advanced automation technology investment and the costly process of integrating with legacy IT systems and capabilities is cited as a leading barrier to Industry 4.0 adoption—both in Maryland and globally. Today, many states, including Maryland, will provide targeted incentives to manufacturers to hire new employees or to re-locate their operations. These initiatives and resources are viewed by many manufacturers as outdated and out of touch with their more relevant focus on productivity-enhancing investments, which are increasingly digital in nature, and even include software purchases. Several states—including Connecticut, Indiana, Iowa, and Massachusetts—are now reconsidering the focus of their traditional economic development incentives for manufacturers and expanding their purview to provide significant resources for Industry 4.0 technology investments.

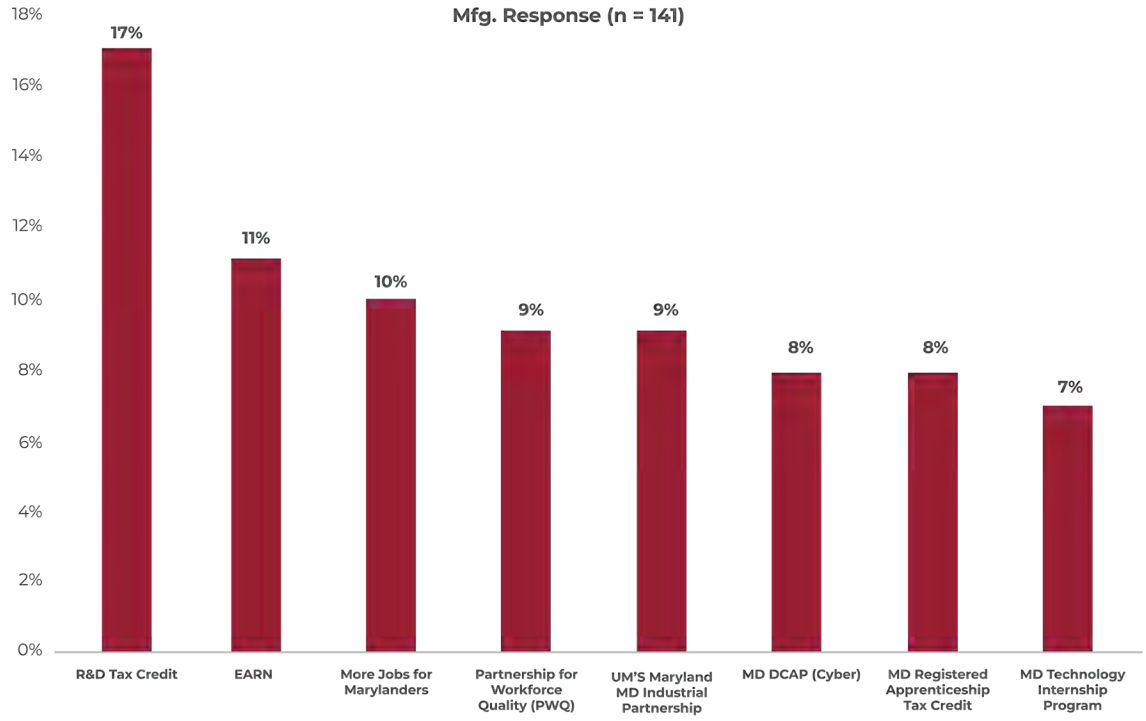
> "As a state, we're 100% in the dark [with respect to Industry 4.0], our leadership is not fostering a culture...we're way behind."
>
> **Maryland Manufacturing Leader**

To remain competitive in a truly global manufacturing marketplace and to adjust to the reality of fewer skilled employees upon which to draw, Maryland manufacturing must advance Industry 4.0 adoption broadly. The centerpiece of the recommendations made under this strategic priority is a re-orientation of resources to de-risk strategic digital investments.

In addition, while the state provides several appropriate programs, initiatives, and incentives to support workforce development, the shifts occurring for manufacturers in an Industry 4.0 environment are significant and require expanding some existing programming as well as embracing new and flexible approaches.

In general, there is a lack of awareness among manufacturers of key state incentives and programs; and, despite some positive experiences with programs as noted in the "strengths" section above, many programs are seen as burdensome, challenging, and expensive to access. Figure 24 shows the share of 141 manufacturing firms responding to the Maryland DoC survey regarding familiarity with numerous state programs—typically 10% or fewer were familiar with programs designed for or most relevant to manufacturers.

Figure 24: Survey of Manufacturers Finds Lack of Awareness of Key Maryland Programs, Incentives
Question: *Please indicate which of the following Maryland business tax credits, financial programs, and assistance you are familiar with. Select all that apply. (Only selected programs shown here).*



Source: Maryland Dept. of Commerce, 2021 Maryland Manufacturing Survey.

The following recommended actions are designed to assist manufacturers in successfully adopting and deploying Industry 4.0 technologies by de-risking technology investments through targeted assistance, further leveraging current incentive programs, addressing cybersecurity threats, and supporting shifting workforce dynamics.

Action 2.1: Develop and deploy a state incentives program—The Maryland Manufacturing Innovation Fund—to de-risk and address cost challenges for SMEs to invest in digital, Manufacturing 4.0 Technologies.

- Recognizing the upfront costs and funding concerns of small firms, it is recommended Maryland utilize a matching grants approach for most effectively addressing the needs of SME manufacturers (vs. tax credits).
- Consider capping matching grants at a per-project cost maximum.
- Align incentives with a set of pre-approved implementation and integration paths associated with Industry 4.0 and, guided by MD MEP, consider full costs of both hardware and software purchases.

Action 2.2: Build awareness among Maryland manufacturers of existing state incentives and programs, particularly those applicable to Industry 4.0 investments and workforce and talent development.

- Survey data and project interviews reveal a stark disconnect between manufacturers and their awareness of a varied menu of state incentives and programs. It is recommended that MD MEP, in partnership with Maryland Departments of Commerce and Labor, work to proactively educate manufacturers on types of incentives available and how to access resources—this could include via workshops or other events, or via peer networking leveraging those who have successfully made use of programs.
- Specific programs with an orientation (or potential orientation) toward assisting on the Industry 4.0 journey, including Partnership for Workforce Quality training/up-skilling matching grants, EARN, and accelerated depreciation.

Action 2.3: Advance broad-based assistance and strategic partnerships in addressing cybersecurity threats to manufacturers.

- MD MEP already assists manufacturers under the Defense Cybersecurity Assistance Program or DCAP, which targets funding and assistance for defense contractors to comply with Defense Federal Acquisition Regulation Supplement (DFARS) and NIST standards for cybersecurity.
- The defense focus of cyber assistance is highly appropriate, but cyber-related challenges are experienced across manufacturing, and a broader level of assistance is needed.
- Deploy company-specific assessments and explore collaboration to leverage extensive expertise in and across Maryland, including strategic partnerships with Maryland research institutions.

Action 2.4: Support both up-skilling and broad-based training of Maryland's manufacturing workforce–both among incumbent workers and across the education pipeline–at an appropriate scale for impending rise of Industry 4.0.

- Up-skilling the existing manufacturing workforce requires practical and flexible approaches, primarily short-duration education/training. The state should embrace and adopt 4.0-focused micro-credentialling approaches, certificates, and other "stackable" credentials
  - » Particularly for middle-skilled incumbent workforce, and
  - » Consider incentivizing data science-related cross-training for Engineering, Scientific, and Tech professals.
- Universities should continue to advance advanced analytics and data sciences programs and curriculum—particularly in a hybrid approach complementing engineering, scientific, and tech degree programs.

- Consider expanding and scaling up Partnership for Workforce Quality (PWQ) training grants with a continued focus on SME incumbent workforce, ensuring appropriate focus on Industry 4.0 tech.
    - » PWQ training/up-skilling matching grants are highly appropriate for incumbent worker training and up-skilling, but it is a program that needs to reach greater scale—in FY 2021, just 17 companies participated, only 8 of which were manufacturers.
- Leverage public-private partnerships for automation credentialling (e.g., "SACA" in Robotics)
- Leverage the EARN Maryland program for talent development around maintenance and automation techs and other high-demand positions relevant for 4.0 Tech. Just as the state has targeted "Green," Cyber/IT, and Clean Energy, there is an opportunity to focus on Manufacturing 4.0 from a strategic perspective.

Example programs and illustrative best practices related to these recommendations include:

Indiana: Conexus' Manufacturing Readiness Grants

- Conexus Indiana is partnering with the Indiana Economic Development Corporation (IEDC) to launch a new grant program.
- **Up to $200,000 in matching grants** for companies committing to increasing their competitiveness by integrating smart technologies and processes in order to improve capacity, capability, speed and quality.

MANUFACTURING 4.0 TECHNOLOGY INVESTMENT PROGRAM
Innovative Technology Infrastructure Grants

- Provides grants that assist SMEs with the adoption and integration of smart technologies into existing operations in the state. Two types of grants are offered through this program (Requires 1:1 match):
    - **Mfg. Innovation Equipment Grants- Up to $50,000 grants**
    - **Mfg. IIoT Infrastructure Investment Grants- Up to $25,000** for the purchase of specialized hardware or software in the Industry 4.0 technology groups.

MA: Funding Capital Investments & Preparing Supply Chains

- Launched a **new $2 million grant program that will invest in small- to medium-sized manufacturers** across the Commonwealth. The new Massachusetts Manufacturing Accelerate Program (MMAP) aims to co-invest in small- to medium-sized manufacturers **to better prepare their businesses to meet the demands of 'Industry 4.0,'** the innovation-driven production methods powered by smart technologies such as data analytics, cloud computing, artificial intelligence, automation, and connected technologies to stay competitive.

Consider the examples highlighted above spanning new programming across several states leveraging significant resources:

- Connecticut: $8.3M recently released from a $20M fund to support series of manufacturing technology, workforce initiatives via Connecticut Manufacturing Innovation Fund.
- Iowa: $25M designated for Manufacturing 4.0 Innovation Grants.
- Indiana: $6.7M awarded for Manufacturing Readiness Grants; $20M for extending the program through 2023.
- Massachusetts: $2M for new SME grant programs
- Michigan: allocating $3M for various Industry 4.0 initiatives, proposals.

Workforce-related examples and illustrative best practices include:

Purdue University "Stackable" Tech "Badges" as Micro-Credentialing Tool

- Badges are earned online and can potentially be stacked toward a graduate degree. Cummins in Indiana recently began an "Analytics" pilot program; Intel has also worked with Purdue in Cybersecurity.
- Example Courses in Analytics: Introductory Analytics; IoT Intro; Machine Learning Technologies

Wisconsin: Gateway Technical College SC Johnson iMET Center

- Home to 12 academic programs taught in smart factory environments in partnership with a variety of national companies
- Focus on I4.0 technical professions such as IT & Data Analytics Specialists, CNC Production Techs and Programmers, and Advanced Manufacturing Specialist certification that includes training in robotics, mechatronics, motor control, PLC and HMI programming, industrial controls, and IIoT (developed in part with Rockwell Automation)
- Houses 3D industrial design "Fab Lab" maker space for training and prototyping
- Utilizes hands-on training with Rockwell Automation, Fanuc mfg. systems

To track progress on this strategy into the future, industry stakeholders should measure and track:

- Levels and trends in manufacturing GSP, both overall and for the seven Maryland clusters and the state's position relative to the nation.
- Levels and trends in manufacturing productivity, both overall and for the seven Maryland clusters and the state's position relative to the nation.
- Once implemented, track usage of Manufacturing Innovation Fund and types of projects integrated.
- Track the share of SME manufacturers receiving cybersecurity assessments.
- Via Department of Commerce surveys of manufacturers, track awareness of relevant programs/incentives.
- The share of SMEs that are reaching scale in Industry 4.0 adoption.

STRATEGIC PRIORITY 3: STRENGTHENING INTRA-STATE SUPPLY CHAIN CONNECTIONS

Maryland manufacturers are eager to connect with other Maryland manufacturers, largely for strategic reasons and increasingly due to pandemic-induced supply chain challenges or reality checks. But this interest, if seized upon and enabled through targeted efforts, can be extremely beneficial for the overall state manufacturing sector to achieve a coveted "win-win" situation.

> "When we know a good supplier in Maryland, we prefer to go with them...but we don't have the time or resources to investigate."
>
> **Maryland Manufacturing Leader**

When surveyed in 2021, 37% of Maryland manufacturers indicated it was "very important" to have access to suppliers or customers located within Maryland (Figure 25), and an additional 31% reported it was at least "somewhat important." These interests were emphasized in interview discussions.

The challenge for manufacturers is a lack of awareness of other firms and their product and service offerings to tap. In response to this challenge, states and regions often "map" supply chains for specific sectors and industry verticals to share information, enable strategic partnering and connections, and advertise expertise and capabilities outside of the region. Maryland has undertaken supply chain mapping for its defense industry conducted by Towson University[14] and should consider targeting other clusters for similar mapping opportunities. There should be no illusions that this is easy to develop or to actively maintain, but as one pillar of a two-pronged approach to achieving the win-win, is worth undertaking. Armed with information, the second pillar of the strategy is then providing financial incentivizes for supply chain connections and to "Buy Maryland."

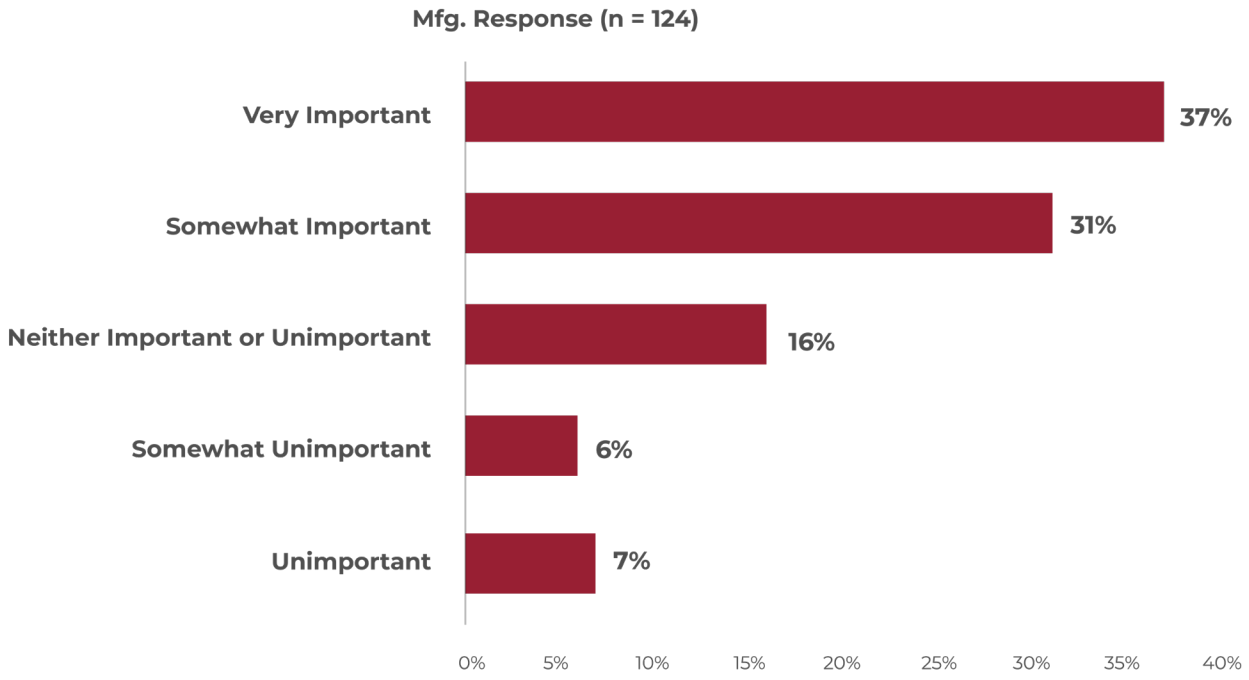
These potential connections will certainly have limitations. Conversations with manufacturers revealed that many source commodity inputs from outside the state, both domestically and very much internationally due to competitive cost differentials, and Maryland manufacturers do not produce every input to serve the production needs of their counterparts in-state. But today there are connections on key items. Examples highlighted in interviews include a food manufacturer sourcing ingredients like spices and seasonings as well as packaging solutions, and an aerospace and defense firm utilizing local machining and additive manufacturing capabilities.

The COVID-19 pandemic and resulting supply chain shocks and shortages, particularly among industries of strategic importance to the United States (and other nations) have spurred conversations around strategic "reshoring" opportunities for manufacturing—returning (or newly rooting) the production of strategic supply chain components back to US soil. The results have been mixed thus far, but the focus has been renewed with, for example, Congress writing the "CHIPS" legislation in response to a greater concentration of global semiconductor manufacturing located in Asia. Likewise, there is a focus in the United States to more firmly root or return critical biopharmaceutical inputs and production of vaccines and therapeutics, and the sensitivity and security of vast aerospace and defense supply chains are a focus as well—both industries in which Maryland has strengths. While not assured, this is a movement that can represent an economic development attraction and recruitment focus worth exploring, and ensuring there is an understanding and "marketability" of Maryland assets (e.g., via supply chain mapping) is one step in this process.

As just one gauge on prospects and priorities for reshoring, PwC's Health Research Institute, in a survey of pharmaceutical company executives, reported that 82% expect to "reshore" components of their supply chains in the next two to five years.

[14] Regional Economic Studies Institute. Mapping the Defense Industry in Maryland," 2016 Towson University.

Figure 25: Importance of Intra-State Manufacturing Connections (Share of Maryland Manufacturers)
Question: *How important is it to have access to suppliers or customers located within Maryland?*



Source: Maryland Dept. of Commerce, 2021 Maryland Manufacturing Survey.

The following recommendations are designed to meet these objectives and seize the opportunities raised.

Action 3.1: Develop Maryland supply chain mapping and directory resources for targeted manufacturing clusters.

- Mapping requires intensive research to initiate, and in-state research universities are often able to take the lead on development. To ensure relevance for manufacturing connections, these efforts require upkeep with ever-changing business dynamics and regular "maintenance," so require ongoing resources to maintain.
- Maryland should consider piloting a mapping effort for one discrete manufacturing cluster as an appropriate first step.
- Interests for intra-state connections span all firm sizes, so it is important to ensure the ultimate directory or map is "bi-directional" so both large manufacturers and OEMs as well as SMEs can effectively conduct searches and access information.

[15] PwC Health Research Institute Survey,
see: https://www.pwc.com/us/en/industries/health-industries/library/pharmaceutical-supply-chain-tax-considerations-2021-qa.html.

Action 3.2: Incent, promote in-state supply chain connections, sourcing, purchasing.

- Consider linking tax credits—e.g., a "Buy Maryland Manufacturing Tax Credit"—to in-state supply chain sourcing, i.e., how much of your product supply chain utilizes Maryland manufacturing or Maryland-based services? Consider a sliding scale approach to ensure majority of benefits accrue to SMEs.

Action 3.3: Proactively pursue potential "reshoring" opportunities in targeted industries.

- Coordinated outreach to targeted cluster representatives should be undertaken to understand supply-chain challenges and opportunities for rooting additional capabilities in Maryland from overseas.
  - » Primary targets should be aerospace and defense, recognizing its extensive, well-established and well-articulated supply chains both within Maryland and nationally, as well as life sciences.
- Coordination should occur among MD MEP and economic development leadership in Maryland, including those at the state's Department of Commerce.

Example programs and illustrative best practices related to these recommendations include:

Automation Alley®

Michigan: Automation Alley's "Industry 4.0 Supplier Reboot"

- Day-long training and implementation workshop focused on a company and its key suppliers.
- Automation Alley member companies present to you and your suppliers on pre-identified high-priority Industry 4.0 areas
- Follow-on opportunities for personalized Industry 4.0 assessments offered to suppliers

IV Industrial Value Chain Initiative

Japan: Industrial Value Chain Initiative

- Founded in 2015 to target integration of Industry 4.0 and other connected hardware into manufacturer supply chains
- Hosts a number of workgroups with a specific emphasis on helping small and mid-sized enterprises in the supply chain incorporate IoT technologies into their businesses to aid more comprehensive digital connectivity across the country's manufacturing base

To track progress on this strategy into the future, industry stakeholders should measure and track:

- Once operable, track usage of supply chain mapping pilot project, request feedback on successful connections made via the tool.
- Identify companies successfully reshored and associated economic impacts of those re-locations or new locations to Maryland.

STRATEGIC PRIORITY 4: SEIZING EMERGING MANUFACTURING INDUSTRY AND MARKET OPPORTUNITIES FOR ENGAGEMENT AND ASSISTANCE BY MD MEP

While life sciences represent a long-standing targeted industry and economic strength for Maryland, the cluster is a relatively untapped strategic opportunity for MD MEP and others in the manufacturing sphere to provide expertise and assistance. In recent years, MD MEP has engaged a handful of life sciences firms on "light" touch efforts, such as supervisor efficiency training and participation in Lean peer groups. The baseline analysis has illuminated the outsized importance of life sciences within the Maryland manufacturing sector where it represents:

- The leading manufacturing cluster in value-added per worker (productivity)
- The leading manufacturing cluster in export sales
- A leader in industrial R&D, reflecting its leading innovation status and position globally
- A pipeline of future opportunity given the size, growth, and specialization of Biotech R&D
- Emerging companies that will be looking to advance into commercial production in Maryland or elsewhere

Ensuring this sector is firmly rooted, and manufacturing expertise within the state is leveraged, should be a leading priority across the Maryland economic development and manufacturing community. It must be acknowledged that life sciences manufacturing is extremely unique, and building manufacturing expertise in this space is especially challenging under a highly regulated production environment that requires Good Manufacturing Practice (GMP) facilities and extensive documentation. The cluster is not monolithic, with diverse production environments that span medical device manufacturing, biopharmaceutical production, and biomanufacturing. But Maryland is home to key assets like the bioprocessing center at UM, the vast federal NIH research complex, and military research and medical expertise at installations such as Fort Detrick, home to the US Army's Medical Research and Development Command and major bio-defense capabilities.

For MD MEP, engaging with the life sciences will require acquiring and building expertise, but recognizing the numerous assets within Maryland, the existing manufacturing-specific expertise of MD MEP represents a highly complementary partnering opportunity even today. In fact, in a recent effort to acquire federal grant funding and seize upon emerging opportunities, MD MEP collaborated with the Maryland Tech Council, an organization dedicated to advancing state Tech and Life Sciences sectors, to propose a major "Bio Hub" initiative that would combine workforce development with co-working and shared lab space with access to capital and manufacturing assistance. Although the grant was not awarded, this exercise established the basis for further future collaboration and better understanding the capabilities and competencies across organizations—just the type of collaborative approaches that this strategy envisions for MD MEP.

But assistance and partnerships are also a two-way street, and a common lament or refrain of manufacturing leaders and stakeholders is often expressed as "we will be engaged when life sciences companies wake up and realize they are manufacturers." This reflects a fundamental disconnect between this community and the cluster. In fact, most life sciences companies do understand they are manufacturers, but the sector is so unique, they have difficulty finding common ground with metals manufacturers, food processors, or injection molders.

With that acknowledged, there is common ground in areas such as manufacturing technology challenges and talent needs that span engineering, process flow, robotics, and advanced data analytics. Life sciences companies, like many of their Maryland counterparts, have little awareness of state incentives and programs and can find yet another area of common ground for assistance. While engaging with this cluster will likely require separate and unique approaches, there is common ground upon which to establish beneficial relationships.

Beyond life sciences and recognizing the vast federal purchasing complex in and around Maryland and the National Capitol region, a specialized analysis was conducted to understand the degree to which Maryland manufacturers are supplying major federal installations in the state. These installations have vast procurement needs and should and can be regularly probed for connections to and opportunities for Maryland manufacturers to source products "locally."

High-level insights emerge from a quantitative federal procurement and supply chain assessment regarding the purchasing activity of "manufactured products" by key Maryland federal government facilities (identified by the industry NAICS code of the supplier). It finds opportunities exist to increase the level of federal purchases from Maryland manufacturers across all four federal facilities examined, with a particularly low share of Maryland-manufactured goods supplied to Goddard (just 0.8% of its total).

Table 7: Manufacturing Spend by Maryland-Based Federal Agencies/Offices, FY2019-20

Agency/Office	Total Spend ($M)	Maryland ($M)	% of Total
Goddard	$845.9	$7.0	0.8%
Aberdeen	$418.2	$88.6	21.2%
NIST	$123.8	$38.3	31.0%
Ft. Detrick	$14.2	$3.5	24.4%

Source: Federal procurement data via USAspending.gov; TEConomy calculations and analysis.

The following recommendations are designed to meet these objectives and seize the opportunities raised.

Action 4.1: Increase engagement between MD MEP and the Maryland life sciences cluster to leverage strategic partnerships and collaborations with life sciences-focused state organizations and strategic life sciences assets.

- Recommend that MD MEP openly engage the industry by hosting targeted forums and focus groups for existing life sciences companies as well as emerging Biotech companies representing next generation of Maryland manufacturers. Purpose is to understand their production needs and challenges, and to ensure they understand the manufacturing resources, expertise available to them, and the value proposition for rooting production in the state.
- Strengthen strategic collaborations with key life science-related organizations and assets including the UM Bioprocess Scale-Up Facility, the Maryland Tech Council, military, and others. Ensure an understanding of expertise and value proposition that each brings to life sciences assistance and engagement.
- Partner to target joint grant, programming, education and training infrastructure investment, and other initiatives such as the "Bio Hub" opportunity to further deepen collaborations and industry engagement.
- For MD MEP, proactively engage life sciences companies regarding awareness of state economic development and other incentives and programming.

Action 4.2: Identify and seize Federal procurement opportunities for Maryland manufacturers.

- Regularly examine opportunities to increase the level of federal purchases from Maryland manufacturers across all in-state federal facilities. In particular, look for opportunities requiring purchasing needs aligned with Maryland's seven manufacturing industry clusters.
- Proactively communicate with federal leadership to better understand directions for future procurement needs for local manufacturers to strategically pivot toward.

To track progress on this strategy into the future, industry stakeholders should measure and track:

- Project and other direct engagement of the life sciences industry with and by MD MEP
- Partnering activities of MD MEP with key organizations in the life sciences
- Share of federal procurement expenditures among Maryland-based installations going to Maryland manufacturers

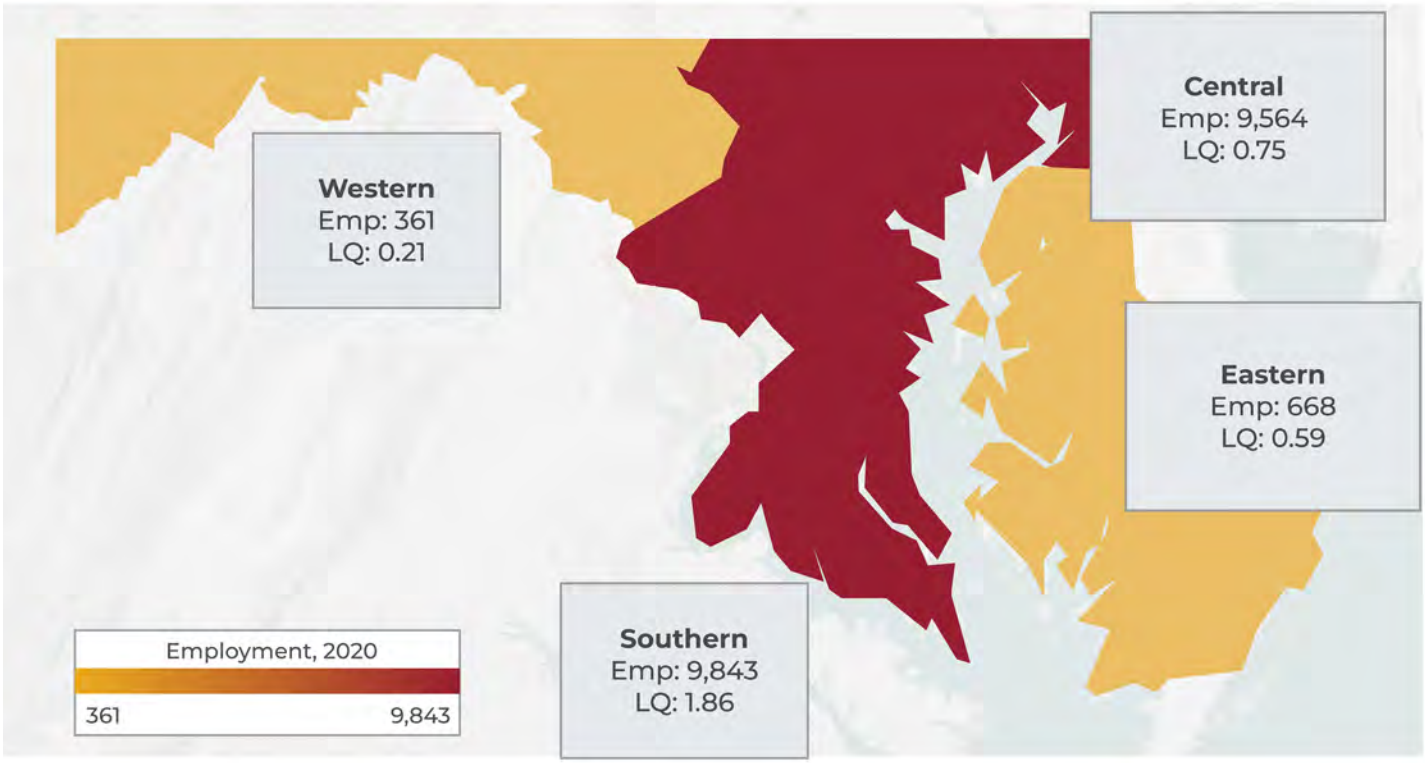
APPENDIX A: MANUFACTURING INDUSTRY CLUSTER PROFILES

AEROSPACE & DEFENSE SYSTEMS

Aerospace & Defense Systems	2020 Metrics						Recent Jobs Performance		
	Establishments	Employment	Employment Concentration (LQ)	Average Establishment Size	Productivity (GRP/EMP)	Average Wage	% Change 2015-2019	% Change 2019-2020	% Change 2015-2020
Maryland Metrics & Performance	329	20,740	0.95	63	$347,981	$120, 595	13.3%	3.2%	16.9%
US Performance				78	$257,462	107,863	6.4%	-1.3%	5.0%

- **Growth from 2015-2019**, continuing through 2020, significantly outpacing the United States.
- **Industry Targeting Analysis:** Emerging Strength
- **Key Subclusters:**
  - **Navigation, Guidance, & Security Instrumentation:** Accounts for 12,552 (61%) of employment, an LQ of 3.48, and emp growth of 27% from 2015-2020
  - **Aerospace:** Accounts for 3,178 (15%) of employment
  - **Communications Equipment:** Accounts for 2,894 (14%) of employment and an LQ of 2.44
- **Example Maryland Companies:** Northrup Grumman Systems Corporation, Lockheed Martin, Raytheon, Boeing, L3Harris, Textron Systems (AAI Corporation), Advanced Thermal Batteries

Regional Cluster Employment:



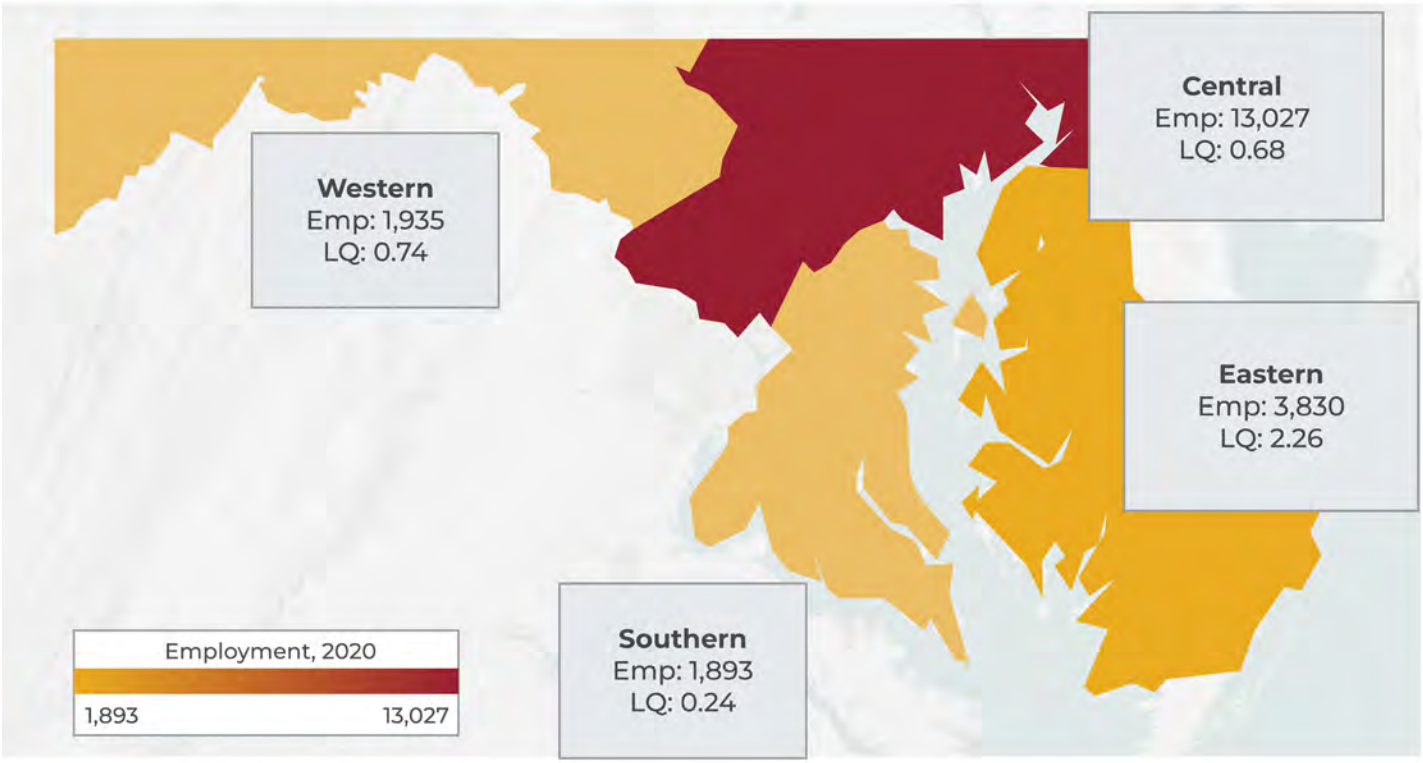
Source: TEConomy analysis of enhanced US Bureau of Labor Statistics CEW data (from Emsi, Datarun 2021.2)

FOOD & BEVERAGE MANUFACTURING

Food & Beverage	2020 Metrics						Recent Jobs Performance		
	Establishments	Employment	Employment Concentration (LQ)	Average Establishment Size	Productivity (GRP/EMP)	Average Wage	% Change 2015-2019	% Change 2019-2020	% Change 2015-2020
Maryland Metrics & Performance	7,195	20,908	0.64	29	$143,216	$52,548	17.8%	-0.7%	17.1%
US Performance				29	$136,441	$51,589	11.1%	-1.9%	8.9%

- **Significant growth from 2015-2019**, with slight 2020 decline likely due to COVID-19; Significantly outpacing the nation.
- **Industry Targeting Analysis:** Emerging Strength
- **Key Subclusters:**
  - » **Food Manufacturing:** Accounts for 17,115 (82%) of employment
  - » **Beverage Manufacturing:** Employment growth of 33% from 2015-2020
- **Example Maryland Companies:** Perdue Farms, McCormick & Company, Smithfield Foods, Synutra International, Northeast Foods, Ingredion, Inc., Fuchs North America, Eight O'Clock Coffee

Regional Cluster Employment:



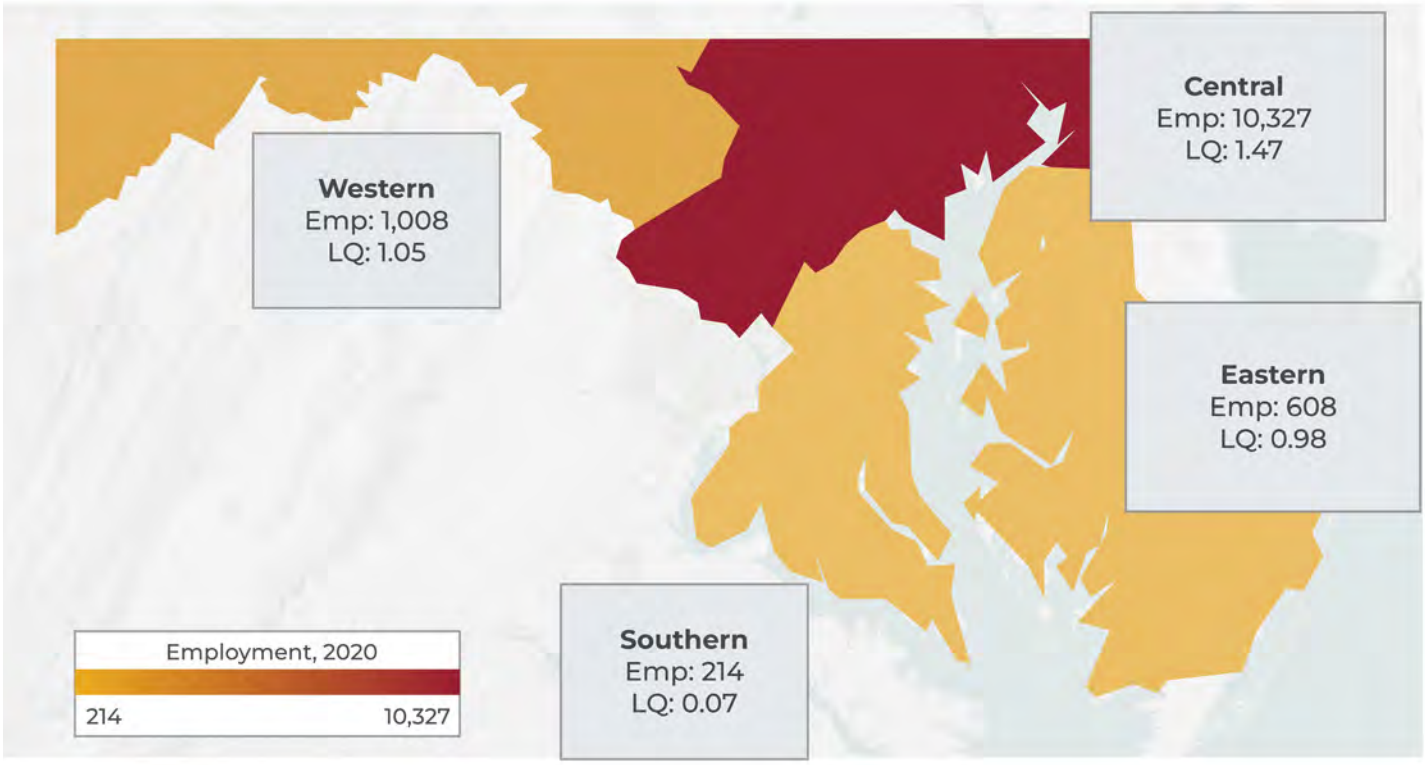
Source: TEConomy analysis of enhanced US Bureau of Labor Statistics CEW data (from Emsi, Datarun 2021.2).

LIFE SCIENCES

Life Sciences	2020 Metrics						Recent Jobs Performance		
	Establishments	Employment	Employment Concentration (LQ)	Average Establishment Size	Productivity (GRP/EMP)	Average Wage	% Change 2015-2019	% Change 2019-2020	% Change 2015-2020
Maryland Metrics & Performance	298	12,604	1.06	42	$130,760	$142,789	25.8%	2.6%	29.1%
US Performance				48	$383,255	$108,317	10.1%	0.8%	11.0%

- **Significant growth from 2015-2020,** outpacing the US by more than double
- **Industry Targeting Analysis:** Existing Strength
- **Key Subclusters:**
  - **Pharmaceuticals:** Accounts for 9,517 (76%) of employment, growth of 31% from 2015-2020 and an LQ=1.77
  - **Medical Devices & Equipment:** Accounts for 3,087 jobs and growth of 24% from 2015-2020.
- **Example Maryland Companies:** Celegene, Orgenesis, AstraZeneca (Medimmune), Emergent Biosolutions, Meridian Medical Technologies, Trinity Sterile, Inc., Action Products, Inc.

Regional Cluster Employment:



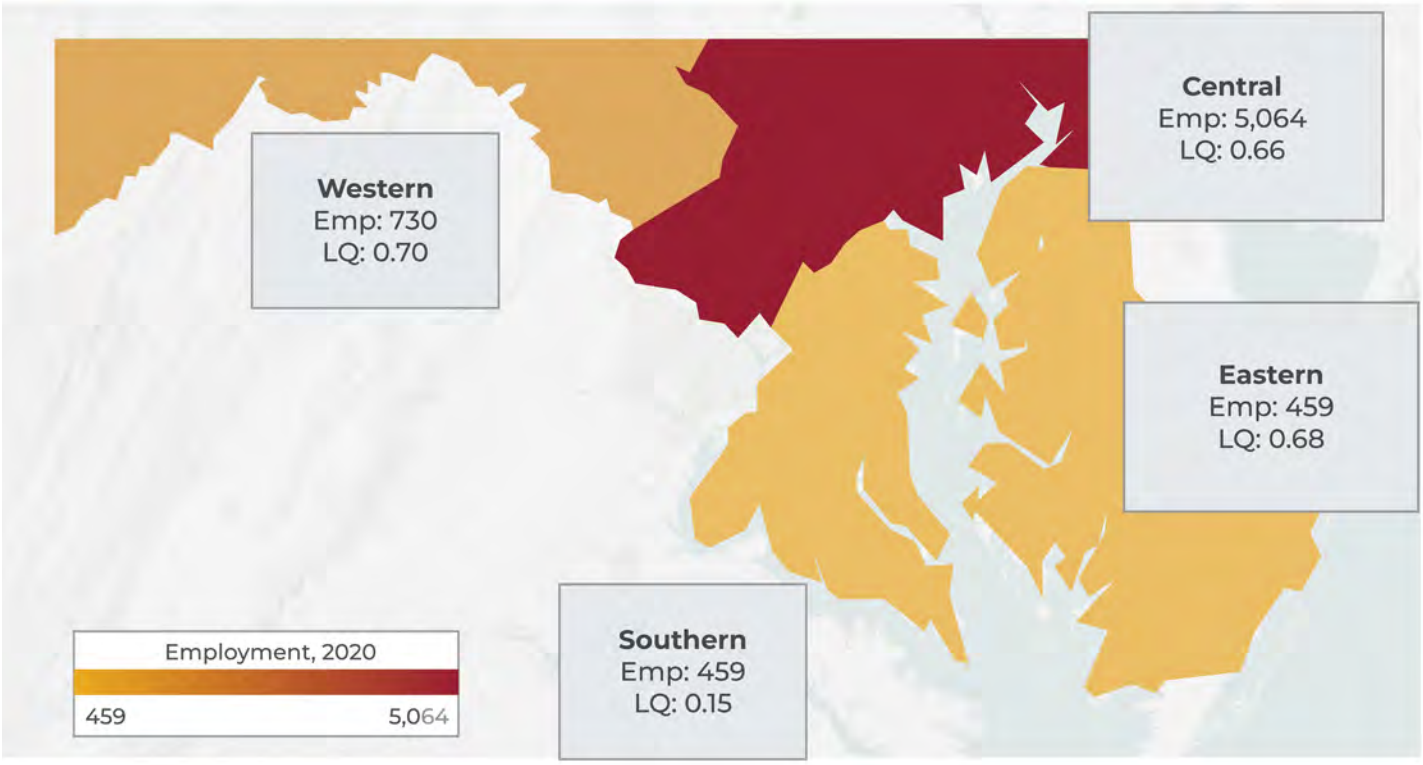
Source: TEConomy analysis of enhanced US Bureau of Labor Statistics CEW data (from Emsi, Datarun 2021.2).

POLYMERS & RELATED PRODUCTS

Polymers & Related Products	2020 Metrics						Recent Jobs Performance		
	Establishments	Employment	Employment Concentration (LQ)	Average Establishment Size	Productivity (GRP/EMP)	Average Wage	% Change 2015-2019	% Change 2019-2020	% Change 2015-2020
Maryland Metrics & Performance	143	6,826	0.53	48	$205,016	$80,892	3.6%	1.3%	4.9%
US Performance				48	$157,577	$62,311	5.2%	-4.8%	0.2%

- **Growth from 2015-2019 and holding its own through 2020.** Outpacing US growth.
- **Industry Targeting Analysis:** Emerging Strength
- **Key Subclusters:**
  - » **Plastic & Rubber Products:** Accounts for 5,151 (75%) of employment and growth of 8% from 2015-2020
  - » **Adhesives, Coatings & Paint:** Employment LQ=1.24
- **Example Maryland Companies:** W. L. Gore & Associates, Inc., Berry Plastics, Fawn Industries, Wm. T. Burnett & Co., Tenax Corporation

Regional Cluster Employment:



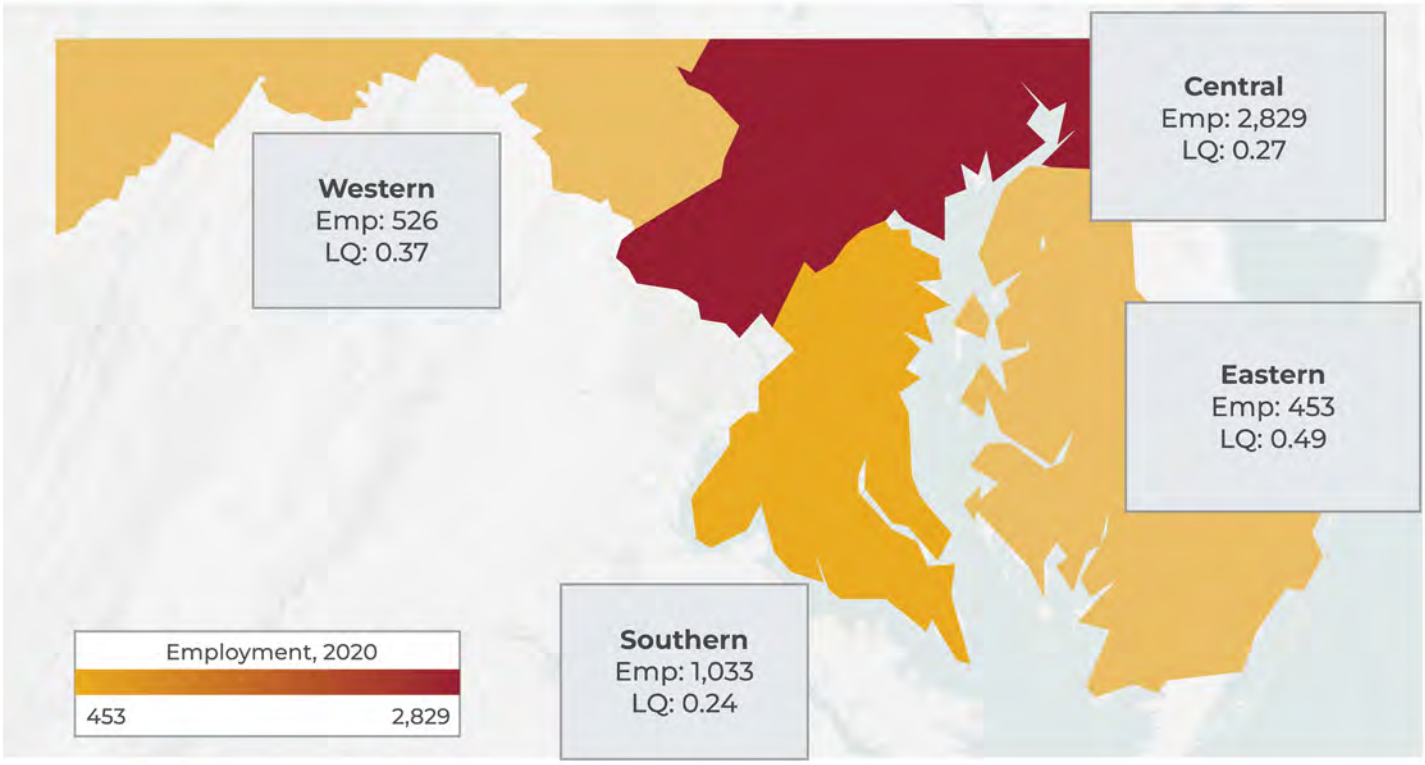
Source: TEConomy analysis of enhanced US Bureau of Labor Statistics CEW data (from Emsi, Datarun 2021.2).

PRECISION MANUFACTURING

Precision Manufacturing	2020 Metrics						Recent Jobs Performance		
	Establishments	Employment	Employment Concentration (LQ)	Average Establishment Size	Productivity (GRP/EMP)	Average Wage	% Change 2015-2019	% Change 2019-2020	% Change 2015-2020
Maryland Metrics & Performance	313	4,944	0.28	16	$139,624	$68,049	5.7%	-5.1%	0.3%
US Performance				22	$126,507	$66,938	-0.2%	-0.2%	-6.1%

- **Growth from 2015-2019**, with much of that growth lost in 2020 likely due to COVID-19. Overall period (2015-2020) growth outpaced decline at the national level.
- **Industry Targeting Analysis:** Emerging Strength
- **Key Subclusters:**
  - » **Precision Metalworking:** Accounts for 2,706 (55%)
- **Example Maryland Companies:** Dixon Valve & Coupling Company; Cambridge International (Rexnord), Kenlee Precision Corporation, Danko Arlington, The Bechdon Company, Inc.; Raloid Corporation

Regional Cluster Employment:



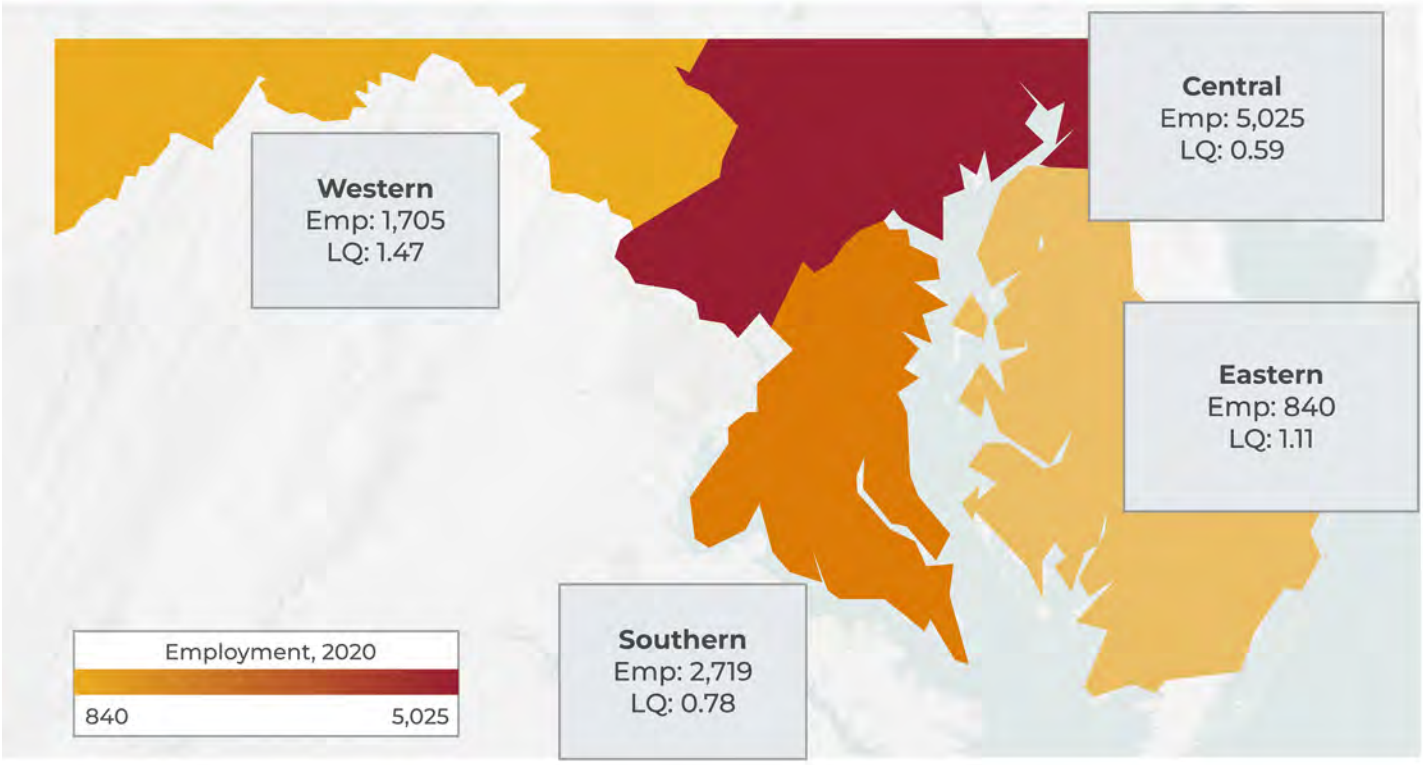
Source: TEConomy analysis of enhanced US Bureau of Labor Statistics CEW data (from Emsi, Datarun 2021.2)

PRINTING & PACKAGING

Printing & Packaging	2020 Metrics						Recent Jobs Performance		
	Establishments	Employment	Employment Concentration (LQ)	Average Establishment Size	Productivity (GRP/EMP)	Average Wage	% Change 2015-2019	% Change 2019-2020	% Change 2015-2020
Maryland Metrics & Performance	464	10,354	0.72	22	$111,040	$56,362	-0.4%	-9.3%	-9.7%
US Performance				23	$122,089	$58,408	-1.0%	-5.0%	-5.9%

- **Slight employment decline**, likely exacerbated in 2020 due to COVID-19. Overall US cluster also losing employment.
- **Industry Targeting Analysis**: Limited Prospects
- **Key Subclusters:**
  - » **Printing:** Accounts for 6,805 (66%) of employment
- **Example Maryland Companies:** Plastipak, Altium Packaging, Spartech, Phoenix Color, Atlas Container Corporation, CCL Label, WebbMason Marketing

Regional Cluster Employment:



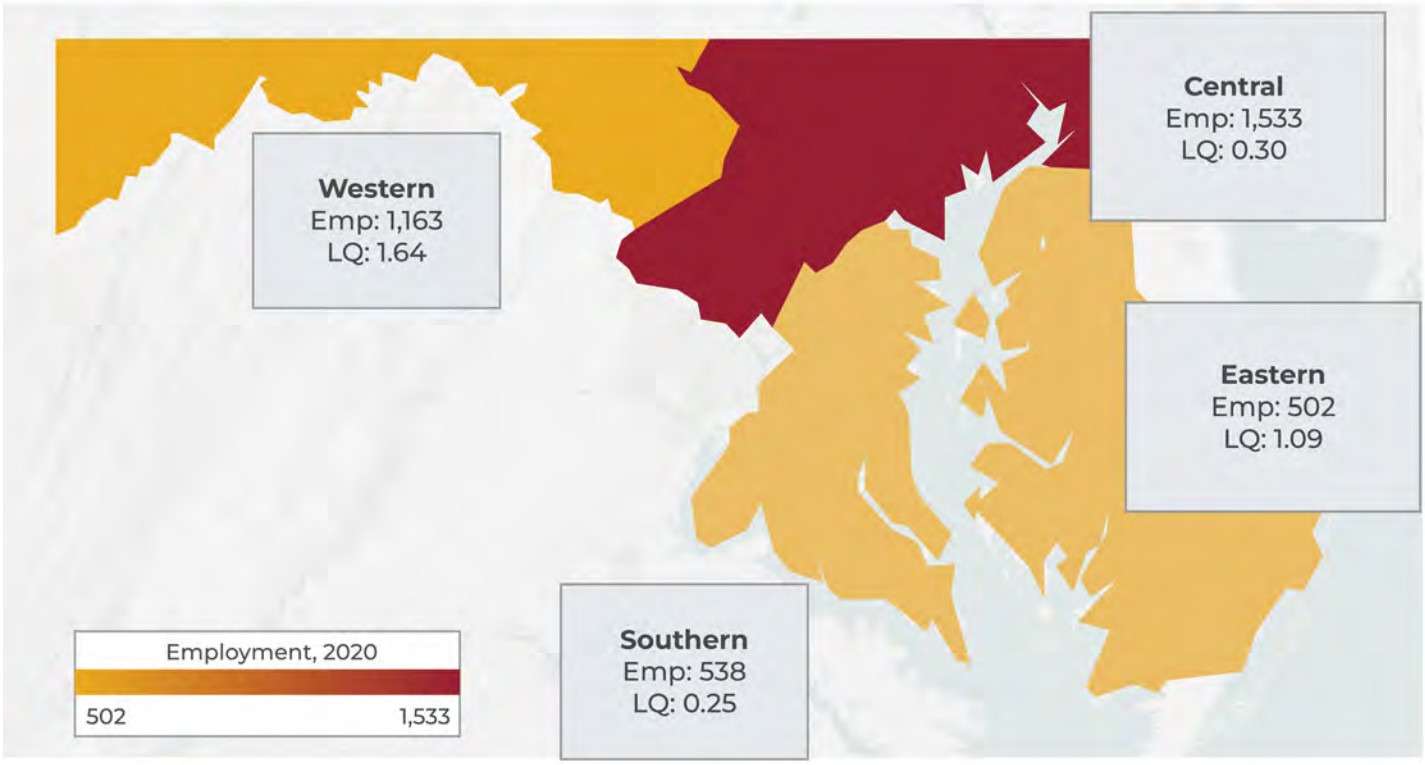
Source: TEConomy analysis of enhanced US Bureau of Labor Statistics CEW data (from Emsi, Datarun 2021.2)

WOOD PRODUCTS

Wood Products	2020 Metrics						Recent Jobs Performance		
	Establishments	Employment	Employment Concentration (LQ)	Average Establishment Size	Productivity (GRP/EMP)	Average Wage	% Change 2015-2019	% Change 2019-2020	% Change 2015-2020
Maryland Metrics & Performance	243	3,870	0.44	16	$122,031	$55,072	12.1%	-0.4%	11.6%
US Performance				19	$93,547	$47,301	-5.7%	-2.9%	2.7%

- **Solid growth from 2015-2019,** with a slight decline in 2020. Outpacing US cluster growth by over four times.
- **Industry Targeting Analysis:** Emerging Strength
- **Key Subclusters:**
  - » **Lumber & Building Products:** Accounts for 2,063 (53%) of employment
- **Example Maryland Companies:** Shelter Systems, Washington Woodworking, The Taney Corporation, Beachley Furniture Company, Helmut Guenschel, Inc.

Regional Cluster Employment:



Source: TEConomy analysis of enhanced US Bureau of Labor Statistics CEW data (from Emsi, Datarun 2021.2)

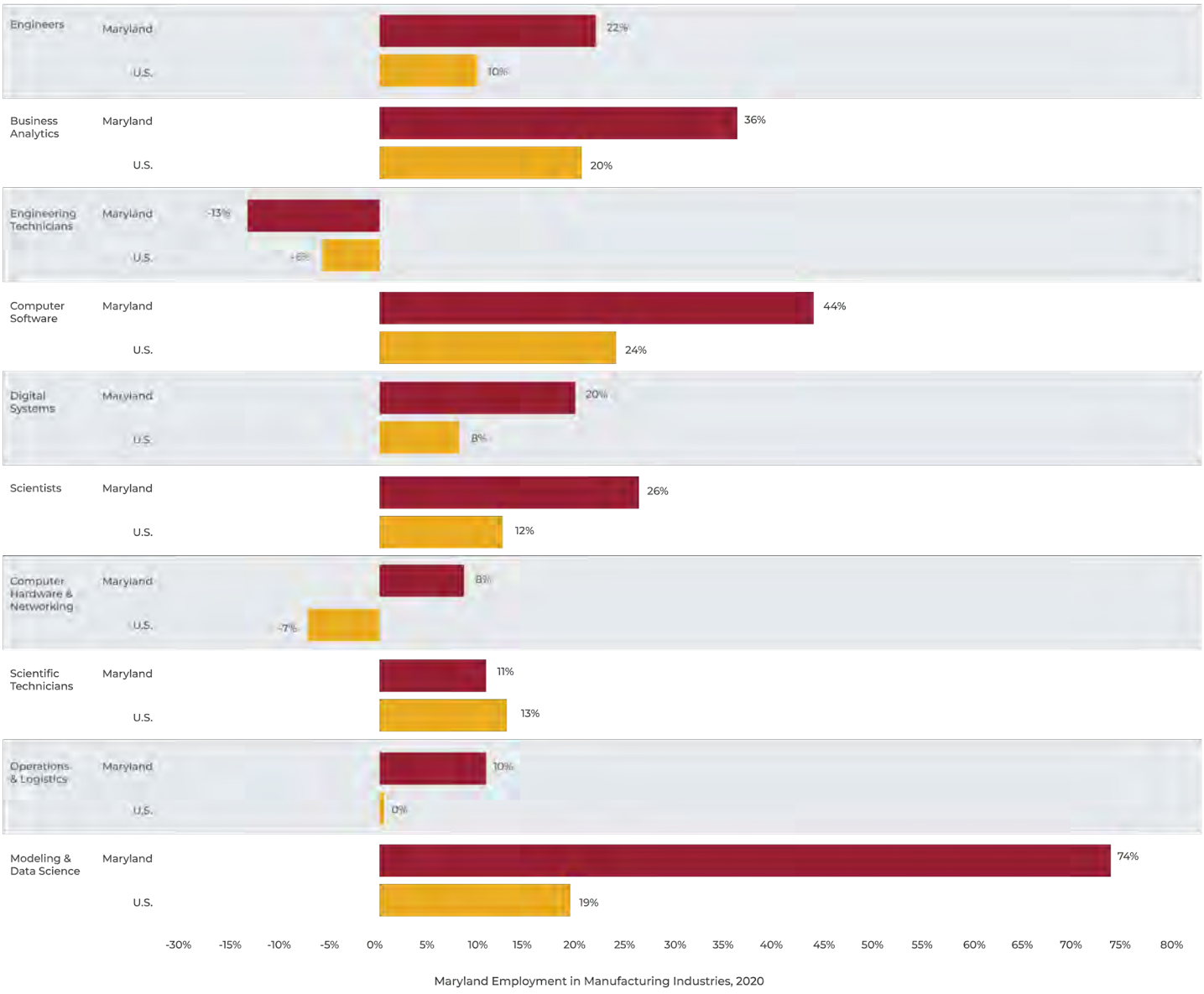
Figure A-1: Summary Employment Metrics for Maryland Manufacturing Clusters, 2020

Maryland Key Manufacturing Industries and SubSectors	Establishments		Employment				Average Wage	GRP & Productivity			
	Total, 2020	Change, 2015-2020	Total, 2020	LQ	Change, 2015-2020	Change Rel. to US, 2015-2020		Estimated Gross Regional Product ($B)	GRP Change, 2015-2020	Productivity, 2020	Productivity Change, 2015-2020
Manufacturing, Total	4,170	14%	109,244	0.52	5%	6%	$83,648	$27.58	23%	$252,472	16%
Aerospace & Defense Systems	329	15%	20,740	0.95	17%	12%	$120,595	$7.22	30%	$347,981	11%
Aerospace	36	1%	3,178	0.35	10%	3%	$90,514	$0.79	27%	$247,931	16%
Arms, Munitions, and Land Vehicles	12	48%	198	0.22	-51%	-65%	$88,997	$0.05	-32%	$263,377	40%
Communications Equipment	58	7%	2,894	2.44	-3%	-1%	$116,151	$1.15	13%	$398,328	16%
Microelectronics	71	15%	1,652	0.26	15%	15%	$68,436	$0.25	61%	$154,163	40%
Battery Manufacturing	5	6%	267	0.40	65%	19%	$83,914	$0.07	69%	$254,395	2%
Navigation, Guidance, & Security (NGS) Instrumentation	148	22%	12,552	3.48	27%	23%	$137,375	$4.90	35%	$390,527	6%
Food & Beverage	719	39%	20,908	0.64	17%	8%	$52,548	$2.99	26%	$143,216	8%
Beverage Manufacturing	216	102%	3,793	0.82	33%	6%	$50,665	$0.76	35%	$199,424	2%
Food Manufacturing	503	23%	17,115	0.62	14%	8%	$52,965	$2.24	23%	$130,760	8%
Life Science	298	58%	12,604	1.06	29%	18%	$142,789	$7.71	33%	$611,873	3%
Medical Devices & Equipment	161	59%	3,087	0.47	24%	13%	$92,797	$0.93	44%	$302,057	16%
Pharmaceuticals	137	57%	9,517	1.77	31%	20%	$159,005	$6.78	31%	$712,374	0%
Polymers & Related Manufactured Products	143	6%	6,826	0.53	5%	5%	$80,892	$1.40	20%	$205,016	0%
Adhesives, Coatings, & Paint	28	-14%	1,371	1.24	4%	-1%	$84,979	$0.42	30%	$308,374	25%
Plastic & Rubber Products	95	14%	5,151	0.29	8%	8%	$81,447	$0.91	18%	$176,877	9%
Polymers, Resins, and Fibers	20	0%	304	0.16	-28%	-27%	$53,031	$0.07	2%	$215,764	42%
Precision Manufacturing	313	1%	4,944	0.28	0%	6%	$68,049	$0.69	9%	$139,624	9%
Metal Services	40	13%	437	0.19	15%	20%	$54,839	$0.05	26%	$120,002	10%
Precision Machinery	54	21%	1,257	0.26	15%	20%	$73,266	$0.22	38%	$173,060	20%
Precision Metalworking	156	-6%	2,706	0.34	-2%	5%	$67,048	$0.32	1%	$117,020	3%
Industrial Instruments & Controls	63	-3%	543	0.20	-22%	-16%	$71,597	$0.10	-14%	$190,683	10%
Printing & Packaging	464	-13%	10,354	0.72	-10%	-4%	$56,362	$1.15	-4%	$111,040	6%
Packaging	51	-13%	2,988	0.43	-18%	-21%	$57,772	$0.38	-13%	$125,586	6%
Printing	393	-13%	6,805	1.01	-6%	7%	$54,033	$0.70	-1%	$102,261	5%
Production Machinery	20	-6%	562	0.81	-2%	1%	$77,081	$0.08	15%	$140,030	17%
Wood Products	243	11%	3,870	0.44	12%	9%	$55,072	$0.47	50%	$122,031	35%
Lumber & Building Components	101	25%	2,063	0.41	17%	12%	$61,782	$0.29	91%	$142,633	64%
Wood Cabinets, Furniture, & Millwork	142	2%	1,807	0.48	6%	6%	$47,413	$0.18	11%	$98,513	4%
Total Private Sector	172,012	4%	2,072,107	1.00	-2%	-3%	$64,193	$287.10	13%	$138,553	15%

Source: TEConomy analysis of enhanced CEW data from Emsi (Emsi Release 2020.2)

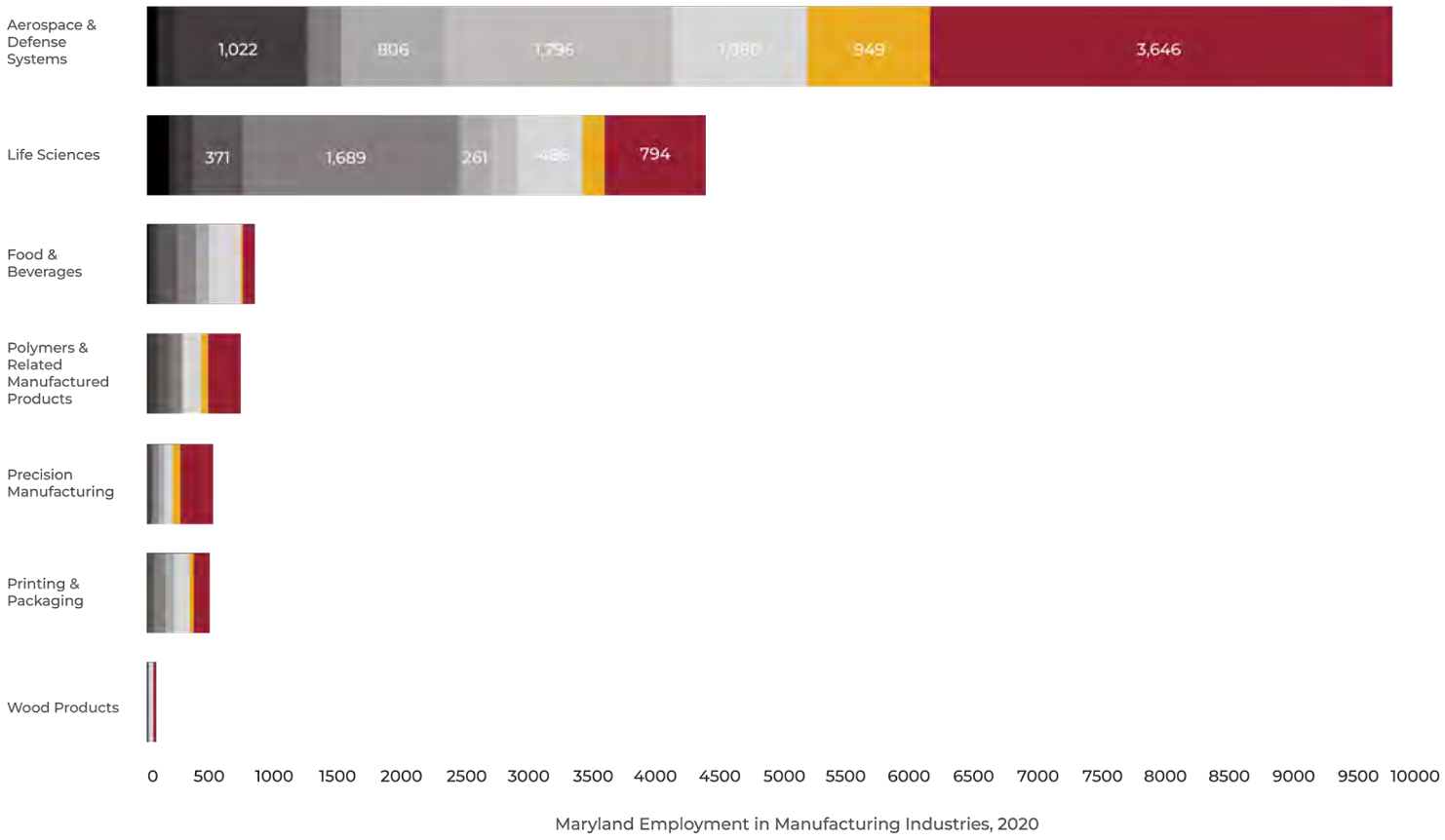
APPENDIX B: ADDITIONAL WORKFORCE & TALENT ANALYSIS OF INDUSTRY 4.0-ENABLING SEGMENTS

Figure B-1: Maryland and US Growth in Industry 4.0-Enabling Segments, 2015-2020



Source: TEConomy analysis of occupational data from Emsi (Emsi Release 2021.2)

Figure B-2: Detailed Industry 4.0-Enabling Occupational Employment within Maryland's Manufacturing Industry Subclusters



Source: TEConomy analysis of occupational data from Emsi (Emsi Release 2021.2)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