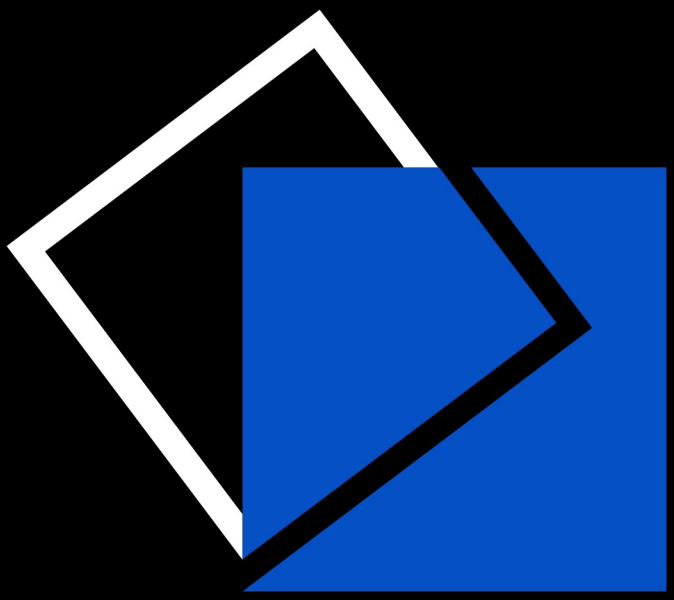
Wisconsin's Comprehensive Electrification Industry Strategy



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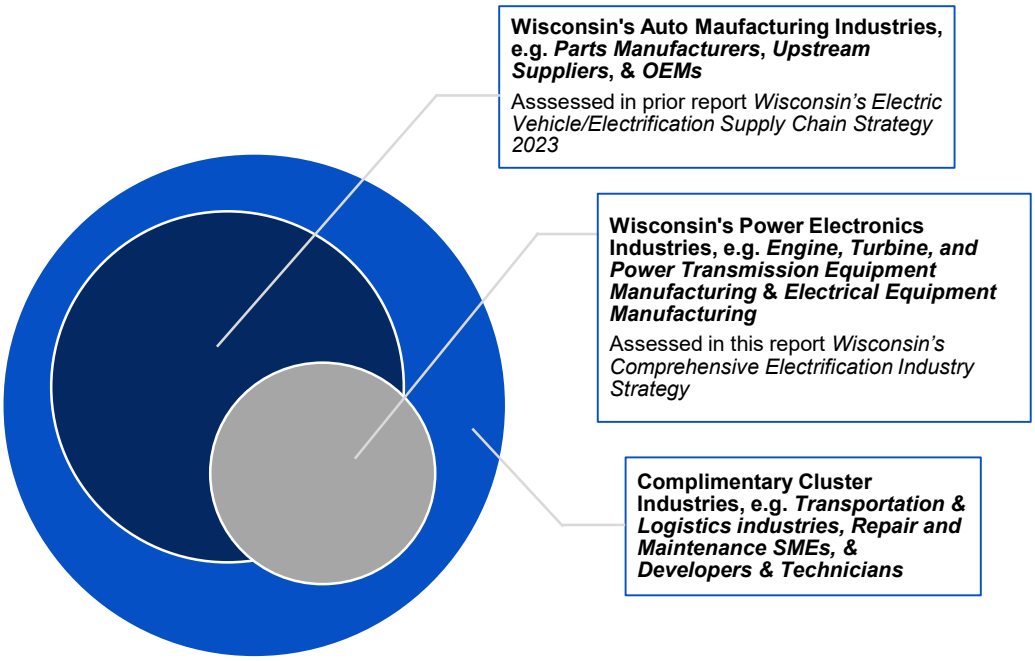
Executive Summary

States across the country are ramping up electrification efforts to meet critical environmental, national security, and competitiveness goals. Among those active in promoting electrification, Wisconsin is uniquely positioned to lead, with an outsized concentration of jobs and businesses in the cluster compared with the broader United States. The Wisconsin Economic Development Corporation (WEDC) has committed to assessing and meeting the demands of the growing electrification market and supporting state businesses with programs, strategies, and partnerships to help them invest and mitigate risk associated with the transition to electrification. As such, WEDC partnered with SRI to develop two reports, each focused on distinct components of Wisconsin's electrification cluster, including analysis and recommendations to grow and strengthen the cluster. Wisconsin's electrification cluster is diverse and composed of auto manufacturing, power electronics, and complimentary industries.

Component Industries of Wisconsin's Electrification Cluster



The first report, which was released in March 2023, *Wisconsin's Electric Vehicle/Electrification Supply Chain Strategy*, detailed the impacts on and opportunities for Wisconsin's automotive manufacturers, workforce, and communities stemming from the transition to electric vehicles (EVs). SRI's analysis found that the state's automotive suppliers are less vulnerable to disruption because they manufacture components for both ICE and EV products. The twin threats of lagging productivity rates and a misalignment of skills, however, threaten competitiveness over time. The report offers strategies to secure Wisconsin's EV manufacturing leadership, from upskilling and worker training to increasing EV market access and promoting connections between innovators and industry.

Building on this work, WEDC collaborated with SRI to extend the analysis and recommendations beyond auto manufacturing to the fuller group of industries within the electrification cluster, notably small power electronics, other electrification-related technologies, and specialized component parts.

This supplemental assessment of Wisconsin's electrification cluster reveals that the state has a concentration of employment and industry in power electronics that is nearly six times that of the United States. Despite its competitiveness, growth in much of the cluster has been stagnant over the past decade. The supply chain for Wisconsin's power electronics-related industries within the electrification cluster is moderately self-sufficient and localized, though opportunities exist to further develop supplier industries. Additionally, there may be opportunities to diversify the cluster's customer base as a disproportionately large share of in-state sales is made to Heavy Duty Truck manufacturing. Wisconsin's rich history in power electronics research, development, and manufacturing is shown by the plethora of companies and academic institutions that are actively involved in electrification technology development. However, stakeholders have noted the fragmented and siloed nature of power electronics R&D as the foremost challenge to the development of a successful electrification cluster in Wisconsin.

This report provides actionable strategies to advance the state's electrification cluster. Strategy 1 is a foundational strategy focused on building an institutional capacity to support the implementation and long-term sustainability of the cluster. Although subsequent strategies would benefit from stronger institutional capacity, the strategies themselves are independent, complementary, and targeted to specific cluster goals. Strategy 2 focuses on advancing research with commercial applications. Strategy 3 focuses on accelerating power electronics adoption and integration into other end-users with a strong presence in Wisconsin. Strategy 4 focuses on expanding the market for the Wisconsin electrification cluster.

Strategy 1: Build institutional capacity

Action Item 1.1: Launch a power electronics industry conference.

Action Item 1.2: Convene a Steering Committee of power electronics and electrification experts.

Action Item 1.3: Launch a "WI Are Electric" marketing campaign to attract funding and partnerships and raise awareness of Wisconsin's specialization in power electronics.

Action Item 1.4: Create a dynamic toolkit to support the power electronics industry.

Strategy 2: Advance research with commercial applications

Action Item 2.1: Convene a consortium of electrification university research labs and industry representatives.

Action Item 2.2: Create a power electronics commercialization consulting team.

Action Item 2.3: Establish a "hard tech" entrepreneurial mentorship network that connects experienced entrepreneurs and investors to promising power electronics, mechanical engineering, and advanced manufacturing startups or researchers seeking to commercialize new technologies.

Strategy 3: Accelerate adoption and integration of power electronics into other end-users with strong presence in Wisconsin

Action Item 3.1: Establish an equipment and space purchasing program for manufacturing SMEs that help the state meet clean energy objectives.

Action Item 3.2: Fund and promote power electronics implementation & R&D centers.

Strategy 4: Expand the market for the Wisconsin electrification cluster

Action Item 4.1: Expand Wisconsin's extremely high specialization in electrification-related industries into complementary industries like charging stations.

Action Item 4.2: Highlight and specifically cater to power electronics businesses in the WEDC export support program ExporTech.

Assessment of Wisconsin's Electrification Cluster

- Wisconsin's specialization in industries that make up its electrification cluster is extremely high; concentration of cluster jobs in Wisconsin is almost 5.7 times that of the United States.
- The electrification cluster employs approximately 25,000 Wisconsin workers and is largely concentrated in Motor and Generator Manufacturing, Relay and Industrial Control Manufacturing, and Other Engine Manufacturing.
- Wisconsin's strength in power electronics and other electrification-related technologies is underrecognized both inside and outside of the state.
- Despite its competitiveness, growth in the majority of Wisconsin's electrification cluster has been stagnant over the past decade.
- The supply chain for Wisconsin's electrification cluster is moderately self-sufficient and localized, though opportunities exist to further develop some supplier industries. Additionally, there may be opportunities to diversify the cluster's customer base as a disproportionately large share of in-state sales is made to Heavy Duty Truck manufacturing.

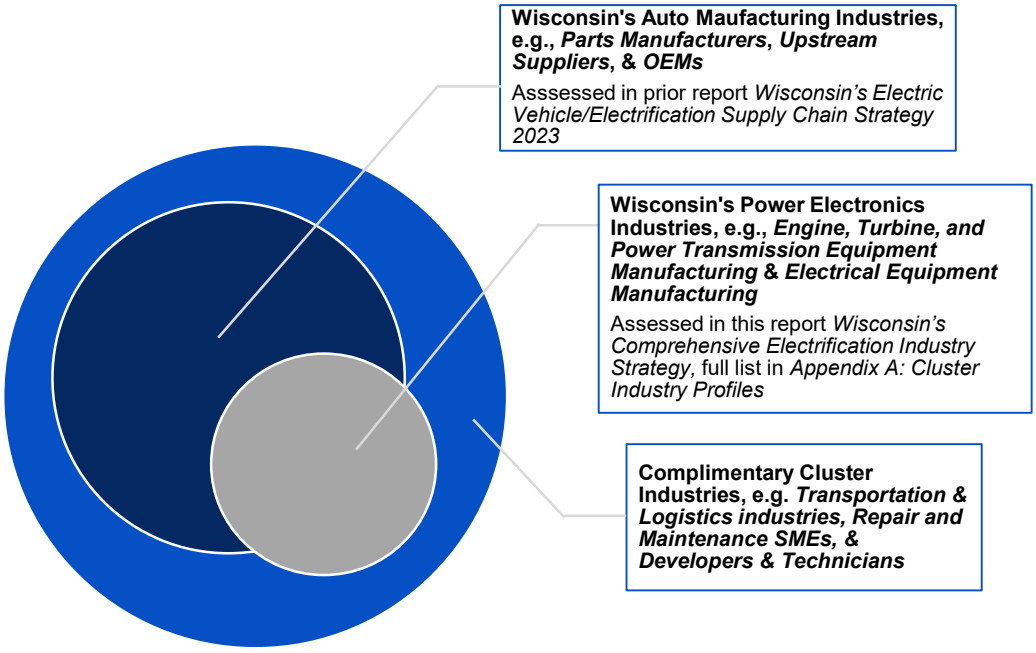
Localized economic growth is robust and resilient economic growth. When locally and regionally sourced industry-specific supply chains are paired with nearby R&D centers, innovative startups, and proactive government regulations, an industry cluster forms that becomes the bedrock for a strong economy. Industry clusters promote innovative practices, inter-industry collaborations, advanced applied research, and diverse job opportunities.[1] Each part of the industry cluster compliments the other and overtime these relationships between the constituent parts deepens to form strong knowledge and talent networks. WEDC will ensure long-term grow for Wisconsin by cultivating its own electrification cluster.

The economic benefits of industry clusters are various.[2] Clusters localize industry experts, researchers, business leaders, and innovative entrepreneurs geographically near one another, which more easily builds and grows mature industry networks. These networks facilitate important industry connections, like matching customers to suppliers, but they also encourage new knowledge spillovers to diffuse across businesses more rapidly, alerting industry leaders to new innovations or technologies. Strong industry networks can then be leveraged to better align workers in the area with potential jobs, providing an attractive talent pool that discourages businesses from moving or outsourcing parts of their production process, and that are also more resilient to economic shocks. Connections between producers, suppliers, and workers are not sufficient though: these industries must also have strong partnerships with local universities and research centers. Universities are the center of new innovations and technologies, but robust engagement with industries encourages more practical and applicable research objectives, and it builds strong pipelines between an emerging skilled workforce and matching industries. These academia-industry connection encourage an entrepreneurial attitude, which promotes a culture of innovation in the area, leading to startups, R&D innovations, and adaptive industry practices which promote greater efficiency and impact. Collaborations between firms, startups, and research centers need to be supplemented with strong and effective government support. Good tax incentives, government funding, and proactive regulation creates the necessary political environment for an industry cluster to emerge, while disruptive government intervention and burdensome regulations could drive industries away and limit the cluster's growth. WEDC must act to bring all the necessary stakeholders together and to create the regulatory environment to allow them to flourish.

WEDC collaborated with SRI to examine eight six-digit NAICS industries in Wisconsin's electrification cluster. Wisconsin's electrification cluster also includes industries examined in the original *Wisconsin's Electric Vehicle/Electrification Supply Chain Strategy 2023*, which are not re-analyzed in this supplement. Four of industries examined here are part of NAICS 3336: Engine, Turbine, and Power Transmission Equipment Manufacturing (see *Table 2*). The four remaining industries are part of NAICS 3353: Electrical Equipment Manufacturing (see *Table 3*). Together, the eight industries in the power electronics portion of Wisconsin's electrification cluster employ almost 25,000 workers (see *Appendix A* for a detailed profile of each industry in Wisconsin).[3] *Figure 1* further describes the relationship between core industries within Wisconsin's electrification cluster:

- **Small Gray Circle: Wisconsin's Power Electronics Industries, e.g., *Engine, Turbine, and Power Transmission Equipment Manufacturing* & *Electrical Equipment Manufacturing***
    - Assessed in this report *Wisconsin's Comprehensive Electrification Industry Strategy* (full list of industries in *Appendix A*). This is Wisconsin's power electronics-related industries. These industries have a small degree of overlap with the parts manufacturers from the prior report *Wisconsin's Electric Vehicle/Electrification Supply Chain Strategy 2023*.
- **Medium Dark Blue Circle: Wisconsin's Auto Manufacturing Industries, e.g., *Parts Manufacturers*, *Upstream Suppliers*, & *OEMs***
    - Assessed in prior report *Wisconsin's Electric Vehicle/Electrification Supply Chain Strategy 2023.* This is Wisconsin's auto manufacturing related industries. These industries have a small degree of overlap with the power electronics related industries detailed in this report (e.g., *Other Engine Equipment Manufacturing)*.
- **Large Blue Circle: Complimentary Cluster Industries**
    - This includes other complimentary industries within the electrification cluster, such as transportation & logistics industries, repair and maintenance SMEs, developers & technicians.

Figure 1: Component Industries of Wisconsin's Electrification Cluster



For the remainder of the report, “electrification cluster” refers to the eight power-electronics related industries specifically. In Wisconsin, the employment concentration in industries that make up power electronics is approximately 5.7 times that of the United States. In almost all industries in the cluster, Wisconsin is at least twice as specialized—and in some cases more than seven times as specialized—as the United States in the manufacturing of industrial electrical equipment.

Wisconsin’s electrification cluster is largely concentrated in three of its eight constituent industries. These three industries—Other Engine Equipment Manufacturing, Motor and Generator Manufacturing, and Relay and Industrial Control Manufacturing—hold approximately three-quarters of the cluster’s jobs. That is, almost 18,000 of the cluster’s 25,000 workers are employed in these three industries. The high employment levels in the industries, when viewed in combination with the industries’ extremely high location quotients (6.75 for Other Engine Equipment Manufacturing, 8.37 for Motor and Generator Manufacturing, and 7.24 for Relay and Industrial Control Manufacturing), underscore Wisconsin’s competitive advantage in engine production, power electronics manufacturing, and electrical control technology.

According to stakeholders, this competitive advantage has been underrecognized both inside and outside of Wisconsin. Yet, the technologies at the core of these industries are expected to play a critical role in the global transition to electrically powered systems and the development of power grids and infrastructure that sustain them. As such, Wisconsin is uniquely positioned to harness its strengths in electrification technology manufacturing and research to transform its electrification cluster into a powerful driver of future economic growth.[4]

If left to its current trajectory, however, Wisconsin’s electrification cluster will not realize its potential. In the past decade, most industries within Wisconsin’s electrification cluster have seen stagnant or negative employment growth, aligning with trends in Wisconsin’s automotive industry as outlined in *Wisconsin’s Electric Vehicle/Electrification Supply Chain Strategy 2023*.

Such stagnant growth in most of the cluster stands in contrast to the explosive growth in the Motor and Generator Manufacturing industry, where employment increased by 50% in the past 5 years (from 4,000 in 2017 to 6,000 in 2022) due in part to Generac’s expansion of its Wisconsin operations.[5]

Nevertheless, the stagnation and unevenness exhibited by recent employment trends in the cluster conveys a sense of urgency. If Wisconsin seeks to capitalize on its strength in electrification, it may have a limited window of opportunity to reinvigorate the cluster’s growth and dynamism before other regions develop their own competitiveness in electrification technologies.

Wisconsin Enjoys a Very High Specialization in Electrification and Power Electronics Technologies; Approximately 25,000 Wisconsin Workers are Employed in the Electrification Cluster.

Table 1: Performance of Wisconsin’s Electrification Cluster, 2021. *Source: SRI analysis of Lightcast data.*

Employment in Wisconsin	Share of U.S. Jobs	Wisconsin Location Quotient	5-Yr Employment Growth	10-Yr Employment Growth	5-Yr Productivity Growth	10-Yr Productivity Growth
24,773	10.9%	5.67	5.3%	9.8%	17.5%	18.9%

Table 2: Industry Breakdown and Performance in NAICS 3336: Engine, Turbine, and Power Transmission Equipment Manufacturing, 2021. *Source: SRI analysis of Lightcast data.*

Industry NAICS Code	NAICS 3336	NAICS 333611	NAICS 333612	NAICS 333613	NAICS 333618
Industry Name	Engine, Turbine, and Power Transmission Equipment Manufacturing	Turbine and Turbine Generator Set Units Manufacturing	Speed Changer, Industrial High-Speed Drive, and Gear Manufacturing	Mechanical Power Transmission Equipment Manufacturing	Other Engine Equipment Manufacturing
Employment in Wisconsin	9,126	224	1,569	1,403	5,930
Share of Cluster Jobs	36.8%	0.9%	6.3%	5.7%	23.9%
Share of US Jobs	10.3%	1.1%	14.2%	11.1%	13.2%
Wisconsin Location Quotient	5.32	0.58	7.37	5.73	6.84
5-Yr Employment Growth	-3.6%	-1.3%	-17.6%	-8.5%	2.2%
10-Yr Employment Growth	2.4%	-11.1%	-24.7%	-8.0%	17.4%
5-Yr Productivity Growth	15.1%	6.7%	10.2%	8.2%	17.5%
10-Yr Productivity Growth	10.2%	-8.6%	-5.1%	15.9%	13.6%

Table 3: Industry Breakdown and Performance in NAICS 3353: Electrical Equipment Manufacturing, 2021. *Source: SRI analysis of Lightcast data.*

Industry NAICS Code	NAICS 3353	NAICS 335311	NAICS 335312	NAICS 335313	NAICS 335314
Industry Name	Electrical Equipment Manufacturing	Power, Distribution, and Specialty Transformer Manufacturing	Motor and Generator Manufacturing	Switchgear and Switchboard Apparatus Manufacturing	Relay and Industrial Control Manufacturing
Employment in Wisconsin	15,647	1,936	5,847	1,984	5,880
Share of Cluster Jobs	63.2%	7.8%	23.6%	8.0%	23.7%
Share of US Jobs	11.4%	7.5%	16.3%	5.8%	14.1%
Wisconsin Location Quotient	5.89	3.91	8.47	2.98	7.32
5-Yr Employment Growth	11.3%	4.9%	49.9%	0.4%	-7.3%
10-Yr Employment Growth	14.7%	-3.5%	65.2%	9.1%	-6.4%
5-Yr Productivity Growth	19.6	19.3	22.7	1.8	23.8
10-Yr Productivity Growth	25.7%	29.8%	49.0%	17.1%	17.1%

Opportunities exist to strengthen existing supply chains and fill potential gaps in supplier and customer networks. For example, inputs to the cluster from industries such as Iron and Steel Mills and Copper Rolling are mostly imported from out-of-state firms, while the outputs produced from the cluster are disproportionately concentrated in Heavy Duty Truck Manufacturing.

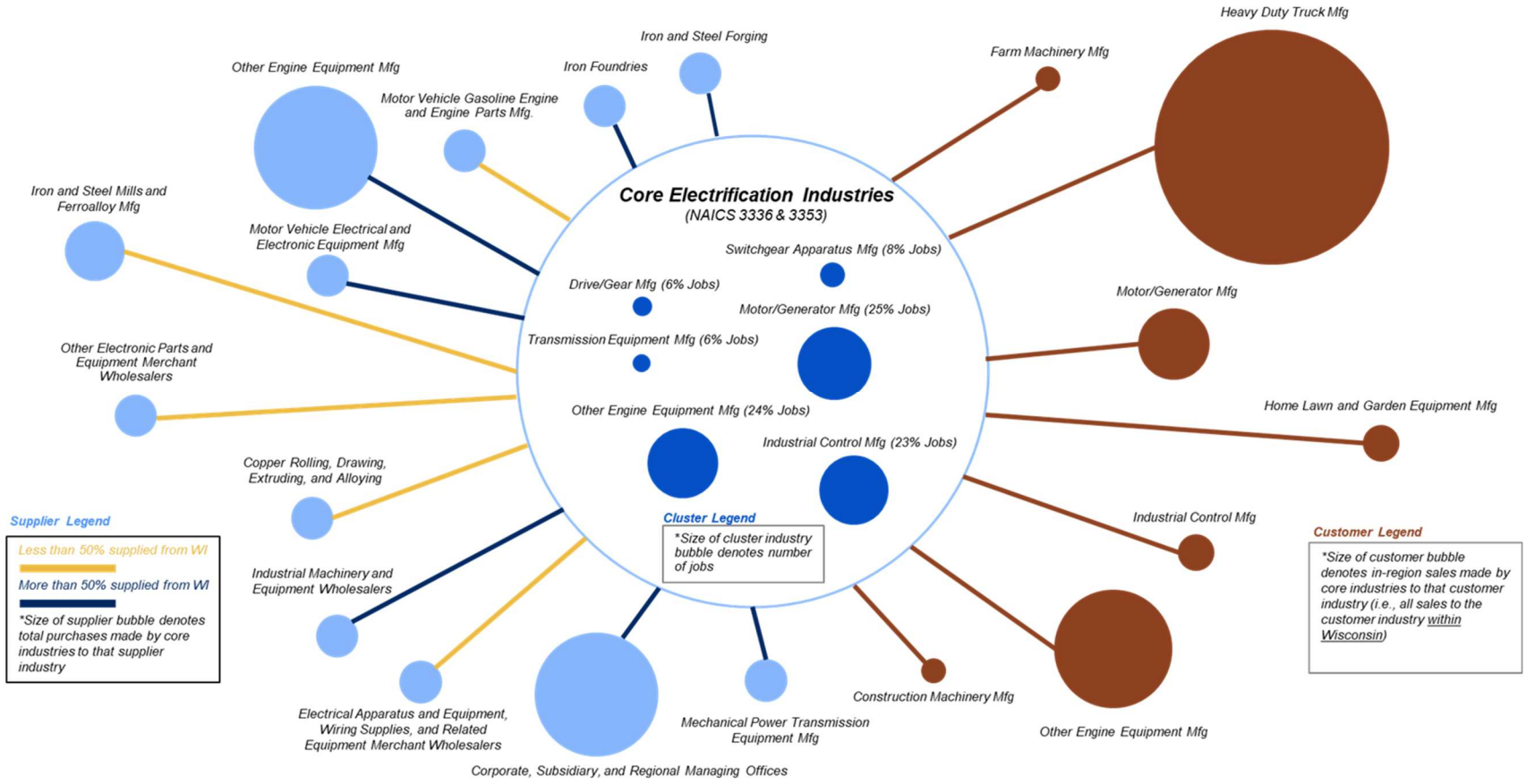
When firms within the cluster are well-served by in-state suppliers, their purchases not only fuel the development of the products they export, but also strengthen local and regional complimentary sectors and benefit the state's communities and workers. Therefore, helping to develop an adequate supplier network in the state is a primary way to strengthen the overall cluster and advance the state's economy.

In Wisconsin, the share of cluster purchases that is captured by local suppliers varies by supplier industry. In general, the high concentration of engine equipment manufacturers, motor vehicle electronics equipment manufacturers, industrial machinery wholesalers, iron foundries, and iron and steel forges in Wisconsin has translated to these industries successfully capturing most cluster purchases. In other words, the supply chain elements related to these industries include mostly Wisconsin firms that supply millions of dollars' worth of goods and services annually to firms in Wisconsin's electrification cluster.[6]

On the other hand, Wisconsin's electrification cluster relies on out-of-state imports for its other supplier needs, notably from electrical equipment wholesalers, motor vehicle engine and engine parts manufacturers, and manufacturers of copper-based components. These industries therefore represent opportunities for continued development, such that Wisconsin can further strengthen its electrification cluster if in-state firms in these supplier industries can capture a greater share of cluster purchases.

The Supply Chain for Wisconsin's Electrification Cluster Is Moderately Self-Sufficient, Though Opportunities Exist to Further Develop Some Supplier Industries. A Disproportionately Large Share of the Cluster's In-State Sales Are Made to Heavy Duty Truck Manufacturing, and There May Be Opportunities to Diversify its Customer Base in Wisconsin.

Figure 2: Supply Chain of Wisconsin's Electrification Cluster. Source: SRI analysis of Lightcast input-output tables.



NOTE: Cluster industries are denoted as dark blue in the center bubble, industries which supply inputs to the cluster are denoted as light blue on the left-hand side, and industries which purchase goods and service from the cluster are denoted as brown on the right-hand side. The bubble size of supplier and customer industries denotes the dollar value of inputs supplied to/purchased from the cluster in 2021. The bubble size of cluster industries denotes employment in the industry. On the supplier (left-hand) side, the color of the lines illustrates whether most inputs supplied (as measured by their dollar value) originated from Wisconsin firms or were imported from out-of-state. Dark blue lines denote that more than 50% of inputs to the cluster were supplied by Wisconsin firms. Yellow lines denote that more than 50% of inputs to the cluster were supplied by out-of-state firms.

As *Figure 2* shows, customer industries to which Wisconsin's electrification cluster sells goods and services (denoted by brown lines on the right hand side of the figure) include Heavy Duty Truck Manufacturing, Home Lawn and Garden Equipment Manufacturing, Farm Machinery Manufacturing, and Construction Machinery Manufacturing. It should be noted that data on customer industries to whom the electrification cluster sell goods and services is limited to Wisconsin. As such, sales by cluster firms to firms and industries located outside Wisconsin are not captured in *Figure 2*.

The fact that roughly 30% of all in-state sales made by firms in Wisconsin's electrification cluster flow to Heavy Duty Truck Manufacturing—a large share of which is represented by Oshkosh Corporation and its subsidiaries—constitutes a key finding in this supply chain analysis. As such, opportunities exist to diversify the cluster's in-state customer base into other sectors in which Wisconsin's economy possess a competitive advantage. These industries include farm machinery manufacturing, construction machinery manufacturing (each currently capturing less than 2% of in-state sales), and lawn and garden equipment manufacturing (currently capturing 3% of in-state sales). Given Wisconsin's high specialization in these industries, there are opportunities for the state's economic developers to develop stronger supply chain linkages between firms in the electrification cluster and other sectors of Wisconsin's economy.

A second feature of Wisconsin's electrification cluster is that it is moderately self-sufficient. Firms within the cluster purchase and sell goods and services to each other. For example, *Figure 2* shows that the Other Engine Equipment Manufacturing industry is the cluster's largest supplier industry and its second largest customer industry. Yet, the industry is also part of the electrification cluster. This peculiar feature suggests that firms within the electrification cluster have sufficient diversity in their product offerings that they routinely purchase and sell parts and components from each other.

For Wisconsin's engine equipment manufacturers in particular, the high level of intra-industry transactions is a sign of an ecosystem of interconnected engine and engine component makers. In a prior analysis of auto electrification, the related motor and transmission parts suppliers were identified as being "high risk" from electrification transition, meaning that they are dependent on the production of components specific to ICE-powered equipment. Outside of auto manufacturing, according to data obtained from stakeholder interviews and other sources, a notable portion of engine equipment manufacturing firms are actively working to adapt to the electrification transition through investments in electrically powered products, in engines that rely on alternative fuels or hybrid power, and in increasing the fuel efficiency and environmental friendliness of internal combustion engines. This indicates that Wisconsin's electrification cluster is stronger and more stable in areas that are complementary to auto manufacturing. As will be discussed later in the next section of this report, a significant opportunity in the electrification cluster's development lies in the coordination of R&D efforts to accelerate these areas.

Wisconsin is nationally competitive in power electronics-related patent invention and ownership.

Table 4: Wisconsin power electronics-related patent invention summary statistics, 2018-2022. *Source: SRI analysis of U.S. Patent and Trademark Office (USPTO) data.*

	Patents	Patents per 100k Residents	Percent of Patents Owned by Wisconsin Organizations	Number of Unique Inventors on Patents	Average Number of Inventors per Patent
Value	1899	32.23	40.4%	2054	3.27
State Rank	12th	7th	19th	11th	4th

Table 5: Top Wisconsin power electronics-related patent inventors, 2018-2022. *Source: SRI analysis of USPTO data.*

Inventor Name	Patents	Inventor City
Robert Koenen	51	Pewaukee
Kirk H. Drees	46	Cedarburg
Richard A. Himmelmann	44	Beloit
Michael J. Wenzel	43	Oak Creek
Nader Nasr	38	Neenah
Richard A. Davis	37	Mequon
Eric A. Davis	37	Mequon
Deepak Shukla	35	Oshkosh
Matthew J. Mergener	34	Mequon
Wayne M. Jaszewski	32	Sparta

Table 6: Top Wisconsin power electronics-related patent ownership organizations, patents by a Wisconsin inventor, 2018-2022. *Source: SRI analysis of USPTO data.*

Organization Name	Patents	Percentage of Wisconsin Patents Owned	Organization City	Organization State	Physical Presence in Wisconsin
Brunswick Corporation	164	8.64%	Mettawa	Illinois	✓
Milwaukee Electric Tool Corporation	157	8.27%	Brookfield	Wisconsin	✓
Rockwell Automation Technologies, Inc.	136	7.16%	Mayfield Heights	Ohio	✓
Illinois Tool Works Inc.	123	6.48%	Glenview	Illinois	✓
Kohler Co.	110	5.79%	Kohler	Wisconsin	✓
Briggs & Stratton, LLC	92	4.84%	Wauwatosa	Wisconsin	✓
Hamilton Sundstrand Corporation	80	4.21%	Charlotte	North Carolina	✓
General Electric Company	47	2.47%	Schenectady	New York	✓
Johnson Controls Technology Company	46	2.42%	Auburn Hills	Michigan	✓
Oshkosh Corporation	39	2.05%	Oshkosh	Wisconsin	✓

Table 7: Wisconsin power electronics-related patent invention and ownership activity by city, 2018-2022. *Source: SRI analysis of USPTO data.*

City	Number of Unique Inventors on Patents	Number of Wisconsin-Invented Patents Owned
Milwaukee	172	65
Oshkosh	141	59
Madison	133	50
Wauwatosa	83	97
Waukesha	73	26
Fond du Lac	60	1
Appleton	59	4
Mequon	55	4
Brookfield	55	158
Pewaukee	35	14
Kohler	11	91

Table 8: Top Wisconsin power electronics-related patent competitors, 2018-2022. *Source: SRI analysis of USPTO data.*

State	Region	Patents	Patents per 100k Residents	Number of Unique Inventors	Average Number of Inventors per Patent	Percent of Patents Owned by in-State Organizations	Percent of Patents by Wisconsin Inventors Owned
California	West	13715	35.14	16564	2.55	60.0%	1.8%
Michigan	Midwest	6271	62.50	6451	3.26	73.0%	2.9%
Texas	Southwest	4674	15.56	4748	2.30	53.1%	0.5%
Connecticut	Northeast	3820	105.34	2204	3.96	81.2%	0.5%
New York	Northeast	3115	15.83	3125	2.32	58.9%	4.2%
Ohio	Midwest	2977	25.32	2835	3.49	23.1%	7.6%
Massachusetts	Northeast	2914	41.74	2902	2.16	39.5%	0.7%
Washington	West	2659	34.15	3541	2.63	49.6%	0.1%
Illinois	Midwest	2434	19.35	2657	2.55	50.1%	17.9%
Florida	Southeast	2200	9.89	2213	2.28	36.5%	<0.1%
Indiana	Midwest	1946	28.48	1783	3.33	79.1%	1.9%
North Carolina	Southeast	1703	15.92	1643	2.04	30.2%	6.0%
Pennsylvania	Northeast	1585	12.22	1607	2.06	24.2%	0.9%
Minnesota	Midwest	1244	21.76	1785	2.77	53.9%	2.8%
Wisconsin	Midwest	1899	32.23	2054	3.27	40.4%	40.4%

SRI conducted an analysis of Wisconsin's USPTO patent activity since 2018, providing a five-year lookback at the state's performance. Power electronics-related patents are a defined set of the USPTO patent database, aggregating patents with the terms, "Engine, Motor, Generator, Converter, Turbine, Electric Power, Power Transmission, Inverter, Transformer, Armature, Ballast, Switchgear," and “Switchboard" in the patent title or abstract.

This patent analysis was purposefully broad to get a holistic view of Wisconsin's patent activity and competitiveness in power electronics. Ultimately, patent innovation can be an indicator of ecosystem health and economic potential. Patents directly measure R&D capacity and commercialization potential in an industry or region.

Key metrics from this analysis include the number of unique patents produced, patents per 100,000 to get a per capita measurement of patent activity, the number of unique inventors from the state, and the average number of inventors per patent. In the rare event of a cross-state collaboration, where a patent had inventors from different states, each state received credit for the patent. The analysis examined match rates between patent invention and ownership. Invention is the driver of R&D activity and innovation potential. Invention cannot occur without talent and access to R&D resources (e.g., funding, facilities, regulatory support). Ownership provides insight into who owns the IP, who may be situated to benefit most from its commercialization or licensing, and who may be empowering researchers and innovators to conduct R&D activity and patent filings. Several tables investigate these differences, where inventors may help invent a patent that is owned by an organization (e.g., corporation, university, nonprofit institute, R&D facility) based in a different state. This organization may have a physical presence (e.g., a regional office or satellite campus) in Wisconsin, so it is important to examine some ownership organizations on a case-by-case basis.

Table 4 provides summary statistics and rankings for Wisconsin's patent activity: the state boasts the 7th highest patent output per 100,000 residents and above-average match in patent invention and ownership, with Wisconsin organizations owning over 40% of patents invented in the state. Wisconsin inventors filed 1899 patents in the last five years. In this broad patent analysis, the state performs extremely high in average inventors per patent. However, there is no evidence of organizational collaboration, as each of the 1899 patents were issued to one organization, whereas there is evidence of shared ownership occurring in other states/regions. *Table 5 and Table 6* provide descriptive statistics for the top 10 state power electronics-related patent inventors and ownership organizations of Wisconsin-invented patents. Even the out-of-state organizations listed in USPTO have significant physical presences in Wisconsin. Brunswick Corporation, for example, has business unit offices and manufacturing offices all over the Midwest, including two Manufacturing operations facilities in Wisconsin (Menomonee Falls, Fond du Lac). Mercury Maine is a $2.6 billion division of Brunswick Corporation, headquartered in Fond Du Lac, and considered a leading manufacturer of marine propulsion systems.[7] About 66% (108/164) of Brunswick Corporation’s patents had at least one inventor contributing from Mercury Marine in Fond Du Lac. Also, Rockwell Automation has its Global Headquarters in Milwaukee and another location in Mequon. This trend suggests that Wisconsin's power electronics industry is relatively connected in terms of patent invention and ownership, where R&D organizations are enabling Wisconsin inventors to conduct research, innovate, and file patents in Wisconsin.

Table 7 shows patent invention and ownership activity by city. While patent activity is clustered in Milwaukee and surrounding areas, there is a moderate spread of activity in Southern and Central Wisconsin, with less activity in the state's Northern regions. *Table 8* provides a detailed view of Wisconsin's power electronics-related patent competitors, comparing key metrics, including patent total, patent output per 100,000 residents, number of unique inventors, the percentage ownership of state-invented patents, and percentage ownership of Wisconsin-invented patents. *Table 8* shows that midwestern peers own notable percentages of patents with at least one Wisconsin-based inventor. Illinois, Ohio, Michigan, and Minnesota-based organizations own over 31% of Wisconsin-invented patents. From a peer state comparison, Michigan, Ohio, and Illinois are all outperforming Wisconsin when it comes to total patent activity and total number of unique inventors, indicating more aligned R&D innovation and commercialization activity and potentially a stronger infrastructure is needed to support inventors in patent filings.

Opportunities and Challenges in Electrification R&D

- Wisconsin's rich history in power electronics research, development, and manufacturing is shown by the plethora of companies and academic institutions that are actively involved in electrification technology development.
    - Major initiatives are underway across Wisconsin's electrification cluster to transition toward electrification and electrically-power technologies.
    - Wisconsin universities operate various research labs and organizations dedicated to electrification research.
- However, stakeholders have noted the fragmented and siloed nature of electrification R&D as the foremost challenge to the development of a successful electrification cluster in Wisconsin.
    - Opportunities exist to establish a venue for collaboration between both industry and academic stakeholders to address shared technical challenges and to coordinate cluster development efforts.
    - Opportunities to increase collaboration between industry and academic in R&D and commercialization activities. Other regions boast partnerships between universities and industry where two or more organizations share ownership of patents.

Wisconsin's rich history in manufacturing is closely tied to the development and production of various forms of electrical equipment that have enabled the electrification of various economic sectors in the 20th Century. For example, stakeholders noted that Wisconsin firms and universities were pivotal in the development of more sophisticated electric switches, mobile transformers, grid and microgrid technologies, and electric vehicle charging equipment. In the 21st Century, Wisconsin firms have continued to make significant advances in the electrification of engine and power systems for a wide range of applications. Examples include:

- **Generac's** rapid and ongoing development of sustainable smart grid and smart home technologies[8]
- **Harley Davidson's** development of the LiveWire electric motorcycle[9]
- **Briggs & Stratton's** development of the zero-turn electric lawnmower and various commercial battery products[10]
- **Kohler's** acquisition of Curtis Instruments and Heila Technologies, two electrification-oriented companies, to drive the electrification and hybridization of its power systems portfolio[11]
- **Eaton Corporation's** recent launch of its e-mobility business division, which produces parts for both EVs and EV charging stations[12]
- **Odyne Systems'** continued development of electrification and hybrid systems for medium- and heavy-duty trucks[13]
- **Oshkosh Corporation's** development and production of:[14]
    - Electric mail delivery vehicles for the United States Postal Service
    - Electric-hybrid Joint Light Tactical Vehicle for the U.S. Army and Marine Corps
    - Electric fire trucks

    - Electric aircraft rescue and fire fighting vehicles
    - Electric cement mixer trucks
- **Leonardo DRS's** development of microgrid technologies to enable the electrification of U.S. Navy ships (Leonardo DRS operates R&D labs in Milwaukee and Menomonee Falls)[15]
- **Johnson Controls'** development of distributed energy storage and other energy technologies[16]
- **Ingeteam's** production of:
    - wind turbine generators in Milwaukee, the only producer of wind turbine generators in the United States[17]
    - recently announced production of EV charging stations in Milwaukee

In addition to innovation from industry, Wisconsin's universities continue to operate various labs and consortiums with a focus on electrification technologies and clean energy research. Much of this research being conducted by Wisconsin institutions focuses on improving the controllability, flexibility, stability, and robustness of grid technologies, such as miniaturizing insulation for high-voltage systems or increasing the energy density of batteries. According to stakeholders interviewed for this report, this type of research is more difficult to market to the public than more high-profile technologies such as artificial intelligence, nuclear fusion, or robotics. Yet, it is expected to have a pivotal impact on the development of the United States' future energy infrastructure.

In Wisconsin, academic institutions that conduct this type of research include:

- **Center for Grid-Connected Advanced Power Electronics Systems (GRAPES).** A National Science Foundation Industry/University Cooperative Research Center (I/UCRC) whose mission is to accelerate the adoption and insertion of power electronics into the electric grid to improve system stability, flexibility, robustness, and economy. UW-Milwaukee is a key member institution of the center, which includes several other universities across the United States. The UW-Milwaukee site focuses on distributed generation integration, AC and DC microgrids, distribution and protection, ancillary services, smart distribution, grid connected energy storage systems, and SiC-based converters.[18]
- **Wisconsin Electric Machines and Power Electronics Consortium (WEMPEC).** A technology center at UW-Madison with professors, staff, graduate students, and international scholars to conduct research and develop novel technologies and techniques in electrification and power electronics technologies. WEMPEC is supported by more than 70 corporate sponsors, many of whom provide input on the direction and focus on the consortium's applied research efforts.[19]
- **Connected Systems Institute (CSI).** A center for collaboration between industry and academia to conduct research on advanced manufacturing technologies and processes. Research topics include the Industrial Internet of Things, factory automation, and the implementation of Industry 4.0 solutions.[20]
- **UW-Milwaukee Johnson Controls Battery Research.** Two labs at UW-Milwaukee, supported by Johnson Controls, that conduct research on efficient energy storage. Johnson Controls also supports an Endowed Professorship in Energy Storage Research, which is shared between UWM and UW-Madison, and graduate fellowships at both universities.[21]
- **Industrial Assessment Center at UW-Milwaukee**. An organization at UW-Milwaukee's College of Engineering and Applied Science that provides technical assistance to help manufacturers cut their energy costs, improve energy efficiency and productivity, and reduce waste. The center also trains students in industrial energy system management and assessment.[22]

Though Wisconsin is endowed with a strong and diverse base of assets in both industry and academia, stakeholders have noted the fragmented and siloed nature of electrification R&D as the foremost challenge to the development of a successful electrification cluster. Between industry and academia, this disconnect is partly due to the time frame during which new technologies are developed. While some university projects may take ten years to become commercially viable, many industry stakeholders measure the pace of technology development in months. However, even among industry stakeholders, product development takes place in isolation and at different rates. Some companies have experienced headwinds, such as Briggs & Stratton, and are now retooling toward electrification. Others, such as Milwaukee Tool and Generac, are ramping up their electrification efforts. Despite companies' mutual movement toward electrification and with many facing the same technology challenges, collaboration between companies has been limited.

In academia, the main organization dedicated to electrification research is the Wisconsin Electric Machines and Power Electronics Consortium (WEMPEC). While WEMPEC's industry sponsors include major firms within Wisconsin's electrification cluster (as well as many out-of-state firms), the technology development being conducted by the consortium's five faculty members and their staff and graduate students lack the scale to draw significant investment from large manufacturers.

The other related organization for electrification research was the Mid-West Energy Research Consortium (M-WERC). Although M-WERC's activities have been dissolved, stakeholders interviewed for this project noted that, before it became inactive, M-WERC laid the groundwork for an effective venue through which university researchers can work alongside industry partners on use-inspired projects.

Regardless of the reasons for the siloed and fragmented nature of Wisconsin's electrification R&D landscape, this assessment identifies a clear need in the state for an organization that facilitates collaboration between the plethora of industry and academic organizations working in the field of electrification. Such an organization would coordinate dialogue between stakeholders in a way that underscores the shared challenges and opportunities in electrification R&D. It would also better inform university researchers about industry needs and priorities so that they can better align their work. Further, the organization would seek to build stronger research partnerships between universities across Wisconsin so that academics possess the scale and capability to confront applied problems of high relevance to industry. Lastly, it would engage with industries and stakeholders that increasingly use electrification technologies, such as farm machinery and power tool manufacturers, to guide and improve product development.

SWOT Analysis of Wisconsin's Electrification Cluster

This SWOT analysis summarizes the findings of the Economic Assessment to inform Wisconsin's path forward as it continues to develop its electrification cluster. In the SWOT analysis, 1) strengths refer to characteristics of Wisconsin's economy that impart a competitive advantage, 2) weaknesses refer to characteristics of Wisconsin's economy that put the state at a competitive disadvantage, 3) opportunities refer to elements in the environment that Wisconsin could leverage to further its objectives, and 4) threats refer to elements in the environment that could hinder Wisconsin's efforts to achieve its objectives.

Figure 3: SWOT Analysis of Wisconsin's Electrification Cluster

STRENGTHS

- **Long history of competitiveness** in power electronics research, development, and manufacturing
- **Specialization in power electronics and electrification-related industries** that is 5.7 times that of the United States
- **Large employment base** of 25,000 workers that hold jobs in cluster industries
- **Moderately self-sufficient and localized supply chain**, where many inputs purchased by cluster industries are supply by in-state firms
- Abundant and diverse range of stakeholders in both industry and academia that are **dedicated to electrification technology development**

WEAKNESSES

- **Fragmented and siloed electrification R&D ecosystem**, in which stakeholders individually conduct their own technology and product development
- **Stagnant growth** in much of the cluster over the past decade
- **Concentration of in-state sales** to Heavy Duty Truck Manufacturing suggests a need to diversify the customer base of cluster industries
- Several electrification research organizations in Wisconsin universities **lack the capacity to take on large-scale applied research projects**

OPPORTUNITIES

- **Establishment of a centralized venue to facilitate collaboration** in electrification R&D and to coordinate industry development efforts
- **Greater collaboration between electrification researchers** in universities across Wisconsin would create the scale and capacity to take on larger projects alongside industry partners
- Integration of power electronics and electrification-related industries into **other end-user sectors that have a strong presence in Wisconsin**
- **More effective marketing** that focuses on Wisconsin's strengths in electrification research and manufacturing—and its importance in the development of the energy infrastructure of the future—can draw additional investment from both public and private sector entities

THREATS

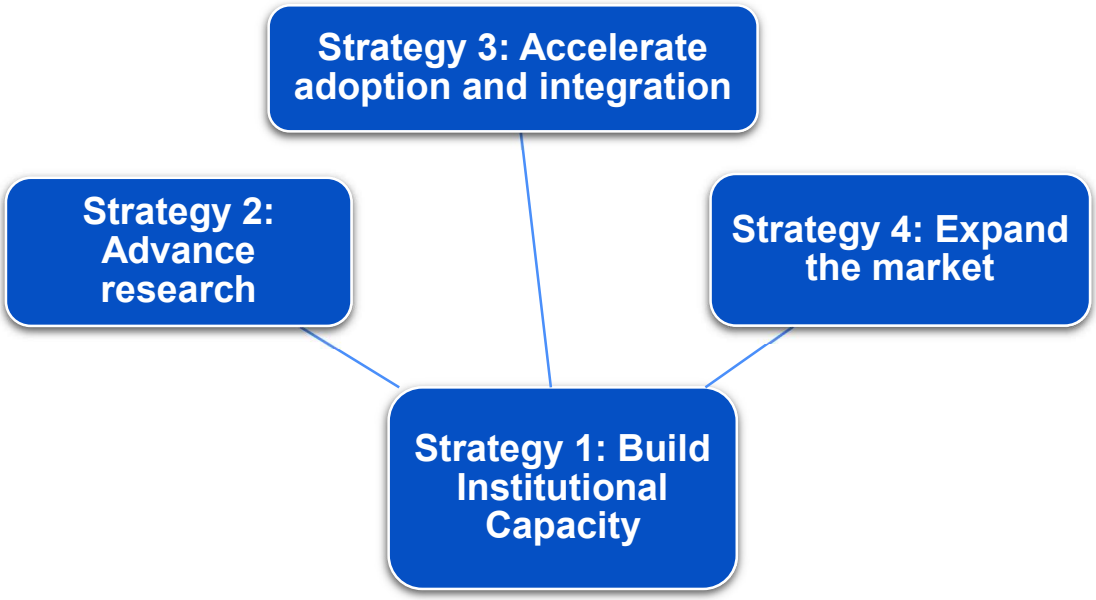
- **Stagnant or declining employment** in some cluster industries may threaten Wisconsin's competitiveness in the cluster
- **Competition from other regions** that are developing research and manufacturing capabilities in electrification poses a risk to Wisconsin's historical dominance in power electronics. Peer states (MI, OH, IL) outpace Wisconsin in overall patent activity and number of unique patent inventors over the last five years
- Continuation of a system in which individual companies attempt to transition to electrification in isolation **may lead some companies to fail in their electrification transition efforts**

Recommendations Overview

Wisconsin employs about 25,000 people in its electrification or power electronics cluster and has a very high specialization in the industries that make up the cluster: nearly six times the concentration in these kinds of jobs than the United States broadly. Leveraging Wisconsin's competitive advantage in these industries is important to the state's economic development. The recommendations in this document serve to expand and diversify Wisconsin's electrification or power electronics cluster.

The recommendations within this report are organized into four strategies. Strategy 1 is a foundational strategy focused on building an institutional capacity for the power electronics cluster to grow into an ecosystem. Strategy 1, and notably the recommended steering committee, is intended to serve as a support to the implementation and long-term sustainability of the overall cluster strategy. Although subsequent strategies would benefit from stronger institutional capacity, the strategies themselves are independent, complementary, and targeted to specific cluster goals. Strategy 2 focuses on advancing research with commercial applications. Strategy 3 focuses on accelerating power electronics adoption and integration into other end-users with a strong presence in Wisconsin. Strategy 4 focuses on expanding the market for the Wisconsin electrification cluster.

Figure 4: Strategies for Wisconsin's Electrification Cluster



The strategies and their associated action items will achieve the expansion and diversification of the electrification or power electronics cluster through concrete steps to be taken by stakeholders in Wisconsin's manufacturing and economic development ecosystem. Each action item is accompanied by a description of the specific activities to be performed and designates lead and supporting organizations responsible for conducting these activities. Each action has an approximate time frame for execution, as well as a rough indication of the estimated costs to execute the action. Estimated costs and timelines are generally determined based on respective three interval scales.

Estimated Costs	Timelines
Less than $100,000	0–2 years (short-term actions)
$100,000 to $500,000	3–5 years (medium-term actions)
Greater than $500,000	6–20 years (long-term actions)

Timelines for actions are classified as short, medium, and long. Activities with a short timeline could be mostly accomplished or completed within 2 years. Those in the medium category could plausibly be conducted in 2 to 5 years. Activities with long timelines may require 6 or more years to carry out but could exhibit meaningful progress in a shorter period with prompt implementation.

Estimated Costs for actions are classified on a three-value scale. An action with lower estimated costs may be accomplished with less than $100,000. Activities in the moderate category are likely to need more investment, generally in the range of $100,000 to $500,000. Higher estimated costs indicate that the activity requires a large level of investment, likely more than $500,000.

The opportunity to build on the state's electrification cluster is greater than ever with the availability of several federal funding streams that could support several of the initiatives described in the following recommendations. Federal dollars are made available by the Department of Transportation, Department of Energy, Environmental Protection Agency focused on public transit improvements, electric vehicle (EV) and alternative fueling infrastructure, more capable power electronics hardware, and new renewable energy and energy efficiency programs. *Table 33* in *Appendix B*: Federal Funding Sources describes several federal funding sources available to help support and advance Wisconsin's power electronics cluster.

Strategy 1

Build Institutional Capacity

Economic clusters are dynamic systems where the whole is greater than the parts. When a geographic area contains a specialization of research institutions, companies and manufacturers, workers, and innovative commercial networks, the interactions of these entities can create a vibrant community, the interplay of which advances each. This combination of broader technical and management networking, advanced and technical expertise, and supply chain relationships create an environment that promotes innovation, adaptation, and training. Simply having these parts in the same area though is not sufficient: they must be integrated, they must interact in productive ways, and these relationships need to be continuously cultivated and coordinated, often supported by a government or state entity.[23] With time these clusters can thrive and grow, and eventually they become a greater ecosystem, the spill off which benefits other adjacent industries and businesses.

The growth of the Wisconsin power electronics cluster would significantly benefit from enhanced institutional capacity to serve as a focal point for the cluster, to encourage integration within the cluster, and to support implementation and sustainability of the overall cluster strategy. This institutional capacity includes a steering committee of experts guiding the strategy, a marketing campaign to create awareness of the cluster and bring new opportunities to the cluster, and a toolkit of state programs to attract and expand cluster industries. By facilitating connectivity and awareness of the state's power electronics industry, the state can better integrate and focus efforts of existing stakeholders through coordinated initiatives and promote Wisconsin power electronics both inside and outside the state.

Strategy 1, building institutional capacity, provides a broad set of action items that aim to provide cluster coordination and aid in the development of strategies 2, 3, and 4. These subsequent strategies are complimentary, and while they can be accomplished independent of each other and of strategy 1, they will be more effective and successful with strong institutional capacity to help cultivate relationships, broaden cluster opportunities, coordinate resources, and solve common problems. For example, while R&D is not necessary for greater industry adoption, more research with commercial application in the state will generate opportunities for adoption and integration. Bolstering institutional capacity will help ensure that the whole is greater than the sum of the parts. Strategy 1 provides a set of action items that frame the goals of each strategy into a single roadmap, while also directly increasing the interplay between each strategy so that they work to each's mutual benefit.

Action Item 1.1: Launch a power electronics industry conference.

- **Lead:** Wisconsin Economic Development Corporation
- **Timeline:** 0-2 years
- **Support:** Power electronics industry leaders
- **Est. Resource Requirements**: Less than $100,000

Wisconsin possesses a vibrant power electronics cluster that needs more connectivity, research activity, and diversified customer base. The annual power electronics industry conference will primarily serve to facilitate dialogue between suppliers and adopters of power electronics to improve transparency within the state's ecosystem and support small and mid-sized power electronics suppliers' R&D and commercialization.

For example, Wisconsin's small and mid-size power electronics suppliers especially continue to be overlooked by regionally- and even state-headquartered customers, leaving them more vulnerable to shocks and less competitive than their peers. Moreover, even as more manufacturing suppliers have been outsourced nationally and internationally, Wisconsin remains a critical part of the midwestern automotive supply chain. The state's proximity to these automotive clusters in the region well position it for long-term business relationships with Original Equipment Manufacturers (OEMs) and downstream parts manufacturers, both inside and outside the automotive industry. Yet, these relationships need to be cultivated and without a catalyst to build network connections, the state remains in danger of losing its homefield advantage to other national or international suppliers.

With a better sense of the state's supplier capabilities, the conference could help small and mid-sized suppliers better source components, design services, and manufacturing needs, thereby strengthening connections in the regional power electronics value chain, and capturing more economic activity for the benefit of local businesses and workers. A successful example of this type of industry conference would be the I-90 Conference in Idaho, which promotes aerospace-related business in northern Idaho. WEDC could further leverage Wisconsin's position in the automotive supply chain to build upon existing relationships, especially as automotive OEMs and downstream manufacturers throughout Minnesota, Illinois, Michigan, Indiana, and Ohio seek new more local suppliers to support increased EV production. Although the automotive industry would be an important industry to focus on, WEDC would not need to limit the conference to automotive manufacturers. OEMs that specialize in any type of manufacturing that use power electronics, such as gardening equipment or electric generators, and electrifying industries that are building new electric systems, like fabricators, would all align with the needs of power electronics suppliers in Wisconsin.

Case Study:

Coeur d'Alene Area Economic Development Corporation-Jobs Plus: Model for integrating industry stakeholders to enable regional growth

For example, the Coeur d'Alene Area Economic Development Corporation-Jobs Plus in Idaho determined assets in the region that can support aerospace manufacturing connected to industry growth in nearby eastern Washington. Jobs Plus worked with businesses and workforce service providers to facilitate collaboration between the aerospace industry and industry associations in both states and Montana, to create the I-90 Conference. The annual conference brings together aerospace businesses and service providers, creates valuable opportunities for small businesses in the region to connect with the procurement officers of large businesses, and is spurring growth of other businesses with precision technology and a strong, specialized workforce. In 2022, the conference had 260 attendees and 55 exhibitors, demonstrating that even post-COVID, in-person networking events offer significant incentives for customers and suppliers looking for more local growth opportunities.[24]

Within the industry conference, WEDC and its partners can provide additional support and promotion for manufacturers and suppliers from minority and underserved communities. For minority-owned, service-disabled veteran owned, and woman-owned businesses, additional barriers to entry exist that discourage entry and expansion. WEDC can engage the Wisconsin Supplier Diversity Program as a conference partner to promote relationships between prospective customers and power electronic suppliers from minority and underserved communities.

The first power electronics industry conference can be used to generate excitement about the strategies discussed in this report and momentum for future engagement. As a kickoff event to strengthen Wisconsin's power electronics cluster, WEDC should coordinate the inaugural power electronics industry conference. WEDC is suited to facilitate this initiative with interests aligned with several key regional and local stakeholders in the business development, job creation, partnership building, sustainability, and strategic investment worlds as well as preliminary engagements with power electronics suppliers and leaders.

After the kickoff year, WEDC can use the inaugural event to present a vision for the state's power electronics cluster, starting with how the steering committee (discussed in Action Item 1.2) can be a leading mechanism to discuss, iterate, and execute on many of this report's recommendations and action items.

Action Item 1.2: Convene a Steering Committee of power electronics and electrification experts.

- **Lead:** Power electronics industry leaders
- **Support:** Wisconsin Economic Development Corporation, UW and private research universities, Wisconsin Electric Machines and Power Electronics Consortium
- **Timeline:** 0-2 years
- **Est. Resource Requirements:** Less than $100,000

Following the momentum generated by the state's first power electronics industry conference, the steering committee will generate collaboration and connectivity within the state's power electronics cluster, identify gaps in the ecosystem, and inform the development and growth of the future programs and initiatives. Convening the steering committee will be led by industry leaders identified during the organization and execution of the power electronics conference (discussed in Action Item 1.1) with support from WEDC, the state's research universities, and other organizations such as WEMPEC. Once the steering committee is convened, WEDC's involvement will focus on facilitating steering committee meetings and serving as the corridor between power electronics and electrification stakeholders and state funding opportunities and investment mechanisms for ecosystem activities. WEDC should maintain representation at each steering committee gathering. Ultimately, participants of the steering committee will drive meeting agendas, focus areas, cross-sector initiatives, and partnership building to advance Wisconsin's power electronics cluster.

In terms of potential representatives on the steering committee, there are plenty of options of industry, academic, nonprofit, and public members that could play a valuable role in supporting the development of Wisconsin's power electronics ecosystem. For example, Wisconsin is home to several large power electronics industry leaders such as Generac, Kohler, Briggs & Stratton, Cummins Emissions Solutions, Regal Rexnord, Milwaukee Electric Tool, Johnson Controls, Rockwell Automation, Eaton, Oshkosh Corporation, ABB, and more. A number of small, midsize and startup companies are also active in the state, including COnovate, Blue Line Battery, and Silatronix. Wisconsin is also home to academic institutions like the University of Wisconsin at Madison (UW-Madison), University of Wisconsin at Milwaukee (UW-Milwaukee), Marquette University, and Milwaukee School of Engineering that provide a strong base of researchers and talent that focus on electrification technologies and clean energy research. The steering committee should also include representation from Wisconsin's Technical College System and Vocational Public High Schools to include alternative education program pathways to power electronics. Other electrification leaders and invested stakeholders could come from existing manufacturing or economic development partnerships within the state such as the Wisconsin Center for Manufacturing and Productivity.

The steering committee should feature the relevant policy and government staff from the Wisconsin Department of Transportation (WisDOT) and the Office of Sustainability and Clean Energy. A steering committee, made up of leaders within Wisconsin's electrification cluster, will work together to continually define cluster goals, support elements of the other strategies, provide feedback on existing and proposed policies and programs, and create a space for ecosystem participants to identify ecosystem gaps or seek opportunities for partnership. Pertinent steering committee members could also serve on the research consortium (action item 2.1), support the commercialization consulting team (action item 2.2), or help activate the mentorship network (action item 2.3). Further, the standing body could advise WEDC how best to allocate federal or state funding dollars for workforce development, business development, or infrastructure investments into Wisconsin's power electronics ecosystem. Lastly, the steering committee could present annual updates and future project plans to industry at the annual industry conference discussed in Action Item 1.1.

Action Item 1.3: Launch a "WI Are Electric" marketing campaign to attract funding and partnerships and raise awareness of Wisconsin's specialization in power electronics.

- **Lead:** Wisconsin Economic Development Corporation
- **Timeline:** 0-2 years
- **Support:** key strategic industry partners
- **Est. Resource Requirements**: $100,000-$500,000

Highlighting Wisconsin's specialization in power electronics and its electrification cluster would help attract talent, companies, R&D funding, and partnerships with other states with specialties along the electrification supply chain. As WEDC develops the power electronics marketing campaign in tandem with new power electronics ecosystem funding and assets, you begin to create a positive feedback loop, where new assets and activities feed and support each other, multiplying the impact of these efforts. For example, as the State's applied research capabilities increase, the opportunities for publication in existing power electronics research journals increases, which sheds light on Wisconsin's power electronics research capabilities to an external audience and gives the State another talking point in any promotion or marketing strategy. For example, Institute of Electrical and Electronics Engineers (IEEE) Power Electronics Society publishes the Journal of Emerging and Selected Topics in Power Electronics, which boasts leading power electronics academic researchers from across the world.[25] Generally, however, the target audiences for this marketing campaign are wide, ranging from students, researchers, companies, and institutions located outside of Wisconsin. From the talent perspective, greater knowledge of the power electronics activity and opportunities in Wisconsin could attract students and recent graduates to the area.

Raising general awareness of Wisconsin's advantages in these areas could also raise awareness to the rest of the country about what goes into wider adoption of electric and clean technologies, and support Wisconsin's existing power electronics firms, since the state specializes in the more behind-the-scenes components. As one stakeholder interviewed said, it is usually not as exciting to people that Wisconsin makes the generators powering a local K-Mart. People are used to associating electric technology with the envelope-pushing, innovative developments made by universities and R&D at the outer edges of what is possible. People would gain a more practical and accurate understanding of electric technology usable today and soon with a sense of Wisconsin's power electronics cluster and where it fits in the stream of electric products (upstream).

Greater connectivity with other midwestern states could create opportunities for larger partnerships or collaborations, generating more value and notoriety for Wisconsin's power electronics ecosystem. For example, drawing attention from other states that specialize in other stages on an electric-future supply chain will also help naturally grow efficient industrial partnerships and speed up the implementation and adoption of electric technologies. Other midwestern states specialize more in downstream products related to electric vehicles, for example. As other states with different electric specialties become aware of Wisconsin's strengths, there will be opportunities to collaborate for an electric future.

To support the marketing campaign, WEDC should require that all power electronics assets existing or created and recipients of its funding be strategically cobranded under a phrase like "WI Are Electric" (said like "We Are Electric"). Conferences, literature, and central spaces used by the ecosystem would be opportunities to market Wisconsin's specialization in the power electronics space. People could find resources online related to the State's ecosystem offerings through this kind of brand marketing. WEDC should also require participation in its power electronics events or programming, as well as require testimonials, to qualify for funding through WEDC channels. These strategic branding efforts will help bring attention to Wisconsin's electrification cluster. In summary, a marketing campaign would be especially useful to forging customer-seller partnerships with other midwestern states that specialize in different electric components (e.g., EV production). It would also raise general awareness about the larger supply chain of electric technology, beyond frontline innovation, and potentially attract talent and funding as a result. To make the campaign successful, WEDC should require that all assets existing or created and recipients of its funding be strategically cobranded and require participation in power electronics events or programming and testimonials for funding.

Action Item 1.4: Create a dynamic toolkit to support the power electronics industry.

- **Lead:** Wisconsin Economic Development Corporation
- **Support:** Wisconsin Department of Transportation, Public Service Commission
- **Timeline:** 6-20 years
- **Est. Resource Requirements**: Greater than $500,000

While our recommendations focus heavily on building collaboration and connectivity within Wisconsin's power electronics cluster, industry growth depends on aligning state programs to make it easy for power electronics businesses to launch, grow, and relocate to Wisconsin. This concerted effort to recruit mature companies and support the expansion of incumbent power electronics companies could be through various tools, including infrastructure or capital grants, financial incentives for hiring and growth objectives, state-sponsored internship/apprenticeship programs, and more.

Creating an industry "concierge" could be a useful part of that toolkit. The concierge would be a central source of information about power electronics in Wisconsin; WEDC could designate a staff member or team to be called upon and keep a network of informers (e.g., Wisconsin Department of Transportation, Public Service Commission) on the power electronics industry. The concierge would have the knowledge to direct industry representatives to specific state offices or programs, streamlining Wisconsin's state support to power electronics firms. In addition to fostering more conversations with industry players within Wisconsin, establishing an industry concierge could help facilitate economic connectivity with the rest of the Midwest—and bring business from the rest of the Midwest into Wisconsin. Centralizing industry information will help efficiently foster more sales connections and industry players find more applications of power electronics technology.

Space Florida offers an example of a model in which a state agency leads an integrated industry recruitment strategy that involves close partnerships with the private sector and a dynamic toolkit of business incentives and support programs.

Case Study:

Space Florida: Dynamic toolkit to support Florida's space industry

In 2006, the Florida Legislature passed the Space Florida Act, merging three space entities into a single new organization called Space Florida. [26] Prior to this legislation, the state's aerospace industry lacked visibility, strategic direction, and an informed, single point of contact for businesses and entrepreneurs. [27] Space Florida is a unique economic development organization that can earn profit, borrow, and lend money, and partner with public and private entities to strengthen Florida's position as a global aerospace hub. Space Florida's activities fall broadly into four mission areas: 1) increase investment activity, 2) maximize capacity and capability, 3) accelerate innovation, and 4) enable statewide industry growth. Since its creation, Space Florida has successfully become the industry point of contact with the human capital, connections, resources, and partnerships with research and testing facilities across the state to serve all types of stakeholders in the industry. Now, Space Florida can lean on the state's distinct advantages and assets for the space industry, making its programs that support ease of doing business in the state more attractive.

To maximize capacity and capability and enable statewide industry growth, Space Florida can rely on a unique toolbox to financially entice aerospace businesses to locate and grow in Florida. The organization offers conduit financing, synthetic leases, and property or infrastructure acquisition from government entities on behalf of a business. In terms of impact and industry support, the organization can collaborate directly with banks to create innovation and business development opportunities for the aerospace ecosystem. For example, Space Florida worked with two local commercial banks to finance over $45 million for a new manufacturing facility and high-value equipment for two aerospace companies to operate and create over 400 jobs in Florida.[28, 29]

Based on its creation and state mandate, Space Florida has found unique ways to support and incent mature companies to come to Florida and grow in the state.

Strategy 2

Advance research with commercial applications

Strategy 2 focuses on promoting R&D in applications of electric motor and generator technology applicable to industries outside of itself with large presence in Wisconsin, such as Small Electrical Appliance Manufacturing; Measuring, Dispensing, and Other Pumping Equipment Manufacturing; Major Household Appliance Manufacturing; All Other Miscellaneous Fabricated Metal Product Manufacturing; and Air-Conditioning and Warm Air Heating Equipment and Commercial and Industrial Refrigeration Equipment Manufacturing. The most innovative and successful approaches to commercialization at research institutions require strong university-industry collaboration and ecosystem connectivity.

Action Item 2.1: Establish a consortium of electrification university research labs and industry representatives.

- **Lead:** University of Wisconsin-Madison Office of Business Engagement, University of Wisconsin-Milwaukee Research Foundation, Marquette University Office of Economic Engagement, Milwaukee School of Engineering Office of Corporate and Foundation Relations
- **Timeline:** 3-5 years
- **Support:** Wisconsin Economic Development Corporation, Wisconsin Alumni Research Foundation, University of Wisconsin System, Wisconsin Technical College System, WiSys
- **Est. Resource Requirements**: $100,000-$500,000

A consortium of electrification university research labs and industry representatives can energize inter-institutional and industry collaboration within the ecosystem through ideation, problem-solving, research project design, and industry engagement. The consortium can be a difference-maker for Wisconsin power electronics by yielding more research with commercial applications and testing opportunities.

In a recommendation in *Wisconsin's Electric Vehicle/Electrification Supply Chain Strategy 2023*, we proposed a "manufacturing innovation consortium" to build relationships between innovations and industry through collaborative applied research. Although it is broadened here, the justification of our original recommendation still applies to Wisconsin power electronics. There is more that needs to be done to increase collaborative research and identify opportunities for commercialization in the state. A consortium of electrification university research labs and industry representatives helps the state better align technology R&D in academia with industry needs, increasing the opportunities for commercialization and technology transfer.

The economic engagement and technology transfer experts of core academic institutions in Wisconsin, including the University of Wisconsin-Madison Office of Business Engagement, University of Wisconsin-Milwaukee Research Foundation, and Marquette's Office of Economic Engagement could help lead the creation of the consortium by inviting their institution's electrification researchers, research labs, and relevant industry connections to participate, and help sort out the planning and logistics behind collaborative research, project investments, and licensing and technology transfer agreements.

The previous assessment of Wisconsin's EV supply chain identified several large companies with advances in the electrification of engines and power systems (e.g., Generac, Harley Davidson, Briggs & Stratton, Kohler, Rockwell) and academic research centers or consortiums (e.g., Wisconsin Electric Machines and Power Electronics Consortium or WEMPEC) focused on electrification technologies and clean energy research that could serve as members of a statewide collaborative research effort. However, it is important to receive input from key stakeholders and leaders, especially those participating on the recommended Steering Committee. The Steering Committee may have core recommendations and ideas for researchers and industry representatives to participate in the consortium, especially those who have the capacity or an idea for a collaborative research project.

Alongside economic engagement experts from Wisconsin's academic institutions, WEDC, Wisconsin Technical College System, and University of Wisconsin System can support the creation of the consortium by developing an inventory of electrification research initiatives, labs, and testing facilities that can be used as sites for collaborative research. It is important to ensure the map of these sites is distributed throughout the state: innovation and industry growth relies on including historically underserved entrepreneurial businesses and workers in the state. R&D is already widely distributed throughout the state: even just within Regal Rexnord Corporation, R&D positions in the industry are open from the southernmost part of the state in Beloit to the northern coast in Marinette, as well as in Madison and Milwaukee.

The consortium could work with private and public universities to expand public lab and testing opportunities for researchers and companies. The demand for public research and testing facilities often exceeds capacity. Without building new space for these activities, power electronic manufacturers could partner with existing R&D labs, testing facilities, and other innovation centers/coworking spaces to increase research/testing capacity by extending operating hours or providing funding for staffing and facility upkeep.

Existing research centers like WEMPEC, the Massachusetts Life Sciences Center's Neuroscience Consortium, and the Wisconsin Energy Institute provide examples of how this type of research and industry engagement can be done.

Case Study:

WEMPEC: Facilitating industry and academic collaboration through a membership/sponsorship model

Created in 1981 with the goal of becoming a hub for power electronics and electromechanical power conversion and their applications, WEMPEC provides an existing model for an industry-sponsored technology-focused research center with a team of University of Wisconsin-Madison professors, faculty, staff, researchers, and engineers. WEMPEC's primary research focuses are advanced machines, power converters, and controls & sensor technology.[30]

WEMPEC was created by a group of University of Wisconsin-Madison faculty in electric machines who recognized the need to expand the university's program to become a key player in the emerging field of energy research and power electronics. To support this proposed growth at the institution, faculty gained the support of a small group of industry contracts, including Allen-Bradley Company and the Eaton Corporation, which eventually worked with university faculty on the expansion proposal. Together, the proposal led to the creation of WEMPEC, intending to build close working relationships between faculty, students, and industrial sponsors. WEMPEC would emphasize generic research projects of a basic and widely applicable nature so researchers could quickly communicate the results and add value for industry sponsors.[31] WEMPEC's sponsorship model could be built upon for a research consortium. Its sponsorship model provides industry partners access to faculty research and graduate students, results of long-term research, technology transfer opportunities, and license benefits for intellectual property in exchange for an $17,500 annual membership fee. The model is mutually beneficial, providing industry with unprecedented access to emerging power electronics research and talent and the funds go back to graduate students through research assistantships, tuition remission support, funds for research laboratory equipment, and funds for program staff. WEMPEC industry members include a wide range of engine and power systems for a wide range of applications. Notable members include John Deere, Lockheed Martin, Rockwell Automation, Oshkosh Corporation, Nissan Research Center, and Ford Motor Company.

Ultimately, WEMPEC is a valuable model for industry-academic research collaboration, which Wisconsin can leverage to create its own consortium of electrification university research labs and industry representatives that drives more research with commercial applications and testing opportunities. However, if creating the new entity with representation across the state's other academic institutions is too large of a burden, there could be an opportunity to support WEMPEC's expansion to allow for applied industry-driven research projects.

Industry partners do not directly dictate the specific research projects conducted at WEMPEC. In contrast, another potential model centers on client-sponsored R&D, in which industry partners pay a consortium of innovators a fee to undertake specific research projects. Under this client-sponsored R&D model, the financial incentives better align academic research to the needs of industry. Organizations such as the Massachusetts Life Sciences Center have seen much success using this model to strengthen industry-academia collaboration.

Case Study:

Massachusetts Life Sciences Center: Facilitating industry and academic collaboration through the Neuroscience Consortium

The Massachusetts Life Science Center's (MLSC) Neuroscience Consortium is reflective of the goals and organization of the proposed consortium of power electronics-researchers. The Neuroscience Consortium's focus is to facilitate dialogue and collaboration between industry and academia. Consortium membership is composed of both Massachusetts-based researchers and industry partners.

Organizationally, the Neuroscience Consortium relies on the commitment of member biotech companies, such as AbbVie, Biogen, Celgene, and Novartis, to identify research needs and design novel projects with a translational focus. These projects are then shared with researchers who apply for research funding provided by the biotech companies. In the consortium's first call for proposals in 2012, industry members Abbott, Biogen Idec, EMD Serono, Janssen Research & Development, Merck, Pfizer, and Sunovion Pharmaceuticals all contributed $250,000.[32]

Given significant legal and other barriers involved in collaborations in the biotech industry, MLSC has been touted for bringing together academic and industry stakeholders, enabling collaboration and project-funding that would otherwise not exist. Since 2013, the consortium has raised almost $10 million in industry commitments for pre-clinical neuroscience research projects of 30 principal investigators in the state.

Case Study:

Wisconsin Energy Institute: Collaboration Between Clean Energy Research and Industrial Application

The Wisconsin Energy Institute (WEI), administered by the Office of the Vice Chancellor for Research and Graduate Education at UW-Madison, is the collaborative nexus of energy research and education at the University of Wisconsin-Madison.[33] Scientists and engineers lead WEI to transition toward new, clean energy systems and solutions. The Institute's core research areas are electricity systems, transportation and fuels, and sustainability and society. It partners with industry through inventions for licensing technologies, sponsoring research, collaborating on grant proposals, joining research consortiums, sharing information and materials, as well as sponsoring education, outreach events, and student competitions. The building is designed as a translational space for peer researchers and private industry representatives to produce marketable green technology.

WEI employs undergraduate students, graduate assistants, postdoctoral researchers, and research scientists from a wide range of disciplines, including plant chemistry, fusion energy, power electronics, and the economics of energy.[34] WEI attracts industry representatives with opportunities to collaborate with WEI on research and competitive proposals. WEI also helps broker relationships between researchers and federal government representatives with overlapping research interests from agencies such as the Department of Defense, Department of Energy, National Science Foundation, and Department of Agriculture.

WEI offers researchers communications and marketing support, planning and management, human resources, information technology support, and post-award research financial administration. Additionally, WEI routinely compiles a list of federal and non-federal funding opportunities around energy research and offers pre-award communications consultation and research administration. The Institute will also provide media relations to help craft and distribute news and offer media training.[35] WEI offers another important model for a research consortium with a unique combination of interdisciplinary researchers, collaborative working spaces, industry partnerships, and support resources to enable clean energy applied research and commercialization.

Action Item 2.2 Establish a power electronics commercialization consulting team.

- **Lead:** Wisconsin Alumni Research Foundation, University of Wisconsin-Milwaukee Research Foundation, Marquette University Office of Economic Engagement
- **Timeline:** 3-5 years
- **Support:** Wisconsin Economic Development Corporation, state startup support, accelerator, and incubator organizations
- **Est. Resource Requirements**: $100,000-$500,000

In the medium- to long-term, Wisconsin's power electronics cluster could benefit from an innovation consulting team that can support its collaborative applied research consortium and other commercialization activities.

The power electronics commercialization consulting team would likely be a natural extension of the electrification consortium discussed in action item 2.1 and built from internal stakeholders, snowball to their connections, and supplement external experts as needed. Members of the consulting team should understand Wisconsin's power electronics environment.

Research consortiums are often supported by a team of technical, commercialization, and regulatory experts that increase the likelihood of successful technology translation for power electronics technologies developed by power electronics researchers. On the technical side, the consulting team should consist of experts with deep engineering experience and an emphasis on bridging the gap between early-stage prototypes developed in academic labs and advanced prototypes that meet industry engineering standards and are ready for user testing. Experts may have specific technical power electronics areas of expertise (e.g., solar applications, electric vehicles, performance modeling, power transfer) to support researchers conducting related research. The regulatory team would be dedicated to regulatory compliance, commercialization, and IP generation.

It is important to note that Wisconsin has access to commercialization experts with established, supporting organizations like WARF and its intellectual property, health and safety, licensing, contracts and accounting, and subject-matter specialists. The University of Wisconsin-Milwaukee and Marquette University Office of Economic Engagement have similar areas of expertise but a smaller scope than WARF. They provide innovation training and strategic partnerships/corporate engagement, technology transfer, and licensing support to their institution's communities. The Advanced Research Projects Agency and National Robotics Engineering Center all show how a dedicated, experienced team can impact research innovation and commercialization efforts.

Case Study:

Advanced Research Projects Agency: The Tech-to-Market Team's value-add for funded research teams and technology translation

The Advanced Research Projects Agency (ARPA-E), housed with the Department of Energy, is mandated to advance high-potential and high-impact energy technologies for private-sector investment and societal application. ARPA-E understands that this translation-focused research requires human capital expertise to help the transition for lab to market.[36]

To accommodate funded startups, universities, and other research institutions advanced the commercial viability of their technology, ARPA-E built the Tech-to-Market Team (T2M), a group of commercialization advisors who work with funded teams to expedite private-sector deployment of new technologies. T2M provides teams with market insights to inform the design and launch of projects, skills such as market analysis and product research, ideation sessions on commercialization opportunities, and potential financiers to support continued technology development. T2M Advisors are full-time, partially remote positions that are required to serve for at least three years. Advisors require strong technical backgrounds, diverse work and business experiences, and impeccable communication skills to support funded teams.

Case Study:

National Robotics Engineering Center: Robotics R&D projects led by staff with deep technical knowledge

Carnegie Mellon University's National Robotics Engineering Center (NREC) brands itself as the world's largest robotics research and development organization.[37] The 100,000 square foot facility includes two high-bays, large lab spaces, a prototype fabrication shop, large sites for outdoor testing, and more. NREC is run mostly by robotics experts with significant engineering or science backgrounds.15% of NREC's staff are project support staff who focus on business development, technology transfer, commercialization, and administrative activities. Its team integrates over 700 years of combined robotics experience to support major clients including NASA and DOD, as well as a variety of collaborations and development projects with industry and startups.[38]

Ultimately, NREC's staffing capabilities drive its INNOVATE™ Process to understand client needs and maximize success for applied robotics developments and research projects. This process requires NREC staff to be able to assess the client's problems and objectives, analyze technical/business requirements and constraints, invent technology, develop prototypes, test, and demonstrate engineered solutions, and license, transfer, and commercialize the developed technology.[39] NREC emphasizes the importance of a knowledgeable and experienced staff for supporting applied robotics R&D projects focusing on technology transfer and commercialization.

Action Item 2.3: Establish a "hard tech" entrepreneurial mentorship network that connects experienced entrepreneurs and investors to promising power electronics, mechanical engineering, and advanced manufacturing startups or researchers seeking to commercialize new technologies.

- **Lead:** electrification consortium from Action Item 2.1, key strategic industry partners
- **Support:** Wisconsin Economic Development Corporation, state startup support, accelerator, and incubator organizations
- **Timeline:** 6-20 years
- **Est. Resource Requirements**: Greater than $500,000

In a recommendation in *Wisconsin's Electric Vehicle/Electrification Supply Chain Strategy 2023*, we proposed a "hard tech" entrepreneurial mentorship network to enhances academic-industry collaboration and commercialization efforts in Wisconsin to build relationships between innovations and industry.

This recommendation directly applies to enhancing Wisconsin's power electronics cluster by creating pathways for startups and researchers to engage with and learn from industry, investors, customers, and commercialization efforts by building around an opportunity or idea. Like action item 2.2, establishing a "hard tech" entrepreneurial mentorship network can be framed as a long-term extension of the electrification consortium from action item 2.1.

The creation of a mentorship program becomes more feasible when established in conjunction with other created assets, such as the steering committee, consortium for collaborative research projects, and innovation consulting team – especially in the context of identifying leaders of the mentorship network should lean on existing or newly created assets to find mentors for the network or sponsor participation of startups or researchers seeking to participate. For example, there could be some crossover between an innovation consulting team and program mentors.

Additionally, the consortium of researchers could likely serve as program ambassadors and refer academics or graduate students at their home institutions and research labs to the mentorship program. It is important to utilize existing assets or newly created assets, in conjunction, to maximize the connectivity between key power electronics stakeholders (e.g., large companies, startups, academic researchers) and economic impact for Wisconsin's power electronics ecosystem.

Compared with the amount of entrepreneurship activity in Wisconsin that is focused on the life sciences and information technology, there are relatively few entrepreneurs developing startups in power electronics and advanced manufacturing technologies. Stakeholders have attributed this absence to a lack of EV innovators with entrepreneurship experience and networks needed to build and grow startups. Without access to more experienced entrepreneurs and the professional networks that guide founders through a startup's early stages, many entrepreneurs are unable to overcome the business, legal, and financial barriers despite possessing promising ideas and technologies.

To cultivate an entrepreneurial ecosystem focused on "hard tech"—technology based on tangible hardware—Wisconsin should consider establishing an entrepreneurial mentorship network which connects experienced entrepreneurs and investors to promising startups developing new power electronics, mechanical engineering, and advanced manufacturing technologies.

While similar programs exist throughout Wisconsin (e.g., Merlin Mentors, UW-Madison's Discovery to Product, UW-Milwaukee/UWM ENGAGE Mentor Program, UW-Madison's ACE Program for Entrepreneurs, BizStarts), a mentorship network dedicated to the "hard tech" space will address the commercialization challenges unique to technology development in EV and advanced manufacturing. Such a network can moreover serve as a commercialization resource for academics to better gauge the market viability of new technologies developed in the lab.

As the case study on the HAX Accelerator below demonstrates, an entrepreneurial network would greatly benefit from the involvement of venture capitalists well-versed in the hard tech space. These venture capitalists can potentially offer access to suppliers, facilities, manufacturers, and local experts who otherwise would be out of reach for founders on their own. Likewise, the case study on the Creative Destruction Lab offers a model for how Wisconsin's hard tech entrepreneurial mentorship network might be set up. CDL's academia-private industry partnerships, highly skilled mentor-led workshops, and networking opportunities with experts and investors all would cultivate the existing assets within Wisconsin's electrification cluster and grow new opportunities. Though the scope and scale of the HAX Accelerator and the Creative Destruction Lab greatly exceed that of the proposed mentorship network at its outset, both are nevertheless useful case studies on the importance of entrepreneurial communities and knowledge networks in developing successful startups.

Case Study:

HAX Accelerator: An Established Model for Helping Hardware Startups Achieve Market Viability

HAX is a hard tech accelerator providing funding and resources to startups developing hardware, robotics, and connected devices. The accelerator program is run by the venture capital firm SOSV and has offices in San Francisco, Shenzhen, and Tokyo. In 2021, HAX announced that it will build a new state-of-the-art facility in Newark, NJ to house its new U.S. headquarters.[40]

The accelerator program consists of 180 days that is divided into 3 phases. The first phase entails rapid product development for startups with submitted initial prototypes and market strategies. Each startup receives a $250,000 seed investment and collaborates with HAX's in-house team of engineers, designers, and entrepreneurs. Much of the work conducted in this phase involves iterating through low-fidelity prototypes and testing to better understand customers, markets, and technology roadmaps. Importantly, HAX grants teams access to its proprietary network of local experts, investors, manufacturers, and supply chains. As startups reach critical milestones in the second phase, HAX support shifts to fundraising strategy development, investor introductions, and continued investment into follow-on rounds from Pre-Seed to Pre-IPO. The third phase involves onward support and continued participation in the HAX community as the startup matures.

According to HAX, the most valuable part of the program is engagement with a globally diverse community of startup founders whose experience and expertise are shared with the program's entrepreneurs. Over time, this community has grown to include a curated group of mentors, experts, and partners, giving early-stage startups the global reach and resources of far larger organizations. To date, over 250 startups have completed the program.

Case Study:

Creative Destruction Lab: A Successful Entrepreneurship Network in Wisconsin

CDL-Wisconsin is a nonprofit innovation and entrepreneurship organization located at the University of Wisconsin-Madison. It is partnered with the Wisconsin School of Business and the School of Computing, Data and Information Sciences, leveraging the technical and professional expertise available. The program provides opportunities to prospective tech entrepreneurs and startups by offering a diverse group of mentors from academia and the private sector to guide and advise aspiring innovators. Specializing in two industry streams, risk management and health and wellness, the lab offers expert advice, funding opportunities, research analysis, and business development support. Additionally, the lab's specially designed workshops, mentoring sessions, and the overall environment foster collaboration, creativity, and future-oriented approaches to emerging industries and disruptive technologies. CDL-Wisconsin is part of the larger worldwide CDL network that supports science- and technology-based startup companies, capitalizing on their international alumni network of talent and experience.[41]

CDL-Wisconsin is a model for Wisconsin's own hard tech entrepreneurial mentorship network. While ambitious to emulate initially, establishing a strong entrepreneurship network with ties between academic researchers, private sector experts, and forward-thinking investors would benefit local innovators, entrepreneurs, and early-stage startups. Wisconsin's electrification cluster already possesses the talent, expertise, and innovative-research assets, but it needs to be deliberatively cultivated to reach its full innovative potential. Expert-run mentoring workshops and funding opportunities, all organized at a central hub will ensure that aspiring startups and technical experts (e.g., engineers, electricians, researchers) collaborate to advance and commercialize new technologies; it will incentive these new companies to seek opportunities locally in Wisconsin rather than at existing hubs out of state; and it will encourage Wisconsin industries to remain competitive and well equipped with the latest technologies and practices.

Strategy 3

Accelerate adoption and integration of power into other end-users with strong presence in Wisconsin

To electrify Wisconsin, innovative manufacturers must create and introduce new electric systems, all of which will need new electrical components. Wisconsin is well positioned to take advantage of this seismic shift as many of its electrical manufacturing industries are upstream component parts manufacturers. As electrification continues, these upstream suppliers are well suited to establish relationships with new prospective end-users and could easily be integrated into the burgeoning electric supply chain. To ensure that Wisconsin's electrification cluster grows, WEDC must cultivate relationships between local upstream suppliers and prospective customers and encourage innovative practices that will bolster the adoption and integration of power electronics into new electric systems. By focusing on industries that already have a strong presence in the state, WEDC will build out the existing economic cluster, expand and decarbonize existing industries in the state, and, with more localized supply chains, solidify strong resilient economic growth.

Action Item 3.1: Establish an equipment and space purchasing program for manufacturing SMEs that help the state meet clean energy objectives.

- **Lead:** Green Innovation Fund
- **Support:** Wisconsin Economic Development Corporation, Small and mid-sized enterprises, Wisconsin banks, credit unions and other commercial lending partners.
- **Timeline:** 1-3 years
- **Est. Resource Requirements**: Greater than $500,000

Small and mid-sized enterprises (SMEs) face difficulties in securing the space, physical infrastructure, and equipment needed for continued growth. As electrification continues, local SMEs are in danger of missing an opportunity to expand into a new burgeoning market space, or of being left behind altogether. To address the gap in support for SMEs, WEDC should consider a capital infrastructure support program for growing companies with a demonstrated need for additional facilities. The Green Innovation Fund (GIF), administered by WEDC, has the purpose of leveraging public and private financing to invest in projects that provide environmental and clean energy solutions. GIF is a good candidate to lead the support program because of its green focus and to increase the program's scope and potential impact, should consider opening the opportunity to manufacturing SMEs contributing to Wisconsin's clean energy objectives. WEDC could review program applications for SMEs contributing to one of the four key pathways identified in the clean energy plan to meet the state's energy objections, including 1) accelerate clean energy technology deployment, 2) maximize energy efficiency, 3) modernize buildings and industry, and 4) innovate transportation. [42] WEDC may consider partnering with the Wisconsin Office of Sustainability & Clean Energy to review applications and help make financing decisions.

Establishing this support program could subsidize the leasing or purchase of facilities as well as the acquisition of other physical equipment that SMEs need to expand. Also, the program could provide support for capital equipment purchases and facilitate partnerships between manufacturers and nonprofit partners that offer technical and business development assistance.

Support could be awarded on a 1:1 cost share basis, such that every incentive dollar is matched by one dollar of investment from the awardee. This program can be extremely valuable for Wisconsin SMEs, for example, by providing the capital investment needed to compete with larger more resource-rich companies and become one of the main suppliers of power electronics in the Midwest.

Considering the difficulties many rural SMEs face, the USDA Rural Business Development Grant could be a model for Wisconsin to emulate when considering a local SME support program.[43] Although grant funding is funneled through rural public entities to support SMEs directly, the grant is flexible, has no cost sharing requirements, and allows SMEs to eventually direct grant funds to their needs, be it training, equipment, or space. As local SMEs seek to make inroads with customers electrifying their business, they will need to keep up with increasing demand. A flexible program will keep rural and small power electronics business in Wisconsin nationally competitive and will ensure that they can build out capacity tailored to the needs of their growing customer base.

Action Item 3.2: Fund and promote power electronics implementation & R&D centers.

- **Lead:** University of Wisconsin System, Wisconsin Technical College System, small and mid-sized enterprises, research & development centers, steering committee from Action Item 1.2, electrification consortium from Action Item 2.1
- **Support:** Wisconsin Economic Development Corporation, National Institute of Standards and Technology, U.S. Department of Energy, U.S. Economic Development Administration
- **Timeline:** 10-20 years
- **Est. Resource Requirements**: Greater than $500,000

As electrification continues, there will be an increased need to develop and implement various types of power electronics, many of which may already be produced, into new, more efficient electrical systems and machinery. Whereas a consortium (Action Item 2.1) focuses on increasing the opportunities for collaborative research and commercialization in Wisconsin's electrification cluster, implementation and R&D centers can advance technology integration and adoption efforts.

These centers would function as venues in which researchers and end-users interface to apply the technology in the real world, thereby creating a virtuous cycle in which the application of technologies generates user feedback and improves the development and deployment of new technologies. Implementation centers add value to products of collaborative research and early-stage companies that may not have the infrastructure for testing to accelerate adoption. They can also help small and mid-sized power electronics suppliers with established power electronics technologies diversify their applications and customer base.

Implementation centers should strategically focus on region-specific economies. For example, as Wisconsin builds out its electrification cluster, eastern counties near and including Manitowoc and Sheboygan that have a strong metal fabrication or foundry industry may be well served to host an implementation center that specializes in power electronics for fabricators and foundries.

Other areas in southeastern Wisconsin may place a greater focus on centers that integrate power electronics into automotive manufacturing, especially in EVs where standardization is less prevalent.

At a more granular level, these centers serve as a hub that can connect early-stage or small- and medium-sized businesses to expertise and business development opportunities and ease barriers to adoption via access to workforce training and capital improvement opportunities. By demonstrating the opportunities afforded by adoption and the types of workforce and capital investments needed, implementation centers would help local suppliers and customers in Wisconsin make informed decisions and targeted investments in technology integration.

Although each center would tailor its activities and programs to the needs of its regional economy, the centers would be connected by a common set of standard operating procedures and a management team that works closely with the leadership of each center as well as with the host institution. Implementation centers would likely be affiliated with an existing university or technical college in Wisconsin. The steering committee of power electronics and electrification experts discussed in Action Item 1.2 can play a critical leadership role in the organization and management of implementation centers in Wisconsin. The steering committee's involvement in establishing and supporting this initiative should fuel cluster-wide buy-in across power electronics leaders into the implementation and R&D centers. Support from and engagement with the host institution will be critical to the success of each implementation center, and topics such as the degree of user access and how resources will be shared will need to be negotiated with each host institution.

Case Study:

UMichigan's Mcity Test Facility: A regional hub for autonomous vehicle research and innovation

With help from a substantial National Science Foundation grant, the University of Michigan has built and grown a large autonomous vehicle (AV) testing ground with state-of-the-art instrumentation, sensors, and multiple surface roads to test AV prototypes and refine applied algorithms for AVs. The facility supports an advanced data science center, a simulation center to perfect AV algorithms, and a physical testing space to apply those algorithms to AVs. This hugely attractive facility, known as Mcity, has positioned the University of Michigan as a leader in AV technologies by giving researchers, technical experts, and interested industry leaders the opportunity to test and advance AV prototypes. Current industry partners include Ford, Honda, and Toyota, all benefiting from access to the facility and its researchers. Mcity also publishes working papers that detail relevant discoveries or failures that may interest the broader AV community. The facility provides additional real-world training to University of Michigan students, who can apply their theoretical knowledge and work with industry leaders before graduation.[44]

Wisconsin could benefit from similar implementation centers for power electronics. A smaller, less research-focused power electronic implementation centers for green technologies such as solar cells, semiconductors, or electric vehicles would be a practical way to integrate the state's electrification cluster into a broader green technology industry, and it would attract a small but potentially vibrant advanced green technology R&D.

Case Study:

DOE Combined Heat and Power (CHP) Program: Technical Assistance Partnerships role in improving the environment for CHP installations in the United States

Combined Heat and Power (CHP), also called cogeneration, is a technology that enables simultaneous, onsite production of electricity and heat. DOE's CHP Deployment program creates and disseminates resources to help stakeholders identify CHP market opportunities and potential CHP solutions. It supports implementing CHP systems in industrial, federal, commercial, and other sectors. One of the program's significant features is regional Technical Assistance Partnerships (CHP TAPs) which form a nationwide network of energy experts who help execute program goals on the ground. These partnerships are awarded to universities and research centers (e.g., Houston Advanced Research Center, University of Illinois Chicago, University of Maine) whose goal is to positively influence the environment for CHP technology in their region.[45] Home institutions are awarded $500,000 annually from DOE to run one CHP TAP Region that covers several states.

TAP's primary activities are technical assistance, end-user engagement, and stakeholder engagement. Technical assistance involves free consulting services to facilities interested in a CHP system. The work includes preliminary screenings, payback period estimations, and a decision recommendation if their site is suitable for CHP. TAPs offer more advanced technical assistance to facilities that want to move forward and look at feasibility or project plans for a CHP system. TAPs work actively to engage with both end-users and stakeholders of CHP to educate individuals and firms about the benefits of the technology and generate interest for technical assistance.

The value-add of TAP activities on the environment for CHP could align closely with the intended impact of the power electronics implementation and demonstration centers in Wisconsin. Distributed across the state, these centers are made up of experts in in the field and work to ease end-users' adoption. Like the TAPs, they could play a role in supporting the environment for power electronics and identifying new end-users or diverse applications of the technology, beyond just demonstrations. For example, implementation centers could engage with potential end-users on the efficiency and performance gains from advanced power electronics technologies, provide resources to ease the technological transition, and encourage adoption. Further, implementation centers could provide preliminary screenings for potential end-users to see if their site is suitable for a particular power electronics technology of interest (e.g., electric motors, DC/DC converters or AC/DC converters, on-board chargers).

Strategy 4

Expand the market for the Wisconsin electrification cluster

Strategy 4 focuses on expanding the electrification cluster to complementary and adjacent industries within the state and to new customers through trade. As the Electrification Cluster Assessment revealed, Wisconsin's strength in power electronics and other electrification-related technologies is underrecognized both inside and outside of the state. Despite its competitiveness, growth in the majority of Wisconsin's electrification cluster has been stagnant over the past decade. Additionally, as the cluster increases research and adoption, it is likely that new cluster-related industries will emerge. The action items presented in this strategy help seize the opportunity to expand Wisconsin's power electronics cluster, both current and future.

Action Item 4.1: Expand Wisconsin's extremely high specialization in industries that make up its electrification cluster into complementary industries like charging stations.

- **Lead:** Wisconsin Department of Transportation
- **Support:** Wisconsin Economic Development Corporation, Wisconsin Department of Agriculture, Trade and Consumer Protection's Bureau of Weights and Measures, Wisconsin Public Service Commission
- **Timeline:** 0-2 years
- **Est. Resource Requirements**: Less than $100,000

Expansion of EV-related business activities in Wisconsin can have multiplier effects throughout the EV industry in the state. For example, charging stations require power electronics input and components. Wisconsin's specialization in power electronics would give it a leg up in building charging stations and operationalizing the larger EV vision across the Midwest. Wisconsin can also capitalize on the national focus of developing the infrastructure to support not only personal and light-duty electric vehicles, but also, low-emission or zero-emission buses (e.g., public transit, student transportation, private charter services), which have distinct charging needs. WisDOT could work with WEDC to identify and connect businesses that assemble charging stations to Wisconsin's power electronics suppliers, and bolster in-state business in power electronics.

For example, Ingeteam, a Spanish company that recently opened an electrical equipment production plant in Milwaukee, specializes in renewable energy equipment and is the only wind turbine generator in the United States. The company recently announced that it would expand production into manufacturing EV charging stations and strengthen its networks within the new EV charging supply chain in Wisconsin through funding from the Inflation Reduction Act.[46] WisDOT can promote these localized supply chain opportunities by building out networks that pair domestic manufacturers with prospective buyers, championing Wisconsin's electrification cluster into new industries. This action item supports power electronics input into EV infrastructure and related businesses, specifically into charging stations, maintenance and repair centers, and electrical grid centers.

Action Item 4.2: Highlight and specifically cater to power electronics businesses in the WEDC export support program ExporTech.

- **Lead:** Wisconsin Economic Development Corporation
- **Support:** Wisconsin Manufacturing Extension Partnership, Northwest Wisconsin Manufacturing Outreach Center, U.S. Commercial Service Milwaukee
- **Timeline:** 0-2 years
- **Est. Resource Requirements**: Less than $100,000

WEDC's ExporTech, which helps small to midsize companies grow their export business in partnership with the Wisconsin Manufacturing Extension Partnership (WMEP) and the Northwest Wisconsin Manufacturing Outreach Center, is a wonderful strategy for expanding Wisconsin's manufacturing cluster. WEDC should also consider leveraging its specialty in power electronics more specifically: as a cluster Wisconsin wants to strengthen and expand, consider aiming marketing for the ExporTech program specifically to businesses in power electronics. As a narrower list of industries and businesses than Wisconsin manufacturing more generally, word should spread faster and more effectively among small and midsize businesses in power electronics, helping compound the success.

WEDC may also be able to leverage support from the U.S. Commercial Service, part of U.S. Department of Commerce's International Trade Administration, which has an office in Wauwatosa, serving the entire state of Wisconsin, and offers services to support businesses in exporting and expanding to new markets.[47] The U.S. Commercial Service has a deep bench with over 100 U.S. and 70 international offices, providing export support expertise and networking channels that can generate value for Wisconsin's power electronics businesses.

As WEDC knows, existing small business and entrepreneurship support efforts can be strengthened by bolstering an exporting component to improve market access. Smaller businesses often face more significant barriers than larger, well-established businesses, including limited experience and financial resources to navigate external markets and understanding the sometimes complex legal and logistical steps to trade. Without assistance, many small businesses are unable to make the large upfront financial commitment to begin exporting. Export assistance programs provide small businesses with guidance, training, and market research to help them make informed decisions about the viability of an export strategy and build the strategic capacities needed to enter a foreign market. When targeting support efforts, businesses most likely to benefit from these programs are those that are stable with a proven product or service and are exporting on a small scale to one or two countries or indirectly exporting as suppliers for larger companies that export a finished product.

To the extent that WEDC does not already practice these strategies in the ExporTech program, one important step is to regularly communicate with businesses through efforts such as conducting interviews with company CEOs, partnering with the Small Business Development Center (SBDC), and holding roundtables with chambers of commerce. This communication will inform how WEDC can better support export activities, including adjusting local regulations to make sure that the policy environment encourages growth; passing along the information about area businesses interested in exporting to regional, state, and federal stakeholders; making sure businesses interested in exporting are connected to available trainings, missions, and assistance; and celebrating exporting success stories.

Generally, by connecting small power electronics businesses in Wisconsin with exporting capabilities, Wisconsin would expand the customer base of its electrification cluster and provide some foundational business diversity to the large companies in the market. By creating a narrower lane to concentrate on power-electronics-related small businesses, either by trying to attract those businesses through new marketing efforts and industry-academic discussions or by giving preference to businesses in power electronics over other kinds of manufacturing in Wisconsin, WEDC will be growing the base of the cluster beyond the major players.

Appendix A

NAICS 333611: Turbine and Turbine Generator Set Units Manufacturing

Table 9: Performance metrics of the Turbine and Turbine Generator Set Units Manufacturing industry in Wisconsin, 2011-2021. *Source: SRI analysis of Lightcast data.*

Industry Metrics		Description
Employment in Wisconsin	224	Manufacturing of turbines (except aircraft); and complete turbine generator set units, such as steam, hydraulic, gas, and wind.
Share of Cluster Jobs	0.9%	
Share of US Jobs	1.1%	
Wisconsin Location Quotient	0.58	
5-Yr Employment Growth	-1.3%	
10-Yr Employment Growth	-11.1%	
5-Yr Productivity Growth	6.7%	
10-YrProductivity Growth	-8.6%	

In Wisconsin, Turbine and Turbine Generator Set Units Manufacturing employs less than 300 individuals, which is roughly 1.1% of the cluster's employment. The industry has a location quotient of 0.58, which indicates that the state's specialization in Turbine and Turbine Generator Set Units Manufacturing is significantly lower than that of the United States. Employment in Turbine and Turbine Generator Set Units Manufacturing has declined by 1.3% since 2016 and by 11.1% since 2011. It is worth noting, however, that Wisconsin has the only wind turbine generator in the country, Ingeteam, which has manufactured over 3,000 wind generators in Milwaukee since its opening in 2011.[48]

Over the past ten years, productivity in Wisconsin's Turbine and Turbine Generator Set Units Manufacturing industry decreased by 8.5%, with output decreasing from $208,496 per worker to $190,666 per worker, but over the past five years productivity has risen 6.7%, with output increasing from $176,690 to $190,666 per worker. Both productivity and employment has declined in this industry over the past decade within Wisconsin.

The three largest industries that supply inputs to Turbine and Turbine Generator Set Units Manufacturing are 1) Turbine and Turbine Generator Set Units Manufacturing (itself), 2) Iron and Steel Mills and Ferroalloy Manufacturing, and 3) Iron and Steel Forging. Turbine and Turbine Generator Set Units Manufacturer purchases more than 50% of their inputs from two of these top three supplying industries from within Wisconsin, which indicates strong cluster behavior and local benefits.

Table 10: Top supplier industries to Turbine and Turbine Generator Set Units Manufacturing in Wisconsin, 2021. *Source: SRI analysis of Lightcast data.*

Top Supplier Industries	Total Purchases	% Total Purchases	% Purchases In-State
Turbine and Turbine Generator Set Units Manufacturing	$3,670,167	7.3%	58.5%
Iron and Steel Mills and Ferroalloy Manufacturing	$2,852,225	5.7%	1.5%
Iron and Steel Forging	$2,627,627	5.2%	57.2%

As shown in *Table 11*, the industry is its own largest customer in-state. The second and third largest customer industries in the state are Fossil Fuel Electric Power Generation and Other Engine Equipment Manufacturing. Less than 50% of the sales of Wisconsin-made Turbine and Turbine Generator Set Units Manufacturing products go to in-state firms.

Table 11: Top customer industries to whom sales are made from Turbine and Turbine Generator Set Units Manufacturing in Wisconsin, 2021. *Source: SRI analysis of Lightcast data*.

Top Customer Industries	Total Sales to In-State Customers	% In-State Sales
Turbine and Turbine Generator Set Units	$2,146,850	41.4%
Fossil Fuel Electric Power Generation	$540,565	10.4%
Other Engine Equipment Manufacturing	$506,390	9.8%

NAICS 333612: Speed Changer, Industrial High-Speed Drive, and Gear Manufacturing

Table 12: Performance metrics of the Speed Changer, Industrial High-Speed Drive, and Gear Manufacturing industry in Wisconsin, 2011-2021. *Source: SRI analysis of Lightcast data.*

Industry Metrics		Description
Employment in Wisconsin	1,569	Manufacturing gears, speed changers, and industrial high-speed drives (except hydrostatic).
Share of Cluster Jobs	6.3%	
Share of US Jobs	14.2%	
Wisconsin Location Quotient	7.37	
5-Yr Employment Growth	-17.6%	
10-Yr Employment Growth	-24.7%	
5-Yr Productivity Growth	10.2%	
10-Yr Productivity Growth	-5.1%	

In Wisconsin, this industry employs over 1,500 workers, which is 6.3% of the cluster's employment. Of all jobs in this industry across the U.S., 14.2% are in Wisconsin. With a location quotient of 7.37, Wisconsin has an exceptionally high specialization in in the industry. Employment in Speed Changer, Industrial High-Speed Drive, and Gear Manufacturing has declined by 17.6% since 2016 and by 24.7% since 2011.

Over the past ten years, productivity in Wisconsin's Speed Changer, Industrial High-Speed Drive, and Gear Manufacturing industry decreased by 5.1%, with output decreasing from $147,753 per worker to $140,178 per worker, but over the past five years, productivity has risen 10.2% from a ten year low of $125,058 in 2016 to $140,178 in 2021. Both productivity and employment has declined in Wisconsin in this industry over the past decade.

The largest industries that supply inputs to Speed Changer, Industrial High-Speed Drive, and Gear Manufacturing, not including "Corporate, Subsidiary, and Regional Managing Offices," include 1) Mechanical Power Transmission Equipment Manufacturing, 2) Iron and Steel Forging, and 3) Iron and Steel Mills and Ferroalloy Manufacturing.

For the first two industries that supply most to Speed Changer, etc., over 60% of inputs originate from Wisconsin firms, indicating strong supply chain localization.

Table 13: Top supplier industries to Speed Changer, Industrial High-Speed Drive, and Gear Manufacturing in Wisconsin, 2021. Source: *SRI analysis of Lightcast data.*

Top Supplier Industries	Total Purchases	% Total Purchases	% Purchases In-State
Mechanical Power Transmission Equipment Manufacturing	$16,190,328	8.2%	63.4%
Iron and Steel Forging	$13,169,933	6.7%	83.7%
Iron and Steel Mills and Ferroalloy Manufacturing	$10,002,185	5.1%	2.7%

As shown in *Table 14*, Farm Machinery and Equipment Manufacturing is the industry's largest in-state customer. The next two largest customer industries are Other Engine Equipment Manufacturing and Packaging Machinery Manufacturing.

Table 14: Top customer industries to whom sales are made from Speed Changer, Industrial High-Speed Drive, and Gear Manufacturing in Wisconsin, 2021. *Source: SRI analysis of Lightcast data.*

Top Customer Industries	Total Sales to In-State Customers	% In-State Sales
Farm Machinery and Equipment Manufacturing	$4,926,388	11.0%
Other Engine Equipment Manufacturing	$4,172,952	9.3%
Packaging Machinery Manufacturing	$2,902,037	6.5%

NAICS 333613: Mechanical Power Transmission Equipment Manufacturing

Table 15: Performance metrics of the Mechanical Power Transmission Equipment Manufacturing industry in Wisconsin, 2011-2021. *Source: SRI analysis of Lightcast data.*

Industry Metrics		Description
Employment in Wisconsin	1,403	Manufacturing of mechanical power transmission equipment (except motor vehicle and aircraft), such as plain bearings, clutches (except motor vehicle and electromagnetic industrial control), couplings, joints, and drive chains.
Share of Cluster Jobs	5.7%	
Share of US Jobs	11.1%	
Wisconsin Location Quotient	5.73	
5-Yr Employment Growth	-8.5%	
10-Yr Employment Growth	-8.0%	
5-Yr Productivity Growth	8.2%	
10-Yr Productivity Growth	15.9%	

The Mechanical Power Transmission Equipment Manufacturing industry produces plain bearings, clutches (except motor vehicle and electromagnetic industrial control), couplings, joints, and drive chains. The industry specifically does not produce motor vehicle and aircraft equipment.

In Wisconsin, Mechanical Power Transmission Equipment Manufacturing employs over 1,400 workers, which is 5.7% of the cluster's employment. Of all jobs in this industry across the U.S., 11.1% are in Wisconsin. The industry has a location quotient of 5.73, which indicates that the state's specialization in Mechanical Power Transmission Equipment Manufacturing is over 5 times that of the U.S. Employment in Mechanical Power Transmission Equipment Manufacturing has declined by 8.5% since 2016 and by 8.0% since 2011.

Over the past ten years, productivity in Wisconsin's Mechanical Power Transmission Equipment Manufacturing industry increased by 15.9%, with output increasing from $132,129 per worker to $153,083 per worker, while in the past five years, productivity increased by 8.2%, with output increasing from $142,279 per worker to $152,083 per worker. While productivity has gone up, industry employment has declined over the past decade.

The three largest industries that supply inputs to Mechanical Power Transmission Equipment Manufacturing, not including "Corporate, Subsidiary, and Regional Managing Offices," are 1) Iron and Steel Mills and Ferroalloy Manufacturing, 2) Iron and Steel Forging, and 3) Mechanical Power Transmission Equipment Manufacturing. The industry purchases more than 70% of products from two of the top three supplying industries from within Wisconsin, which indicates strong supply chain localization.

Table 16: Top supplier industries to Mechanical Power Transmission Equipment Manufacturing in Wisconsin, 2021. *Source: SRI analysis of Lightcast data*.

Top Supplier Industries	Total Purchases	% Total Purchases	% Purchases In-State
Iron and Steel Mills and Ferroalloy Manufacturing	$20,409,840	11.6%	5.9%
Iron and Steel Forging	$9,167,870	5.2%	76.7%
Mechanical Power Transmission Equipment Manufacturing	$8,104,559	4.6%	78.9%

As shown in *Table 17*, Heavy Duty Truck Manufacturing is the industry's largest in-state customer. The second and third largest in-state customer industries in the state are Other Engine Equipment Manufacturing and Speed Changer, Industrial High-Speed Drive, and Gear Manufacturing, respectively. Slightly under 50% of the sales to Heavy Duty Truck manufacturing are in-state, and even lower percentages of the sales to the other customer industries are in-state.

Table 17: Top customer industries to whom sales are made from Mechanical Power Transmission Equipment Manufacturing in Wisconsin, 2021. *Source: SRI analysis of Lightcast data.*

Top Customer Industries	Total Sales to In-State Customers	% In-State Sales
Heavy Duty Truck Manufacturing	$51,233,833	45.7%
Other Engine Equipment Manufacturing	$21,882,256	19.5%
Speed Changer, Industrial High-Speed Drive, and Gear Manufacturing	$10,264,531	9.2%

NAICS 333618: Other Engine Equipment Manufacturing

Table 18: Performance metrics of the Other Engine Equipment Manufacturing industry in Wisconsin, 2011-2021. *Source: SRI analysis of Lightcast data.*

Industry Metrics		Description
Employment in Wisconsin	5,930	Manufacturing of internal combustion engines (except automotive gasoline and aircraft).
Share of Cluster Jobs	23.9%	
Share of US Jobs	13.2%	
Wisconsin Location Quotient	6.84	
5-Yr Employment Growth	2.2%	
10-Yr Employment Growth	17.4%	
5-Yr Productivity Growth	17.5%	
10-Yr Productivity Growth	13.6%	

In Wisconsin, The Other Engine Equipment Manufacturing industry employs 5,930 workers and is one of the largest industries within the electrification cluster and comprising 13.2% of the cluster's employment. While employment in most cluster industries declined in the past five years, Other Engine Equipment Manufacturing employment grew by 2.2% since 2016 and by 17.4% since 2011. Of all jobs in this industry across the U.S., 13.2% are in Wisconsin. Furthermore, the industry has a location quotient of 6.84 in Wisconsin, indicating that the state's specialization in Other Engine Equipment Manufacturing is more than 6 times that of the U.S.

Over the past ten years, productivity in Wisconsin's Other Engine Equipment Manufacturing industry increased by 13.6%, with output increasing from $152,132 per worker to $172,756 per worker, while productivity has increased 17.5% over the last five years, with output increasing from $146,082 per worker to $172,756 per worker. This constitutes strong evidence that firms in the industry, in addition to hiring more workers, are making technology investments that increase workers' productivity.

The three largest industries which supply inputs to Other Engine Equipment Manufacturing, not including Corporate, Subsidiary, and Regional Managing Offices, are 1) Other Engine Equipment Manufacturing, 2) Motor Vehicle Electrical and Electronic Equipment Manufacturing, and 3) Iron Foundries. Across the top three supplier industries, most Other Engine Equipment Manufacturing's purchases are made from in-state firms, indicating strong supply chain localization.

Table 19: Top supplier industries to Other Engine Equipment Manufacturing in Wisconsin, 2021. Source: SRI analysis of Lightcast data.

Top Supplier Industries	Total Purchases	% Total Purchases	% Purchases In-State
Other Engine Equipment Manufacturing	$145,046,785	8.7%	82.3%
Motor Vehicle Electrical and Electronic Equipment Manufacturing	$67,021,818	4.0%	58.2%
Iron Foundries	$55,219,379	3.3%	67.5%

As shown in *Table 20*, Heavy Duty Truck Manufacturing is the industry's largest in-state customer. The others, respectively, are Other Engine Equipment Manufacturing and Motor and Generator Manufacturing.

Table 20: Top customer industries to whom sales are made from Other Engine Equipment Manufacturing in Wisconsin, 2021. *Source: SRI analysis of Lightcast data*.

Top Customer Industries	Total Sales to In-State Customers	% In-State Sales
Heavy Duty Truck Manufacturing	$330,479,139	53.0%
Other Engine Equipment Manufacturing	$119,358,435	19.2%
Motor and Generator Manufacturing	$43,118,411	6.9%

NAICS 335311: Power, Distribution, and Specialty Transformer Manufacturing

Table 21: Performance metrics of the Power, Distribution, and Specialty Transformer Manufacturing industry in Wisconsin, 2011-2021. *Source: SRI analysis of Lightcast data*.

Industry Metrics		Description
Employment in Wisconsin	1,936	Manufacturing of power, distribution, and specialty transformers (except electronic components). Industrial-type and consumer-type transformers in this industry vary (e.g., step up or step down) voltage but do not convert alternating to direct or direct to alternating current.
Share of Cluster Jobs	7.8%	
Share of US Jobs	7.5%	
Wisconsin Location Quotient	3.91	
5-Yr Employment Growth	4.9%	
10-Yr Employment Growth	-3.5%	
5-Yr Productivity Growth	19.3%	
10-Yr Productivity Growth	29.8%	

In Wisconsin, Power, Distribution, and Specialty Transformer Manufacturing employs 1,936 workers, which is 7.8% of the cluster's employment. Employment in this industry grew by 4.9% since 2016 but is 3.5% lower than 2011 levels. However, with a location quotient of 3.91, the industry is highly specialized in Wisconsin compared to the rest of the U.S.

While employment in this industry has declined between 2011 and 2021, total industry output grew from $108,859 per worker in 2011 to $141,282 in 20221 and productivity as measured by output per worker increased by 29.8% over the past ten years. These trends indicate that the industry is likely undergoing automation.

One more feature to note is that this industry manufactures for a few ignition-related manufacturing areas: 1) burner ignition transformers manufacturing, and 2) ignition transformers for use on domestic fuel burners manufacturing. Ignition system manufacturing was identified as high-risk of being adversely impacted by the EV transition in the *Wisconsin's Electric Vehicle/Electrification Supply Chain Strategy 2023*. Power, Distribution, and Specialty Transformer Manufacturing produces manufacturing parts for 35 other areas, but it is worth noting this is one (and the only industry here) that raises a flag for electrification transition risk in Wisconsin's electrification cluster.

The three largest industries that supply inputs to Power, Distribution, and Specialty Transformer Manufacturing are 1) Copper Rolling, Drawing, Extruding, and Alloying, 2) Iron and Steel Mills and Ferroalloy Manufacturing, and 3) All Other Miscellaneous Electrical Equipment and Component Manufacturing. Of these three industries, only All Other Miscellaneous Electrical Equipment and Component Manufacturing has a significant presence in the state.

Table 22: Top supplier industries to Power, Distribution, and Specialty Transformer Manufacturing in Wisconsin, 2021. *Source: SRI analysis of Lightcast data.*

Top Supplier Industries	Total Purchases	% Total Purchases	% Purchases In-State
Copper Rolling, Drawing, Extruding, and Alloying	$29,783,429	13.0%	10.4%
Iron and Steel Mills and Ferroalloy Manufacturing	$27,295,967	11.9%	1.3%
All Other Miscellaneous Electrical Equipment and Component Manufacturing	$19,424,581	8.5%	41.9%

The three largest in-state industries that purchase from this industry are 1) Motor and Generator Manufacturing, 2) Irradiation Apparatus Manufacturing, and 3) Wood Window and Door Manufacturing. Transformers are widely used in electronic devices, but the fact that industrial customers make significant purchases from transformer manufacturers suggest that this industry is closely integrated into Wisconsin's manufacturing supply chain.

Table 23: Top customer industries to whom sales are made from Power, Distribution, and Specialty Transformer Manufacturing in Wisconsin, 2021. *Source: SRI analysis of Lightcast data.*

Top Customer Industries	Total Sales to In-State Customers	% In-State Sales
Motor and Generator Manufacturing	$6,083,689	14.4%
Irradiation Apparatus Manufacturing	$4,693,287	11.1%
Wood Window and Door Manufacturing	$3,488,803	8.2%

The largest companies in this industry include American Transmission Company (headquartered in Pewaukee, WI), Electro Power (multiple facilities in Wisconsin), AZZ Incorporated (operates a subsidiary in Oshkosh, WI), and Cramer Magnetics (based in Saukville, WI).

NAICS 335312: Motor and Generator Manufacturing

Table 24: Performance metrics of the Motor and Generator Manufacturing industry in Wisconsin, 2011-2021. *Source: SRI analysis of Lightcast data.*

Industry Metrics		Description
Employment in Wisconsin	5,847	Manufacturing of electric motors (except internal combustion engine starting motors), power generators (except battery charging alternators for internal combustion engines), and motor generator sets (except turbine generator set units). This industry includes establishments rewinding armatures on a factory basis.
Share of Cluster Jobs	23.6%	
Share of US Jobs	16.3%	
Wisconsin Location Quotient	8.47	
5-Yr Employment Growth	49.9%	
10-Yr Employment Growth	65.2%	
5-Yr Productivity Growth	22.7%	
10-Yr Productivity Growth	49.0%	

In Wisconsin, Motor and Generator Manufacturing employs 5,847 workers, which is approximately a quarter of the cluster's employment. While employment in most cluster industries declined in the past five years, Motor and Generator Manufacturing employment grew by 49.9% since 2016 and by 65.2% since 2011. This growth is driven by large companies such as Generac, which has expanded operations and hiring in Wisconsin. Of all jobs in this industry across the U.S., 16.3% is in Wisconsin. Furthermore, the industry has a location quotient of 8.47 in Wisconsin, indicating that the state's specialization in Motor and Generator Manufacturing is more than 8 times that of the U.S.

Over the past ten years, productivity in Wisconsin's Motor and Generator Manufacturing Industry increased by 49.0%, with output increasing from $106,718 per worker to $159,019 per worker, while over the past 5 years, productivity increased 22.7% from $134,755 per worker to $159,019 per worker. This constitutes strong evidence that firms in the industry, in addition to hiring more workers, are making technology investments that increase workers' productivity.

The three largest industries which supply inputs to Motor and Generator Manufacturing are 1) Other Engine Equipment Manufacturing, 2) Copper Rolling, Drawing, Extruding, and Alloying, and 3) Motor and Generator Manufacturing (the industry supplies itself). It should be noted that Other Engine Equipment Manufacturing is another key element of Wisconsin's electrical equipment cluster. It is by far the largest supplier to Motor and Generator Manufacturing, and the majority (about 60%) of purchases from this industry are made from in-state firms.

Together, Motor and Generator Manufacturing and Other Engine Equipment Manufacturing supply half of all jobs in the cluster and are closely linked within the supply chain.

Table 25: Top supplier industries to Motor and Generator Manufacturing in Wisconsin, 2021. *Source: SRI analysis of Lightcast data.*

Top Supplier Industries	Total Purchases	% Total Purchases	% Purchases In-State
Other Engine Equipment Manufacturing	$71,709,502	9.4%	60.1%
Copper Rolling, Drawing, Extruding, and Alloying	$43,509,429	5.7%	7.7%
Motor and Generator Manufacturing	$41,581,382	5.4%	88.2%

As shown in *Table 26*, Motor and Generator Manufacturing is its own largest in-state customer. The second and third largest in-state customer industries in the state are Small Electrical Appliance Manufacturing and Measuring, Dispensing, and Other Pumping Equipment Manufacturing, respectively. As such, the data suggests that a notable share of motor and generator products are being sold to Wisconsin-based pumping equipment makers and other manufacturers that make metal products.

Table 26: Top customer industries to whom sales are made from Motor and Generator Manufacturing in Wisconsin, 2021. *Source: SRI analysis of Lightcast data.*

Top Customer Industries	Total Sales to In-State Customers	% In-State Sales
Motor and Generator Manufacturing	$36,683,677	18.5%
Small Electrical Appliance Manufacturing	$13,604,977	6.9%
Measuring, Dispensing, and Other Pumping Equipment Manufacturing	$13,322,761	6.7%

The four largest companies in this industry with a significant presence in Wisconsin are Generac, Briggs & Stratton, Cummins Emissions Solutions, and Regal Rexnord. Industry employment is heavily concentrated among these companies, and smaller firms employ only a negligible share of the industry's workforce.

The overwhelming share of jobs in the industry are concentrated in the Milwaukee area. The area is home to Briggs & Stratton's corporate headquarters, manufacturing facilities of the company's Engine Power Products Group, and Generac's corporate headquarters. Other firms and subsidiaries such as Toshiba American Energy Systems, ABB Drives, and Tramont operate in or close to Milwaukee.

Outside the Milwaukee area, Regal Rexnord operates sizable facilities in Beloit and Black River Falls, while Generac operates additional facilities in the Oshkosh area.

NAICS 335313: Switchgear and Switchboard Apparatus Manufacturing

Table 27: Performance metrics of the Switchgear and Switchboard Apparatus Manufacturing industry in Wisconsin, 2011-2021. *Source: SRI analysis of Lightcast data.*

Industry Metrics		Description
Employment in Wisconsin	1,984	Manufacturing of switchgear and switchboard apparatus
Share of Cluster Jobs	8.0%	
Share of US Jobs	5.8%	
Wisconsin Location Quotient	2.98	
5-Yr Employment Growth	0.4%	
10-Yr Employment Growth	9.1%	
5-Yr Productivity Growth	1.8%	
10-Yr Productivity Growth	17.1%	

In Wisconsin, Switchgear and Switchboard Apparatus Manufacturing employs 1,984 workers, which is 8% of the cluster's employment. In the long-term, employment has grown 9.1%, and productivity has increased 17.1%, from $132,812 per worker to $155,517 per worker. With a location quotient of 2.98, Wisconsin's specialization in this industry is almost three times that of the United States. Despite this high specialization and long-term growth, industry employment in the state grew by only 0.4% in the past 5 years. Productivity growth has also been relatively stagnant, as output per worker increased only by 1.8% in the past 5 years whereas other cluster industry experienced productivity growth of more than 10% in the same period.

The three largest industries which supply inputs to Switchgear and Switchboard Apparatus Manufacturing are 1) Iron and Steel Mills and Ferroalloy Manufacturing, 2) Switchgear and Switchboard Apparatus Manufacturing, and 3) Other Electronic Parts and Equipment Merchant Wholesalers. A significant portion of inputs from Switchgear and Switchboard Apparatus Manufacturing and Other Electronic Parts and Equipment Merchant Wholesalers are supplied by Wisconsin firms. However, most inputs from Iron and Steel Mills and Ferroalloy Manufacturing are imported from outside the state. It is also worth noting that Switchgear and Switchboard Apparatus Manufacturing is its own second largest in-state customer, indicating a lot of internal activity to the cluster.

Table 28: Top supplier industries to Switchgear and Switchboard Apparatus Manufacturing in Wisconsin, 2021. *Source: SRI analysis of Lightcast data.*

Top Supplier Industries	Total Purchases	% Total Purchases	% Purchases In-State
Iron and Steel Mills and Ferroalloy Manufacturing	$17,566,498	6.9%	1.4%
Switchgear and Switchboard Apparatus Manufacturing	$10,483,653	4.1%	67.0%
Other Electronic Parts and Equipment Merchant Wholesalers	$10,258,705	4.1%	27.8%

In Wisconsin, Relay and Industrial Control Manufacturing is the largest customer for switchgear and switchboard equipment, followed by Switchgear and Switchboard Apparatus Manufacturing and Other Engine Equipment Manufacturing. These trends suggest that switchgear manufacturing is an intermediary input to the production and assembly of industrial electrical control equipment and of engine and engine-related components.

Table 29: Top customer industries to whom sales are made from Switchgear and Switchboard Apparatus Manufacturing in Wisconsin, 2021. *Source: SRI analysis of Lightcast data.*

Top Customer Industries	Total Sales to In-State Customers	% In-State Sales
Relay and Industrial Control Manufacturing	$9,763,145	15.0%
Switchgear and Switchboard Apparatus Manufacturing	$7,026,333	10.8%
Other Engine Equipment Manufacturing	$6,649,268	10.2%

While few companies in this industry are headquartered in Wisconsin, the state is home to the manufacturing and R&D facilities of major industry players. These facilities include Littelfuse's Product Evaluation, Reliability, and Application Lab in Lake Mills, S&C Electric's manufacturing plant in Franklin, and Exponential Power's facilities in Milwaukee and Appleton.

NAICS 335314: Relay and Industrial Control Manufacturing

Table 30: Performance metrics of the Relay and Industrial Control Manufacturing industry in Wisconsin, 2011-2021. *Source: SRI analysis of Lightcast data.*

Industry Metrics		Description
Employment in Wisconsin	5,880	Manufacturing of relays, motor starters and controllers, and other industrial controls and control accessories
Share of Cluster Jobs	23.7%	
Share of US Jobs	14.1%	
Wisconsin Location Quotient	7.32	
5-Yr Employment Growth	-7.3%	
10-Yr Employment Growth	-6.4%	
5-Yr Productivity Growth	23.8%	
10-Yr Productivity Growth	17.1%	

In Wisconsin, Relay and Industrial Control Manufacturing employs more than 5,800 workers, nearly a quarter of the cluster's employment. Despite the industry's high overall employment and the fact that Wisconsin's specialization in this industry is more than seven times that of the United States, statewide industry employment has declined by 7.3% since 2016.

However, productivity within the industry notably increased in recent years. Output per worker grew by 23.8% since 2016 from $137,012 to $164,201 in 2021, indicating that firms in the industry are making significant investments in automating the manufacturing of industrial control systems.

The three largest industries which supply inputs to Relay and Industrial Control Manufacturing are 1) other firms in Relay and Industrial Control Manufacturing, 2) All Other Miscellaneous General Purpose Machinery Manufacturing, and 3) Other Electronic Parts and Equipment Merchant Wholesalers. It should be noted that 94% of purchases from other Relay and Industrial Control Manufacturing firms are made from Wisconsin suppliers. Wisconsin suppliers also account for 55.7% of purchases from All Other Miscellaneous General Purpose Machinery Manufacturing.

Table 31: Top supplier industries to Relay and Industrial Control Manufacturing in Wisconsin, 2021. *Source: SRI analysis of Lightcast data.*

Top Supplier Industries	Total Purchases	% Total Purchases	% Purchases In-State
Relay and Industrial Control Manufacturing	$52,340,917	10.4%	94.0%
All Other Miscellaneous General Purpose Machinery Manufacturing	$37,029,789	7.4%	55.7%
Other Electronic Parts and Equipment Merchant Wholesalers	$28,992,150	5.8%	30.7%

As shown in *Table 32*, Relay and Industrial Control Manufacturing is its own largest in-state customer. The second and third customer industries in the state are Motor and Generator Manufacturing and Switchgear and Switchboard Apparatus Manufacturing. The data therefore suggests that the industry is closely integrated to other industries in which Wisconsin has a competitive advantage.

Table 32: Top customer industries to whom sales are made from Relay and Industrial Control Manufacturing in Wisconsin, 2021. *Source: SRI analysis of Lightcast data.*

Top Customer Industries	Total Sales to In-State Customers	% In-State Sales
Relay and Industrial Control Manufacturing	$49,210,599	28.8%
Motor and Generator Manufacturing	$8,913,329	5.2%
Switchgear and Switchboard Apparatus Manufacturing	$8,264,528	4.8%

Wisconsin firms in this industry include Rockwell Automation (headquartered in Milwaukee and operates multiple facilities throughout the state), Eaton Corporation (operates multiple manufacturing plants in the Milwaukee area), and Siemens (operates multiple manufacturing plants in the Milwaukee area).

Appendix B: Federal Funding Sources

Table 33: Federal funding sources available to Wisconsin's power electronics cluster[49]

Name	Agency	Amount Available	Summary Description	Related Action Item
National Electric Vehicle Infrastructure (NEVI) Formula Program	Department of Transportation (DOT)	$5B	Noncompetitive funding to deploy EV charging infrastructure and a network to facilitate data collection, access, and reliability	4.1
Low or No Emission Vehicle Program	Federal Transit Administration	$1.2B	Competitive funding for the purchase or lease of zero-emission and low-emission transit buses, including acquisition, construction, and leasing of required supporting facilities	4.1
Unlocking Lasting Transformative Resiliency Advances by Faster Actuation of power Semiconductor Technologies (ULTRAFAST) program	Department of Energy (DOE) Advanced Research Projects Agency-Energy	$48M	Competitive research funding to develop faster, more capable power electronics for greater resiliency, reliability, and control of power flow at all grid interfaces.	2.1, 3.2
Congestion Mitigation and Air Quality (CMAQ) Improvement Program	DOT	$2.5B annually	Competitive funding to state departments of transportation, local governments, and transit agencies for projects and programs that help meet the requirements of the Clean Air Act by reducing mobile source emissions and regional congestion on transportation networks	4.1
State Energy Program (SEP) Funding	DOE	$60M	Competitive funding through grants to assist in designing, developing, and implementing renewable energy and energy efficient programs	2.1, 3.2
Clean School Bus	U.S. Environmental Protection Agency	$500M	Competitive funding for the replacement of existing school buses with clean, alternative fuel school buses or zero-emission school buses	3.2
Public Transportation Research, Demonstration, and Deployment Funding	DOT	$38M annually	Competitive and noncompetitive funding for research, demonstration, and deployment projects involving low or zero emission public transportation vehicles	2.1, 3.2
Charging and Fueling Infrastructure Grants	DOT	$2.5B over 5 years	Competitive funding to fill gaps in publicly accessible electric vehicle charging and hydrogen, propane, and natural gas fueling infrastructure in community locations, such as parking facilities, public schools, public parks, or along public roads	4.1
Truck Emissions Reduction Study and Grant at Port Facilities	DOT	$80M annually	Competitive funding to test, evaluate, and deploy projects to reduce idling truck emissions, including port electrification and efficiency improvements particularly from heavy duty vehicles	3.2
Carbon Reduction Program (CRP)	DOT	$1.26B annually	Noncompetitive funding for projects including truck stop electrification, diesel engine retrofits, vehicle-to-	4.1

			infrastructure communications equipment, public transportation, port electrification, and deployment of alternative fuel vehicles, including charging or fueling infrastructure and the purchase or lease of zero emission vehicles	
Renew America's Schools Program	DOE	$500M	Competitive grant program for energy improvement upgrades, including installation of alternative fuel vehicle (AFV) fueling or charging infrastructure on school grounds and purchase or lease AFVs	4.1
National Multimodal Cooperative Freight Research Program	DOT	$3.75M annually	DOT is collaborating with the National Academy of Sciences (NAS) to recommend a national research agenda on improvements in the efficiency and resiliency of freight movement, including adapting to future trends such as zero-emissions transportation, and NAS may award research contracts or grants under the Program	2.1
Bus and Bus Facilities Grants	DOT	$470M	Competitive funding for the financing of buses and bus facilities capital projects, including replacing, rehabilitating, purchasing, or leasing buses or related equipment, and rehabilitating, purchasing, constructing, or leasing bus-related facilities	4.1
Commercial Fabrication Facilities	NIST/U.S. Department of Commerce	$52.7B	Competitive funding to private companies, nonprofit organizations, and consortia thereof that can substantially finance, construct, or expand a U.S. facility that fabricates, assembles, tests, packages, produces, or researchers either semiconductors, semiconductor materials, or equipment used in the manufacturing of semiconductors	2.1, 3.2
FY2023 Vehicle Technologies Office Program Wide Funding	DOE	TBD	Competitive funding to advance research, development, demonstration, and deployment to achieve net-zero greenhouse gas emissions by 2050, including: reduction of weight and cost of batteries, reduction in life cycle emissions of advanced lightweight materials, reduced costs, and advanced technologies for both on- and off-road vehicle charging and infrastructure, innovative public transit solutions, and training to increase deployment of these technologies among diverse communities	2.3, 3.2
Apprenticeships Building America	Department of Labor	$121M	Competitive grant program to expand the number of Registered Apprenticeship Programs and apprentices, diversify the industries that use Registered Apprenticeship, and increase access to, and completion of, RAPs for underrepresented populations and underserved communities	2.3

Endnote(s)

[1] Harvard Business Review: https://hbr.org/1998/11/clusters-and-the-new-economics-of-competition
[2] Chicago Metropolitan Agency for Planning: https://www.cmap.illinois.gov/programs/industry-clusters#:~:text=An%20industry%20cluster%20is%20a,and%20other%20economies%20of%20scale.
[3] SRI analysis of Lightcast data
[4] From stakeholder interviews
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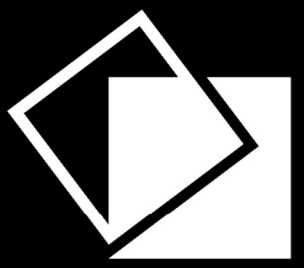

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