A COLLABORATIVE REPORT HIGHLIGHTING OPPORTUNITIES FOR WISCONSIN TO GROW OUR MANUFACTURING BASE FOR GREEN ENERGY TECHNOLOGIES.

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Executive summary

The transition from fossil fuel energy sources to advanced renewable sources is well underway in Wisconsin, but at present Wisconsin manufacturers are not optimally positioned to integrate themselves into the supply chain for advanced energy generation technologies such as wind, solar, and biogas, along with energy storage technologies such as lithium-based batteries.

In this report we evaluate the market conditions for existing Wisconsin manufacturers to further develop products and processes to support green energy industries, and we identify specific R&D opportunities to leverage existing capacity and capabilities to meet the current development requirements of the wind, solar, biogas, and lithium battery industries.

Global climate change will require changes in how we produce energy. At the same time, recent geopolitical events combined with the COVID-19 outbreak is certain to lead to a reevaluation of global supply chains. Taken in combination it is likely that market and policy changes will create significant opportunities for the domestic manufacture of the components associated with the production of ‘green’ energy. Using a combination of NAICS industrial data and proprietary firm data, that is scalable to the national level, we determine the real capacity for Wisconsin State manufacturers to participate in the component supply chain associated with wind and solar power. We find that there exists significant untapped manufacturing capacity that could be utilized in the relatively short term if required and if opportunity costs are deemed appropriate. We also address bridgeable capacity gaps and workforce-related issues.
1. Introduction: Changing Climate, Consumer Preferences, and Producer Preferences.

A growing consensus regarding the policy significance of global climate change is likely to require relatively swift changes to how we produce energy. This change, as with all changes, will bring both challenges and opportunities. With this study, we hope to provide assistance to Wisconsin manufacturers to minimize the former while enabling us to more fully exploit the latter. The broad manufacturing base of the state, combined with a solid transportation network, and a strong educational system is well placed to become a significant component to the supply chains of so-called green technologies.

Countries worldwide are now facing dual challenges of combating climate change while fueling economic growth. Renewable energy is one of the most viable solutions to control and reduce the impact of greenhouse gases produced by conventional fossil fuels. The transition to renewable energy is well underway both in Wisconsin and nationally, and in this report we intend to identify Wisconsin firms that are well-suited and well-positioned to shift into the manufacture of components for green industries. Due to the nature of these products, we have focused primarily – although not exclusively – on firms engaged in manufacturing across the state. We have sought to identify the specific businesses that have expertise and capability that is aligned with what would be needed to participate in manufacturing for wind, solar, biogas, or batteries. From this we consider the current size (in terms of the value of output and employment) to arrive a rough measure of capacity.

This work should be seen as the first step to a better understanding of how Wisconsin industry might transition in the face of changing consumer and producer preferences. This way, if change is to occur, we might minimize disruption to the Wisconsin economy, the many businesses doing fine work, and the tens of thousands of people who depend upon the jobs in these sectors. The next steps would be to reach out to some of the firms identified below to better understand how and if these transitions might be made, to identify obstacles that might exist, and to better align the State’s incentives to its long-run economic objectives.

2. Current Green Energy Generation in the United States and Future Projections

Green energy, such as solar and wind power, has grown rapidly in the United States over the past decade. As of 2018, fossil fuels still dominated in meeting American energy demands, but the generation of renewable energy increased by 100% from 2000. Specifically, about 17.1% of U.S. electricity consumed in 2018 was from renewables, and this number is expected to grow to 24% by 2030 and 38% by 2050.1 Most of the increase will likely be attributed to solar and wind.

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As projected by the U.S. Energy Information Administration (EIA, hereafter), the U.S. electricity generation from renewables is expected to exceed coal and nuclear by 2021 and to surpass natural gas by 2045 (Figure 2.1). In the meantime, the electricity generated from wind and solar will surpass geothermal, hydroelectric and other sources by 2022 and make up nearly 80% of the renewable total by 2050 (Figure 2.2).
3. The Current State of Wisconsin Manufacturing

The manufacturing sector, as defined by the North American Industrial Classification System (NAICS); “Comprises establishments engaged in the mechanical, physical, or chemical transformation of materials, substances, or components into new products.”2 Manufacturing remains a significant part of the Wisconsin economy and is a significant employer in the State. Before the onset of the COVID-19 epidemic, Wisconsin employment in manufacturing was at a near 10 year high (See figure 3.1 below) with a little over 480,000 people compromising roughly 16% of all employment across the State (versus just over 10% nationwide3).

According to the most recent census data (2015) there exist roughly 8,800 establishments engaged in manufacturing across the State (NAICS codes 31-33).4 These are spread across more than two-hundred subsectors. On the whole, the sector is highly dynamic and highly diverse.

Figure 3.1

When compared to other sectors within the State, manufacturing has proven to be more resilient to changes brought about by the epidemic. On the far right-hand side, we see that the share of manufacturing employment has risen in the last few months from the aforementioned 16% to roughly 17.5% of total State employment (Figure 3.2 below). Thus, while the Wisconsin economic ‘pie’ has been contracting rapidly manufacturing has remained relatively more robust resulting in it now having a larger share of total employment.

We should, however, be careful to not read too much into this. Given the sharp downward reaction of the manufacturing sector to the financial crisis of the last decade, it cannot be said that this sector is generally more resilient. Still, if pandemics such as the one we are currently experiencing are to be more common in the future, it is useful to know about which sectors are likely to be relatively resilient. This also reinforces the value of a diversified State economy is facing a variety of economic calamities.

2 Definition downloaded from https://www.naics.com/naics-code-description/?code=31-33
In terms of output, manufacturing contributes roughly 58 Billion annually to the Wisconsin Economy (Figure 3.3 below). This amounts to roughly 19% of the total State output by value, which makes manufacturing the single largest share of the State economy. Moreover, the share held by manufacturing has remained relatively consistent in recent years. Of particular note is the especially large number of suppliers to the automotive industry (gearboxes, precision machining, bearings, and molding), producers of industrial transformers and generators, as well as fiberglass manufacturers (See table 3). Each of these has application in the green energy supply chain.
Exports of Wisconsin manufactured goods (Figure 3.4 below) grew steadily during the first decade of the millennium, recovered relatively quickly from the 2008-2009 financial crisis, and have remained relatively stable since that time. The fact that Wisconsin manufacturing continues to be globally competitive with relatively high production costs strongly suggests that a uniquely productive and resourceful set of firms exist within this sector. It also suggests that changes in global economic policy incentivizing green energy could lead to an improvement in the State’s export demand bringing in much-needed incomes to Wisconsin households.

Figure 3.4

Although Wisconsin exports of manufactured goods are strong the State has, in recent years, come to be a net importer. In Figure 3.5 below we see the value of Wisconsin manufactured imports subtracted from the value of manufactured imports. This suggests that there exists untapped local demand should producers be able to increase production at a competitive price.

Figure 3.5
In sum, manufacturing in Wisconsin accounts for a significant amount of State economic activity. When compared to the rest of the United States Wisconsin manufacturing is larger, more diverse, and provides more jobs at higher pay. As such, significant alterations in the demand for manufactured goods and services are potentially highly disruptive to the State economy as a whole. A better understanding of how the industry might be able to effectively react to changing consumer preferences as well as legislative mandates and incentives could help to maintain State macroeconomic and employment stability over time.


As the national energy landscape and manufacturing have been transforming to meet new and diversified opportunities, renewable energy remains under-developed across Wisconsin (Figure 4.1), and the state still largely relies on fossil fuels to power its economy.

However, its neighboring states, at the same time, have outshined Wisconsin in the development, deployment, and usage of green energy. Minnesota, for example, is very similar to Wisconsin in terms of climate, demographics and geography. However, Minnesota has pursued far more aggressive goals in renewables by prioritizing green energy and adopting policies to boost its sustainable growth. The EIA data indicates that only 9.3% of Wisconsin’s utility-scale net electricity came from renewables in 2019, among which wind and solar contributed less than 3%. By contrast, about 25% of Minnesota electricity production was green in 2019, with wind and solar accounting for roughly 22% of the state’s electric power (Figure 4.2). Minnesotans are expected to enjoy more clean energy to power their homes, businesses and industries over the next several decades (Hubbuch (2020)).

Iowa, another neighboring state of Wisconsin, is also a national leader in renewables, particularly, wind power (Figure 4.3). As of 2019, Iowa ranked first in the nation for wind energy which generated about 42% of the state’s electricity. It also ranked second in terms of installed wind capacity which attracted explosive capital investments ($19 billion throughout 2019) from wind industry. Those wind projects generated $61 million of local and state tax revenues. So far, Iowa has become home to several major wind manufacturers including producers of turbine and blade, such as Siemens Gamesa Renewable Energy and blade manufacturer TPI Composites. Jobs created in Iowa’s wind industry increased to nearly 10,000 in 2018 alone. In Wisconsin, only 5,500 workers are employed by wind and solar businesses combined as of 2019.

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6 Wisconsin ranks 24th in terms of installed wind capacity as of June 2019.
7 Data Source: Clean Jobs Midwest, 2019.
Wisconsin Net Electricity Generation by Source, Feb. 2020

Source: Energy Information Administration, Electric Power Monthly

Figure 4.1

Minnesota Net Electricity Generation by Source, Feb. 2020

Source: Energy Information Administration, Electric Power Monthly

Figure 4.2
Renewable energy is cost-competitive, reliable, predictable and consistent in supply relative to conventional fossil fuels. During the past decade or so, green energy swept across the nation and our neighbors such as Iowa and Minnesota already became superstars. Wisconsin, unfortunately, has fallen behind in both green energy supply chain and manufacturing facilities. It is time for us to close the gap by identifying more opportunities for Wisconsin to participate in renewable energy. We should fully commit to spurring our green energy generation by expanding our existing and potential manufacturing capacities accordingly.

5. Methodology and Methodological Challenges to Estimating Current Capacity to Participate in Green Energy Production

The are several methodological challenges to determining the capacity to produce physical output that may be devoted to any specific end. These revolve around the small and nearly endless differences between manufactured products. To understand this, consider the seemingly simple example of “aluminum ingot”. To know whether this product is suitable as an input for a specific manufacturing process and in what amounts we must also have answers to the following questions. What is the specific grade of the aluminum? What specific refining processes are to be employed, what is the loss rate of the aluminum during this process? If we wish to understand how existing production might be converted to meet future demands the number of questions and answers we must find increases significantly. It is for these reasons that economists long ago resorted to relying on market prices rather than physical output to measure economic activity.

In most cases, reliance on market prices yields satisfactory information. If the price of a specific commodity rises, holding all else equal, we can ascertain that demand for that commodity is increasing relative to all other substitutes. We can further infer that, over time, production will increase to meet that demand. However, in periods of significant structural realignment, social or environmental change, market prices cannot allow us to effectively forecast what specific goods and services we might be able to produce in the future, altered, economic climate.
Thankfully, economies rarely experience short term, radical, structural reform. Unfortunately, this means that the techniques for guiding economies through these periods also remains highly underdeveloped. A rare example of significant structural economic reform – and manufacturing in particular – occurred with the onset of the Second World War. Although efforts to shift United States manufacturing to a wartime footing began years before December 1941 U.S. entry into the conflict significantly increased the pace at which structural changes would have to occur. Questions of capacity to produce raw materials such as iron, steel, brass, cotton, and wool and finished goods such as aircraft, naval vessels, uniforms, and bullets became immediately critical. Of course, no data was available to answer these questions. As a result, the war production board was forced to cast an increasingly wider while also more specific nets in an attempt to ascertain exactly what, how much, and in what timeframe the industrial base of the nation could be brought to bear upon the production of the necessary goods and services to win the war.

With this in mind, we have cast the net wide. Using a combination of NAICS industrial data and proprietary firm data, that is scalable to the national level, we determine the real capacity for Wisconsin State manufacturers to participate in the component supply chain associated with wind and solar power. In the majority of cases, these producers are not currently engaged in these supply chains but there exists reason to believe that they might be.

To determine a list of potentially eligible current Wisconsin manufacturers a three-step process was employed: first, a list of components associated with the production of solar cells, and wind turbines were developed (more on this below). Separately, a master list of all Wisconsin industries was created using Census data (roughly 110,000 firms across 3000 industries). Using the industrial and components lists, a narrower list of industries was constructed (roughly 3000 firms across 25 industries). The remaining 25 NAICS industrial codes were then used to search within a proprietary database containing basic firm-level information. Within this group, individual firms were further researched to determine their potential to produce output compatible with the aspect of the components list. The result of this process is the 150 plus Wisconsin firms listed on the components list and, in the table, below which we believe constitute a reasonable basis for beginning to think about Wisconsin State capacity to engage in aspects of Green energy production.

6. Current Industry Assessment

Below we have compiled a list of Wisconsin businesses that might contribute to or already contribute to the production of green energy or participate in the supply chain. Ideally, we would have liked to identify all firms that are already engaged in some way with green energy. As it is, we have only noted the firms that self-identify themselves as green energy producers. The firms listed here range from very large firms with more than 1 Billion USD in annual sales and over 2000 employees to very small firms with roughly $100,000 in annual sales and just a handful of employees. Our rationale for including these very small firms is that while large scale production is almost certain to be beyond their capacity smaller firms are often highly nimble and can produce prototypes and conduct research and development within short timeframes. In total the annual sales of the firms listed is roughly 32 Billion USD and total employment is over 28,000.

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Wisconsin firms of all sizes are already engaged in either the production of green energy or in the green energy supply chain. Very large firms including Regal Beloit Corporation of Beloit, Wisconsin Power and Light of Madison, and Cardinal Glass of Mazomanie; medium-size firms such as the Enerpac Corporation of Milwaukee and Scan Pac Manufacturing Incorporated of Menomonee Falls; and small firms including Arteche PQ Incorporated also of Menomonee Falls (see table 3) are explicitly engaged in either the production of green energy or green energy supply chains. These firms, or others listed in the spreadsheet below, would be good places for policymakers to engage with business leaders to; first, better determine what the specific capacity might exist for expanded production, second learn more about what obstacles to expansion exist in these marketplaces, and c) to determine other firms that might be able to be drawn into the green energy supply chains should rapid market or non-market changes occur.

Table 6.1 provides a list of the major components necessary for wind turbine manufacture, along with a brief description of the component and a list of Wisconsin firms that we believe might be able to participate in that particular aspect of the broader production supply chain.
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<tr>
<th>Component</th>
<th>Description</th>
<th>Who Makes It</th>
<th>NAICS Code Industry</th>
<th>Firms</th>
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| Rotor blades    | Primarily made of a composite (usually fiberglass); also uses vinyl adhesives, other metal fasteners, and foams | Rotor blade manufacturers or wind turbine manufacturing OEMs (e.g. Vestas, GE, Siemens) | 333611 - Turbine and Turbine Generator Set Units Manufacturing 32721 - Glass and Glass Product Manufacturing | Advanced Fiber Products  
http://www.afpfiberglass.com/index.html  
Fiberglass Solutions  
https://www.fiberglasssolutions.us/  
Custom Fiberglass Molding  
http://www.customfiberglassmolding.com/  
Mekco  
https://www.mekco.com/  
OHS Fiberglass Manufacturing  
https://ohsfiberglass.com/products/  
EFC Inc  
http://www.engineeredfiberglass.com/palmer%20bowls%20flumes.htm  
Fiberdome  
https://www.fiberdome.com/divisions.asp  
Fiber-tech incorporated  
http://www.fiber-techinc.com/industries/telecommunications/  
Composites One  
https://www.compositesone.com/  
AM Fiberglass Manufacturing  
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GPI Composites  
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FRP Composites  
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Fiberglass Innovations  
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Brown-Campbell Company  
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Sintex-Wausaukeee Composites |

Table 6.1

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<td>Main shaft</td>
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<th>Firms</th>
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</thead>
</table>
| Main frame       | Iron; supports the nacelle                | Wind turbine manufacturers e.g. (Steel Wind Industries [https://www.steelwindindustries.com/](https://www.steelwindindustries.com/), Ram Tool Inc. [https://ramtoolinc.com/](https://ramtoolinc.com/), Manor Tool [https://www.manortool.com/](https://www.manortool.com/) | 33110 - Iron and steel mills and ferroalloy manufacturing 332111 - Iron and steel forging | Waupaca Foundry | [www.waupacafoundry.com](http://www.waupacafoundry.com)  
|                  |                                           |                                                                               |                                                          | Metalcraft of Mayville | [Mitcraft.com](http://www.mitcraft.com)  
|                  |                                           |                                                                               |                                                          | Baker Manufacturing | [https://www.bakermfg.com/](https://www.bakermfg.com/)  
|                  |                                           |                                                                               |                                                          | Aarrowcast Inc | [https://aarrowcast.com/](https://aarrowcast.com/)  
|                  |                                           |                                                                               |                                                          | Willman Industries Inc | [https://willmanind.com/](https://willmanind.com/)  
|                  |                                           |                                                                               |                                                          | Mid-City Foundry Company | [http://midcityfoundry.com/](http://midcityfoundry.com/)  
|                  |                                           |                                                                               |                                                          | Torrance Casting | [https://www.torrancecasting.com/](https://www.torrancecasting.com/)  
|                  |                                           |                                                                               |                                                          | Wisconsin Precision Casting Corp | [https://www.wisconsinprecision.com/](https://www.wisconsinprecision.com/)  
|                  |                                           |                                                                               |                                                          | AFK Foundry | [https://www.afkfoundry.com/facilities](https://www.afkfoundry.com/facilities)  
|                  |                                           |                                                                               |                                                          | Washburn Iron Works | [https://washburnironworks.com/](https://washburnironworks.com/)  
|                  |                                           |                                                                               |                                                          | Tomahawk Foundry | [http://www.tomahawkfoudnry.com/commercial](http://www.tomahawkfoudnry.com/commercial)  
|                  |                                           |                                                                               |                                                          | Strohwig Industries | [https://strohwig.com/](https://strohwig.com/)  
|                  |                                           |                                                                               |                                                          | Casting Services Inc | [https://castingservicesinc.com/](https://castingservicesinc.com/)  

Table 6.1

Table 6.1 continued on next page
Tower | Typically steel; concrete can also be used (or hybrid) | Wind turbine manufacturers or wind turbine tower manufacturers (e.g. Broadwind) | 3312 - Steel Product Manufacturing from Purchased Steel | Endres Mfg  
Veritas Steel  
[https://veritassteel.com/services/bridges](https://veritassteel.com/services/bridges)  
Felker Bros Corp  
Appleton Stainless  
[https://www.appletonstainless.com/all-products/](https://www.appletonstainless.com/all-products/)  
Lejune Steel Company  
[https://www.lejuneosteel.com/](https://www.lejuneosteel.com/)  
Mid-City Steel  
[https://www.mid-citysteel.com/](https://www.mid-citysteel.com/)  
Spirit Fabs  
[https://spiritfabs.com/](https://spiritfabs.com/)  
Steel Wind Industries  
[https://www.steelwindindustries.com/](https://www.steelwindindustries.com/)  
National Steel Fabricators  
Obrien Steel  
[https://www.obriensteel.com/](https://www.obriensteel.com/)  
Lakeside Steel  
[https://lakesidesteel.net/](https://lakesidesteel.net/)  
Super Steel  
[https://supersteel.com/](https://supersteel.com/)  
Central Steel and Wire Company  
[https://www.centralsteel.com/](https://www.centralsteel.com/)  
Charter Steel  
[https://www.chartersteel.com/](https://www.chartersteel.com/)  
Evers Manufacturing Inc  
McNeilus Steel Inc  
[https://www.mcneilus.com/](https://www.mcneilus.com/)  
Middle West Manufacturing  
[https://middlewestmfg.com/](https://middlewestmfg.com/)  
Alro Steel  
[https://www.alro.com/](https://www.alro.com/)  
Endres MFG  
BMC Automation  
Appleton Stainless  
[https://www.appletonstainless.com/all-products/](https://www.appletonstainless.com/all-products/)  
US Custom Manufacturing  
[https://uscustommanufacturing.com/](https://uscustommanufacturing.com/)  
Robbins Manufacturing Inc  
[https://uscustommanufacturing.com/](https://uscustommanufacturing.com/)  
SSL Industries  
[https://sslindustries.com/](https://sslindustries.com/)  
Irving Manufacturing  
[https://www.irvinginc.com/index.html](https://www.irvinginc.com/index.html)  
Wisconsin Metal Parts Inc  
[https://www.wisconsinmetalparts.com/](https://www.wisconsinmetalparts.com/)  
Chaseburg Manufacturing  
Apache Stainless  
[https://www.apachestainless.com/](https://www.apachestainless.com/)  

Transformer | Raises the voltage of the electricity | Electrical/technology companies (e.g. ABB, GE, Siemens) | 335311 – Power, Distribution, and Specialty Transformer Manufacturing | US Custom Manufacturing  
[https://uscustommanufacturing.com/](https://uscustommanufacturing.com/)  
Robbins Manufacturing Inc  
[https://uscustommanufacturing.com/](https://uscustommanufacturing.com/)  
SSL Industries  
[https://sslindustries.com/](https://sslindustries.com/)  
Irving Manufacturing  
[https://www.irvinginc.com/index.html](https://www.irvinginc.com/index.html)  
Wisconsin Metal Parts Inc  
[https://www.wisconsinmetalparts.com/](https://www.wisconsinmetalparts.com/)  
Chaseburg Manufacturing  
Apache Stainless  
[https://www.apachestainless.com/](https://www.apachestainless.com/)  

Table 6.1
Table 6.1

Similar to the above table, table 6.2 below provides a list of the major components necessary for solar module manufacture, along with a brief description of the component and then finally a list of Wisconsin firms that we believe might be able to participate in that particular aspect of the broader production supply chain.
<table>
<thead>
<tr>
<th>Component</th>
<th>Description</th>
<th>Who Makes It</th>
<th>NAICS Code</th>
<th>Companies which can produce</th>
</tr>
</thead>
</table>
|                    |                                                                              |                                                                              |                                                                             | Howard Precision Metals Inc [https://www.howardprecision.com/](https://www.howardprecision.com/)  
|                    |                                                                              |                                                                              |                                                                             | Gordon Aluminum Industries Inc [https://gordonaluminum.com](https://gordonaluminum.com)  
|                    |                                                                              |                                                                              |                                                                             | Mid-States Aluminum Corp [http://www.midstal.com/](http://www.midstal.com/)  
|                    |                                                                              |                                                                              |                                                                             | B & D Fabricators LLC [https://www.bdfabricators.com/](https://www.bdfabricators.com/)  
|                    |                                                                              |                                                                              |                                                                             | Mid-City Steel Inc [https://midcitysteel.com/](https://midcitysteel.com/)  
|                    |                                                                              |                                                                              |                                                                             | Clinton Aluminum [https://www.clintonaluminum.com/products/](https://www.clintonaluminum.com/products/)  
|                    |                                                                              |                                                                              |                                                                             | Basic Metals [http://www.basicmetals.com](http://www.basicmetals.com)  
|                    |                                                                              |                                                                              |                                                                             | Fabral [https://midcitysteel.com](https://midcitysteel.com)  
| **Cover glass**    | Low-iron float glass                                                         | Float glass producers (e.g. DuPont)                                          | 327211-Flat glass manufacturing                                               | Cardinal Glass Industries [https://www.cardinalcorp.com](https://www.cardinalcorp.com)  
|                    |                                                                              |                                                                              |                                                                             | Planet Earth Solar & Hvac OMNI Glass & Paint, INC [https://omnigp.com](https://omnigp.com)  
| **Encapsulant**    | Typically made from ethylene-vinyl acetate (EVA)                            | Chemical companies (e.g. DuPont)                                             | 325510-Paint and Coating Manufacturing                                         | Encapsys [http://www.encapsys.com/table/main-content/our-technology](http://www.encapsys.com/table/main-content/our-technology)  
| **Solar cells**    | Anywhere from 48-72 cells in a typical module                               | Solar cell manufacturers (e.g. JA Solar, Tongwei Solar, Trinko Solar)         | 334413-Semiconductor and Related Device Manufacturing                       | BAE Batteries US [https://www.baebatteriesusa.com](https://www.baebatteriesusa.com)  
|                    |                                                                              |                                                                              |                                                                             | Liberty Flag & Specialty Co Inc [http://www.worldclassflags.com](http://www.worldclassflags.com)  
|                    |                                                                              |                                                                              |                                                                             | Power Products LLC (Subsidiary of Mastervolt) [https://www.mastervolt.com](https://www.mastervolt.com)  
| **Back sheet**     | Largely made from polyvinyl fluoride (PVF) in the form of Tedlar® from DuPont| Chemical/materials producers (e.g. DuPont)                                  | 326113 – Unlaminated Plastics Film and Sheet (except Packaging) Manufacturing | Epic Resins [http://www.epicresins.com](http://www.epicresins.com)  
| **Junction box**   | Made from plastics; houses electrical components (wires)                     | Electronics companies (TE Connectivity, Mitsubishi Electric, Jinko Solar)    | 335932 - Noncurrent-Carrying Wiring Device Manufacturing                     | HellermannTyton [https://www.hellermanntyton.us](https://www.hellermanntyton.us)  
| **Racking/ mounting system** | Either aluminum or steel                                                  | Solar metal fabrication companies (Sunpower Corp., NEXTracker, Array Technologies) | 321111-Iron and Steel Forging 322112-Nonferrous Forging                    | Walker Forge Inc [https://www.walkerforge.com](https://www.walkerforge.com)  
|                    |                                                                              |                                                                              |                                                                             | Komatsu Surface Mining [https://mining.komatsu](https://mining.komatsu)  
|                    |                                                                              |                                                                              |                                                                             | Unit Drop Forge Co Inc [https://www.unitforgings.com](https://www.unitforgings.com)  
|                    |                                                                              |                                                                              |                                                                             | Cleveland Hardware and Forging [https://www.clevelandhardware.com](https://www.clevelandhardware.com)  

Table 6.2

Table 6.2 continued on next page
<table>
<thead>
<tr>
<th>Component</th>
<th>Description</th>
<th>Who Makes It</th>
<th>NAICS Code</th>
<th>Companies which can produce</th>
</tr>
</thead>
<tbody>
<tr>
<td>Solar inverter</td>
<td>Convert DC into AC</td>
<td>Electronics/technology companies (e.g. Huawei, SMA Solar Technology)</td>
<td>334413-Semiconductor and Related Device Manufacturing</td>
<td>None identified</td>
</tr>
</tbody>
</table>

Table 6.2

(Shown in landscape format)
Table 6.3 below gives an alphabetical listing of all the firms that we estimate may be well suited to one or more aspects of the supply chain of either solar cell or wind turbine manufacture.

<table>
<thead>
<tr>
<th>Business</th>
<th>Description</th>
<th>Address</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aarrowcast Inc</td>
<td>Leading producer of high quality and ductile iron castings</td>
<td>2900 E Richmond St Shawano WI 54166-3804</td>
</tr>
<tr>
<td>ABB</td>
<td>Multinational company, produces transformers and generators</td>
<td>16250 W Glendale Dr, New Berlin, WI 53151-2858</td>
</tr>
<tr>
<td>Absolute Custom Extrusions, Inc.</td>
<td>Offer custom plastic extrusion, profiles, and tubing designed to reflect your specific needs down to the last detail.</td>
<td>3868 N Fratney St. Milwaukee, WI, 53212-1341</td>
</tr>
<tr>
<td>Absolute Machine LLC</td>
<td>Produce casting, CNC Mill &amp; Lathe, Wire and Hole EDM</td>
<td>1604 W Haskel St Ste B, Appleton, WI 54914-5012</td>
</tr>
<tr>
<td>Advanced Composites, LLC</td>
<td>Produce mixed resins and plastics. Our process is able to take all grades of plastic and blend them into one form.</td>
<td>97 S Pioneer Rd Ste 300, Fond Du Lac, WI 54935-3803</td>
</tr>
<tr>
<td>Advanced Fiber Products</td>
<td>Manufacture standard and custom fiberglass pultrusions</td>
<td>2910 Luoyang Ave, La Crosse, WI 54601-3067</td>
</tr>
<tr>
<td>Advanced Nanotechnology Solutions, LLC</td>
<td>Part of Scientific Research &amp; Development Services Industry</td>
<td>513 Isle Royal Dr, Madison, WI, 53705-2416</td>
</tr>
<tr>
<td>APK Foundry</td>
<td>Provide grey and ductile casting services</td>
<td>300 Pacific St Ripon, WI 54971-1317</td>
</tr>
<tr>
<td>Alliant Energy Corporation*</td>
<td>Subsidiary in Wisconsin: (Wisconsin Power and Light Company), currently produces and transports wind energy</td>
<td>4902 N Biltmore Ln Ste 1000, Madison, WI 53718-2148</td>
</tr>
<tr>
<td>Alpha Industries (Steel Rule Dies)</td>
<td>Manufacturer of precision steel rule dies</td>
<td>3650 N 126th St Brookfield, WI 53005-2421</td>
</tr>
<tr>
<td>Alro Steel</td>
<td>Metals, industrial supplies and plastic provider</td>
<td>43 E 10th Ave Oshkosh, WI, 54902-6001</td>
</tr>
<tr>
<td>Altus Vinyl LLC</td>
<td>Expert capabilities for heat sealing products, as well as customizing features such as foil stamping, debossing, screen printing, and custom design.</td>
<td>2234 Northwestern Ave, Racine, WI, 53404-2519</td>
</tr>
<tr>
<td>AM fiberglass Manufacturing</td>
<td>Construct, Manufacture and repair most fiberglass products</td>
<td>817W 7th Street North, Ladysmith, WI 54848</td>
</tr>
<tr>
<td>AM Spectra Inc</td>
<td>World-wide known developer and manufacturer of navigation lights, marine searchlights and acoustic signalling equipment.</td>
<td>727 S Washington St, Shawano, WI, 54166-3039</td>
</tr>
<tr>
<td>American Aluminium Extrusion Co</td>
<td>Provide superior quality aluminium extrusion, fabricated products and customized services</td>
<td>1 Saint Lawrence Ave Beloit, WI 53511-6246</td>
</tr>
<tr>
<td>American Metal Technologies LLC</td>
<td>Leading manufacturer of precision-machined parts in cast iron, ferrous and non-ferrous castings, steel forgings, and sand permanent mold castings.</td>
<td>8213 Durand Ave, Sturtevant, WI, 53177-1945</td>
</tr>
<tr>
<td>Apache Stainless</td>
<td>Manufacturer of commercial, industrial and wholesale capital equipment for food, beverage, pharmaceutical, energy and other essential industries</td>
<td>200 Industrial Dr Beaver Dam, WI 53916-1136</td>
</tr>
<tr>
<td>Appleton Stainless</td>
<td>Speedy manufacturer which provides services such as custom stainless fitting and flanges, stainless steel fabrication and specialty machining</td>
<td>5561 W Clairemont Dr Appleton, WI 548013-8857</td>
</tr>
<tr>
<td>Aqualand Manufacturing Of Woodruff, Inc</td>
<td>Has a specialty line of Marine Products for docking purpose.</td>
<td>1301 1ST Ave, Woodruff, WI, 54568 United States</td>
</tr>
<tr>
<td>Arimon Technologies</td>
<td>control panel and box build assembly, wiring harnesses, cable assemblies, and electromechanical assembly</td>
<td>251 E 5TH St, Montello, WI, 53949-9752</td>
</tr>
<tr>
<td>Arteche PQ Inc*</td>
<td>International Electrical manufacturing and distribution company. Currently produces generators and is involved with grid integration for wind energy</td>
<td>NS2w13670 Northpark Dr, Menomonee Falls, WI 53051-7061</td>
</tr>
</tbody>
</table>

Table 6.3 continued on next page
<table>
<thead>
<tr>
<th>Business</th>
<th>Description</th>
<th>Address</th>
</tr>
</thead>
<tbody>
<tr>
<td>ATI Ladish LLC</td>
<td>Designs and manufactures high-strength forged and cast metal components for aerospace and industrial markets.</td>
<td>5481 S Packard Ave, Cudahy, WI, 53110-2244</td>
</tr>
<tr>
<td>Audio Visual Equine Systems</td>
<td>Part of the Animal Production Industry.</td>
<td>80 E Galley Dr, Sturgeon Bay, WI, 54235-3634</td>
</tr>
<tr>
<td>Austin Foundry</td>
<td>Produces of high quality gray and ductile iron casting</td>
<td>814 N Wildwood Ave Sheboygan, WI, 53081-3582</td>
</tr>
<tr>
<td>B&amp;G Fabricators LLC</td>
<td>Provide custom, specially designed attachments</td>
<td>810 Tamarack Avenue, Edgar, WI, 54426</td>
</tr>
<tr>
<td>Bachubber Manufacturing Corp (BMC Automation)</td>
<td>Stamping and fabricating firm</td>
<td>450 Steel Lb Mayville, WI 53050-1148</td>
</tr>
<tr>
<td>BAE Batteries US</td>
<td>Provides a full line of stationary VLA and VRLA batteries, chargers, racks, spill containment and accessories.</td>
<td>484 Country Road Vv, Somerset, WI 54025-9031</td>
</tr>
<tr>
<td>Baker Manufacturing</td>
<td>Produces gray and ductile iron custom castings for automotive, marine, and agricultural market.</td>
<td>133 Enterprise ST Evansville, WI 53536-1497</td>
</tr>
<tr>
<td>Baldor Power Solutions</td>
<td>Manufacturer of a variety of products: Industrial Electric Motors</td>
<td>5000 S Emmer Dr, New Berlin, WI 53151-7358</td>
</tr>
<tr>
<td>Basic Metals</td>
<td>Independent metal supplier in cut-to-lenth aluminium sheet, slit aluminium and aluminium circles</td>
<td>W180n11819 River Ln Germantown, WI, 53022-2419</td>
</tr>
<tr>
<td>Berntsen International, Inc</td>
<td>Part of the fabricated Metal Manufacturing industry.</td>
<td>5418 Monument Ln, Madison, WI, 53704-6127</td>
</tr>
<tr>
<td>Bierte, Inc.</td>
<td>Part of the Sign Manufacturing Industry.</td>
<td>1619 Doubletree Dr, Janesville, WI, 53546-1425</td>
</tr>
<tr>
<td>Briggs &amp; Stratton Corporation</td>
<td>Produces standy and portable generators</td>
<td>12301 W Wirth St, Milwaukee, WI 53222-2110</td>
</tr>
<tr>
<td>Briggs and Stratton</td>
<td>Subsidiary of Briggs and Stratton Corp</td>
<td>3560 N 124th St, Milwaukee, WI 53222-2103</td>
</tr>
<tr>
<td>Brown-Campbell Company</td>
<td>Manufacture, fabricate and distribute a wide breadth of products and offer a dull line of engineering and fabrication services.</td>
<td>7100 W Calumet Rd, Milwaukee, WI 53223-4040</td>
</tr>
<tr>
<td>Campbell Brown Company</td>
<td>Manufacture, fabricate and distribute a wide breadth of products and offer a dull line of engineering and fabrication services.</td>
<td>7100 W Calumet Rd, Milwaukee, WI 53223-4040</td>
</tr>
<tr>
<td>Cardinal Glass Industries*</td>
<td>Manufactures residential glass for windows and doors, produce premium solar control, superior IG units, impact resistance products for hurricanes.</td>
<td>420 Wick Dr, Mazomanie, WI 53560</td>
</tr>
<tr>
<td>Castalloy Inc</td>
<td>Producer of high alloy castings</td>
<td>1701, Industrial Ln Waukesha, WI 53189-7397</td>
</tr>
<tr>
<td>Casting Services Inc</td>
<td>Specialize in casting grey iron, ductile iron, steel, stainless and copper based aluminium</td>
<td>304 N Chicago Ave South Milwaukee, WI 53172-1243</td>
</tr>
<tr>
<td>Centaur Forge LLC</td>
<td>Distributor to farrier and blacksmith industry</td>
<td>117 N Spring St, Burlington, WI, 53105-1500</td>
</tr>
<tr>
<td>Central Steel and Wire Company</td>
<td>Leading metals distributor and fabricator with service center across the United States</td>
<td>4343 S 6th St Milwaukee, WI 53221-2477</td>
</tr>
<tr>
<td>Charter Steel</td>
<td>Include services such as steel melting, bar and rod rolling, tool processing and wire drawing.</td>
<td>1658 Cold Springs Rd Saukville, WI 53080-1647</td>
</tr>
<tr>
<td>Chasiburg Manufacturing</td>
<td>Provide services such as custom steel fabricators</td>
<td>102 Rack Berg Lb Coon Valley, WI 54623-8004</td>
</tr>
<tr>
<td>Chemisphere, Inc</td>
<td>Air Strippers and VOC Removal, Gas Analyzers, gas detectors, groundwater sampling, landfill liquid plumbing, landfill products, product recovery, remediation pumping, soil sampling, and wireless data systems.</td>
<td>200 Industrial Dr Beaver Dam, WI 53916-1136</td>
</tr>
<tr>
<td>Cleveland Hardware and Forging Company</td>
<td>Includes products such as truck, bus, van, rescue, enclosures, toolboxes.</td>
<td>1341 State St, Green Bay, WI 54304-3532</td>
</tr>
<tr>
<td>Clinton Aluminum</td>
<td>Supplier of aluminium and stainless steel plate products</td>
<td>400 Freedoom Ln Janesville, WI 53546</td>
</tr>
<tr>
<td>Composites One LLC</td>
<td>Produce raw materials and processing supplies and over 2,000 product categories while partnering with over 600 of the best suppliers in the business.</td>
<td>850 Heritage Rd, De Pere WI 5411503149</td>
</tr>
</tbody>
</table>

Table 6.3
<table>
<thead>
<tr>
<th>Business</th>
<th>Description</th>
<th>Address</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cooper Power Systems</td>
<td>Manufacturer of medium and high-voltage electrical equipment, components and systems</td>
<td>1045 Hickory St, Pewaukee, WI 53072-3712</td>
</tr>
<tr>
<td>Cope Plastics, Inc</td>
<td>Provide best materials and plastics solutions the industry can offer.</td>
<td>170 Wild Rose Rd, Genoa City, WI, 53128-2093</td>
</tr>
<tr>
<td>Cotta Transmission Company, LLC</td>
<td>Provide high-speed gearboxes, custom-build solutions and high-performance products.</td>
<td>1301 Prince Hall Dr, Beloit, WI 53511</td>
</tr>
<tr>
<td>Cramer Coil &amp; Transformer Co Inc.</td>
<td>Supplier of PC mountable magnetics of various industries. Supplies to both US and China</td>
<td>401 N Progress Dr, Saukville, WI 53080-1651</td>
</tr>
<tr>
<td>Cramer Coil &amp; Transformer Co Inc.</td>
<td>Variable Frequency Drives</td>
<td>401 N Progress Dr, Saukville, WI 53080-1651</td>
</tr>
<tr>
<td>Cramer Coil &amp; Transformer Co Inc.</td>
<td>Mechanical Power Transmission Products</td>
<td>401 N Progress Dr, Saukville, WI 53080-1651</td>
</tr>
<tr>
<td>Cramer Coil &amp; Transformer Co Inc.</td>
<td>Power Distribution and Industrial Automation Products</td>
<td>401 N Progress Dr, Saukville, WI 53080-1651</td>
</tr>
<tr>
<td>Crystal Finishing Systems Inc</td>
<td>Provide aluminum and plastic services</td>
<td>4704 Bayberry St Schofield, WI 54476-6097</td>
</tr>
<tr>
<td>Cummins</td>
<td>International business that produces in a variety of different segments</td>
<td>505 S Wuthering Hills Dr. Janesville, WI 53546-8309</td>
</tr>
<tr>
<td>Cummins</td>
<td>International business that produces in a variety of different segments</td>
<td>101 W Venture Dr Ste 110, Janesville, WI 53546-9147</td>
</tr>
<tr>
<td>Custom Fiberglass Molding</td>
<td>Part of the specialty contractors industry.</td>
<td>E5880 Little River Rd, Weyauwega, WI 54983-9511</td>
</tr>
<tr>
<td>Dietz Electric Co Inc</td>
<td>Distributor and manufacturer of electric motor, drives and power transmission products</td>
<td>4329 W Lincoln Ave, Milwaukee, WI 53219-1687</td>
</tr>
<tr>
<td>Drs Naval Power Systems, Inc</td>
<td>Part of the Search, Detection, Navigation &amp; Guidance System Manufacturing Industry.</td>
<td>4265 N 30TH St, Milwaukee, WI, 53216-1821</td>
</tr>
<tr>
<td>Eaton Cooper Power Systems Inc</td>
<td>Power, Distribution, and Specialty Transformer Manufacturing</td>
<td>2300 Badger Dr, Waukesha, WI 53188-5951</td>
</tr>
<tr>
<td>EFC Inc</td>
<td>Specialize in quality manufactured fiberglass building, shelters &amp; flumes</td>
<td>301 Bickford St New Lisbon, WI 53950-1524</td>
</tr>
<tr>
<td>Electrical Testing Solutions, Inc.</td>
<td>Provide Field Services, Engineering, Generators, Acceptance &amp; Commissioning, Safety training and shop services</td>
<td>2515 Lamplight Ct, Oshkosh, WI, 54904-7305</td>
</tr>
<tr>
<td>Encapsys</td>
<td>Part of the Remediation &amp; Environmental Cleanup Services Industry.</td>
<td>2500 W Wisconsin St, Portage, WI 53901-1023</td>
</tr>
<tr>
<td>Endres Manufacturing Co</td>
<td>AISC certified fabricators of structural steel, piers and shoreline equipment</td>
<td>802 S Century Ave Waunakee, WI 53597-1608</td>
</tr>
<tr>
<td>Enerpac Corp*</td>
<td>Wind turbine parts and installation products</td>
<td>6101 N Baker Rd, Milwaukee, WI 53209-3703</td>
</tr>
<tr>
<td>Enterprise Tool &amp; Die, Inc</td>
<td>Produce precision machining, Injection Mold design &amp; fabrication, CNC Milling, Grinding, Turning, CNC EDM Burner &amp; Design Injection Molds</td>
<td>8296 Commerce Pkwy Ste, Chippewa Falls, WI, 54729-5064 United States</td>
</tr>
<tr>
<td>Epic Resins Corporation</td>
<td>Produce electronic potting, LED Encapsulants, Adhesive, Filtration Resins, Composite Materials etc.</td>
<td>600 Ind Blvd, Palmyra, WI 53156</td>
</tr>
<tr>
<td>Evers Manufacturing Inc</td>
<td>Provide services such as metal fabrication</td>
<td>7327 N 51st ST Milwaukee, WI 53223-4727</td>
</tr>
<tr>
<td>Fabick, Inc.</td>
<td>Offers a wide range of coatings for the industrial, furniture, OEM, and truck markets.</td>
<td>4118 Robertson Rd, Madison, WI, 53714-3119</td>
</tr>
<tr>
<td>Fabral</td>
<td>Premier supplier of metal roofing systems</td>
<td>1820 E 26th St Marshfield, WI 54449-5510</td>
</tr>
<tr>
<td>Falls Packaging, Inc</td>
<td>Manufacturer of Quality Corrugated Shipping Containers and Corrugated Packaging Products</td>
<td>N73W15339 Paseo Ct, Menomonee Falls, WI, 53051-4553</td>
</tr>
<tr>
<td>Felker Brother Corp</td>
<td>Leading manufacturer of stainless steel piping products and fabricated piping</td>
<td>22 N Chestnut Ave Mrshfield, WI 54449-2056</td>
</tr>
</tbody>
</table>

Table 6.3
<table>
<thead>
<tr>
<th>Business</th>
<th>Description</th>
<th>Address</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fiber-Tech, Inc</td>
<td>Custom molder of fiberglass composites for OEM markets national and international.</td>
<td>4155 Courtney Rd, Franksville, WI 53126-9794</td>
</tr>
<tr>
<td>Fiberdome Incorporated</td>
<td>Offering a diverse range of services in all aspects of FRP production such as fiberglass production, tooling and engineering requirements.</td>
<td>865 Stony Rd, Lake Mills, WI 53551-1715</td>
</tr>
<tr>
<td>Fiberdome Incorporated</td>
<td>Leader in fiberglass tooling, fabrication and manufacturing fiberglass production, tooling and engineering requirements.</td>
<td>865 Stony Rd, Lake Mills, WI 53551-1715</td>
</tr>
<tr>
<td>Fiberglass Solutions, LLC</td>
<td>Fiberglass for cheese production, dairy manufacturers, the pulp &amp; paper industry, wastewater treatment facilities, water utilities, chemical companies, plating &amp; coating industries etc.</td>
<td>1933 Cofrin Dr, Green Bay, WI 54302-2027</td>
</tr>
<tr>
<td>Fiberpro, Inc.</td>
<td>Subsidiary of Advanced Fiber Products. Produce custom shapes fiberglass pultrusions, standard shapes fiberglass pultrusions, pultrusion fabrication services, pultrusion painting services.</td>
<td>2970 Luoyang Ave, La Crosse, WI 54601-3067</td>
</tr>
<tr>
<td>Five-Star Plastic, Inc</td>
<td>rapid tooling, rapid prototyping, design support, engineering, cast urethane models, tooling solutions, quality metrology solutions, injection molding, sonic welding, pad printing, hot stamping, and assembly.</td>
<td>1339 Continental Dr, Eau Claire, WI, 54701-7047 United States</td>
</tr>
<tr>
<td>FRP Composites</td>
<td>Manufacturer of custom made corrosion resistant fiberglass products</td>
<td>2220 36th Streeth North, Wisconsin Rapids, WI</td>
</tr>
<tr>
<td>Galland Henning Nopak Inc</td>
<td>World’s most experienced manufacturer of high-density balers and hydraulic and pneumatic valves and cylinders.</td>
<td>10179 S 57th St, Franklin, WI 53132</td>
</tr>
<tr>
<td>Gas Atmospheres</td>
<td>Designs and builds Nitrogen generators, Inert Gas Generators, and Co-generation systems for the heat treat, annealing, brazing, petrochemical, aseptic packaging, and agriculture industries.</td>
<td>369 W Western Ave, Port Washington, WI 53074-2233</td>
</tr>
<tr>
<td>GE Waukesha Gas Engines</td>
<td>Gas turbines~</td>
<td>1101 W Saint Paul Ave, Waukesha, WI 53188-4961</td>
</tr>
<tr>
<td>Generac</td>
<td>Produces a variety of generators, subsidiary of Generac Holdings Inc</td>
<td>757 N Newcomb St, Whitewater, WI 53190-1475</td>
</tr>
<tr>
<td>Generac Holdings Inc</td>
<td>Produces a variety of generators</td>
<td>545w29290 State Road 59, Waukesha, WI 53189-9071</td>
</tr>
<tr>
<td>Generac Mobile Products</td>
<td>Subsidiary of Generac Inc</td>
<td>215 Power Dr, Berlin, WI 54923-2420</td>
</tr>
<tr>
<td>Generac Power Systems Inc</td>
<td>Produces a variety of generators, subsidiary of Generac Holdings Inc</td>
<td>Hillside Rd &amp; Hwy 59, Waukesha, WI 53187</td>
</tr>
<tr>
<td>Gentec LLC</td>
<td>Electrical equipment supplier that utilizes in-house R&amp;D, engineering, tech support and manufacturing</td>
<td>2305 Stonebridge Rd, West Bend, WI 53095-5726</td>
</tr>
<tr>
<td>Gordon Aluminium Industries Inc</td>
<td>Provides extruded and fabricated aluminum components</td>
<td>1000, Mason Street, Schofield WI, 54476</td>
</tr>
<tr>
<td>GPI Corporation</td>
<td>Manufacturer composite tanks and custom molded products</td>
<td>101 Norther Rd Schofield, WI 54476 - 1873</td>
</tr>
<tr>
<td>Grede Casting</td>
<td>Leading developer, manufacturer, assembler and supplier of ductile, gray and specialty iron castings and machined components</td>
<td>700 Ash St Reedsburg, WI 53959-2134</td>
</tr>
<tr>
<td>Groupventure LLC</td>
<td>Part of the Medical Equipment &amp; Supply Wholesalers Industry.</td>
<td>743 Wilfred Rd, Hudson, WI, 54016-7684</td>
</tr>
<tr>
<td>Grover Gear Division-Regal Beloit</td>
<td>Motor and Generator Manufacturing</td>
<td>1525 15th Ave, Union Grove, WI</td>
</tr>
</tbody>
</table>

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<tbody>
<tr>
<td>Hader Industries Inc</td>
<td>Manufacturer and remanufacture of hydraulic components supplying the material handling market. Produces control valves, cylinders-power steering &amp; hydraulic, pumps and control units.</td>
<td>15600 W Lincoln Ave, New Berlin, WI 53151</td>
</tr>
<tr>
<td>Hammond Power Solutions</td>
<td>Transformers for wind power generation.</td>
<td>1100 Lake St, Baraboo, WI 53913-3000</td>
</tr>
<tr>
<td>HellermannTyton</td>
<td>Industrial products (Junction Box)</td>
<td>7930 N Faulkner Rd, Milwaukee, WI 53224-3423</td>
</tr>
<tr>
<td>Howard Precision Metals Inc</td>
<td>Specializes in precision sawing of aluminum plate and extruded bar products</td>
<td>8058 North 87th Street, Milwaukee, WI, 53224</td>
</tr>
<tr>
<td>Innerface Concepts, Inc</td>
<td>Part of the Plastic &amp; Rubber Product Manufacturing Industry.</td>
<td>2609 Elmwood Blvd, Wausau, WI, 54403-7016</td>
</tr>
<tr>
<td>Irving Manufacturing</td>
<td>Specialize in machining, fabrication &amp; polishing of stainless steel &amp; stainless alloys</td>
<td>5704 46th St Kenosha, WI 53144-1899</td>
</tr>
<tr>
<td>Johnson Electric Coil Company</td>
<td>Engineering for specialty buildings and equipment, general site work and demolition, environmental consulting and civil engineering.</td>
<td>821 Watson St, Antigo, WI 54409-2753</td>
</tr>
<tr>
<td>Kepa Services Inc.</td>
<td>Engineering for specialty buildings and equipment, general site work and demolition, environmental consulting and civil engineering.</td>
<td>6525 W Bluemound Rd 14, Milwaukee, WI, 53213-4073</td>
</tr>
<tr>
<td>Kirsh Foundry Inc</td>
<td>Provides high-quality engineered iron castings</td>
<td>125 Rowell St Beaver Dam, WI 53916-2343</td>
</tr>
<tr>
<td>Kleiss Gears, Inc</td>
<td>Subsidiary of Victrex, produce high-precision gear design, prototyping, testing and manufacturing capabilities using VICTREX HPG™ polymers.</td>
<td>390 Industrial Ave, Grantsburg, WI, 54840-6600 United States</td>
</tr>
<tr>
<td>Komatsu Mining Corp.</td>
<td>Known worldwide for usage in high productivity mining solutions</td>
<td>100 E Wisconsin Ave Ste 270, Milwaukee, WI 53202-4127</td>
</tr>
<tr>
<td>Lakeside International, LLC</td>
<td>Part of the Automobile Dealers Industry.</td>
<td>11000 W Silver Spring Dr, Milwaukee, WI, 53225-3134</td>
</tr>
<tr>
<td>Lakeside Steel</td>
<td>Provide metal fabrication for power generation industry, material handling, construction equipment and original equipment</td>
<td>4117 13th Ct Kenosha, WI 53140-5601</td>
</tr>
<tr>
<td>Lemke Industrial Machine, LLC</td>
<td>Manufactures machinery and operating equipment for locks, dams, and movable bridges</td>
<td>143454 County Road Nn, Marathon, WI 54448-7573</td>
</tr>
<tr>
<td>Liberty Flag &amp; Specialty Co Inc</td>
<td>Company’s line of business includes the wholesale distribution of non-durable goods. Part of Advertising &amp; Marketing Serviced Industry.</td>
<td>E7556 State Hwy 23 And 33 Reedsburg, WI 53959-9584</td>
</tr>
<tr>
<td>Luk, Corporation</td>
<td>Producing the finest quality with on-time deliveries such as tool and design, 3D Printing, RTV Molding &amp; Casting, CNC Machining, Aluminium &amp; Steel Tooling, Injection Molding, Finishing</td>
<td>1801 Indianhead Dr E, Menomonie, WI, 54751-8501 United States</td>
</tr>
<tr>
<td>Masonry Restoration, Inc</td>
<td>Provide restoration services such as façade cleaning, epoxy &amp; urethane injections, parking structures, historic preservation, stone &amp; terra cotta, façade inspection, sealant replacement etc.</td>
<td>9522 W Schlinger Ave Milwaukee, WI 53214-1239</td>
</tr>
<tr>
<td>McM Systems, Inc</td>
<td>Provide services such as machine wiring, system design and construction, testing and start-up services, control panel assembly etc.</td>
<td>8208 Moasis Dr, Little Chute, WI, 54140-1251</td>
</tr>
<tr>
<td>McMillan Electric Company</td>
<td>Produces motors and Generator heads</td>
<td>400 Best Rd, Woodville, WI 54028-9535</td>
</tr>
<tr>
<td>McNally Industries, LLC</td>
<td>Manufacturing of hydro and electro-mechanical systems/sub-systems and precision machined components for critical defense and aerospace application.</td>
<td>340 W Benson Ave Grantsburg, WI 54840-7004</td>
</tr>
<tr>
<td>McNeilus Steel Inc</td>
<td>Full-line steel distributor and processor</td>
<td>123 E Larsen Dr Fond Du Lac, WI 54937-8519</td>
</tr>
</tbody>
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<tr>
<td>Mekco Manufacturing Inc</td>
<td>Manufactures custom, project-specific, pre-engineered and pre-fabricated fiberglass shelters, fiberglass enclosures, fiberglass sheds and fiberglass buildings</td>
<td>11110 State Road 42, New Berlin, WI 53063-9759</td>
</tr>
<tr>
<td>Merit Gear</td>
<td>Subsidiary company, part of the machinery manufacturing industry</td>
<td>810 Hudson St, Antigo, WI 54409.</td>
</tr>
<tr>
<td>Metalcraft of Mayville</td>
<td>Leading provider of custom automation manufacturing solutions serving the Midwest</td>
<td>2600 Metalcraft RD West Bend, WI 53095-5249.</td>
</tr>
<tr>
<td>Mid Central Electric Inc</td>
<td>Supplier of transformers, repairs and assembly</td>
<td>880 Market St, Oregon, WI 53575-1010.</td>
</tr>
<tr>
<td>Mid-City Foundry Company</td>
<td>Produces complex gray, ductile, compacted graphite, high silicon-, oly ductile and allowed iron castings</td>
<td>1521 W Bruce St Milwaukee, WI 53204-1224.</td>
</tr>
<tr>
<td>Mid-City Steel Inc</td>
<td>Provide services in advanced steel fabrication</td>
<td>115 Buchner Pl La Crosse, WI 54603.</td>
</tr>
<tr>
<td>Mid-States Aluminum Corp</td>
<td>Provide aluminum extrusion applications</td>
<td>32 Trowbridge Dr, Fond du Lac, WI 54937.</td>
</tr>
<tr>
<td>Middle West Manufacturing</td>
<td>Offers services such as custom fabrication, general fabrication, machining, rolling, tank fabrication, weldments, etc</td>
<td>N93w16591 Falls Pkwy Menomonne Falls, WI 53051-1476</td>
</tr>
<tr>
<td>Midland Plastics, Inc.</td>
<td>Offer a wide variety of sheet, rod and tubes as well as custom manufacturing, thermoforming, fabrication and extrusions.</td>
<td>5405 S Westridge Ct. New Berlin, WI 53151-7951</td>
</tr>
<tr>
<td>Motion Industries, Inc.</td>
<td>Supplier of bearings, pneumatics, hydraulics and mechanical power transmission products</td>
<td>510 25th Ave N, Wisconsin Rapids, WI 53455-2220</td>
</tr>
<tr>
<td>National Steel Fabricator</td>
<td>Specialize in custom structural steel fabrication, custom railings and welding</td>
<td>W16890 Us Highway 8 Rice Lake WI 54868-8607.</td>
</tr>
<tr>
<td>NGS Capital Management, LLC</td>
<td>Manufacture ball and roller bearings</td>
<td>856 Armour Rd, Oconomowoc, WI 53066-3976.</td>
</tr>
<tr>
<td>Nicolet Plastic LLC</td>
<td>Wide variety of injection molding and assembly</td>
<td>16685 State Rd 32, Mountain WI 54149.</td>
</tr>
<tr>
<td>Nord Gear Corp</td>
<td>Produces 300 motors and 650 gear units</td>
<td>800 Nord Dr, Waunakee, WI 53979-9598.</td>
</tr>
<tr>
<td>Northlake Engineering Inc</td>
<td>Produces transformers</td>
<td>8320 193rd Ave, Bristol, WI 53104-9549.</td>
</tr>
<tr>
<td>Obrien Steel</td>
<td>Provide customer with quality steel products</td>
<td>6001 S Pennsylvania Ave Cudahy, WI 53110.</td>
</tr>
<tr>
<td>OFC Fiberglass Manufacturing</td>
<td>Custom fiberglass products</td>
<td>W3611 State Road 60 Neosho, WI 53059-9764.</td>
</tr>
<tr>
<td>Ogre Manufacturing LLC</td>
<td>Part of the Consulting Services Industry.</td>
<td>231 S 79TH St, Milwaukee, WI 53214-1416.</td>
</tr>
<tr>
<td>Omni Glass &amp; Paint, Inc</td>
<td>Engages in Glass work</td>
<td>3530 Omni Dr Oshkosh, WI 54904-8171.</td>
</tr>
<tr>
<td>Orchid Monroe LLC</td>
<td>Design engineering, testing validation, injection molding, and painting plating services.</td>
<td>350 21st St, Monroe, WI 53566-2739.</td>
</tr>
<tr>
<td>P A Electronics Corporation</td>
<td>Designer and manufacturer of transformers and magnetic devices, both military and commercial</td>
<td>675 Industrial Ct, Hartland, WI 53029-2351.</td>
</tr>
<tr>
<td>Planet Earth Solar &amp; Hvac</td>
<td>Part of the Plumbing &amp; HVAC Contractors Industry.</td>
<td>N3227 State Road 16, La Crosse, WI 54601-3018</td>
</tr>
<tr>
<td>Plasma Technics</td>
<td>Manufacturer of high-voltage transformers</td>
<td>1900 William St, Racine, WI 53404-1875.</td>
</tr>
<tr>
<td>Plastics Unlimited, Inc.</td>
<td>Providing quality laminating, identification products, and binding materials to national and international businesses as well as individuals.</td>
<td>12012 W Fairview Ave, Milwaukee, WI 53226-3846</td>
</tr>
<tr>
<td>Poclain Hydraulics</td>
<td>World leading specialist in hydrostatic transmission, produce motors, pumps, electronics, hydraulic autounits and high performance products.</td>
<td>1300 Grandview Pkwy, Strutewa, WI 53177.</td>
</tr>
<tr>
<td>Polyone Corporation</td>
<td>Is part of the Plastic Resin &amp; Synthetic Fiber Manufacturing Industry</td>
<td>N7660 Industrial Rd, Portage, WI 53901-9451.</td>
</tr>
<tr>
<td>Power Products, LLC</td>
<td>Subsidiary of Mastervolt company, Part of the semiconductor &amp; other electronic component manufacturing industry.</td>
<td>16250 W Woods Edge Rd, New Berlin, WI 53151-8015</td>
</tr>
</tbody>
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<tr>
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<tbody>
<tr>
<td>Powers Holdings, Inc</td>
<td>Makes electrical and electronic components, such as terminal blocks, relay sockets, radio-frequency interference (RFI) power line filters, liquid level controls, and related accessories.</td>
<td>2400 S 43RD St, Milwaukee, WI, 53219-2311</td>
</tr>
<tr>
<td>Professional Power Products</td>
<td>Produces enclosures that might be used for wind turbines, and 2.5Mw Mobile Generator systems.</td>
<td>448 W Madison St, 448 W Madison St. Darien, WI 53114-1511</td>
</tr>
<tr>
<td>Professional Power Products, Inc.</td>
<td>Experience in mechanical, electrical, and control systems associated with power generation systems</td>
<td>448 W Madison St, Darien, WI, 53114-1511</td>
</tr>
<tr>
<td>Ram-PAC International Inc</td>
<td>Manufacture hydraulic systems in Wisconsin plant.</td>
<td>16600 W lincoln Ave, New Berlin, WI 53151</td>
</tr>
<tr>
<td>Regal Beloit</td>
<td>Motor and Generator Manufacturing subsidiary of Regal Beloit Corporation</td>
<td>W9919 Bauer Rd, Black River Falls, WI 54615-5532</td>
</tr>
<tr>
<td>Regal Beloit Corporation*</td>
<td>Motor and Generator Manufacturing</td>
<td>200 State St, Beloit, WI 53114-6254</td>
</tr>
<tr>
<td>Rexnord Corp</td>
<td>Concentrated multiplatform industrial leader with exceptional and trusted brands.</td>
<td>4701 W Greenfield Ave, Milwaukee, WI 53214</td>
</tr>
<tr>
<td>Robbins Manufacturing</td>
<td>Word class metal fabrication &amp; power coating</td>
<td>200 Steel Rd Fall River, WI 53932-9405</td>
</tr>
<tr>
<td>Roloff Manufacturing Corporation</td>
<td>Family owned gray iron foundry</td>
<td>400 Gertrude St Kaukaybam WI 54130-1424</td>
</tr>
<tr>
<td>Roma Tool &amp; Plastics, Inc.</td>
<td>Part of the Plastic &amp; Rubber Product Manufacturing Industry.</td>
<td>107 Prospect Ave W, Almena, WI 54805-7050</td>
</tr>
<tr>
<td>Scan-Pac Mfg, inc*</td>
<td>Produce Gemini, Gatke, Oilfield, Rigid Molded. Involved in markets for material handling, rail, winches, PT equipment, Paper, Oilfield, Wind Power, Metals, Construction etc.</td>
<td>N84W13480 Leon Rd Ste A, Menomonee Falls, WI, 53051-3396</td>
</tr>
<tr>
<td>Schwahn Tool &amp; Plastic Co</td>
<td>Manufactures custom plastic injection mold products and parts for a variety of industries, including automotive, marine, food &amp; beverage, consumer products, industrial, and dental.</td>
<td>15 E Walnut St, Chippewa Falls, WI, 54729-2938</td>
</tr>
<tr>
<td>SNC Manufacturing Co Inc</td>
<td>Operates in 3 different locations. Manufacturer and marketer of electrical transformers, utility products, and information and communication products</td>
<td>101 W Waukau Ave, Oshkosh, WI 54902-7299</td>
</tr>
<tr>
<td>Solarcrystal Technologies</td>
<td>Part of the Professional Services Sector Industry.</td>
<td>803 W Lawrence Ave, Milwaukee, WI, 53225-5036</td>
</tr>
<tr>
<td>Spirit Fabrication</td>
<td>Premier provider of structural steel and pipe fabrication services for customers.</td>
<td>3261 Spirit Way Green Bay, WI 54304-5638</td>
</tr>
<tr>
<td>SPX Transformer Solutions Inc</td>
<td>Produces transformers (subsidary of Spx Corp)</td>
<td>400 S Prairie Ave, Waukesha, WI 53186-5969</td>
</tr>
<tr>
<td>SSL Industries</td>
<td>Manufacturing company in stainless steel tables and product line</td>
<td>Luey Ln, Plymouth, WI 53073</td>
</tr>
<tr>
<td>Stamped Out LLC</td>
<td>Part of the Steel Service Centers &amp; Other Metal Wholesalers Industry</td>
<td>942 E Lindbergh St, Appleton, WI, 54911-3074</td>
</tr>
<tr>
<td>Steel Wind Industries</td>
<td>Large capacity fabrication shop offering heavy custom metal steel fabrication services</td>
<td>7550 S 10th St Oak Creek, WI 53154-1910</td>
</tr>
<tr>
<td>Strohwig Industries</td>
<td>Specialize in die cast, injection mold and custom machining shop</td>
<td>3825 Industrial Rd Richfield WI 53076</td>
</tr>
<tr>
<td>Super Steel</td>
<td>Provide manufacturing service in steel products, steel fabrication, complex manufacturing and engineering</td>
<td>7900 W Tower Ave Milwaukee, WI 53223-3253</td>
</tr>
<tr>
<td>Sussek Machine Corporation</td>
<td>Industry experts in machined parts and assemblies.</td>
<td>805 Pierce St, Waterloo, WI 53594-1523</td>
</tr>
<tr>
<td>Synchrotek Inc*</td>
<td>Specializes in electrical power generation systems / solutions, specifically for alternative energy and specialty high efficiency applications. Currently works with wind energy</td>
<td>610 Baeten Rd, Green Bay, WI 54304-5702</td>
</tr>
<tr>
<td>Tomahawk Foundry</td>
<td>Specialize in commercial castings and &quot;one of a kind&quot; castings from original parts</td>
<td>2337 29th St Rice Lake, WI, 54868-9052</td>
</tr>
</tbody>
</table>

Table 6.3 continued on next page
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<tbody>
<tr>
<td>Toman Tool Corporation</td>
<td>Custom designs and manufactures thermal press machines, or heat staking machines, for precise assemblies.</td>
<td>WS224 N Chipmunk Rd, Stoddard, WI, 54658-9730</td>
</tr>
<tr>
<td>Torrance Casting Inc</td>
<td>Provide services such Grat, Ductile and Ni-Hard Iron Castings</td>
<td>3131 Commerce St La Crosse, WI 54603-1756</td>
</tr>
<tr>
<td>Tsi Power Corp</td>
<td>Makes the highest-quality power solutions available such as off-the-shelf and custom products are engineered to perform continuously and reliably.</td>
<td>1103 W Pierce Ave, Antigo, WI, 54409-3103</td>
</tr>
<tr>
<td>Turbine Technologies Ltd</td>
<td>Creator of educational laboratory products that relate to science, engineering and technology.</td>
<td>410 Phillips St, Chetek, WI 54728-9385</td>
</tr>
<tr>
<td>Twin Disc</td>
<td>Makes heavy-duty power transmission equipment for the marine and off-highway vehicle markets. It also serves the energy and natural resources and industrial markets.</td>
<td>1328 Racine St, Racine, WI 53403</td>
</tr>
<tr>
<td>Unit Drop Forge Co, Inc.</td>
<td>Manufacturer of custom designed closed-die forged steel components.</td>
<td>1903 S 62ND St, West Allis, WI 53219-1464</td>
</tr>
<tr>
<td>US Custom Manufacturing</td>
<td>Custom manufacturing in automotive industry, furniture, lawn and garden equipment, frame components, and handles/rails</td>
<td>425 S Washington St Combined Locks, WI 54113-1049</td>
</tr>
<tr>
<td>US Military Manufacturing Inc</td>
<td>Part of the Machinery Manufacturing Industry</td>
<td>2465 S 84TH St, Milwaukee, WI, 53227-2503</td>
</tr>
<tr>
<td>Utility Tool &amp; Trailer, Inc</td>
<td>Specialize in the manufacturing of trailers and components as well as providing welding, painting and engineering services.</td>
<td>97 S Pioneer Rd Ste 300, Fond Du Lac, WI 54935-3803</td>
</tr>
<tr>
<td>Valley Grinding &amp; Manufacturing, Inc</td>
<td>Provide valley grinding, blades, sharpening, industrial knives, knife manufacturer, blade manufacturer, foil converting, film converting.</td>
<td>1717 Hamilton Ct Little Chute, WI 54140-2536</td>
</tr>
<tr>
<td>Veritas Steel</td>
<td>Leader in fabricating bridge and other structures</td>
<td>2800 Melby St Eau Claire, WI, 54703-0562</td>
</tr>
<tr>
<td>Walker Forge Inc</td>
<td>Produce closed die steel forgings.</td>
<td>222 E Erie St Ste 300, Milwaukee, WI 53202-6000</td>
</tr>
<tr>
<td>Washburn Iron Works</td>
<td>Provide high quality gray and ductile iron casting</td>
<td>112 E Bayfield St Washburn, WI 54891-1132</td>
</tr>
<tr>
<td>Waukee Engineering Co Inc</td>
<td>Manufacturer of equipment for measuring &amp; controlling the flow of gases used in the heat processing &amp; associated industries</td>
<td>6724 S 13th St, Oak Creek, WI 53154-1423</td>
</tr>
<tr>
<td>Waupaca Foundry</td>
<td>Industry leading provider of quality gray iron, ductile iron, high strength ductile iron castings</td>
<td>1955 Brunner Dr Waupaca, WI 54981-8866</td>
</tr>
<tr>
<td>WC BRANHAM Inc</td>
<td>Leading fluid power and power transmission manufacturing company, and it is part of the Machinery Manufacturing Industry.</td>
<td>398 Troy Street, River Falls, WI 54022-1582</td>
</tr>
<tr>
<td>Weimer Bearing &amp; Transmission Inc</td>
<td>Offers in-housing engineering support, complete machining and fabrication services, as well as product repair and custom tailored inventory solutions.</td>
<td>N112W13131 Mequon Rd, Germantown, WI, 53022-36612</td>
</tr>
<tr>
<td>Werner Electric Supply Co</td>
<td>Provides smarter, scalable network infrastructure and industrial electrical wiring solutions.</td>
<td>4800 W Prospect Ave, Appleton, WI, 54914-8900</td>
</tr>
<tr>
<td>Willman Industries Inc</td>
<td>Provide Quality Castings</td>
<td>338 S Main St Cedar Grove, WI 53013-1611</td>
</tr>
<tr>
<td>Wisconsin Metal Parts Inc</td>
<td>Provide metal stamping services to a variety of industries</td>
<td>N4w22450 Bluemound Rd Waukesha, WI 53186-1621</td>
</tr>
<tr>
<td>Wisconsin Precision Casting</td>
<td>Producing high quality engineered components faster and more economically than the traditional metalworking processes</td>
<td>300 Interchange N Lake Geneva, WI 53147-8916</td>
</tr>
<tr>
<td>Zahn Electronics Inc</td>
<td>Manufacturer of convertors</td>
<td>4133 Courtney Rd Ste S, Franksville, WI 53126-9127</td>
</tr>
</tbody>
</table>

* Denotes firm is already producing green energy or part of green energy supply chain.
7. Manufacturing Opportunities in Wind Energy

In this section, we highlight specific opportunities for Wisconsin manufacturers & researchers to participate in advances in the wind energy sector and build industrial capacity in the associated manufacturing technologies. Our approach was to survey current areas of research & development in wind energy manufacturing, and then select topics that best match the capabilities of the companies/industries in section 6, above. The section concludes with a list of resources for manufacturers to explore collaborations or to pursue funding for technology development.

7.1 Advanced composite materials for wind turbine blades

A rotor blade waiting for assembly at a wind farm in Oulunsalo, Finland.

Description of the technology

Wind turbine blades become more efficient as they are made larger, so the industry is currently using blades up to 250 feet in length, with that number expected to continue to grow as technology allows and as offshore turbines continue to be developed. Wind turbine blades need high stiffness (to retain their shape), high strength, and a low density to reduce the overall weight of the system. To achieve this, manufacturers use advanced composite materials composed of resin and E-glass or carbon fiber reinforcement. In addition to stiffness, strength, and weight, blades also need to be able to resist torsion and fatigue, and need to withstand degradation from heat, sand, salt, and water.

Need for continued advancements

The wind industry seeks continued advancements in both the resin and fiber components of the composite materials. Technical needs include higher-stiffness, lighter-weight reinforcing materials, better adhesion between resin and fiber, and reduced materials costs. One area of active development is the use of thermoplastic (rather than thermoset) resins that do not require a post-molding cure step and are repairable. Advances are also needed in non-destructive testing methods to detect voids, lack of bonding, and fiber mis-orientation in the composite. Further, there are a variety of composite processing needs that are described under a separate opportunity in this document.

7.2 3D printing of molds for turbine blades

Big Area Additive Manufacturing apparatus developed by Oak Ridge National Laboratory.

(©) Photo by Oak Ridge National Laboratory https://www.flickr.com/photos/oakridgelab/20027498486/in/photostream/

**Description of the technology**

A primary method of forming wind turbine blades is by resin infusion. In this process, a heated and vacuum-capable mold is used to shape the blade prior to the application of the resin, which then cures into the final blade shape. Given the very large (~250 foot) length of modern turbine blades, these molds are large, expensive, and have significant technical requirements including tight dimensional tolerances, integrated heating and vacuum equipment, and a need to vary the mold design to test different blade geometries.

**Need for continued advancements**

To construct these very large and highly customized resin infusion molds, the wind industry is exploring Big Area Additive Manufacturing (BAAM). In this process, plastic extrusion replaces the typical filamentary feedstock used in fused deposition modeling (FDM), and a gantry system is used to construct the 3D-printed part over very large areas. Current state-of-the-art units achieve 200 inch/sec peak velocities and extrusion rates up to 1000 in³/hr, with positional accuracies of 0.002 inches₁¹. The industry seeks continued advances in the BAAM gantry and extrusion systems for speed and precision. Of particular interest is developing a greater diversity of feedstock materials and extrusion methods, to allow materials with increased thermal conductivity and reduced coefficients of thermal expansion to be used to build the mold₁². This, in turn allows the infused resin to be cured without a large external heating chamber, significantly reducing the cost and size of the overall manufacturing system.


7.3 Drivetrain advances

A drivetrain testing facility at Clemson University

(CC BY-SA) Photo by Ryan Johnson
https://commons.wikimedia.org/wiki/File:Clemson_University%27s_wind_turbine_drivetrain_testing_facility_(1217380885).jpg

Description of the technology

In a wind turbine, a gearbox is used to convert the low-speed rotation of the shaft (50 – 60 rotations per minute, or rpm) to a higher speed (1,000 – 1,800 rpm) needed for optimal generator performance. The gearbox is the most mechanically complicated portion of the entire wind turbine assembly, and responsible for the majority of breakdowns and reliability problems in a wind turbine\textsuperscript{13}.

Need for continued advancements

To improve reliability of the gearbox and overall drivetrain, the wind industry seeks improvements in several key areas. A primary mode of failure is axial cracks in the bearings on the high-speed stages of the gearbox. Bearings with improved toughness and fatigue life are needed, as well as improved analytical modeling of the transient loads that can lead to bearing failures. To reduce the complexity of the overall drivetrain, novel designs for single-stage gearboxes are also sought, which could improve reliability and reduce the weight of the nacelle\textsuperscript{14}. Finally, designs for medium-speed permanent magnet generators are sought to (1) reduce the highest speeds needed on the shaft and gearbox, (2) reduce the volume of rare-earth magnet metals used, and (3) reduce the operating voltage of the generator.


\textsuperscript{14} U.S. Dept. of Energy; “Advanced Drivetrain Manufacturing”; summary of advancing manufacturing of wind turbine drivetrains
7.4 End of life management

Description of the technology

Wind turbines have a life span of 20-25 years\textsuperscript{15}, and their capacity factor (the efficiency with which they produce electricity) declines during that time period\textsuperscript{16}. As blade and drivetrain technology improves, there is also an effort to repower older wind turbines with more efficient components. All of these factors create a steady waste stream from wind turbines. While steel and aluminum components of the tower and nacelle can be easily recycled, the composite fiber blades are much more difficult to repurpose, and given their large size, consume significant landfill space if they are discarded. Further, due to their high strength and stiffness, turbine blade composite materials are difficult to cut, grind, or otherwise section for repurposing. This challenge is now a widely-recognized environmental concern for the sustainability of wind turbine technology as a whole, and it has received attention not just in engineering circles but also in the popular press\textsuperscript{17}.

Need for continued advancements

The wind industry is seeking novel approaches to section and re-use the glass-epoxy composite material that comprises most wind turbine blades. On-site processing methods to reduce the large blades to sizes or forms more amenable to transportation are particularly welcome.

7.5 Additional resources and funding opportunities

DOE Blade Reliability Collaborative\textsuperscript{18}

Run by Sandia National Laboratories, the Blade Reliability Collaborative (BRC) combines turbine blade data from manufacturers and cutting-edge research in order to find solutions to industry problems and advance blade designs. The BRC then works together with partnered companies to ensure that manufacturers can produce the most efficient and reliable turbine blades possible. Working with the BRC, companies are provided access to research test results on over 500 materials for blade applications and can utilize expertise on topics relevant to blade manufacturing, such as the fabrication of composite materials. Specific areas of interest that the BRC is involved with include composite materials research, optimized carbon fiber composites, and the effects of turbine blade defects.

\textsuperscript{15} U.S. Energy Information Administration, “Repowering wind turbines adds generating capacity at existing sites”


\textsuperscript{17} C. Martin, “Wind turbine blades can’t be recycled, so they’re piling up in landfills,” accessed from the Los Angeles Times, Feb. 6, 2020.

\textsuperscript{18} Sandia National Laboratories; “Blade Reliability Collaborative”; overview of SNL and DOE’s Blade Reliability Collaborative
NREL CoMET facility\textsuperscript{19}

At NREL’s Composites Manufacturing Education and Technology (CoMET) Facility, companies can partner with NREL to have access to the facility’s composites manufacturing resources, including prototyping of novel blade materials, tooling for full-sized blade components, and materials such as fiberglass, epoxy, and carbon fiber. Manufacturing equipment and techniques intended specifically for the wind industry include 3D printed tooling and vacuum-assisted resin transfer molding. Further, CoMET also provides training and development for the composite manufacturing industry, helping to grow an experienced workforce that can meet the needs of the growing industry.

Industrial consortia

\begin{itemize}
  \item \textbf{American Wind Energy Association} (AWEA) - U.S. wind industry trade association; consists of manufacturers, researchers, and utilities and aims to promote the use of wind power throughout the United States; members receive access to a database of wind projects and manufacturing facilities in the U.S.
  \item \textbf{Global Wind Energy Council} (GWEC) - International wind industry trade association; works internationally with manufacturers, suppliers, utilities, and research institutes and help to find opportunities for countries to grow and develop their wind power industries
  \item \textbf{Institute for Advanced Composites Manufacturing Innovation} (IACMI) - Brings together government, industry, and academic institutes in order to support the commercialization of advanced composite materials; aims to lower the cost and energy use associated with the manufacturing of these advanced materials
  \item \textbf{Manufacturing Demonstration Facility} (MDF) at Oak Ridge National Laboratory - Facility created to help bring advanced additive manufacturing and advanced composites technologies to industry, for the purpose of clean energy applications
  \item \textbf{Lightweight Materials National Laboratory Consortium} (LightMAT) - Consortium that connects industry to relevant resources (both expertise and technologies) available at national laboratories; works to increase development and utilization of lightweight materials, especially for clean energy applications (DOE Energy Materials Network consortium)
  \item \textbf{America Makes} - National institute for additive manufacturing/3D printing that involves industry, research and academia, and government organizations to innovate in the additive manufacturing capabilities of the United States
\end{itemize}

\textsuperscript{19} NREL; “Composites Manufacturing Education and Technology Facility”; overview of NREL’s CoMET facility
## SBIR funding opportunities

### Wind

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<th>Opportunity</th>
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<td>Advanced composite materials for wind turbine blades</td>
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<tr>
<td>Composite fabrication/processing routes for blades</td>
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<tr>
<td>3D printing (BAAM) for turbine blades</td>
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<tr>
<td>Drivetrain</td>
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<tr>
<td>End of life management</td>
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</table>
8. Manufacturing Opportunities in Solar Energy

8.1 Bifacial solar modules

A bifacial module can utilize sunlight that has been reflected onto its reverse side, resulting in an increase in power output when compared to non-bifacial modules

(© BY-SA) Photo by Canaan Jardines de la Rambla de Sants | https://commons.wikimedia.org/wiki/File:Jardins_Rambla_Sants5.jpg

Description of the technology

Advancements in solar cell technology have led to the production of bifacial cells that can generate electricity from sunlight incident on both the top and bottom of the cell\(^{20}\). As a result, bifacial modules have begun being produced in greater quantities. Unlike standard solar modules, bifacial modules are transparent on both sides; in place of a white or black backsheet is a transparent backsheet or additional glass. The glass-glass design is more durable and transparent than the glass-backsheet design, but it also comes with a significantly higher weight. The durability of the glass-glass design has also led to it being adopted by non-bifacial modules as well\(^{21}\).

Need for continued advancements

In standard modules, ethylene vinyl acetate (EVA) is used as the encapsulant material that surrounds the solar cells. However, EVA encapsulants are associated with corrosion, something that the glass-glass modules are especially susceptible to. Because of this, alternative encapsulant materials are often used for glass-glass designs, with thermoplastic polyolefin (TPO) being a preferred material.\(^2\) However, TPO is more expensive than EVA; therefore, advances are sought to either lower the cost of production of TPO or find a new encapsulant material that is non-corrosive and inexpensive. Backsheet design also presents opportunities for advances, as materials that are more durable and transparent than those in current production would increase the lifespan of the lighter-weight backsheet bifacial modules.


\(^{21}\) S. Chunduri and M. Schmela, “Advanced Solar Module Technology”; advances in PV module and cell technology (2018)
8.2 Light reflecting technologies for solar modules

Description of the technology

In the effort to enhance the performance of solar modules, technologies and materials are being produced that increase the amount of light that the solar cells receive and subsequently absorb. To do so, solar modules use technologies that increase the amount of light that undergoes total internal reflection, or they use white materials that naturally reflect more light. Approaches that have been taken include grooved polymer films that are fitted over the cells and grooved ribbon used for the connections on the cells. An alternative to the ribbon connectors is a multi-busbar design that replaces the connector ribbon with round copper wire, a change that both uses less silver paste and increases amount of internally reflected light.

Need for continued advancements

Advances in light reflecting technologies are sought by the solar industry to increase the amount sunlight that cells receive. Components already used in solar modules (such as electrical connectors) that are modified, or separate components that are ingrained within the module are both paths that have been developing. Other developments in light reflecting technology include the use of white encapsulant materials or white glass; these are especially helpful in glass-glass modules that cannot utilize ordinary reflection as well as standard modules can. However, these specialized components are also more expensive than standard EVA or glass. Novel production methods or materials that can lower the cost of these technologies is needed.

8.3 Processing for half-cut solar cells

A pair of half-cut solar cells contains the same voltage as in one uncut cell, but with half of the current—reducing the resistive losses and increasing power output.

Description of the technology

A simple configurational change to a solar panel that increases the efficiency of the panel is to use half-cut solar cells instead of full-sized cells. During electricity generation, half-cut cells reduce the amount of current flowing through each cell, which then decreases the resistive losses present. In addition, modules using half cells perform better in shade due to a different wiring configuration. These characteristics lead to an increase in overall efficiency and reliability of the modules. Outside of the standard production methods for the cells, there are two altered steps: the cells must undergo the cutting process, and the cells have to use an adapted stringing process due to the smaller sizes of the half cells.

Need for continued advancements

Fast, reliable, and clean cutting techniques to form the half-cells are sought by the solar industry. Cutting methods that utilize mechanical processes place stress on the cells and can lead to cracks, which results in decreased reliability. Therefore, non-mechanical laser cutting processes that minimize the stress on the cells are favored. Advances in the stringing process also are needed, as the half cells require high-precision equipment to string the smaller busbars.
8.4 End-of-life management

Old or broken panels can be recycled and their materials retrieved; glass, comprising more than 80% of total panel mass, accounts for the greatest share of recycled module material.

(CC BY-SA) Photo by Kiran Jonnalagadda | Cracked panel | https://commons.wikimedia.org/wiki/File:Cracked_solar_panel_near_Leh_(4336613925).jpg

Description of the technology

As current solar panels age and the industry grows, older panels will be in need of repair or replacement. As such, the handling of PV system wastes becomes important. One area of significant interest is material recovery, as the recycling of older materials can help lower costs of production, especially when rare metals (such as indium) are considered. Additionally, solar panels use hazardous materials such as lead, tin, and cadmium that may pose safety or environmental risks and so need to be handled properly.27

Need for continued advancements

The waste currently created by the solar industry is moderate and is able to be processed in normal recycling plants. However, as the industry grows, the waste stream will grow as well, and recycling plants dedicated to processing PV waste may be required.1 This would help increase material recovery, particularly of rare materials, for reuse in solar systems or other industries. Also, PV recycling plants would also be better equipped to handle the hazardous materials to mitigate health and environmental risks. Advancements are also needed in the repair of old or broken solar systems to extend their lifespans as an alternative to decommission and replacement.28 Efficient processes for waste disposal and material recovery are needed from these mostly silicon-based solar cells.

---


8.5 Additional resources and funding opportunities

Industrial consortia

Solar Energy Industries Association (SEIA)- U.S. solar industry national trade association


DuraMAT- Consortium between researchers and industry looking to develop and commercialize novel materials for PV modules; aims to lower the cost of PV system electricity (DOE Energy Materials Network consortium)

General renewables/Both solar and wind (advocacy groups)

American Council on Renewable Energy (ACORE)- U.S. national collaborative advocacy group for renewable energies. Wind Solar Alliance (WSA)- U.S. renewable energy advocacy group; will be merging with ACORE

Clean Grid Alliance- Midwest advocacy group for renewable energies

RENEW Wisconsin- Wisconsin renewable energy advocacy group

Midwest Energy Research Consortium- Partners with researchers to solve problems faced in the Energy, Power, and Controls industry and advance the technologies used by the industry

Advanced Materials Industrial Consortium (AMIC)- Allows companies to work with academia in advanced materials research at the UW- Madison campus; access is given to the facilities on the campus in order to assist in innovation

SBIR funding opportunities

<table>
<thead>
<tr>
<th>Opportunity</th>
<th>SBIR/funding opportunities</th>
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<td>Light-reflecting technology</td>
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<td>Processing for half-cut solar cells</td>
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</table>
9. Analysis of Advanced Lithium-Ion Batteries Across Wisconsin

With the development of portable devices and electric vehicles, lithium-ion batteries (LIBs) have been regarded as one of the most important energy storage method. LIB mainly consists of anode, cathode, separator, electrolyte and other components. It can be charged/discharged through the transportation of lithium ions between anode and cathode. Currently, the most common used anode material is graphite. And the majority of cathodes used in LIBs are LiFePO4 (LFP) and LiNi1-x-yMnxCoyO2 (x+y<0.5) (NMC) family, such as LiNi1/3Mn1/3Co1/3O2 (NMC111) and LiNi0.5Mn0.3Co0.2O2 (NMC532). Currently, the focus of the development of LIBs mainly include increasing the energy density and reducing the cost. For example, Department of Energy (DOE) aims to reduce the cost of electric vehicle batteries to less than $100/kWh—ultimately $80/kWh with driving range to 300 miles and charge time to 15 min or less.

Due to the technology improvements and economies of scale, the price of lithium ion batteries decreases steeply in the past few years. Also, the competition between main manufacturers promotes the price dropping. More than 1.18 million electric vehicles are on the road in the U.S. as of March 31, 2019. Except the US, China and the European region are also accounted for maximum sales of electric vehicles. Roughly 1.6 million EVs were on the roads in China in 2018. With the rapid development of EV, the demand of lithium ion batteries is also expected to increase in recent years. The development of some other electric devices and tools is also promoting the development of LIBs. For example, the global battery power tools market was valued at $22,440.0 million in 2018, and is projected to reach $44,062.0 million by 2026, growing at a CAGR of 8.5% from 2019 to 2026. Lithium-ion power battery market size is expected to exceed $51.3 billion by end of 2020 and reach USD 109.72 billion by 2026.
9.1 Development of advanced anode materials

**Graphite:**
Currently, the anode materials of commercial LIBs are mainly graphite, including natural graphite and artificial graphite. The price of natural graphite is lower compared to artificial graphite. However, artificial graphite with high level of purity and quality can meet the demand of high capacity and consistence, which is mainly used in LIBs for EVs.

Main providers of anode: Hitachi, BTR, Nippon Carbon et al.

New entrants on the field: 3M, Dupont, Posco, Dow, Envia, ShinEtsu, Dow Corning et al.

![Graphite demand and price forecasts](image)

**Figure 9.1 Natural/artificial graphite demand details and price forecasts.**

*Natural graphite:* Small growth of demand on natural graphite is expected until 2025 (Figure 9.1). This demand may change if the price decrease is more important for natural graphite compare to artificial graphite. The price will decrease fast because the supply is huge and already over supply in China. Also, a lot of new projects in China and Canada.

*Artificial graphite:* The fast development of electric vehicle market promotes the demand of artificial graphite with high level of purity and high consistency. The price will decrease fast thanks to better process efficiency and new process. Hitachi will keep the lead but some other suppliers market share will increase (Shanshan, China).

**Si-based anodes:**
Except graphite, Si, Sn, TiO2 and some other materials are also used as anode in LIBs. Silicon is regarded as a promising candidate for next generation anode for LIBs, due to its high capacity and availability. Compared to graphite, the theoretical capacity of silicon can reach ~3600 mAh/g. However, some problems still limit the application of silicon, including sever crystallographic expansion (320%) upon lithiation process, slow lithium
diffusion, and high reactivity at high states of charge, resulting in particle cracking, particle isolation, electrolyte reactivity, and electrode delamination issues. A lot of efforts have been applied to overcome the issues limiting the application of silicon, such as core-shell structure, yolk-shell structure, porous structure, SiOx/C composite, silicon nanoparticles, and some other 2d and 3d structures. But the manufacturing cost still block the industrial application of silicon.

Instead of pure silicon, silicon-based materials have been successfully applied as an additive in traditional graphite anode to increase the capacity. Currently, the commercial silicon-based anode including SiOx/C (420 mAh/g), SiC (450 mAh/g) anode, Si-graphene anode (600 mAh/g). There are only several providers of Si anode, including LG and BTR. More research facilities and companies, including DOE, national labs, LG, BTR, Panasonic, Tesla, et al., are spending a lot of effort on developing and promoting the commercialization of Si anode. Recently, some start-up companies are getting into this filed and promoting the application of Si-based anode. The global silicon battery market size is estimated to grow from USD 38 million in 2020 to USD 177 million by 2025; it is expected to grow at a CAGR of 36.2%.


New entrants on the field: Enevate, Targray, Nexeon, Amprius, SILA et al.

### 9.2 Wisconsin LIBs manufacturers

Based on our research, there are several LIBs manufacturers in the Wisconsin area. However, the supply chains supporting these manufacturers are not fully developed. The raw materials including anode materials, cathode materials, separator and electrolyte are mainly provided from Japan, Korea and China. It is necessary to build up the supply chain from raw materials and supplies production to battery manufacturing.

<table>
<thead>
<tr>
<th>Company name</th>
<th>Service type</th>
<th>Location</th>
<th>Service area</th>
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<tbody>
<tr>
<td>Power Products LLC</td>
<td>Manufacturer</td>
<td>Menomonee Falls, WI</td>
<td>Manufacturer of power management solutions, including batteries.</td>
</tr>
<tr>
<td>Storage Battery Systems, LLC</td>
<td>Manufacturer</td>
<td>Wisconsin Locations</td>
<td>Manufacturer of industrial lithium-ion batteries for motive power applications. Available in 25.6 to 83.2 V power supply.</td>
</tr>
<tr>
<td>Fedco Electronics, Inc.</td>
<td>Manufacturer</td>
<td>Fond Du Lac, WI</td>
<td>Manufacturer &amp; Distributor of ENERGY Plus Brand Laptop &amp; Notebook Computer Batteries.</td>
</tr>
<tr>
<td>Blue Line Battery</td>
<td>Manufacturer</td>
<td>Whitewater, WI</td>
<td>Manufacturer of lithium ion batteries and power systems. Industries served include stationary, industrial, small electric vehicle and solar.</td>
</tr>
<tr>
<td>Clarios</td>
<td>Manufacturer</td>
<td>Milwaukee, WI</td>
<td>Low-voltage solutions that help OE manufacturers meet the challenges of increasing vehicle electrification and stringent fuel economy requirements.</td>
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<tr>
<td>Silatronix</td>
<td>Electrolyte provider</td>
<td>Madison, WI</td>
<td>Producer of patented Organosilicon (OS) materials that enable extreme performance in Li-ion batteries.</td>
</tr>
</tbody>
</table>
9.3 Development of advanced lithium ion batteries

The rapid growth of the electric vehicles is promoting the development of LIBs with high performance. As mentioned, the Vehicle Technologies Office of the Department of Energy (DOE) aims to reduce the cost of electric vehicle batteries to less than $100/kWh—ultimately $80/kWh with driving range to 300 miles and charge time to 15 min or less. Tesla and a lot of start-up companies in California are also spending very high effort into the development of LIBs with high performance. More and more projects are receiving funding from DOE, SBIR, STTR and other organizations.

In the anode part, Si-based materials are regarded as the most promising anode material for advanced LIBs. For cathode material, the researchers are focusing on the development of Ni-rich cathode (NMC811), Co-free cathode, 5V cathode and some other cathode material which can significantly improve the energy density of LIBs. Except the development of electrode material, all solid-state LIBs are also attracting numerous attentions from researchers and companies, due to its high energy density, fast charge, high cycling stability and high safety. Another interesting area would be the design and development of LIBs with high performance targeting specific areas. For example, some devices need to operate at ultralow and high temperatures, or some devices need ultrahigh charge/discharge rate. Similar application areas include aerospace, military application, camera drones and some other specific devices and areas.

The development of advanced LIBs is bringing more and more opportunities in the very near future. Many research groups in UW system, including UW-Madison, UW-Milwaukee, are doing researches on the development of LIBs. Technical supports can also from national labs and other organizations, like Argonne National Lab.

9.4 Wisconsin LIBs recycling

As shown in Figure 9.2, with the application of LIBs for electric vehicles, huge amounts of spent LIB packages will be collected by 2030. Recycling of spent LIBs, especially spent LIB packages from electric vehicles and some other large battery powered devices, would bring lots of opportunities. Based on the Wisconsin Recycling Markets Directory from University of Wisconsin Green Bay, there are 76 sites or companies provide service of LIBs recycling in Wisconsin area (in the attached table). The current techniques for LIBs recycling mainly include two traditional methods, pyrometallurgy and hydrometallurgy. Pyrometallurgical process is a high-temperature smelting process, which usually involves burning and subsequent separation. It can quickly remove the organic compounds in LIBs. However, it brings high energy consumption and possible pollution. At the same time, it is difficult to separate the different components with high purity. Hydrometallurgy method is achieved using aqueous chemistry, via leaching in acids and subsequent concentration and purification. It can recycle LIBs with relatively high efficiency. The best destination of the different components from recycled LIBs is the production of new LIBs. But almost all the recycling companies are doing the only business with recycling. Their recycled products are some raw materials which might be able to be used as raw material to produce new cathode materials. However, there is few benefits for the cathode material producers to use the recycled raw materials, which may need further purification to reach the required purity. Further transportation and energy consumption are also problems for the LIBs recycling.
How to build the bridge between LIBs recycling and cathode material production is attracting more and more attentions. This needs further design and optimization of the recycling process. New recycling techniques are also under research in some labs (at UW universities) and companies. With the combined recycling process, the final recycled products would be new cathode materials, which would significantly improve the energy efficiency.

**Figure 9.2** Estimation of spent LIBs in Canada, Mexico, and the USA, 2010-2030 and the market size in North America, USA, China, and globally (supply risk is based on the worldwide governance indicator, WGI; the quality of cathode materials only considers the quality of metals to evaluate the market value of cathode materials; metal prices are the 1-month average price obtained from Shanghai Metals Market)

### 9.5 Summary

In summary, a close-loop from research of advanced LIBs, including the development of anode materials, cathode materials, solid-state LIBs, and LIBs with high performance targeting specific areas, to the manufacturing of LIBs with complete supply chain and LIBs recycling with advanced techniques would bring the LIB industries in WI to a lead place.

The close-loop of LIBs should include the following areas with strong connection each other:

**LIBs R&D:** (i) development of anode materials especially Si-based anode material for next generation LIBs; (ii) development of cathode materials, including Ni-rich cathode (NMC 811 and others), Co-free cathode materials; (iii) solid-state LIBs; (iv) LIBs with high performance targeting specific areas, like aerospace, military application, camera drones, and some other devices need LIBs with special performance.

**LIBs manufacturing:** (i) manufactures with technical support from university research groups and other research facilities; (ii) buildup of complete supply chain including the producers for anode and cathode materials;

**LIBs recycling:** (i) LIBs recycling companies targeting spent LIB packages from electric vehicles and some other large devices; (ii) advanced recycling techniques; (iii) combination of recycling process with production of new cathode materials.
<table>
<thead>
<tr>
<th>Company name</th>
<th>Service locations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Belvidere, Buffalo City &amp; Cochrane</td>
<td>Cochrane</td>
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<td>Best Buy</td>
<td>Green Bay</td>
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<td>BJ Electric Supply</td>
<td>Madison</td>
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<tr>
<td>Brown County Resource Recovery</td>
<td>Green Bay</td>
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<td>Cascade Asset Management</td>
<td>Madison</td>
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<td>City of Mondovi</td>
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<td>Clearview Recycling</td>
<td>Bristol</td>
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<td>Colfax Area Collection Station &amp; Yard Waste Drop-Off Site</td>
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<tr>
<td>Dane County Recycling</td>
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<tr>
<td>Door County Scrap Metal</td>
<td>Sturgeon Bay</td>
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<tr>
<td>Dunn County Solid Waste &amp; Recycling</td>
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<td>Dynamic Recycling</td>
<td>Onalaska</td>
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<tr>
<td>eCycling - St. Croix Valley</td>
<td>Hudson</td>
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<td>Enviro-Safe Resource Recovery</td>
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<td>Faherty Incorporated</td>
<td>Platteville</td>
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<td>File 13 E-Waste Solutions, LLC</td>
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<tr>
<td>First Choice Computer Recycling</td>
<td>Eau Claire</td>
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<tr>
<td>Global Tech Environmental</td>
<td>Columbus</td>
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<tr>
<td>Harter's Quick Clean-Up</td>
<td>La Crosse</td>
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<td>Home Depot</td>
<td>Green Bay</td>
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<tr>
<td>Industrial Recyclers</td>
<td>Milwaukee</td>
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<td>IROW Shredding, Recycling, Waste Services</td>
<td>Mosineee</td>
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<td>ITADlogic</td>
<td>Neenah</td>
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<td>John's Disposal Service, Inc</td>
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<td>Kadingers Inc</td>
<td>Cadott</td>
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<td>Kewaunee Landfill and Recycling Drop-off Site</td>
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<td>La Grange Salvage</td>
<td>Beaver Dam</td>
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<tr>
<td>Lamp Recyclers Inc</td>
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<td>Landfill Reduction &amp; Recycling</td>
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<td>M and K Enterprises</td>
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<td>Marathon County Solid Waste Dept.</td>
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<tr>
<td>Midwest Lamp Recycling</td>
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<tr>
<td>Northern Battery</td>
<td>La Crosse, Cottage Grove, Fond du Lac, Schofield</td>
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<td>OSI Environmental, Inc</td>
<td>Kaukauna</td>
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<tr>
<td>Pierce County Solid Waste</td>
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<tr>
<td>PKK Lighting Inc.</td>
<td>Middleton</td>
</tr>
<tr>
<td>Recycling Technologies, Inc.</td>
<td>Waukesha</td>
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</table>

**LIBs recycling sites in Wisconsin area continued on next page**
LIBs recycling sites in Wisconsin area

<table>
<thead>
<tr>
<th>Company name</th>
<th>Service locations</th>
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</thead>
<tbody>
<tr>
<td>Remy Battery Co., Inc.</td>
<td>Milwaukee</td>
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<tr>
<td>Resource Solutions</td>
<td>Madison</td>
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<tr>
<td>Rice Lake City Hall</td>
<td>Rice Lake</td>
</tr>
<tr>
<td>Sadoff Iron &amp; Metal Company</td>
<td>Green Bay, Fond du Lac, Sheboygan, Oshkosh, Manitowoc</td>
</tr>
<tr>
<td>Scholze’s Ace Home Center</td>
<td>Black River Falls</td>
</tr>
<tr>
<td>Schulz’s Recycling, Inc.</td>
<td>Merrill</td>
</tr>
<tr>
<td>T &amp; R Recycling</td>
<td>Chippewa Falls</td>
</tr>
<tr>
<td>Toner and Inc</td>
<td>Delavan</td>
</tr>
<tr>
<td>Town of Barnes Recycling Center</td>
<td>Barnes</td>
</tr>
<tr>
<td>Toy’s Scrap &amp; Salvage Corp</td>
<td>Eau Claire, Rice Lake</td>
</tr>
<tr>
<td>Universal Recycling Technologies</td>
<td>Janesville</td>
</tr>
<tr>
<td>Waste Management of Wisconsin</td>
<td>Germantown</td>
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<tr>
<td>Alternative Recycling</td>
<td>Lancaster</td>
</tr>
<tr>
<td>American Metal &amp; Paper Recycling</td>
<td>West Bend</td>
</tr>
<tr>
<td>Batteries Plus</td>
<td>Milwaukee, Glendale, Green Bay, Appleton</td>
</tr>
<tr>
<td>Batteries Plus Bulbs</td>
<td>Pleasant Prairie, Madison, West Allis, Stevens Point, Hudson</td>
</tr>
<tr>
<td>Bayfield County Recycling (B.R.B. Recycling Authority)</td>
<td>Bayfield</td>
</tr>
</tbody>
</table>

9.6 Additional resources and funding opportunities

**Rechargeable Battery Association** (PRBA)- Trade association for rechargeable batteries

**Rechargeable Battery Recycling Organization/Call2Recycle** - Independent organization that oversees recycling of batteries

**Critical Materials Institute** - Focuses on challenges in critical materials industries (including battery materials such as lithium), addressing manufacturing, processing, usage, etc. of the materials; tries to minimize the criticality of the materials to increase commercialization rate of clean energy technologies

**ReCell Center** - Developed by Argonne National Laboratory; features collaboration between national labs, industry, and academia to improve recycling processes of lithium ion batteries (or advanced battery designs) and increase the reusability of battery materials

**Joint Center for Energy Storage Research** (JCESR)- DOE Energy Innovation Hub that supports research and development of materials for batteries, as well as the commercialization of these materials; areas of interest include advanced electrode materials and advanced electrolyte materials

**Recycling, end-of-life in general** (for solar, wind, batteries sectors)

**Clean Energy Manufacturing Innovation Institute for Reducing Embodied-Energy and Decreasing Emissions (RE-MADE)** - Consortium that aims to reduce waste and increase manufacturing energy efficiency through the recycling and reuse of materials
## Batteries

<table>
<thead>
<tr>
<th>Opportunity</th>
<th>SBIR/funding opportunities</th>
</tr>
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</table>
| Development of anode materials especially Si-based | **NSF SBIR** | [Topics](#) | [Solicitation](#):  
• Subtopic AM7-Other Advanced Materials Technologies  
• Subtopic S2-Electronic Materials  
  **NIST SBIR** | [Solicitation](#):  
• Section 9-Advanced Manufacturing and Material Measurements  
  **DOE SBIR** | [Topics Release](#) | [Solicitation](#):  
• Subtopic 22b-Carbon Utilization - Production of Solid Carbon Materials |
| Development of cathode materials | **NSF SBIR** | [Topics](#) | [Solicitation](#):  
• Subtopic AM7-Other Advanced Materials Technologies  
• Subtopic S2-Electronic Materials  
  **NIST SBIR** | [Solicitation](#):  
• Section 9-Advanced Manufacturing and Material Measurements |
| Solid-state LIBs | **NSF SBIR** | [Topics](#) | [Solicitation](#):  
• Subtopic EN3-Energy Storage  
• Subtopic S1-Electronic devices |
| LIBs with high performance targeting specific area | **NASA SBIR2020** | [Topics](#) | [Solicitation](#):  
• Focus Area 2, S3.03- Energy Storage for Extreme Environments  
  **DoD SBIR 2020-2-Army** | [Solicitation](#):  
• A20-126-Programmable AC/DC Lithium-ion Battery for High-voltage Applications |
| Manufactures with technical support from university research groups and other research facilities | **NIST SBIR** | [Solicitation](#):  
• Section 9-Advanced Manufacturing and Material Measurements |
| Buildup of complete supply chain including the producers for anode and cathode materials | **DOE SBIR** | [Topics Release](#) | [Solicitation](#):  
• Subtopic 6c-Critical Materials Supply Chain Enabling Research |
| LIBs recycling companies targeting spent LIB packages from electric vehicles and some other large devices | **NSF SBIR** | [Topics](#) | [Solicitation](#):  
• Subtopic AM2-Materials for Sustainability |
| Advanced recycling techniques | **NSF SBIR** | [Topics](#) | [Solicitation](#):  
• Subtopic M8-Sustainable Manufacturing Technology  
  **DoD SBIR 2020-2-DLA** | [Solicitation](#):  
• DLA202-010-Optimizing Lithium-Ion (Li-Ion) Battery Recycling Technology to Recover Cobalt and Nickel from Industrial and Defense Waste Streams |
| Combination of recycling process with production of new cathode materials | **NSF SBIR** | [Topics](#) | [Solicitation](#):  
• Subtopic AM2-Materials for Sustainability |

**SBIR funding opportunities**
10. Manufacturing Opportunities in Biogas

According to the American Biogas Council, Wisconsin ranks 6th out of 50 states for biogas production potential. Wisconsin was once considered a leader in deployment of biogas projects however, new biogas development in Wisconsin has been limited by multiple policy challenges over the last several years. With a high level of dairy production, other agricultural animal production and food processing Wisconsin has readily available sources of biomass suitable for processing via anaerobic digestion. Biogas itself is a useful fuel for heating, transportation, and electricity production (also as CHP – combined heat and power). Chemically the main constituent of biogas and natural gas is the same molecule, methane. However, natural gas has a different composition overall, with a higher methane content and a higher heat value. Raw biogas can be upgraded to the equivalent of natural gas through various forms of upgrading equipment to remove carbon dioxide. The cost of this equipment can be expensive especially if obtaining access to the utility pipeline becomes cost prohibitive.

In this section of the report, we identify policy challenges and opportunities for development that could expand the biogas sector in Wisconsin.

Policy challenge #1: It can be very challenging for biogas producers to inject biogas (even after cleanup and meeting Renewable Natural Gas, RNG, specifications) into utility pipelines. The high costs associated with developing an injection point, the lack of access to an injection point and lack of proximity to national pipelines often times precludes direct injection of RNG as a final destination for biogas in many parts of the state. This challenge prevents the use of biogas for heating and transportation other than through local arrangements or at-site.

Policy challenge #2: Electricity producers rated at more than 20kW are not eligible for net metering (the process of the utility charging for the net amount of electricity used). These producers are treated as utility-scale generators and are paid the wholesale price of the electricity they produce including off-peak rates. This challenge greatly increases the “payback time” for the initial investment in a biogas electricity-generating system. For Wisconsin farmers, a biogas plant is a very expensive initial investment, so the decision to add a biodigester hinges on the payback time.

Opportunity #1: Given the policy challenges above, one research and manufacturing opportunity that could result in new or expanded Wisconsin manufacturers is developing equipment for biogas conversion to liquids or other high-value chemicals. Fracking has helped develop natural gas supplies to the point where it is cheaper than coal for electricity production. Without a significant premium in the Wisconsin market for the renewable nature of biogas, its use as a fuel is the lowest-value use. Any chemical change to the methane molecule can result in a significantly more valuable chemical and may also allow its storage in liquid form, easing storage and transportation issues associated with gases. One example of a chemical transformation of value would be conversion of methane to methanol. Technology exists in several forms for conversion of methane to other chemicals, but less study has been conducted on using biogas in these processes. Further, this would represent another investment from the farm owner and may not be profitable if the energy required to convert the methane costs more than the value of the final product. Solutions in this area that have a low initial cost, low energy input, and produce high-value chemicals will be desirable.
Opportunity #2: One area that would aid in profitability of biogas plants is research into new methods of digestate processing/use. Digestate is the liquid and solid (or together, a slurry) material leftover after the digestion process. Currently this material is often used as a soil amendment in agricultural fields, helping dairy farmers with their nutrient management plan and providing fertilizer for their own fields and those of nearby farmers. However, limitations on nutrient application to fields (see Opportunity #4) and the need to move the material to distant fields may make alternatives attractive. The digestate product may also be used as a fertilizer, livestock bedding, and compost, all of which are relatively low-value materials. Solids have also been used to make “peat” pots for nurseries and building materials such as medium density fiberboard but these face hurdles such as high energy input (cost) or low demand for the product. A good solution in this area would be a high-value product where the “greener” alternative produced from biomass solids would be valued.

Opportunity #3: As more biogas plants are installed in Wisconsin there is an opportunity for a service industry. Small-farm units could benefit from contracted operation and maintenance by a local company as well as a local service and consulting resource. Some of these units are from outside the US and others have few certified technicians. Some farms may not be willing to devote labor to operating a unit but would rather pay for a contract. Since each digester may be monitored remotely and may only require technical service on a monthly (or less) basis, a service firm could have a small group of employees oversee several digesters.

Opportunity #4: Phosphorus continues to be a problematic pollutant in many Wisconsin waterways, leading to unsightly algae blooms which can also impact the health of wildlife and water body users. Large farms are required to develop and follow a nutrient management plan for their manure waste. In many parts of the state one of the main limitations to the amount of manure that can be applied to a field is the phosphorus content due to the impact of runoff on local water bodies. Research to develop (or improve) phosphorus removal systems could lead to new manufacturing opportunities especially if a system is developed that could be attached to almost any kind of biodigester using any kind of biomass. Such a system should use minimal energy input, achieve significant phosphorus reduction in the liquid digestate, and produce a phosphorus-containing solid product that has some market value (struvite is a phosphorus-containing mineral fertilizer which may be produced in biodigesters and can lead to clogged pipes).
Additional resources and funding opportunities

Industrial consortia

**American Biogas Council** - U.S. biogas trade organization

**BiogasWorld** - Biogas industry technical/information network

USDA **Advanced Biofuel Payment Program** - Provides funding for companies to increase the production of advanced biofuels

USDA **Biorefinery, Renewable Chemical, and Biobased Product Manufacturing Assistance Program** - Provides loan guarantees for the development of emerging technologies in the biofuels, biobased products, and renewable chemicals industries

**ChemCatBio** - Research consortium addressing challenges associated with the conversion of biomass/wastes into fuels and materials (DOE Energy Materials Network consortium)

**World Biogas Association** - Worldwide trade organization for biogas and related sectors

**Advanced BioFuels USA** - Group that seeks to educate the public about advance biofuels and increase production and research/innovation in the industry

**Renewable Fuels Association** - National trade organization for bio-based products and renewable fuels

**Wisconsin Biofuels Association** (WBFA) - Helps the biofuels industry in Wisconsin (ethanol, biodiesel, etc.) and increase the adoption of biofuels in Wisconsin

SBIR funding opportunities

<table>
<thead>
<tr>
<th>Biofuels</th>
<th>SBIR/funding opportunities</th>
</tr>
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<td>Subtopic EN4-Petrochemicals, Oil and Gas</td>
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<td>Subtopic 7b- Bioenergy Feedstock Engineering Incubator</td>
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<td>New methods of digestate processing/use</td>
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<td>Phosphorus removal systems</td>
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<td>Subtopic ET6-Water Treatment, Resilience, and Sanitation</td>
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11. Project Findings and Recommendations

Wisconsin manufacturers are well-positioned to transition to more robustly integrate into the supply chains for the green energy technologies explored in this report. With our traditional strengths in areas such as metalworking, plastics production, high precision machining, and controls, our economic analysis indicates that manufacturers in our state have the necessary expertise and market positions to expand their footprints in the areas of wind, solar, biogas, and battery technology.

Breaking into established, commodified industries is challenging, however, so in our technical analysis we focus on needs in the various industries that require innovation and therefore represent growth areas for the industries studied. In this report we also identify consortia and funding opportunities (particularly through the federal government’s Small Business Innovative Research program) that manufacturers may be able to take advantage of as they seek to enter these new areas of development. We propose some methods to better leverage UW System and other resources around the state to assist in this process in our recommendations, below.

In the following paragraphs, we briefly summarize our findings in the areas of wind, solar, biogas, and lithium-ion batteries.

The **wind industry** is rapidly maturing, but significant demand still exists for technical improvements, especially in blade and drivetrain technology. The growth potential for the industry as a whole is uncertain, due to unknown future of the federal Production Tax Credit, which at present is set to expire at the end of 2020, although it has been extended in several instances in past years. Despite this uncertainty, there is a clear and growing need to serve the industry by refurbishing/replacing existing wind turbines with more efficient components that can improve the capacity factor of those units, and we encourage private and public investment in areas such as blade manufacturing, drivetrain design, and lifecycle utilization that we judge to remain strong in the coming decades.

The **solar industry** lagged wind for many years in terms of overall electrical generating capacity and integration into public utility grids. That reality is now rapidly changing, thanks primarily to the strong decrease in the price of photovoltaic cells over the last decade. In many cases now, solar electricity production has a stand-alone economic benefit (i.e. it is cheaper than competing technologies) in addition to the known environmental benefits. Further, for many communities the lower visual profile of a solar installation as compared to a wind farm is attractive. As a result of these factors, we believe continued growth in solar cell and solar module technology will remain strong for many years to come. Competing against large established manufacturers to produce the solar cells themselves may be difficult, so in this report we have identified ancillary technologies and processes that would allow Wisconsin manufacturers to gain a foothold in the solar technology industry, without multi-billion dollar investments in e.g. a thin film growth facility. The alignment of current Wisconsin manufacturing capacity with the needs of the solar industry is judged to be not as high as the alignment with the needs of the wind industry, but the expected continued strong growth of the solar industry makes this an attractive area for further investment.

**Lithium-ion batteries** (LIBs) represent an enormous growth area, driven primarily by the expected continued growth in the electric and hybrid vehicle industries. While much LIB research and development is occurring both in Wisconsin and nationwide, a tighter integration (closed-loop) of the various needs would benefit activities across the state and bring Wisconsin to a place of national prominence in this area. Specifically, this should
include: (i) development of anode materials especially Si-based anode material for next generation LIBs; (ii) development of cathode materials, including Ni-rich cathode (NMC 811 and others), Co-free cathode materials; (iii) solid-state LIBs; (iv) LIBs with high performance targeting specific areas, like aerospace, military application, camera drones, and some other devices need LIBs with special performance. We also identify LIB recycling as a major growth area with some targeted investment.

With our strong agriculture and dairy industries, energy production from biogas is a clear continued growth industry for Wisconsin. However some initial progress in this area has stalled due to both technical and policy challenges. A more robust regulatory framework and targeted investment in technical challenges would allow Wisconsin to regain its national leadership in this area, and become a net “exporter” of biogas technology to neighboring states.

Project recommendations:

The economic and technical analyses we completed here lead naturally to several policy recommendations for state and UW System leaders, in order to create an environment in which manufacturers can more easily pursue entry into the identified growth areas within green energy fields:

- Leverage UW System researchers to act as guides to help manufacturers join existing consortia or pursue federal/state funding for new projects. The disconnect between research needs/goals and industrial capabilities can often be overcome by an expert who can speak the language of both communities. UW System has many such individuals across its 13 campuses.

- Utilize the campus research foundations (WARF, UWM Research Foundation, WiSys) to incentive these connections between UW schools and manufacturers.

- Create a website (e.g. managed by WEDC) that maps existing manufacturer capabilities to needs in green energy technologies, in order to help manufacturers identify areas in which they might be able to enter the various markets studied here.

- Create task forces within the various industries identified here to identify further policy/regulatory challenges that could reduce the barriers to entry into these fields

For more information, to discuss the policy recommendations, or to investigate a partnership with a UW institution to begin entering one of the identified markets, please contact the report lead author, Dr. Matt Jewell, at jewellmc@uwec.edu.