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Business Opportunities in Clean Energy Supply Chains: Guidebook for Small and Medium-Sized Auto Suppliers

Advanced Energy Technologies

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Business Opportunities in Clean Energy Supply Chains: Guidebook for Small and Medium-Sized Auto Suppliers

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Business Opportunities in Clean Energy Supply Chains:

Insights for Small and Medium-Sized Automotive Suppliers

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Introduction

The auto manufacturing space is evolving quickly. Sales of various electrified vehicles (xEVs) continue to grow steadily, which has medium to long-term ramifications for the thousands of U.S. manufacturers and hundreds of thousands of workers that contribute to the domestic automotive supply chain. In tandem with this growth in xEV sales, domestic clean energy manufacturing is surging (both for the xEV supply chain and other technologies), with public incentives spurring billions in private sector investment. Moreover, the next 2–3 years will see new and expanded industrial facilities come online to make products like hydrogen electrolyzers, solar panels, batteries, advanced electronics—and will create new supply chain needs and business opportunities as they do.

DOE's Office of Manufacturing and Energy Supply Chains (MESC) and Argonne National Laboratory developed this report to help automotive manufacturers—alongside various business support partners—understand these trends and their response options, and to make the most of current federal assistance programs for manufacturers. These market changes may create opportunities for small- and medium-sized manufacturers (SMMs) to expand production, grow profit margins, and diversify their businesses. For instance, SMMs could take advantage of engineering and process design similarities with new end-use industries that might enable greater business growth and stability as markets continue to change. This working paper introduces case studies of manufacturers that have undergone successful product conversion or product diversification initiatives and walks SMMs and their business support partners through possible steps to explore these options for themselves, including:

- **Current automotive sector trends and identifying focal SMM automotive suppliers** that may be more affected by the growth in xEVs (Chapter 1)
- **Opportunities for SMMs to capitalize on new xEV and clean energy opportunities and shore up their business** against automotive market shocks, including archetypes and case studies of how peers have responded (Chapter 2)
- **Steps to generate and evaluate new potential business ideas,** including product diversification, customer expansion, and other business strategy pivots (Chapter 3)
- **A path toward executing on a chosen business strategy,** including financing, workforce development, and process improvement considerations—and assistance programs for support (Chapter 4)

Chapter 1: Trends in automotive and clean energy manufacturing

This chapter overviews the changing market for Internal Combustion Engine Vehicles (ICEVs) and xEVs and respective subcomponents, including an assessment of the automotive supply chain segments that are most likely to be transformed in the evolution from ICEVs to xEVs. It also highlights trends in domestic clean energy manufacturing and that are relevant to automotive small and medium-sized manufacturers (SMMs).[1]

1.A. Vehicle market changes

The US automotive landscape has weathered several shocks in the last two decades. After the massive disruption and fallout of the Great Recession, market conditions for the auto industry did not approach pre-Recession levels of activity until the mid-2010s. Auto manufacturers then were hit by the COVID-19 pandemic, with disruptions to production schedules due to global supply chain snarls for components like semiconductors. Conditions have improved over the past few years; total light vehicle sales recovered to approximately 15.5 million units during 2023 (a 12 percent increase from 2022, and the highest level since 2019), auto manufacturing employment reached its highest level since the mid-2000s, and the U.S. auto manufacturing industry created more than 113,000 jobs during the Biden-Harris Administration.[2]

Amidst these dynamics, low or zero-emission xEVs—including battery-electric vehicles (BEVs), plug-in hybrid electric vehicles (PHEVs), and hybrids—have emerged as a key driver of sector growth and innovation. Automakers sold nearly fifty BEV models in the US during 2023—almost three times the number of BEV models available in 2019—and unit sales reached their highest annual level ever, topping 1.1 million units.[3] When incorporating PHEVs and hybrids sales, sales of xEVs accounted for over 1 in 6 vehicles sold in the US during 2023, representing an over three-fold increase in domestic market share since 2019.

The xEV market has also weathered recent shocks. High interest rates and other factors contributed to a slowdown in demand growth for xEVs and other non-ICE engine platforms in Q1-Q2 2024, particularly among higher-priced models. Nonetheless, underlying growth for electric and hybrid vehicle sales remains positive, and about 20 percent of domestic auto sales in 2024 are expected to come from BEVs, PHEVs, and hybrids (Figure 1.1). National economic data suggest that the growth in xEVs is starting to affect domestic auto supply chains, though broader import-export trends also explain some of these effects.[4]

Import-export data suggest that demand for xEV specialty components (e.g., inverters) is growing rapidly, but it is currently being fulfilled via imports. Excluding lithium-ion batteries, which are the largest-value item in a fully-assembled xEV, real imports of parts and components found in xEVs totaled nearly $14 billion in 2023—more than doubling the levels recorded in 2013 (Table 1.1; Figure 1.2).[5] These xEV components are also coming from different regions compared to ICEV parts: while ICEV parts and components overwhelmingly come from Canada or Mexico, today's xEV components are often coming from European and Asian suppliers. Recent efforts to build out the domestic lithium-ion battery supply chain will further shape these trade patterns in coming years.

1 Business expansion and conversion opportunities could also include other manufacturing subsectors such as semiconductors, defense, aerospace, and medical equipment. However, this report focuses on emerging industries at the heart of the clean energy economy, including next-generation auto manufacturing.

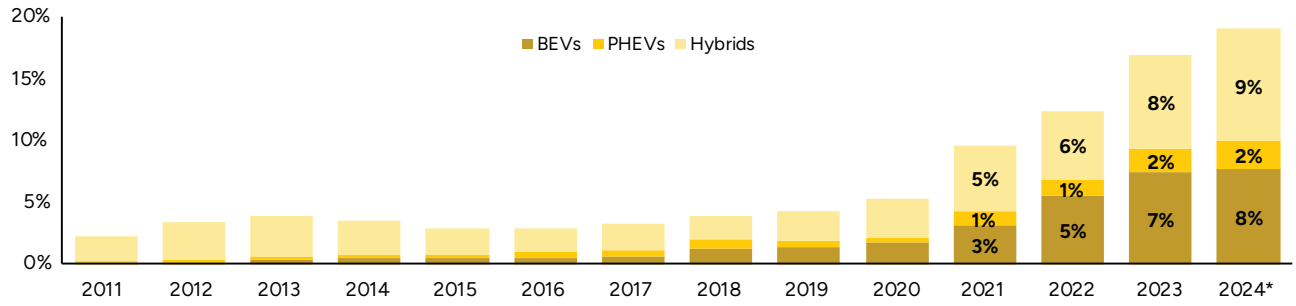
2 Source: USA - Flash report, Automotive sales volume, 2023 - MarkLines Automotive Industry Portal; Source: Automotive Industry: Employment, Earnings, and Hours : U.S. Bureau of Labor Statistics (bls.gov)

3 Source: National Automobile Dealers Association. ***Market Beat***, December 2023.

4 For example, while inflation-adjusted output from the domestic automotive manufacturing sector (parts plus assembly) grew nearly 25 percent from 2013 to 2023, domestic manufacturing of ICE parts like engines, exhaust systems, fuel systems, and mufflers grew more slowly or even decreased, in real terms. At the same time, imports have fulfilled a larger share of the US market for core ICEV parts and systems listed above, suggesting that OEM demand for ICEV parts may not yet be decreasing overall, but rather is being fulfilled by foreign suppliers. Sources: GDP by Industry | U.S. Bureau of Economic Analysis (BEA), US Census Bureau, International Trade data.

5 Inverters and static converters experienced particularly large gains over the past decade (Table 1.2). These components play critical roles in regulating an EV's key systems including propulsion, drivetrain, battery management, and recharging.

Figure 1.1: US xEV sales, shown as a percentage of total US light-duty vehicle sales



Source: Argonne National Laboratory, Wards Auto, Cox Automotive.
*2024 figure is year-to-date share of sales (through Q2).

Figure 1.2: Imports of key xEV components (in $millions, 2023). See Table 1.1 for sources.

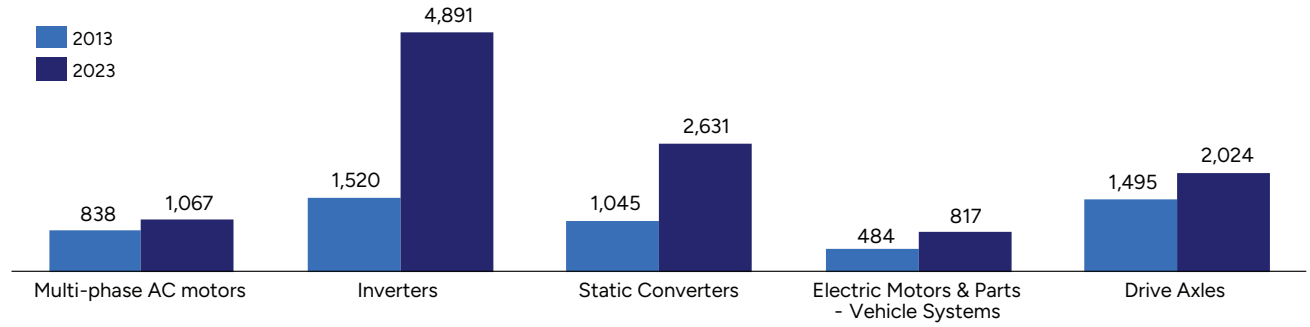


Table 1.1: Trade Flows of Key xEV Components

	N America Imports			Euro Imports			Other Asia Imports*			Total Imports		
	2013	2023	2013–23	2013	2023	2013–23	2013	2023	2013–23	2013	2023	2013–23
Industry Group	mill $	mill $	% change	mill $	mill $	% change	mill $	mill $	% change	mill $	mill $	% change
Multi-phase AC motors	323	295	-9.0%	159	330	106.9%	224	291	29.9%	838	1,067	27.3%
Inverters	49	431	779.5%	421	1,547	268.1%	1,030	2,468	139.6%	1,520	4,891	221.8%
Static Converters	193	728	277.0%	240	665	177.5%	596	1,124	88.5%	1,045	2,631	151.8%
Electric Motors & Parts - Vehicle Systems**	102	351	244.1%	84	118	40.5%	255	290	13.7%	484	817	68.8%
Drive Axles**	1,010	1,041	3.1%	182	408	124.6%	231	359	55.6%	1,495	2,024	35.4%
Current Collectors (Aluminum Foil)	74	21	-72.0%	99	146	47.1%	79	160	103.0%	254	334	31.5%
Battery Housing (Aluminum Plate)	N/A	695	-	N/A	320	-	N/A	619	-	N/A	1,745	-
Polypropylene separator strips	117	144	23.1%	37	71	91.9%	215	167	-22.3%	383	395	3.1%
Total	1,868	3,706	98.4%	1,222	3,605	195.0%	2,630	5,478	108.3%	6,019	13,904	131.0%

Sources: US Census Bureau, US Bureau of Economic Analysis (https://usatrade.census.gov/ and https://www.trade.gov/automotive-parts-tariff-codes); Author's calculations.
Note: Imports expressed in 2023 dollars. Differences in percent changes due to rounding.
*Japan, South Korea, and China account for significant majority of 'Other Asia' import category.
**Electric Motors & Parts and Drive Axles can also appear as part of AC motors depending upon system configuration.

1.B. Effects on the automotive supply chain, especially for auto SMMs

ICEV components (both imported and domestic) will continue to be part of the automotive supply chain for the foreseeable future, but the impact of xEVs on supply chains will continue to grow steadily. While recent slowdown in BEV sales growth and higher uptake of PHEVs in recent quarters add uncertainty to the exact timeline for the ICEV to xEV transition, continued large xEV supply chain investments by public and private entities (in the US and abroad) provide strong evidence that ICEV auto suppliers will experience significantly increased impacts of the xEV transition within the next 3–8 years.[6]

xEVs require fewer parts than ICEVs. For example, an xEV drivetrain contains around 20 moving parts compared to the approximately 200 in an ICEV drivetrain. This parts discrepancy increases when considering the power source: xEV motors only contain two moving parts compared to the dozens to hundreds of moving parts (depending on number of cylinders, etc.) that are required for ICEVs. However, once accounting for overall growth in auto sales, growth in battery component and assembly needs, and new domestic manufacturing incentives, the net effect of the ICEV-to-EV transition may be highly positive for the domestic auto supply chain *as a whole* (i.e., automotive supply chain output and labor requirements will increase overall, when including battery manufacturing and assembly needs).[7]

However, this does not mean all suppliers will benefit from the transition, absent proactive business decisions to capitalize on these market shifts and access to public and private sector resources. For individual suppliers or subsectors, the magnitude and direction of these effects will depend on what they supply and those components' roles in the xEV supply chain. SMMs producing automotive inputs likely to be negatively affected may need to pivot significantly to growing subsectors to mitigate future decline in demand for their products. Expert interviews and market research suggest automotive components fall into three categories (Table 1.2):

- **Tailwinds expected:** Some components expected to grow alongside xEV sales are intuitive, such as the electric drivetrain, battery management system, and the battery cells and packs. Additional knock-on needs are also emerging (e.g., rising demand for harness systems to accommodate by-wire driving, braking, and steering; new interior climate control systems and passenger safety systems needed due to xEV and ICEV differences, such as the lack of engine waste heat that can be routed to interior heating systems).
- **Steady demand, often with some design changes:** xEVs and traditional ICEVs share many components, as they are at their core both automobiles. Some components may require design changes, but these changes can be low-cost (depending on specific machine or tooling needs) and components will remain similar in function (e.g., interior equipment like lighting, seats, and consoles; external features like glass, mirrors, and lighting; chassis components, suspension, and tires/wheels should be identical in design though materials may change, such as to lighter-weight or higher-strength metals to offset the heavier curb weight of xEVs and support the battery pack).
- **Headwinds expected:** Auto suppliers dedicated to core powertrain components of ICEVs may experience the strongest headwinds due to xEV growth. Engines, fuel systems, mufflers and related exhaust systems will be the most directly affected. Similarly, while core drivetrain components such as gearboxes and transmissions do appear in xEVs, nearly all xEVs utilize simpler single-speed transmissions compared to ICEVs' multi-speed gearboxes. Axles, axles housings and driveshafts

6 Projections of future xEV demand suggest new xEV sales will increase between a range of 4-7x by 2030 compared to current levels. This could push the overall number of xEVs on the road to 25-30 million by 2030. Given this backdrop for demand, plus the fact that automakers are slated to ramp up production of some existing xEV lines and roll out several dozen new models in the US (from economy to luxury), supply chain experts concur that the auto supply chain will experience more significant changes in coming years, compared to historical effects. Sources Bloomberg New Energy Finance Electric Vehicle Outlook, PwC Electric Vehicle Charging Outlook, International Energy Agency Global EV Outlook, S&P Global Electric Vehicle Trends.

7 For instance, a recent study finds that labor and assembly requirements for BEV powertrains exceed the combined labor/assembly requirements for ICEVs, once accounting for battery assembly. Source: The transition to electrified vehicles: Evaluating the labor demand of manufacturing conventional versus battery electric vehicle Powertrains

can be found in both types of vehicles, but these drivetrain components are integrated differently and require more fundamental design changes.

The contents of this report are geared especially toward SMMs producing systems or components facing "headwinds." Manufacturers in these sectors accounted for nearly $150 billion in gross US output during 2023, or just over 20 percent of the auto industry's total output.[8] It may be intimidating to see your business in the "headwind" category, but taking just a few initial steps now to identify and gameplan for future trends is a great way to mitigate the risks that come with not preparing early enough for larger market changes.

This document also is geared toward SMMs in states with a high concentration of automotive supply chain activity. Beyond broader national implications of significant production changes for ICEV-related components, ICEV-to-EV transition effects will likely be felt more acutely at the regional level, with these transitions potentially affecting whole communities or a state's overall jobs outlook.

"High concentration" could be defined in many ways (e.g., overall automotive employment, number of SMMs in the auto supply chain, percentage of state economic output tied to automotive production, etc.).[9] For the purposes of this report, "highly-affected states" are defined as the six states where the automotive workforce is over

Table 1.2

Tailwinds These auto supply chain components will likely see increasing demand due to xEV growth	**Steady** These auto supply chain components will see fewer changes in demand due to xEV growth, though designs may change	**Headwinds** These auto supply chain components are most likely to be negatively affected by xEV growth trends
• Battery and components (housing, thermal management, cells) • By-wire components and systems (steer/drive/brake) • Domain Control Units (DCU) • Electric drivetrain • Electric motors and components (e.g., inverters) • Electronics • Interiors (embedded heat pumps) • Occupant Safety Systems • Sensors • Trunk / Frunk	• Air intake systems • Body in white • Brakes • Chassis/frame • Interiors (lighting, seats and components, passenger electronics, dashboard) • Exteriors (glass, mirrors, lighting) • Suspension • Wheels / Tires and components	• Axles, axle housings and shafts (*more significant design change*) • Engines and parts • Exhaust systems and parts (catalytic converters and other emissions controls, heat exchangers, mufflers) • Fuel systems and parts (injectors, lines) • ICE drivetrain components (gearboxes, transmission) • Metal stampings

0.5% of the state's overall workforce and over 30,000

8 Defined as manufacturers in 8 NAICS sectors identified as likely most impacted via Argonne National Laboratory and Society of Automotive Engineers analysis (NAICS sectors: Axle housings and shafts, axles, exhaust systems and parts, fuel systems and parts, metal stampings, motor vehicle engines and parts, Motor vehicle transmission and drivetrain components, and mufflers)

9 For example, the concentration of auto parts manufacturing employment in Michigan, Ohio, Indiana, Kentucky, and Tennessee is 3-8x higher than nationally. Or, Illinois is in the top 10 states for auto parts manufacturing employment and tends to depend more upon SMMs (as indicated by smaller average number of employees per automotive manufacturer).

workers are employed in the automotive sector: Illinois, Indiana, Kentucky, Michigan, Ohio, and Tennessee.[10] These states are also the eligible recipients for $50 million in MESC funding support designed to help automotive SMMs capitalize on ICEV-to-EV transition opportunities. While this report can and should be equally useful to automotive SMMs throughout the country, any state-specific resources focus on these six states.

1.C. Expanding clean energy manufacturing and supply chain needs

Demand for technologies like heat pumps, solar panels, transformers, and others continues to expand—as does demand for all their component parts, including many parts that could be made by ICEV suppliers with minimal changeover costs. At the same time, US policies are driving the onshoring of these technologies' supply chains, further increasing domestic manufacturing needs. Figure 1.3 summarizes announced investments in clean energy manufacturing capacity since the beginning of the Biden Administration. These manufacturing investments are matching growth in demand for—and installation of—clean energy solutions. For example, global sales of residential, commercial, and industrial heat pumps grew by 11% in 2022, with year-over-year growth expected to continue along this trajectory in the coming years.[11] In the solar industry, nearly 250 GW of installed solar capacity is expected to be added across the US by 2029, and more than 100 GW equivalent of solar supply chain capacity (including polysilicon, ingots, wafers, cells, and modules) has been announced or is currently under construction in the US.[12]

All automotive manufacturers may be affected by these trends. Even so, SMMs face particular challenges adjusting to and capitalizing on them. These include lower margins, less access to low-cost capital for upgrades, and greater workforce turnover. Likewise, making changes to the factory floor to accommodate a change in product mix can be difficult for smaller parts producers.

Moreover, many may have built their businesses around supplying one or a few Original Equipment Manufacturers (OEMs) and their direct suppliers, meaning new business development and sales capabilities may be needed. As a result, this document aims to help SMMs access the same kind of guidance and expertise on which larger manufacturers might rely.

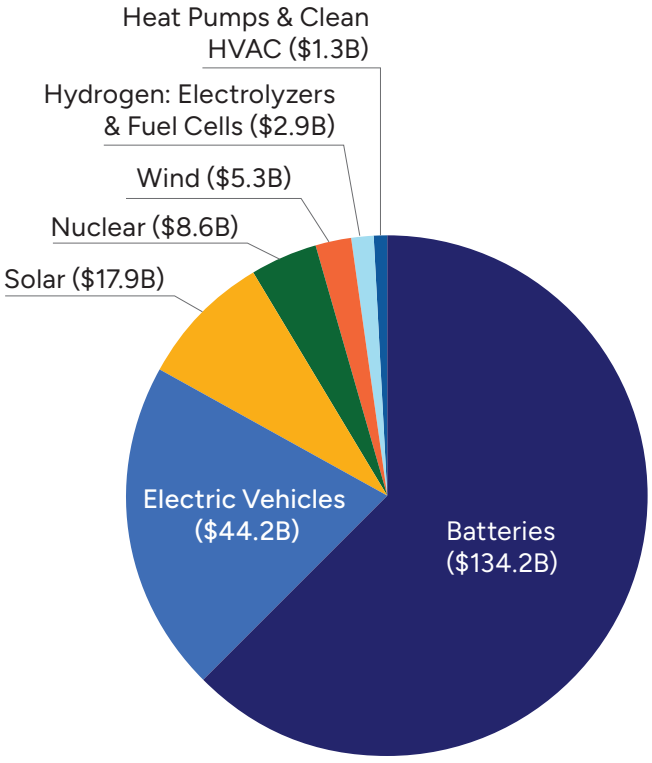


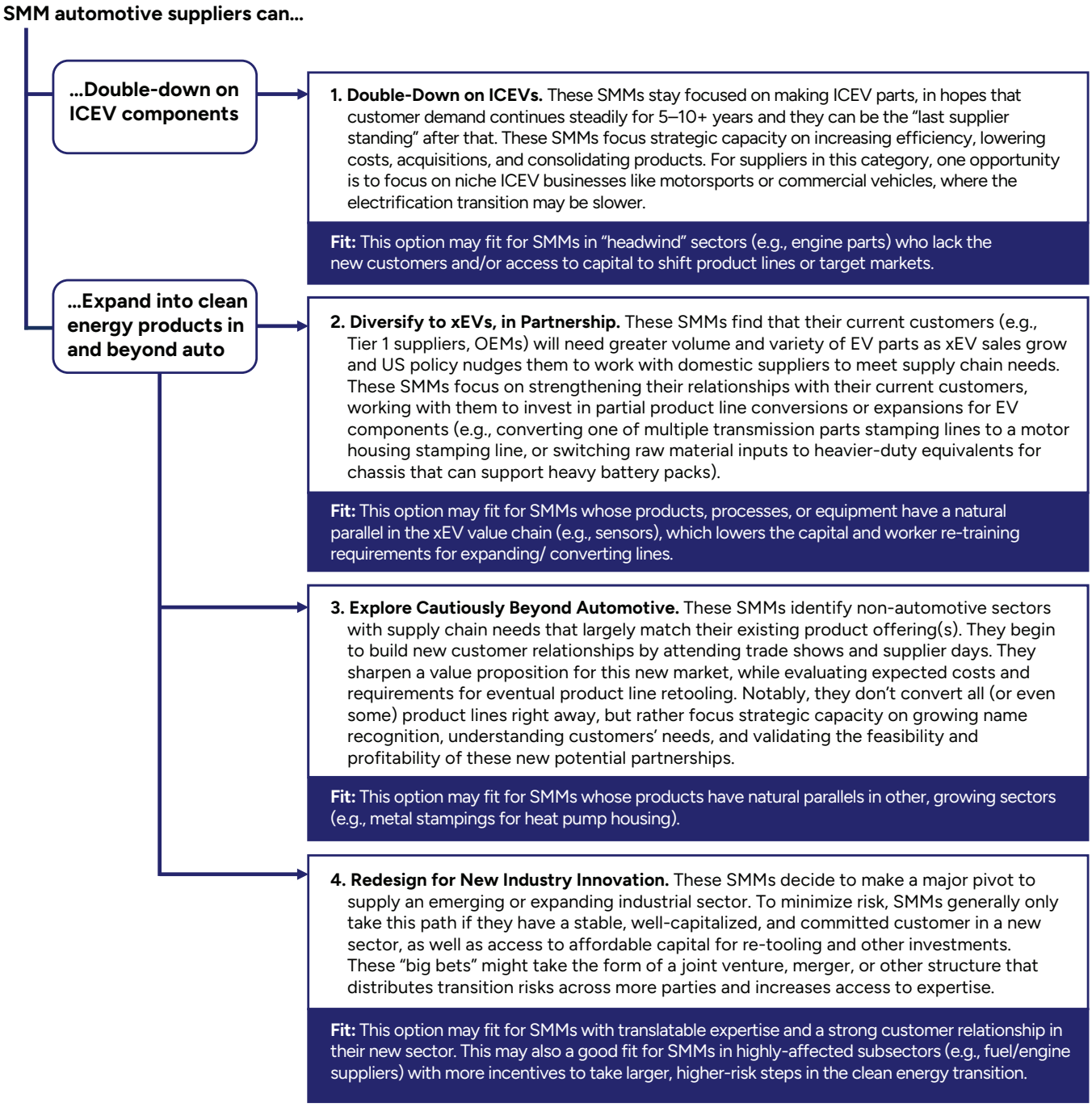
Figure 1.3: Announced investments in clean energy manufacturing capacity since January 2021

10 As determined using Demographic and Health Survey (DHS) employment data
11 IEA | Global heat pump sales continue double-digit growth
12 SEIA | Solar storage Supply Chain Dashboard

Chapter 2: Four archetypes of SMM business strategies

Expert interviews and sector case studies suggest four archetypal responses that SMMs might pursue to capitalize on opportunities in xEV and other clean energy manufacturing supply chains. Each option carries different risks, opportunities, and requirements.

Figure 1.4: Response archetypes for SMMs affected by vehicle market trends



While you may have strong hypotheses about which archetype best applies to your business, consider starting with a broader exploration (see Chapter 3 on how to surface opportunities and choose the best ones for your business). Consider, for instance, the case examples below (all of which are real, but anonymized): these companies learned about diversification opportunities from various sources, including internal research and external engagement. Without that exploration, companies might have missed promising ideas.

Questions to ask as you read the case studies and see which archetype you fit include:

1. **Determining your product trajectory:** To what degree are our product lines eventually likely to face "tailwinds" (increasing demand) or "headwinds" (decreasing demand) from the xEV transition (see Table 1.2), even if these trends are not yet significantly affecting our business?
2. **Deciding whether to double-down on ICEVs versus explore expansions into new products:** If our business is likely to face "headwinds," could we find the resources and partners needed for a significant business pivot, in partnership with supporters like trade associations or Manufacturing Extension Partnerships? If our business is likely to face "tailwinds," how fully have we explored the possible set of opportunities and what it would take to capitalize on them? If considering "doubling-down" for now, what would have to be true for us to decide it is eventually time to pivot to xEV components or other industries? Are there modest, "no regrets" steps we can start taking to be prepared for a possible sudden need to shift, such as investing in initial workforce retraining and readiness or more flexible manufacturing equipment?
3. **Exploring response options in xEVs and other industries:** If considering a larger whole-of-business redesign or pivot, how confident are we in customer relationships? In our workforce's ability to retrain? Are we sufficiently confident that there are not similarly compelling opportunities closer to our current capabilities, which would create less risk?

Archetype	Case Studies (anonymized)
Archetype 1: **Double-Down on ICEVs**	**Exhaust Supplier Co is consolidating its ICEV role.** Exhaust Supplier Co, a Tier 1 supplier with 350 employees, sells mufflers and exhaust systems to two of the Big Three U.S. OEMs. Recently, the CEO noticed that investor enthusiasm in xEVs had driven down the price of a peer SMM who was selling their business. Exhaust Supplier Co decided to buy the competitor's business while the price was low, increasing their market share. The new business lines allowed Exhaust Supplier Co to reach all three Big Three OEMs, and understanding the new facility's production lines has allowed Exhaust Supplier Co to adjust tooling to decrease downtime and reduce costs. This option may work for fewer businesses than one might expect, especially if xEV adoption rates continue to accelerate. Exhaust Supplier Co also forewent the new business opportunities that the other archetypal responses can generate, and they still need to contend with automation and consistent process improvement since the auto market is changing rapidly.

Archetype 2: **Diversify to xEVs, in Partnership**	**Electron Co expanded their product lines for xEV components.** Electron Co, a Tier 2 supplier, defines itself as a company that "makes products that carry electrons" (e.g., connectors, harnesses, antennas and sensors) for ICEVs. Through an acquisition, Electron Co was exposed to sensor applications in xEVs, finding that existing technologies could be applied to transformer and battery applications. Capturing these new markets required new tooling that Electron Co had acquired. Recognizing that the emergent xEV market is still volatile, Electron Co is focusing its diversification efforts initially on more stable market segments, like stationary storage and heavy-duty transportation, while preparing for the standardization needed in the xEV market to justify further investment. At the same time, they are deepening relationships, investing in their workforce's relevant skillsets through on-the-job training, and messaging their new capabilities to their long-time ICE customers, so they are positioned as a go-to supplier when xEV OEMs are ready to expand xEV sensor purchases.
Archetype 3: **Explore Cautiously Beyond Automotive**	**Emissions Controls, Inc found a new market in the hydrogen sector.** Emissions Controls, Inc specialized in manufacturing emissions control systems for the automotive sector, with several plants and 400+ employees. This included designing and manufacturing heat exchangers, which are used in emissions control systems, as well as related manufacturing (e.g., pipes, cooling, cutting, welding). Seeing a shrinking automotive market, Emissions Controls, Inc worked with a manufacturing business consultant to research emerging sectors and learned that high-performing heat exchangers are critical for efficient hydrogen fuel cells and electrolyzers. After securing a purchasing Memorandum of Understanding from an electrolyzer OEM, Emissions Controls, Inc enhanced their heat exchanger devices to enable their use in solid oxide fuel cells and solid oxide electrolyzers. They also created a new value proposition and messaged it to their new customers: *these new heat exchangers can improve efficiency of fuel cells and electrolyzers, making them key components worth purchasing from a reputable supplier with decades of parallel experience. The upfront cost of the product is offset by the efficiency gains expected in the overall system.* Articulating this benefit was a key part of developing a value proposition that appeals to Emissions Controls, Inc's new customers.
Archetype 4: **Redesign for New Industry Innovation**	**Fuel Parts Unlimited pivoted production, with public sector and private partner support.** Fuel Parts Unlimited, a Tier 2 supplier, made ICEV fuel components (e.g., fuel lines) and had previously provided some parts to heavy equipment manufacturers, too. After the Bipartisan Infrastructure Law and the Inflation Reduction Act passed, they started a conversation with one of their non-automotive customers about potential growth opportunities created by these new federal incentives. Together with this larger, well-capitalized customer, they identified a new product opportunity: their product lines could be converted to fluid purification and transportation systems for electric equipment manufacturing. They applied for and won a federal award to defray the investment costs of building out two new product lines, including investing in state-of-the-art smart manufacturing equipment. With the award covering 50% of the project cost, and their major customer lowering risk by agreeing to buy much of the output, Fuel Parts Unlimited could easily justify the Return on Investment (ROI) to cover the remaining 50% of the upgrade project's cost with internal cash reserves. When the transition is complete, they expect to primarily be an electric equipment supplier rather than an automotive supplier. Because of the scale of this pivot, it was especially critical to proactively engage Fuel Parts Unlimited's workforce and attend to change management. The firm's internal communications emphasized the real benefits of this transition, especially job security, significant new job creation for the small rural community, and new training and advancement opportunities with a local technical college.

Chapter 3: Picking the right option for your business

As Chapter 2 highlights, there are many ways that SMMs can respond to market shifts. So, how do you choose what option(s) might be right for you? This next chapter walks through a two-part, iterative approach to this decision-making: idea generation, and subsequent prioritization through risk/return assessment. Note that this chapter focuses on new revenue opportunities from manufacturing new products, rather than cost reduction or business restructuring. (See Section 4.C for a discussion of process improvements that can be implemented alongside new revenue opportunities).

3.A. Identify new customers, products, and strategies

3.A.i Finding inspiration

The following prompts can help you generate potential new customers, product offerings, or other business innovations, both within and beyond the automotive supply chain. As you consider these prompts, think expansively about your business's superstar capacities and comparative advantages (e.g., IP, sourcing relationships for bottleneck inputs, flexible manufacturing equipment, unique or difficult-to-acquire certifications), beyond just the products you currently make. Here are a few common approaches used to identify new opportunities:

- **Talk to current customers:** Reach out to your largest customers. Work with them to explore their biggest pain points today. How could you help solve these challenges? For what upstream inputs are they looking to expand near-term purchasing? Are there creative solutions that the two of you could pilot together, with their resourcing and your credibility derisking the experiment for each other?
- **Look around your neighborhood:** Connect with larger manufacturers or customers in your region. What are their upcoming (1–2 year) supply chain priorities? Do any of their supply chain priorities need to be executed locally (e.g., stamping)? To anticipate and connect with new major manufacturers coming to your area, explore Invest.gov for announced Investing in America projects.[13]
- **Learn from peers:** Consider connecting with local or national trade manufacturing associations and your

"Take it from me": Lessons from SMMs who have undergone significant product line conversion or diversification

1. **Think big.** This transition may require thinking broadly about your capabilities and unique comparative advantage. For Electron Co, a Tier 2 supplier, embracing new opportunities relied on moving from a mindset of "we make connectors and antennae" to "we make things that move electrons."
2. **Validate your customer's data.** Two years ago, Transmission Parts Co (TPC), a family-owned Tier 2 shop with 200 employees, heard from a buyer that massive demand for e-axle gears and inputs was coming, and news stories on xEVs suggested to TPC that their core products would be irrelevant in 2–3 years. TPC quickly invested in a retooled product line suited for e-axle components, and stopped maintaining their legacy line equipment and investing in workforce development. However, the OEM's xEV orders came in smaller than expected, while ICEV transmission orders increased in the short term. TPC was stuck with new, under-utilized product lines without other orders opportunities in the pipeline, and a shortage of skilled labor. "We wish we had validated that data with purchase orders, other customers' perspectives, and our own market research," reflected a TPC executive.
3. **Pick your partners carefully.** Electron Co emphasized that, when exploring new partnerships, "we pay attention to the market studies and go behind the headlines as much as we can. We build out industry networks through standards organizations and through industry groups to understand who the influential players are. We assess who's well-funded and who's not. We have learned a lesson the hard way that new companies who can be clients or partners may have initial funding but lack capability to get to production."

13 The Investing in America agenda refers to the hundreds of new manufacturing and infrastructure investments catalyzed by the Biden-Harris Administration, including investments supported by the American Rescue Plan, Bipartisan Infrastructure Law, CHIPS and Science Act, and the Inflation Reduction Act. Learn more about announced investments at https://www.whitehouse.gov/invest/

local Manufacturing Extension Partnership, which offers low-cost business counseling and supplier scouting services. Ask what other manufacturers like you (broadly defined) make or have started making.

Consider attending a few conferences or trade shows related to industries of interest.

3.A.ii Exploring manufacturing sectors beyond automotive

If you are a supplier who has worked exclusively in the automotive sector for years or decades, it may be overwhelming to consider other manufacturing sectors that could hold opportunity for your business. This section can get you started with some data on opportunities in xEVs and batteries, in established industries that often overlap with automotive supply chains (e.g., food and beverage), and in growing clean energy manufacturing sectors beyond automotive (e.g., solar, grid components) that have strong parallels to automotive sector needs.

If a sector in here seems compelling, the next step may be to meet potential customers: Have you met any potential customers in this field? If not, how could you build those relationships? Keep in mind you don't have to build these new relationships by yourself: identifying new industries and helping broker new supplier-customer relationships is a key place where a business support consultant, your state Manufacturing Extension Partnership, or other resources like those listed in Appendix F can help.

Batteries and Electric Vehicles: As described in Chapters 1–2, many of the most natural business expansion opportunities for ICEV automotive suppliers will be in the xEV and battery supply chain. Table 3.1 provides an overview of the role ICEV components facing "headwinds" could play in the XEV industry.

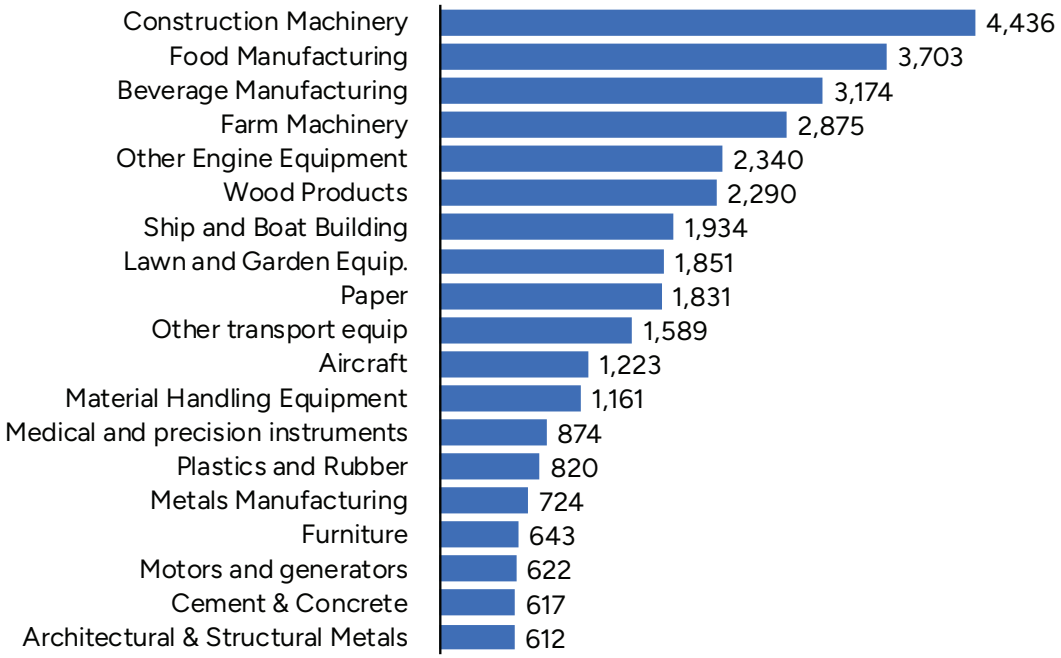
Table 3.1

ICEV Automotive Component	Possible xEV Opportunity	Rationale
Engine Gaskets	EV system gaskets and sealants, especially for battery systems	Gaskets in an ICEV help to ensure tightly-fitting joints, which are crucial in ICEVs because those vehicles have lots of fluids. xEVs still need gaskets to create tight joints, though suppliers may need to adapt their technology to xEV needs (e.g., switching to materials with greater fire resistance, or ones that can withstand greater electrochemical corrosion from battery exposure).
Engine Blocks	Structural components	The block provides the core housing for engine cylinders, pistons, etc. xEV producers may need similarly-cut metal for other components, such as the motor housing or battery housing/battery box components.
Engine Valves	Fluid management needs (e.g., for coolants)	Valves are flexible and suit many different applications.
Exhaust systems and parts	Automotive heat pumps Sensors in xEV electronics systems	Heat pumps in xEVs can support battery range extension, while exhaust systems have numerous sensors to monitor things such as tailpipe emissions. Some companies have started to switch to xEV electronics to using their same capabilities.
Mufflers	Noise, vibration, and harshness (NVH) components Metal stampings	Auto mufflers dissipate noise and vibration from the release of high-pressure gasses released an ICEV's powerplant. xEV producers may need to customize fabrication for metal enclosures and housings to protect sensitive xEV systems from excessive vibrations.

Fuel systems and parts	Coolant systems dielectric and immersion; battery cooling technology; e-fluids testing; low viscosity base stock; driveline lubricants	Fuel systems in ICEVs use a combination of pumps, injectors, filters, sensors and other components to push gasoline into the engine. Some components such as pumps, rails, sensors could be adapted to regulate an xEV's indirect coolant system; additional configurations would be needed for direct cooling systems.
Metal Stampings	xEV stampings xEV charger subcomponents Testing fixtures	Stamping for xEVs follows roughly the same manufacturing process as ICEVs, though with overall fewer parts requirements. The challenge for SMMs in this space will be identifying where their current stamping capabilities fit into an xEV OEM or Tier 1 supplier's needs.
Gearing	EV powertrain gears Steering gears	Though fewer in number than in an ICEV, xEVs still require gears to operate.
Engine Cooling Systems	Battery thermal management Vehicle coolant systems Climate control	Thermal management is a concern with all batteries, especially larger size batteries used in hybrids and xEVs. Cooling technology could be applied to batteries.

Established Non-Automotive Industries: Many auto suppliers already cross-sell to other industries. For instance, bearings (ball, roller, thrust) can be used across numerous manufacturing industries where components must deal with radial, axial, and frictional loading patterns. As another example, food and beverage manufacturers often turn to auto parts suppliers to meet the industry's demand for diverse and sometimes niche machine parts, like punches, dies, valves, hoses, or compressors. One interviewed expert highlighted an example of an automotive supplier who made metal stampings for engines shifting to a similar stamping for the furniture industry. Figure 3.1 highlights well-established manufacturing sectors whose supply chains often overlap with automotive.

Figure 3.1: Leading Intermediate Purchasing Industries of Auto Parts (Millions of $)



Source: US Bureau of Economic Analysis: https://www.bea.gov/industry/input-output-accounts-data

Emerging Clean Energy Industries: Consumer preferences and policy incentives will drive sharp growth in clean energy supply chain needs from now through 2030 (see Section 1.C.). The next pages present four growing sectors and their current supply chain needs and dynamics, to help SMMs identify potential opportunities for further exploration (see Figures 3.2 – 3.5 for more details on each subsector):

- **Heat Pumps (Figure 3.2):** Heat pump manufacturing is a small domestic sector today, but federal incentives and consumer demand are driving growth. Inputs like compressors and housing parallel automotive metal parts manufacturing.
- **Electric Grid (Figure 3.3):** Growing clean energy installation, related manufacturing, and grid aging is driving demand for traditional and advanced grid solutions like transformers, cables, and conductors. SMMs with existing electrical or electronics expertise may be especially well suited to fill supply chain needs.
- **Solar Photovoltaic Components (Figure 3.4):** Much of the solar supply chain is still concentrated overseas, but demand continues to grow and downstream components and inputs like inverters and trackers share strong parallels with automotive supply chains.

On moving into an emerging industry, Electron Co reflects,

"We provide electrical components, like high and low voltage and antenna systems. So, we've migrated a lot of our product knowledge from electrification and automotive applications into the stationary storage world. We found that in terms of the battery controls, battery products, and high voltage products, they're very similar so transitioning has actually been quite easy."

- **Clean Hydrogen (Figure 3.5):** Equipment needs for hydrogen generation and transport are growing, and long lead times for core equipment suggest space for new suppliers. Many inputs (e.g., power electronics, metal, and plastic parts) parallel the automotive sector, though components must be able to withstand greater pressurization, temperature swings, and chemical stress.

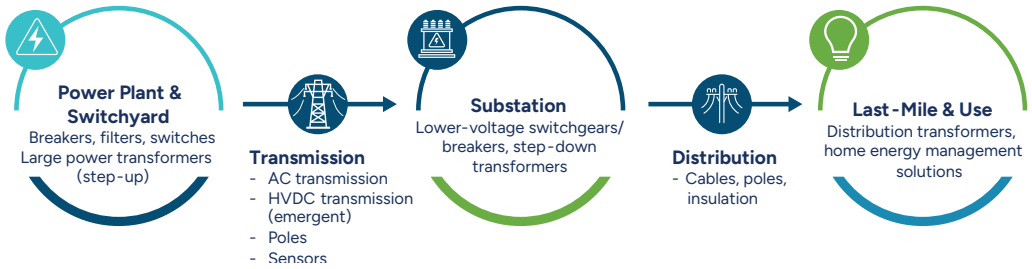
Note that these are not the only growing clean energy manufacturing sectors in the U.S. (e.g., wind energy is another), but this document focuses on these four because there are readily identifiable opportunities in each that may be an especially strong fit for the types of automotive suppliers concentrated in the states identified in Chapter 1.

Figure 3.2 Heat Pumps Overview

Considerations for new entrants	• **The global heat pump market size today is estimated at ~$70–90B,** with a 9–11% CAGR expected over the next 5–10 years[14] • **Many heat pump components utilize similar metal parts and tooling as auto parts,** though suppliers often need greater knowledge of, and capacity for, refrigerant handling. • **OEMs in the heat pump sector operate similarly to auto suppliers:** a few OEMs dominate the market, with supply chains relying on SMMs. Many manufacturers specialize in one heat pump style (e.g., A.O. Smith on HP water heaters).
Key components (supply chain)	• Coils (evaporator) • Compressor • Control system • Fans • Housing and tanks • Insulation • Motors • Piping • Refrigerants • Valves (expansion valves, reversing valves)
Example opportunities for automotive suppliers (V1)	• Engine and components → gaskets, compressors, flexible pipes • Fuel systems → Valves and controls, flexible pipes • Metal stampings → System enclosures, water tanks

14 How automotive suppliers of automotive components can face the xEV transition | McKinsey, Heat Pump Market by Technology, Application, End User - 2029 (market-sandmarkets.com)

Figure 3.3 Electric Grid Overview



Considerations for new entrants	• **Persistently increasing demand for transformers (large power and distribution) is expected to drive market growth of 7%+ CAGR** near- and medium-term, bringing total revenue to nearly $40B by 2030. Meanwhile, the HVDC cables market, while still emerging domestically, is expected to grow from $10B in 2023 to over $30B globally in 2032.[15] • **There are other strong signals that OEMs need new suppliers:** Lead times for transformers currently run from 1–2+ years, and OEMs cite access to sufficient materials & subcomponents as one driver of delays. Complex and time-intensive assembly, especially for larger power transformers, is another key factor. Major OEMs like Hitachi and Eaton are expanding their domestic manufacturing capacity. • **Electric grid component suppliers often require significant controls engineering and electromechanical knowledge,** which may be a pivot or new capability for some auto supplier SMMs
Key components (supply chain)	• Bushings/bearings • Cabling • Cooling systems • Electrical components (capacitors, inductors, resistors, arresters, fuses, switchgears/breakers, tap changers) • Gaskets • Housing (sheet-metal) and tanks for transformers and other components • Insulation materials (polyethylene, pressboard, kraft paper, other cellulose products) • Material inputs (especially copper wire, aluminum, specialty steel, mineral oil) • Transformer coil winding & core assembly
Example opportunities for automotive suppliers (V1)	• Engine components → Bearings, bushings and gaskets; fluid purification, recycling and filtration systems • Fuel Tanks → Housing and tanks for transformers • Coolants and engine thermal management → heat exchangers, insulation and cooling materials

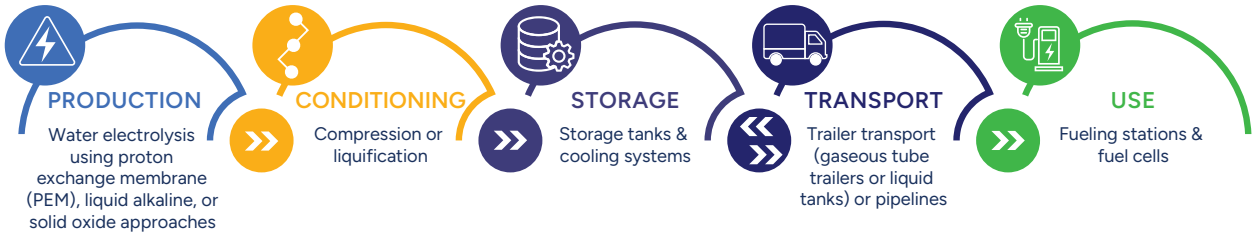
15 Sources: HVDC Cables Market – By Voltage, Installation, Application, & Forecast, 2024–2032; Power Transformer Market Size, Share & Trends Analysis Report By Core, By Insulation, Phase, Rating, Application, Region, and Segment, Forecasts, 2023–2030; Electric Grid Supply Chain Review: Large Power Transformers and High Voltage Direct Current Systems; Pathways to Commercial Liftoff: Innovative Grid Deployment

Figure 3.4 Solar Photovoltaic Components Overview

Considerations for new entrants	• **US solar PV generation capacity was ~140GW in 2022, with upwards of 30% year-over-year growth in new yearly installations.**[16] Currently, solar manufacturing from polysilicon production up through modules is highly concentrated in China. Some policy incentives are encouraging increased domestic production of solar components throughout the supply chain. A currently emerging market for perovskite solar panels (an alternative to silicon-based panels) may also present new supply chain opportunities in the future as that market grows. • **Downstream components will present greater opportunity for auto SMMs,** especially tracking systems, and "balance of system" inputs like inverters, since upstream manufacturing is concentrated in larger and often foreign manufacturers. Many of these inputs involve power electronics, so SMMs interested in these business lines will likely need to increase their electrical engineering and controls engineering capabilities, alongside other electromechanical skills. • **Domestic purchasing volumes from solar customers likely won't match automotive OEM/Tier 1 volumes in the near term.** Interested SMMs should move cautiously, build new customer relationships first, and secure as much early customer certainty as possible to avoid overinvestment and stranded assets.
Key components (supply chain)	• Charge control elements: fuses, circuit breakers, sensors, transistors • Inverters • Module inputs (frames, solar glass/rolled glass, plastic sealants, cells (inputs: polysilicon, ingots, wafers), backsheets • Mounting hardware (fasteners, brackets, clamps, rails) • Production equipment (e.g., ingot pullers) • Tracking systems (drivers, gears, sensors, motors, torque tubes)
Example opportunities for automotive suppliers (V1)	• ICE drivetrain components (e.g., gearbox) → Tracking system inputs like solar torque tubes, gears, and drivers • Axle and axle housings → Tracking systems, racking and mounting hardware • ICE electronics components (e.g., antennae) → Sensors

16 Department of Energy, Solar Energy Technologies Office, Quarterly Solar Industry Update

Figure 3.5 Clean Hydrogen Overview



Considerations for new entrants	• **The steam methane reforming (SMR) hydrogen market is already a $10–12B annual market,** and the global green hydrogen market is expected to grow from $1B in 2023 to as much as $30B in 2030[17] • **Domestic manufacturing is still nascent, but long component lead times suggest room for new capacity** and new suppliers (e.g., the current electrolyzer lead time is 2–3 years, and for tube trailers is at least one year) • **Early clean hydrogen customers will be industrial,** with low-power (i.e., fuel cell) applications further from significant scale or demand. However, some manufacturing of fuel cells for trucking is growing. • **Other considerations for current auto suppliers mirror those of the aerospace sector,** including: – **Greater material stress:** Pressurization, chemical stress, and temperature swings likely require switching to heavier-duty and higher-cost materials (e.g., carbon fiber for tube trailers) relative to auto sector parallels – **Increased precision:** Components for electrolyzers require tighter tolerances relative to automotive parallels
Key components (supply chain)	• Compressors for pipelines and fueling • Electrolyzer and fuel cell components – Heat exchangers – Metal and carbon plates (coatings, joining, stampings) – Metal and plastic structural parts (e.g., for housing/body) – Power electronics to control power to the electrolyzer/fuel system – Raw material inputs (e.g., potassium hydroxide, sodium hydroxide, titanium, nickel, platinum group metals, catalysts, carbon fiber) – Separators, membranes, gas diffusion layers (e.g., roll-to-roll manufacturing) – Water purification and conditioning systems • Pipelines (less demand expected near-term) • Storage tanks for compressed H2 gas and liquified hydrogen (both station tanks and on-vehicle tanks) • Tubes / Tube trailers and components • Valves, nozzles, hoses, and pipes
Example opportunities for automotive suppliers (V1)	• ICE engine systems → Hydrogen valves and compressors • ICE exhaust systems → Electrolyzer heat exchangers • ICE fuel systems → Hydrogen piping, hoses, water purification systems • Metal stampings → Tubes or tanks

17 Green Hydrogen Market, Industry Size Forecast Report, [Latest] (marketsandmarkets.com); US Department of Energy | The Pathway to: Clean Hydrogen Commercial Liftoff

3.B. Evaluate opportunity size, resourcing needs, and risks

You might surface several promising diversification opportunities across multiple technology or product areas. At the same time, the effort and risk involved in pursuing an opportunity may require careful prioritization so as not to take on too much at once. This section describes approaches to prioritizing among potential opportunities.

The objective is not to create near-certainty that a new product line or effort to reach a new customer segment will succeed; that is impossible. Rather, the aim is to provide a structured, consistent approach to evaluating varied potential investments so your executive team can make rigorous decisions based on (1) clear assumptions, (2) minimal influence of preconceived notions or biases, and (3) maximal awareness of questions to explore as you take early implementation steps.

Moreover, this prioritization exercise should be iterative: it's not something you do once and then are done forever. Use it to decide on one or two first priorities. Then take a few early steps, see what you learn, revisit your hypotheses, and adjust the original prioritization as needed. Repeat this process until you have the confidence needed to make larger decisions—and it can take time (see callout).

On finding the right opportunity, Voltage Co (a Tier 3 xEV powertrain supplier) notes:

"We started off with about a year of what we called risk mitigation and discovery during which we really tried to figure out the right place in the market to enter and how to do it and which suppliers and technologies would make sense for the investment we were looking at."

In prioritizing the opportunities you've identified, you might find it useful to consider three sets of factors, each of which is described in more detail below:

OPPORTUNITY SIZE: The potential market size, the market share you believe you can secure, and possible follow-on opportunities once you've established credibility in a new supply chain.

RESOURCING: The financial, engineering, technological, human, and other resources required to pursue the opportunity, including certifications or standards needed to sell to new industries.

RISKS: The variable uncertainties (e.g., speed of market growth, volatility in the price and availability of key inputs) the new opportunity presents—and your own risk tolerance given your business's current situation.

3.B.i. Opportunity size

Of course, one of the most important considerations for a new market opportunity is, *how big is the opportunity?* Consider thinking about this in terms of both the size of the potential market and the share of the market that your business might reasonably hope to win:

- **Market sizing and growth:** Start by estimating the *Total Addressable Market* (TAM) for the new opportunity, accounting for potential growth. TAM estimation is a foundational tool for startups and growing businesses of all kinds. TAM refers to the total amount of revenue possible if you served all of the relevant market. Note that the "relevant market" might not be the total global or even national market, or an entire industry, if you only expect to serve parts of either (e.g., Midwestern midstream suppliers of major OEMs in a given industry). There are several ways to estimate TAM, including filtering industry-wide information from third-party sources down to the most relevant industry subsections or conducting bottom-up estimates using assumptions (e.g., from early conversations) for revenue per customer and the number of customers served. Because many clean energy industries—including and beyond xEVs—are young and emerging, it is valuable to consider several different scenarios for potential industry growth.
- **Market share:** Alongside potential market size and growth, consider the share of the market you might capture given barriers to entry (e.g., incumbents have larger R&D investment capacity, IP barriers, longer OEM product cycles mean windows for new entrants are few and far between). If potential market share is small, the opportunity may not be worth pursuing even if market size or expected growth is large.[18] Even so, exploring some large market size, low market share opportunities can be valuable, especially if profit margins are relatively high and you can identify sub-segments or specialized areas where you could become more dominant due to your customer relationships, geographic location, or other factors.[19]

Don't forget to consider the "indirect opportunity"

Even if a specific market opportunity is relatively small or market share will be hard to secure, it still may be worth exploring if it opens up the possibility of supplying other components in an industry (e.g., by helping you build relationships with customers and establishing your credibility and reliability in a new area) or reinforces your core value proposition (e.g., supplying bespoke components for novel clean industries). Take the example of Tier 3 supplier Voltage Co:

"We started out in the xEV sector supplying motor parts. Pretty straightforward. Over time, we built our ability and credibility to get into second-life battery applications, and then broader energy storage. This was a natural extension of our EV-focused efforts, and it's allowed us to go into a space that Tier 3 ICE suppliers might never have even considered. We can apply the same skillsets and planning. This way, you turn your risk-taking—entering into a new market like electrification—into an asset. That's how we worked our way into the full powertrain system—and now beyond."

3.B.ii. Resourcing

Resourcing requirements—effectively, costs both financial and otherwise—will help gauge whether the potential return from the opportunity is sufficient to justify the investment. Make sure you consider a range of potential costs and investment needs, including:

- **Equipment and technology purchasing, installation, retrofitting, maintenance, and repair:** How significant are the needs? Will new product lines call for higher precision equipment? Is wholly new equipment needed or can existing equipment be repurposed or modified? How much does the new equipment cost, will it require any shutdowns of existing product lines during retooling, and how might lead times or other supply chain difficulties

18 What Is the Growth Share Matrix? | BCG

19 BCG Classics Revisited: The Growth Share Matrix ; Strategies for Low Market Share Businesses (hbr.org). See also tools like this one from Harvard Business School to help in estimating TAM and market share: Marketing Analysis Toolkit: Market Size and Market Share Analysis - Background Note - Faculty & Research - Harvard Business School (hbs.edu).

affect your ability to capitalize on the opportunity? Make sure to consider costs for new IT needs that support your value proposition in the opportunity area (e.g., smart manufacturing technology, more flexible and reprogrammable equipment such as collaborative robots, or better emissions tracking), as well as process changes that may come with costs (e.g., rerouting intermediate product lines).

- **R&D and intellectual property:** Are there new technological innovations needed to make for a compelling value proposition?
- **Inputs and supplier agreements:** How are gross margins affected by the cost of inputs, relative to current product lines? As above, what costs might you incur for inputs that may be difficult to secure? Do any key inputs rely on a small number of suppliers with significant pricing power?
- **Human capital:** What are the direct costs in training or hiring workers as well as any indirect costs in foregone time producing existing product lines? Will there be any need to update collective bargaining agreements or develop new agreements that support workforce continuity, such as project labor agreements for construction or community workforce and local hiring agreements?
- **Professional and business operations services:** Will you seek external services for help with strategy, market research, marketing and business development, legal, financials and accounting, or any other professional services topics?
- **Certifications, standards, and regulatory requirements:** Will your business require new certifications or need to meet new standards to enter a new supply chain? These standards might come from both regulatory requirements in the new target market (e.g., access authorization for nuclear power plants and their vendors, food and pharmaceuticals industries have stronger cleanliness and QA regulations), or common practices that may be different (e.g., aerospace has much stricter tolerances and capability requirements, which may require new tooling).
- **Financing costs:** What external financing, if any, will be needed to fund all the above? Where will that funding come from, what costs may be involved in securing those funds (e.g., in staff time), and what constraints might the new funding place on other potential financing needs? (See Section 4.A. on financing options.)
- **Downtime and other opportunity costs:** What revenue opportunities may you be forgoing, at least temporarily, by pursuing the market opportunity? This missed revenue may come from downtime to modify production lines, leadership time focused on the new opportunity relative to other needs, or other sources.

This list is not meant to discourage pursuit of conversion or expansion opportunities, but rather to help ensure you are thinking comprehensively about costs and estimating a realistic ROI. Moreover, as you work through the questions, you can also consider strategies to mitigate the costs (e.g., through partnerships that enable you to leverage others' capabilities instead of having to build them in-house) or even opportunities to turn the costs into chances to pursue other benefits (e.g., to integrate energy efficient or smart manufacturing technologies—see callout).

Use product line transitions to improve manufacturing performance

It's easier, cheaper, and less disruptive to make improvements to manufacturing equipment and processes (e.g., changes that save energy, add new "smart manufacturing" tools like internet-connected sensors, and otherwise improve productivity) during construction, retrofit, or other downtime. See Section 4.C for more on Process Improvement.

There are several programs that enable SMMs to receive no- or low-cost technical assistance to help with these topics (see Appendix C). Consider taking advantage of them while you're already modifying facilities or manufacturing lines for new market opportunities.

3.B.iii. Risk

Together, opportunity size and resourcing requirements provide a sense of ROI. However, it is important to *think probabilistically* about an opportunity and consider risks and uncertainties. Go beyond one fixed estimate of what the ROI will be to understand the distribution of possible outcomes, the mitigation steps that can narrow that distribution, and your own risk tolerance.[20] Below are some potential categories of risk and uncertainty that may be especially relevant in this context, and which you can break down into more specific considerations for your situation.

- **Macroeconomic and policy risks,** such as if an industry's growth trajectory is highly influenced by the business cycle, interest rates, and supportive government investment and trade policy (this may be especially true for capital-intensive industries like hydrogen or industries exposed to significant foreign competition, such as battery and solar panel manufacturing).
- **Market and technology risks,** such as the speed of market growth and maturation (e.g., as exemplified by standardization of components), the extent of existing market power among established suppliers, and the possibility that the end user's technology will be displaced (e.g., because a different power generation approach proves more scalable or affordable).
- **Contract and product validation risks,** such as the typical contract length and re-competition cycles in the target market. In the automotive industry, for instance, five-year procurement cycles are common; conversely, in aerospace, the cycles may be 10–15 years or variable between OEMs. Additionally, before securing new contracts or receiving payment, manufacturers must often produce initial units and validate product performance, which can create significant validation risk, especially if a manufacturer is developing multiple products at once.
- **Supply chain risks,** such as high and unpredictable variability in the price or availability of key inputs. For instance, the solar industry's domestic supply chain needs are highly sensitive to changes in tariffs and trade policy.
- **Other risks** may include legal and permitting risk (e.g., if you intend to expand, upgrade, or build new facilities in a way that will require environmental permits or National Environmental Policy Act review).

While there are quantitative approaches to assessing risk (e.g., by looking at data on the variance of prices for key inputs), even just a thoughtful qualitative assessment can help set priorities. For each risk or uncertainty you identify, consider (1) the likelihood that it might happen (e.g., given historical variance), (2) the consequences if it does, and (3) possible mitigation steps or other implications for the opportunity (see Table 3.2 for an example). Lastly, you can set a summary risk rating, informed by these more detailed considerations.

20 See this report for more on probabilistic estimates of ROI for capital investments that face varied risks.

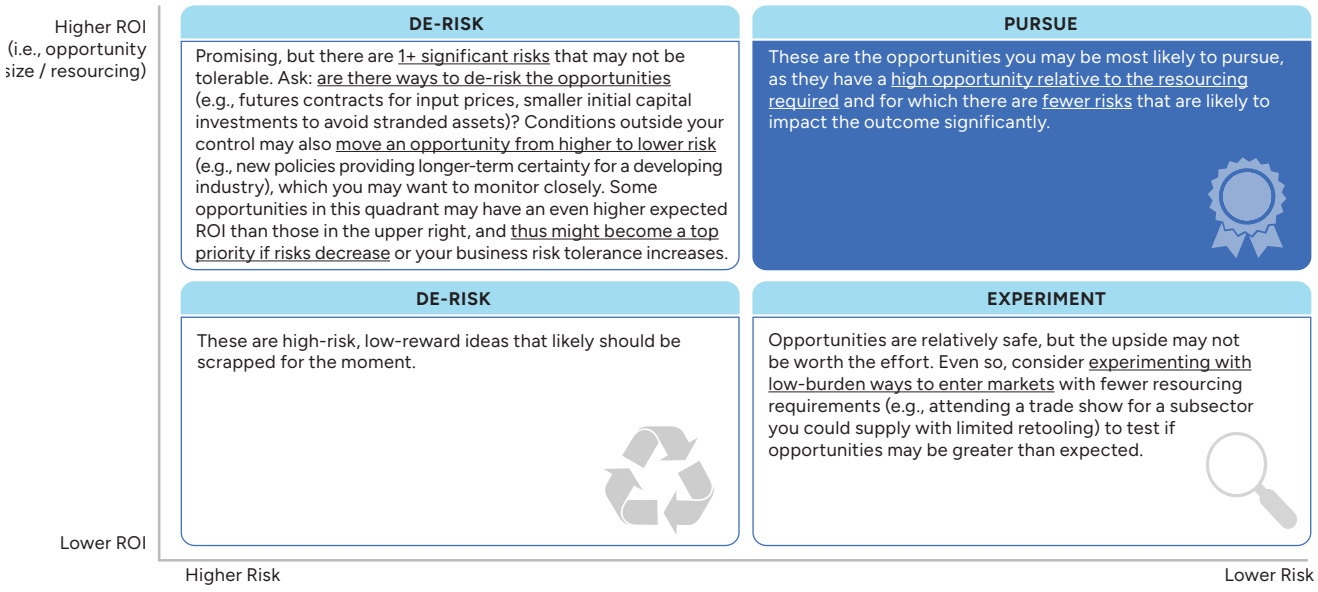
Table 3.2: Example qualitative assessment of risks and uncertainties			
Risk/Uncertainty	**Likelihood**	**Consequence**	**Possible Mitigation / Implications**
Ex. Technology risk: Several possible core technologies are vying for dominance, which require different components	Higher	Medium–High	Ex. Re-design production process to be modular rather than linear, enabling quicker substitution of components[21] Ex. Invest in agile, user-friendly manufacturing equipment such as CNCs and collaborative robots, with flexible tooling and minimal integration needs in case of product changeover
Ex. Contract risk: Early customers may not have funding to enable five-year contracts as is standard for auto OEMs	Medium	Medium	Ex. Make smaller capital investments at first to avoid stranded assets, and secure multiple initial contracts with different customers, even across sectors
Ex. Validation risk: New product line requires third-party validation or testing before customers will purchase significant quantities	Medium	Lower	Ex. Negotiate partial prepayment to help cover testing costs, and avoid developing many new products until initial new product is validated and generating revenue
Ex. Supply chain risk: New market opportunity requires use of critical mineral with high variance in prices (but few availability risks)	Medium	Lower	Ex. Conduct scenario analysis to understand whether futures contracts can mitigate risk
Ex. Summary risk level	Medium–High		Ex. Explore costs of process changes to see if they are manageable enough to warrant more effort.

3.B.iv. Putting it all together to set priorities

With a sense of the opportunity size, resourcing requirements, and risk level for promising opportunities, you can now identify the one or two priority opportunities to explore most actively. One way to do so is to compare the expected return on investment—that is, the opportunity size relative to the resourcing requirements—with the risk level. Place each potential opportunity into one of four quadrants, based on the assessments above:

Remember that prioritization should be iterative, as risks and opportunities may evolve.

Figure 3.1: Leading Intermediate Purchasing Industries of Auto Parts (Millions of $)



21 See, for instance, the example from battery manufacturing here: A variety of new batteries are coming to power xEVs (economist.com).

Chapter 4: Execution Considerations

You've now identified one or two product diversification strategies that match your facility's context and meet your risk-return preferences. The next step is to start developing an execution strategy. Depending on the size of project you've identified, your execution plan could take 3–6+ months to develop, and there are many factors to consider—this chapter does not cover all of them. Rather, this chapter gets you started by presenting considerations for execution categories identified by expert interviews and peer SMMs as especially critical: financing, workforce readiness, and operational process improvement.

4.A. Financing

4.A.i. Financing strategies used by automotive SMMs

Many SMMs face challenges securing appropriate financing and sufficient working capital, especially for major projects like a product line conversion or expansion. Up until the early 2000s, SMMs often received financing from local banks that had experience with many SMMs and expertise on how to appropriately value SMMs' equipment and assets. Many of these smaller banks collapsed or were acquired during the Great Recession, and larger banks today often focus on larger projects and struggle to work with smaller firms. At the same time, SMMs' financial needs are too big for automated lending (e.g., lending used for mortgage qualification). Automotive SMMs are often paid upon parts delivery to Tier 1 suppliers and OEMs, which can create cashflow challenges. At the same time, SMMs often wait until they've obtained a specific purchase order before seeking related financing, to minimize risk.

Despite these challenges, automotive SMMs have developed (and are continuing to develop) cost-effective, suitable financing strategies that leverage a range of capital solutions. Many SMMs may already be familiar with the general categories of financing options available—Figure 4.1 is provided as a reference, if useful. For automotive SMMs, specifically, financing experts and peer firms describe a range of frequently-used financing strategies, with different considerations for each:

- **Internal financing.** This is most SMMs' preference, although it usually requires a guaranteed job that will justify the investment. Many firms only move beyond internal financing when the investment size is too large (i.e., it would consume too much working capital), the payback period is too long, or the risks are too high. For instance, many SMMs use internal financing only if the payback is no more than one or two years.
- **Financing from parent company or ownership group.** For SMMs that are partially or wholly owned by a parent company or investment firm, a common financing pathway is to seek financing from the umbrella entity. This financing is usually structured like traditional debt (loans) but can sometimes come with equity/equity-like terms depending on the size and nature of the investment.
- **Private bank loans.** With traditional bank loans, some SMMs note greater success working with regional banks rather than larger national lenders, and often seek out banks that specialize in industrial lending. Machinery is commonly used as collateral, though this can present challenges if the machinery is required for day-to-day operational needs or is costly to seize and redeploy. Securing favorable loan terms from traditional commercial lenders often depends highly on the SMM's end-customer, so traditional lending may be a challenge for SMMs who want to work with smaller, less-established clean energy customers. Lenders also look for unique capabilities that give their customers a competitive market advantage, so it is important to articulate your unique value proposition to potential lenders (e.g., how in-house design or process improvement capabilities put you ahead of peers).
- **Private bank loans supported by public investment.** Some private lenders offer loans supported by public funding and institutions, including the U.S. Treasury Department's State Small Business Credit Initiative (SSBCI) or the U.S. Small Business Administration (SBA). These lenders are able to provide lower-cost, risk-tolerant lending solutions. For example, jurisdictions participating in SSBCI

might provide a guarantee or other credit support to enhance a borrower's creditworthiness and help them secure a private loan. Banks, credit unions, and loan funds across the country participate in public lending programs, but each program comes with specific qualifications or criteria, which can take staff time to understand and navigate. Community development financial institutions (CDFIs) can also provide forgiving, risk-tolerant capital to SMMs without a strong credit history, especially SMMs located in an underserved community, but these loans are generally relatively small (<$500,000).

- **Customer loans or financing (e.g., from OEM/Tier 1).** In some arrangements, the customer provides an upfront payment (e.g., to finance re-tooling or new machinery purchases), in exchange for lower costs in the future (usually via lower prices for the parts it is ultimately buying). This approach is more often used by SMMs that are struggling more acutely with cashflow or other operational challenges. Another customer-led financing strategy is for an OEM to fund tooling or machinery outright—this is a reliable and low-cost source of investment funding, but it creates significant risk since the OEM generally owns the equipment and could take it to a different business partner, if it wishes. Many OEMs may offer financing for other reasons beyond strictly financial considerations (e.g., providing decarbonization-related financing, especially to businesses in disadvantaged communities, may count towards ESG goals; foreign OEMs may have local content requirements or gain local support by strengthening local supply chains).
- **Rental financing.** This is a relatively newer financing strategy, wherein the financer (e.g., banks, technology providers such as Trumpf, other lenders) works with an SMM to purchase the asset (e.g., new equipment) and then rents the asset back to the SMM. At the end of the rental period, there is an agreed buy-back price or the SMM can choose to keep renting for a second period (also agreed to in the initial agreement). At the conclusion of the second rental period, the SMM then typically owns the asset wholly. This option creates risk for the lender—and considerable additional expense for the SMM—but can help SMMs avoid taking more debt onto their books, depending on the structure of the agreement.
- **Public grants and in-kind support.** At the federal and state levels, many public programs will provide non-dilutive grant funds to SMMs to finance upgrades related to clean energy, energy efficiency, productivity improvements, and manufacturing competitiveness. These programs range in size from ~$50,000 to $50,000,000+. Different programs have different eligibility requirements and stipulations, and different rates of success for applicants, but these programs can be a great source of low-cost capital on very favorable terms for SMMs that meet program criteria. See Appendix D for a list of relevant programs.

Figure 4.1: The spectrum of SMM financing tools[22]

	Debt Capital				Hybrid	Equity-Like Capital / Equity			Grants
Product	**Assets-Based Loans**	**Term Loans**	**Line of Credit**	**Equipment Financing**	**M&A Financing**	**Equity Financing**	**Supply Chain Financing**	**Revenue-Based Financing**	**Grants**
Overview	A loan leveraging assets to secure a line of credit or business term loan	Fixed-term debt product from traditional banks, typically with higher lending requirements	A debt product with a preset borrowing limit that can be tapped into at any time	A loan used to obtain equipment, including assets other than real estate	Mezzanine financing and senior debt to pursue M&A	Long-term financing conditional on an ownership stake in the small business	Product leveraging contracts/ receivables as a collateral for advance financing	An equity-like capital product where firms receive investment for a portion of gross revenue	Non-repayable funds directly to businesses
Potential Capital Uses	Working capital for day-to-day operations and liquidity for business growth and shifts, including retooling facilities and plants			Investment capital for retooling facilities and plants	Capital to foster JVs of other avenues for inorganic growth	Capital to accelerate innovation and new business models	Support gaps in cash flow from lead times from contracts		Test and integrate diversified solutions

22 Figure adapted with permission from Next Street and MI LEO

4.A.ii. Choosing the right financing strategy for your business

As the options above illustrate, there is no one-size-fits-all solution for financing a major project. To determine which options may best fit their business needs, SMMs and their business advisors could consider the following prompting questions:

1. **Investment size:** What is the total investment need (see Section 3.B.ii on estimating total cost and resourcing)? To make financing easier, are there different investment stage-gates or tranches into which this project could be divided, without jeopardizing the overall project success?
2. **Payback period:** When do we expect to see positive financial returns from this investment? Which financing options would work better for shorter versus longer-term payback? What is the range of uncertainty on this prediction (see Section 3.B.iii on risk and 3.B.iv on return on investment)?
3. **Current firm financial status:** What debts or other financial commitments are we already holding, and how does this change our future financing options? Are we struggling with quarter-by-quarter cashflow, or other acute financial challenges? Consider meeting with a traditional bank lender to check your sense of your firm's financial position.
4. **Past relationships and new players:** Who have we worked with on previous financing, and why would they be a stronger or weaker fit for the current need? If we're considering moving into a new industrial sector, what can we learn about common financing strategies in that sector?
5. **Prioritizing across risks:** What types of liabilities and risks are we most willing to take on, given the firm's current financial position and broader business strategy? What downside risks do we most want to avoid? (See Section 3.B.iii on risks) What would we be willing to pay (e.g., in more expensive financing) to avoid these risks?

These questions are just intended to spark discussion—determining a financing strategy will require planning across firm management and working with customers and potential financing providers. As you investigate financing options, it may be helpful to consider these resources recommended by industry advisors and other auto suppliers:

- **Federal technical assistance programs** that help manufacturers connect with public financing opportunities, green banks, or local lenders (see Appendix C)
- **Federal funding and financing programs** that provide direct grants, loans, and other supports to SMMs (see Appendix D)
- **The U.S. Small Business Administration (SBA) Small Business Investment Company (SBIC) directory,** which lists investment companies with historical interest in small business investments. Additionally, leveraging the SBIC program, Monroe Capital intends to launch its "Drive Forward" Fund to provide lower cost capital for small- and medium-sized auto manufactures to refinance, grow, and diversify their businesses; as of October 2024, the fund has not yet launched but will appear in the SBIC directory once live.
- **The Department of the Treasury launched the IRA Taxpayer Resource Hub,** a one-stop-shop for information on the Inflation Reduction Act's clean energy tax benefits. The Hub details how businesses can take advantage of clean energy tax credits to help finance new investments in clean power systems, energy efficiency upgrades, or electric vehicles.
- **Various state-level programs and resources, as well as local utilities' economic development programs** (see Appendix F on state-specific programs in states with a high concentration of automotive supply chain activity).

4.B. Workforce

Changing your production offerings will require a workforce that has both the right skills and will to shift to new ways of working. The following section outlines the steps manufacturers can take to prepare their workforce for a successful business transition:

- Step 1: Assess your current talent retention and attraction challenges
- Step 2: Identify any new skills needed
- Step 3: Select the right worker training strategies and partners

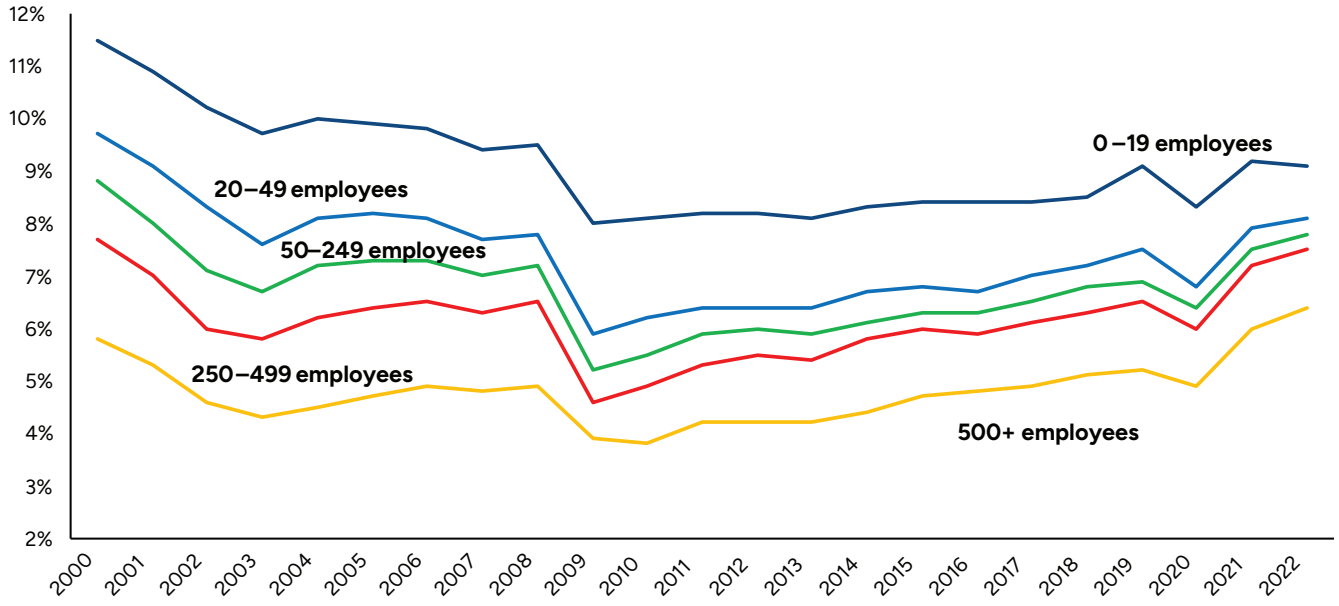
Upskilling, transitioning, or expanding a workforce can require significant time and change-management effort. However, these changes also present opportunities to address workforce challenges regularly affecting many manufacturers, such as reducing turnover and improving employee productivity and well-being. Employers that approach product and process changes with a employees' lens (e.g., by seeking workers' ideas early, communicating transparently, and considering how changes affect workers' incentives) can address turnover, productivity, and business development challenges at once.

4.B.i. Assess your current talent retention and attraction challenges

Independent of product changes, attracting and retaining a skilled workforce is already one of—if not the—top challenges for U.S. manufacturers. Over 65% of manufacturers in the first quarter of 2024 cited an inability to attract and retain workers as their top challenge, surpassing an array of issues like healthcare costs, inflation, and supply chain concerns (National Association of Manufacturers (NAM).[23] Attracting and retaining workers can be especially challenging for small and medium-sized firms: manufacturing establishments with fewer than 250 employees reported worker turnover rates of at least 8% in the last six quarters for which data is available (see Figure 4.2).[24] This marked the longest stretch at or above that rate since the mid-2000s.

Smaller firms face greater retention challenges than larger manufacturers in part because many SMMs may face more barriers to paying competitively with larger firms, offering competitive benefits and advancement opportunities, and making large investments in working conditions and safety enhancements, amongst other

Figure 4.2: Workforce turnover rate by manufacturer size



Source: US Census Bureau, Quarterly Workforce Indicator Explorer: https://qwiexplorer.ces.census.gov/

23 Study: Manufacturing in U.S. Could Need Up to 3.8 Million Workers
24 US Census Bureau | Center for Economic Studies, Quarterly Workforce Indicators Explorer Tool

job quality factors.[25] Some job quality improvements are fundamentally harder for smaller firms to execute (e.g., certain benefits are much cheaper per employee at larger firms and more flexible shifts require a certain workforce size). However, SMMs can and do implement many job quality improvements, like expanding advancement opportunities, improving safety and comfort of working conditions, or supporting collective bargaining. For instance, collaborative relationships with unions and labor organizations can help address recruitment challenges: in 2023, only 24% of unionized businesses in the energy sector (including motor vehicle manufacturing firms) reported that hiring was "very difficult" compared to 40% of non-union firms.[26]

If a manufacturer is already struggling with high turnover and employee morale, product line changes may exacerbate these issues. However, if firms can turn this transition into an opportunity for the existing workforce to improve job satisfaction, learn valuable job skills, improve work-life balance, and advance on a career ladder, they can expand production and solve turnover challenges simultaneously. Adopting new technologies with workers in mind can also improve job quality, by reducing menial or difficult tasks and providing upskilling opportunities for production workers to learn machine operation.[27]

Adopting new technology and/or a new product can require solving turnover challenges—and can also provide a path to doing so. Experienced shop-floor workers can help significantly with de-bugging new processes and quickly solving problems that arise, leading to greater uptime and more revenues. In turn, these revenues make it possible to pay employees more (reducing turnover), without reducing profits.

As a result, before executing your product conversion strategy, it is valuable to assess your current workforce and employment approach to identify job quality gaps and opportunities to mitigate turnover and other risks to product conversions or additions. Frameworks like the U.S. Department of Labor and Department of Commerce's Good Jobs Principles[28] or the National Institute for Standards and Technology's Baldrige Excellence Framework[29] can help organize your self-assessment (see Appendix B for specific prompting questions aligned to the Good Jobs Principles).[30]

Technical assistance providers like NIST's Manufacturing Extension Partnerships can help you locate your largest job quality challenges and identify a few feasible options to improve worker productivity, satisfaction, and readiness for change.

4.B.ii. Identify new skills needed

A full assessment of the new worker skills needed for a product conversion can be a significant task, especially for SMMs. Many large manufacturers will undergo Job Task Analyses, which requires surveying industry professionals, observing job tasks, and administering structured questionnaires of current employees. This section proposes a simpler alternative process that can surface many of the same insights:

1. **First, record your best guesses of what job skills any new equipment and processes will require.** In many cases, new equipment and processes may not require significant new skills, but a thorough self-reflection can help surface both more evident and subtle skill needs. For example, will quality control be more important going forward? Will you need to upskill some machine operators to operate more advanced, high-precision manufacturing equipment? Will you need to upskill machinists and welders to operate and be more comfortable with collaborative robots (cobots), which rely on programming feeds and speeds rather than tacit knowledge? Will you need additional technical staff

25 Data from The Manufacturing Institute's Center for Manufacturing Research and the American Psychological Association (Manufacturing Engagement and Retention Study | The Manufacturing Institute) indicate factors like enjoyment of work, job stability/security, work-life balance, and company culture were ranked highest among workers as reasons why they chose to staying with their current employer. Furthermore, empirical evidence and theoretical models have noted a common set of elements that have been used to determine the quality of a job. These factors include: 1) compensation – wages and benefits; 2) working conditions – safety and flexibility of schedule; 3) job design – task composition; 4) intrinsic value of the job – e.g. including social value; and 5) forward prospects – including training and advancement potential (Katz et al, 2022). See also https://www.dol.gov/general/good-jobs/principles.

26 US Department of Energy | US Energy Employment Jobs Report

27 Harvard Business Review, March-April 2023, A Smarter Strategy for Using Robots

28 See Helper and Martins, "The High Road for Manufacturing" for examples: https://issues.org/helper/ .

29 US Department of Labor, The Good Jobs Initiative: Good Jobs Principles

30 National Institute of Standards and Technologies | Baldridge Excellence Framework

to manage electrical and software complexities of xEV equipment? Will you need sales staff who are comfortable managing a larger and more complex set of customers & technologies? Some sources for information include:

a. Engage your existing workers and reach out to existing training partners (e.g., local community colleges and trade schools), local workforce boards, state or regional office of apprenticeship, and/or labor-management training partner representatives, if applicable. Many training organizations are already preparing for the ICEV-to-EV transition and other advanced manufacturing workforce shifts and may have locally-informed data on new skill needs.

b. Consult a manufacturing skills advisor, including those associated with state or federal programs that may be able to provide no-cost or low-cost services to SMMs (see Appendix C).

c. Reach out to your machine manufacturers, integrators, and suppliers to ask if they have resources or advice on worker skills needed to operate the equipment you're considering. Review their equipment training materials.

d. Ask your customers or would-be customers for their data, and if they have skills analyses they could share with you that would be relevant to your new product line(s).

e. Analyze labor market data, such as the O*NET skills database.[31] See also the overview of xEV and clean energy skills requirements in Section 4.C.iii.

2. **Next, map those skills to your current workers.** Consider both *presence* (e.g., do you have *any* workers with these skills) and *prevalence* of key skills (e.g., you have some workers with the right skills but you will need a greater number for the new opportunity).

4.B.iii. Workforce differences between ICEVs and clean energy manufacturing

Finally, identify the critical-need skills where you have the largest gaps between your current workforce and your needed workforce, and decide what strategy can best close these gaps. Workforce professionals often describe how you can "build, borrow, or buy" the needed skills. For instance, if you have had just 1–2 major customers for many years, you may want to "buy" (hire)—or at least "borrow" (hire consulting support from)—new sales professionals with relationships in other markets. Or, if you have never used advanced robotics, it may make sense to hire a robotics integrator to set up your equipment and provide staff training. On the other hand, skills like engineering for xEVs may be easier to "build" internally (see callout below). There are many organizations who can help here: consider connecting with workforce partnerships in your area for help deciding on a strategy and building an execution plan (see Section 4.C.iv).

Electron Co reflects on building a new workforce from within:

"We started out making battery cell connection systems manually. That required one kind of manufacturing talent. We switched over to robotic manufacturing for higher quality and greater variety. We've got one robotic line in one of our facilities. It's capable of almost 40 different SKUs. A different set of skills is required to manage that line: a knowledge of robotics and of flexible manufacturing.

Most of the team made the transition internally, but there was a challenge. We're on a pretty steep learning curve. Combined with our turnover rate, this leaves us in an intense, ongoing training cycle. It's not like we can hand somebody a document and say, "read this, and you now know how to do your job." Usually it takes three years for a good sensor engineer to get mature enough that they can handle their own projects with oversight.

We've been able to leverage YouTube videos. We also our make our own serviceable videos. We can share knowledge and educate our own people quickly. You put a PowerPoint file together and you do a 15-minute overview on a specific chunk of technology, record it and then it's there for everyone. We've used that process to socialize a new terminology that's used in this industry that's radically different from our ICE upbringing. Knowing the acronyms of a new technology—sometimes that's half the battle. Every month we have a new training session on some element of electrification."

31 O*NET 29.0 Database at O*NET Resource Center (onetcenter.org)

While new job skills required will depend heavily on the conversion or expansion opportunity identified, labor market insights and industry experts do highlight some consistent themes regarding the skills needed for xEV and clean energy manufacturing relative to automotive parallels.

EV-related and other clean energy manufacturing requires many of the same skills, credentials, and certifications as traditional automotive manufacturing. For instance, core certifications like Project Management Professional (PMP) certifications, OSHA industry cards, and driver's licenses (including CDL Class A licenses) are common requirements for both traditional and emerging manufacturing subsectors, and skills like welding, machining, machine operation and maintenance, and fabrication and assembly will likely be just as relevant in the new areas you pursue as they are to your current manufacturing processes. Fundamental workplace readiness skills are also shared across subsectors (e.g., critical reasoning, dependability).

However, national labor market data and industry experts highlight several skills and credentials that are increasingly important to high growth xEV and clean energy manufacturing sectors.[32] These include:

- **Refrigerant handling skills and experience,** for sectors like heat pump manufacturing. This may accompany an increased need for EPA 608 Technician Certification and EPA Universal Certification. These requirements appear to be unique to clean tech manufacturing and are not typically found in auto industry postings. The EPA 608 certification certifies refrigerant handling skills, while the EPA Universal certification certifies technicians to be able to work on any type of HVAC equipment containing refrigerants.
- **Battery and chemical handling and hazard mitigation,** especially for manufacturing in xEV supply chains.
- **Electrical engineering, design, and safety experience,** from controls engineering to technician roles. Electromechanical or mechatronics training can often be required to enable work on advanced machinery and robotic equipment.
- **Increased safety certifications,** commensurate with the risks that come alongside greater use of refrigerants, chemicals, and electrical work in manufacturing. Job listings in xEV and other more often ask for **10-Hour and 30-Hour OSHA General Industry Cards** as a stated requirement. There's also increased stated preference for CPR certifications, perhaps due to greater use of electrified manufacturing equipment. While these are less frequently required in auto industry postings, many auto industry workers involved in quality control or workplace safety roles may already possess these credentials and skills.
- **Diagnostic skills, complex problem-solving, and quality assurance** commensurate with more complex manufacturing equipment and processes and the general trend toward more integrated electromechanical products, often with tighter tolerances relative to automotive.

The relative prevalence and importance of some jobs may also change, largely due to the increased use of advanced manufacturing equipment and techniques in these clean energy supply chains. Labor market data and expert interviews identify job categories with higher prevalence in xEV and other clean energy manufacturing, relative to automotive:

- Chemical Technicians
- CNC Programmers and CNC Operators
- Controls Engineers
- Electronics Engineers and Electronics/Electrical Technicians
- Industrial Mechanics / Maintenance workers with advanced diagnostic skills and safety training
- Quality Control and Quality Assurance technicians

Alongside this increasing demand for some manufacturing skillsets, the ICEV-to-EV transition may lead to declining demand (or much slower growth in demand) for some traditional manufacturing skills. This may include traditional assembly, fabricator, tool-

32 Argonne National Lab analysis; https://www.wri.org/insights/ev-transition-auto-manufacturing-jobs

setting and older machine operation skills, though these workforce shifts are very nascent and not yet well-understood. Additionally, declining demand for some manufacturing skills does not mean there will be a decline in job opportunities for those workers, provided affected workers have sufficient upskilling or re-skilling opportunities. Patterns in ICEV-to-EV skill transitions will likely parallel general trends in manufacturing labor demand as the industrial sector moves toward advanced and automated processes.

4.B.iv. Select the right worker training strategies and partners

As you identify the skills needed to capture the new market opportunities, you may want to work with partners who can help identify these skills and provide the appropriate training and hiring support to fill gaps. Oftentimes, SMMs start this process by connecting with their local trade schools, community colleges, local workforce boards, state or regional office of apprenticeship, and universities (if not already connected), as well as with labor-management training programs, if their workforce is covered by collective bargaining agreements. Additional programs and partners that can help SMMs identify workforce gaps and provide training to fill these gaps are covered in the following appendixes:

- **Appendix C** summarizes federal workforce development and manufacturer assistance programs available for SMMs
- **Appendix E** describes a sample of industry and/or technology-specific workforce and credentialling programs
- **Appendix F** covers state-specific programs to support manufacturing workers and employers in a set of states with high automotive manufacturing employment

4.C. Process Improvement

Implementing process improvements alongside your chosen product diversification strategy can maximize the value created from this often-disruptive process, including better utilizing product line downtime and increasing long-term facility efficiency. Further, process improvements may be necessary to align with requirements of your new products or customers (e.g., higher quality standards, lower-volume but higher-value production). Successful process improvement implementation requires cross-functional collaboration across capital planning/finance, design, and manufacturing functions, but the payoff can be significant, in the form of more efficient, cost-effective, and adaptable operations.

4.C.i. Common manufacturing process improvement goals and approaches for SMMs

SMMs who successfully diversify their product strategy often pursue complementary operational model shifts and process improvements in parallel. These process changes can support a variety of big-picture business goals, including:

1. **Improve process and material efficiency and reduce waste.** One of the most common ways to improve manufacturing efficiency is through implementing lean manufacturing principles. Lean manufacturing uses tools such as 5S, Kanban, and value stream mapping (see Table 4.1) to enhance product flow and minimize non-value-added activities.
2. **Strengthen inventory management and supply chains.** Manufacturers might implement demand-driven (pull) systems, which use Kanban Cards (see Table 4.1) and other tools to reduce excess inventory and enable just-in-time manufacturing.
3. **Improve product quality and consistency.** Improving efficiency and consistency are key for manufacturers interested in continuous flow manufacturing, which can be a good operational model for high-volume, low-variety product portfolios.
4. **Increase operational flexibilit**y. Modular production models can allow facilities to scale-up and down quickly to meet market demand. For these models to be cost-effective, SMMs need to be able to execute quick setup changes, adaptable workflows, and techniques like single-minute exchange of dies (SMED) (see Table 4.1). Similarly, a cellular manufacturing model—which aims to minimize movement, accelerate production, and reduce waste via cellular layouts—can create smooth flow while enabling efficient low-volume production of multiple similar, high-value products.

Each of these big-picture operational goals can be supported by a wide variety of smaller process improvement techniques. Table 4.1 suggests a few approaches used frequently by peer SMMs, as well as sample prompting questions associated with each approach. Section 4.C.ii then presents a series of questions for SMMs and their business support partners to discuss to determine what operational changes and process improvements would best support the SMM's business goals.

Table 4.1: List of Process Improvement Approaches

Opportunity	Approach	Illustrative Questions to Consider
Improve Process Efficiency	Preventative Maintenance Checklists and Training	• What are the key outcomes of the maintenance program (e.g., minimizing downtime, extending equipment lifespan)? • Are breakdowns analyzed to improve maintenance planning? • Which critical assets need the most frequent attention? • Are operators trained for basic maintenance tasks to reduce dependency on maintenance staff and prevent delays?
	Process Mapping	• Which steps in the production process add value? • Are there non-value-added activities that could be minimized?
	Time Studies	• What is the actual time spent on each step of production? • Where could time be reduced to speed up the workflow?
	5S[33]	• Are workspace layouts and manufacturing flows standardized and organized for efficiency?
Improve Material Efficiency and Reduce Waste	Recycling and Reducing Waste	• Are structured waste and recycling procedures in place?
	Energy Efficiency	• Are power-down policies and usage monitoring in place to reduce operational costs? • Have you consulted with your local utility, Manufacturing Extension Partnership, or Industrial Training and Assessment Center to receive an energy audit and identify cost savings opportunities?
Strengthen Inventory Management and Supply Chains	Kanban Cards[34]	• Are inventory levels synchronized with production needs? • Does the current inventory turnover rate meet targets? • How accurate is the current inventory tracking system? • Are production schedules causing inventory bottlenecks?
	Supplier Collaboration	• How well are inventory levels synchronized with demand fluctuations? • What lead times are required by suppliers, are they optimized? • Are suppliers providing accurate delivery schedules? • How often do suppliers delays or errors impact inventory?
Improve Product Quality and Consistency	Standardized Work Instructions	• Are there clear, standardized operating procedures for each production process? • What steps are in place to prevent versus detect defects? • Are root cause analysis methods (e.g., fishbone diagrams) applied consistently?
	Statistical Process Control (SPC)[35]	• How is quality measured and how frequently? • What metrics are tracked and reviewed to maintain quality? • Are customer quality metrics and standards shared with teams?
Increase Operational Flexibility	Single-Minute Exchange of Dies	• How long do changeover processes take and where do delays occur? • Are there unnecessary steps or movement that can be eliminated?
	Continuous Improvement	• Are employees actively involved in identifying improvements? • Are there ways for employees to suggest and test new ideas? • What feedback do workers provide about inefficiencies or challenges in their daily tasks?

33 A workplace organization method that uses five Japanese principles—Sort, Set in order, Shine, Standardize, and Sustain—to create and maintain an organized, clean, and efficient work environment.

34 Visual tools used in a Kanban system to signal the need for inventory replenishment or movement within a production process, helping to manage workflow and ensure just-in-time production.

35 A method of quality control that uses statistical techniques to monitor and control a process, ensuring that it operates at its full potential to produce conforming products with minimal waste.

4.C.ii. Choosing the process improvement(s) that complement your business strategy

Process changes can strengthen your business, but they take time and capital to implement—so stay disciplined and avoid implementing many process improvements at once. Manufacturing process consultants, including free and low-cost options like those listed in Appendix C and Appendix F, can help you set process improvement goals, explore options, and prioritize the highest-value investments. This section suggests sample prompts for SMMs and their partners to help identify the operational changes that would best support the product diversification goals:

- **Your core capabilities:** What are the core capabilities and constraints (e.g., flexibility, scale, capacity, workforce) of your manufacturing operation? Evaluate your existing capabilities and pinpoint areas requiring enhancement.
  - To identify constraints and improvement opportunities in your current operations, consider using a tool called value stream mapping (VSM). This tool helps outline value flows through each stage of your process, highlighting existing constraints and areas for enhancement. (See Appendix G for VSM details and an example.)
  - Another helpful tool to pinpoint improvement opportunities are fishbone diagrams, which help identify specific tasks or processes that could benefit from automation, digitalization, modernization, or other improvements. (See Appendix H for fishbone diagram details and an example.)
- **Demand for new products:** What do forecasts and historical data indicate about your new product's demand? Is demand stable or fluctuating? For example, if the demand is subject to fluctuations or shows signs of a growing market, modular production can offer the necessary flexibility to adapt to market changes. On the other hand, tighter profit margins may require lean manufacturing to reduce waste.
- **Customer needs for customization:** What are the customers' needs and product requirements? Are customers requesting low-volume, high-mix products? Are product requirements highly customizable, or are they primarily high-volume, low-variety products? Cellular manufacturing processes might be well-suited for custom or varied components, such as unique interior pieces and specialized electronics. Conversely, continuous flow manufacturing works best for high-volume standardized parts (e.g., battery cells), that require high-volume output with minimal customization.

Sample Use Case: Use Flexible Manufacturing to Enter Low-Volume, High-Value Production Markets

In growing and emerging markets, SMMs often need to integrate low-volume product mix into production to manage fluctuating demand and mitigate overcapacity risk (i.e., avoiding stranded assets if demand or volume drops). Flexible manufacturing systems combined with SMED improvements enables quick changeovers, allowing SMMs to efficiently handle both low and high-volume production with minimal downtime. This flexibility helps SMMs seize new market opportunities without overinvesting, but instead gradually diversifying their product offerings.

Sample Use Case: Use Value Stream Mapping to Identify Market Transition Opportunities

Fabrication Co., an SMM specializing in metal sheet and pipe fabrication for mufflers, used value stream mapping to pinpoint necessary machinery upgrades and production methods to incorporate into their existing process to enable them to manufacture heat shields. By creating detailed process maps and identifying improvement areas, Fabrication Co. was able to prioritize critical upgrades, enabling a swift transition to new heat shield products.

4.C.iii. Developing an implementation roadmap

After identifying improvement areas, create an actionable roadmap to implement changes. Consider the following steps as you develop your roadmap:

- Set operational goals and priorities:
  - What are your organization's primary goals (e.g., based on your Value Stream Mapping analysis)?
  - Which improvement areas will yield the highest return on investment or bridge the gap between your current operations and new market/product?

- Establish measurable objectives:
  - Are the targets achievable and quantifiable? For example, can setup times be reduced by 15% or a specific waste category be eliminated?
- Pilot small-scale improvements:
  - Where can you run small-scale tests to gauge improvement impacts?
  - Which areas would benefit from early feedback and refinement?
- Monitor and adjust:
  - What metrics will track progress effectively?
  - How often will reviews occur to ensure adjustments align with evolving production needs?

By selecting the right operational model and process improvements, SMMs can streamline production with minimal waste, achieve flexibility to meet new market demands, and position for sustainable, long-term growth.

4.D. Other considerations

While financing, workforce readiness, and process improvement came up in case studies and expert interviews as the three most important initial considerations for a significant business strategy decision, other pieces of advice provided include:

- **Listen to your partners, and manage their expectations carefully.** Don't move too quickly ahead of your customers, at risk of creating stranded assets. At the same time, don't let your partners move you more quickly than you feel comfortable moving (as Voltage Co reflects on in the callout).
- **Confirm with your (new) customers that you'll be able to enter new market(s),** with special attention to the leading incumbents and any policy or legal considerations.

Voltage Co emphasizes their discipline in responding to customers' requests for innovation:

"We try to do whatever we can to say yes to customers. But you can spend millions and millions of dollars to do that. In order to make the right product for them, we have to decide that it's the right product for us to make while staying in business."

- **Assess whether new performance standards, certifications, or other requirements will be needed to sell in the new area**. For instance, SMMs seeking to manufacture battery packs and related components are required to meet Federal Motor Vehicle Safety Standards (FMVSS) No. 305.[36] As newer clean energy manufacturing industries mature, there may be other FMVS and ISO standards that become common practice and expectations.

Conclusion:
There Are Free and Low-Cost Resources to Help You

Product conversion or expansion decisions are complex, highly individual, and often require significant time and effort. This document is intended to guide SMMs through an initial set of strategic discussions, but next steps from here may require additional weeks or months, as well as additional business strategy support.

Luckily, many resources and organizations exist to support this continued process, many at no cost to SMMs. There are many organizations with automotive industry experts available for short-term market studies and overarching business strategy support. Moreover, low- and no-cost technical assistance can be found at various agencies and state economic development offices (see Appendices C and F), covering general manufacturer assistance, targeted assistance for businesses facing acute market shocks or other barriers, and manufacturer workforce training.

36 Notice of Proposed Rulemaking: Electric-Powered Vehicles: Electrolyte Spillage and Electrical Shock Protection | NHTSA

APPENDIX

Appendix A: Approaching the Opportunity

This section provides a potential way to approach the desired business strategy, for consideration by SMMs. Given the variation in opportunities and SMM capabilities, the information should be used as a guide that each SMM can tailor to align with their current situation and goals.

The phases below provide illustrative actions and anticipated outcomes for SMMs to consider when pursuing an opportunity. Additional actions, estimated timeframes, considerations/risks, are provided in the sections below.

Process

Phase	Illustrative Actions	Projected Outcomes
 Discover	1. Assess current product outlook (Tailwind, Steady, Headwind) 2. Conduct market research and engage customers (e.g., Tier 1 and 2 suppliers) to identify and prioritize opportunities[37, 38] 3. Collaborate with customers on design/bid on opportunities 4. Plan for necessary resources[39] 5. Complete preliminary budget, funding, and financing plan[40] 6. Secure funding	• Archetype and opportunities defined (Response to market) • Potential customers/OEMs and vendors • Financial and funding plan • Funding approval documents (company backing and external sources (e.g., loans))
 Design	1. Review customer/OEM specification and quality standards 2. Design the manufacturing process (align on volume/capability) 3. Review and update prioritization (if needed) 4. Begin customer/OEM and/or vendor contracting efforts	• Customer/OEM specification and quality documents • Process design documents • Prioritization report (Updated) • Customer/OEM and/or vendor contracts
 Pre-production	1. Procure equipment (e.g., through vendors) and engage customers/OEMs 2. Prepare the facility + complete workforce planning 3. Execute a pilot (if required) 4. Provide sample materials or components to customers/ OEMs to complete quality assurance testing (Production Part Approval Process (PPAP) if industry remains automotive) 5. Improve process and production plans (if needed) 6. Finalize customer/OEM and/or vendor contracts	• Production equipment and components/ materials • Hired staff (if needed) • Training programs • Prototypes for testing/validation • Quality assurance documents • Prioritized improvement opportunities • Customer/OEM and/or vendor contracts
 Production	1. Ramp-up production 2. Execute early warning quality system 3. Track supply chain to ensure timely material delivery 4. Conduct continuous improvement activities (if needed)	• Maximum production rate figures • Timely product defect detection • Distribution details document (if needed) • Refined training programs or contracts (through refinancing) (if needed)
 Post-production	1. Complete project assessment 2. Socialize findings 3. Complete sustainability analysis 4. Ramp-down contracts/perform end of life inventory management (if needed) 5. Conduct training + monitor performance (ongoing)	• After action report[41] • Executive Report(s) – Can summarize After Action Report + sustainability analysis findings (if needed)

For the actions listed above, this table provides more detailed, illustrative activities throughout the approach phases. Specific activities pursued can be considered based on which archetype, product, and market shift that an SMM makes.

37 Refer to sections 3.A.i and 3.A.ii to help identify potential new customers and opportunities in the xEV space.
38 Refer to sections 3.B.i and 3.B.iii for information to help prioritize opportunities identified.
39 Refer to section 4.B for steps to consider when preparing the workforce for a business transition.
40 Refer to section 3.B.ii for considerations when thinking about resourcing cost/investment needs. Refer to section 4.A for an overview of financial strategies used, questions to consider when thinking about the financial strategy most applicable, and resources that can support financing efforts.
41 An after-action report can include the following elements: Project outcomes, successes, challenges, and areas for improvement which can become lessons learned if a similar opportunity is pursued in the future.

Phase	Actions	Activities
Discover	1. Assess current product outlook (tailwind, steady, headwind)	• Choose the product diversification (Archetype) best suited for the opportunity
	2. Conduct market research and engage customers (e.g., Tier 1 and 2 suppliers) to identify and prioritize opportunities[42,43]	• Identify products aligned to opportunity of interest • Obtain bill of materials (BOMs) for these products and identify which component(s) align closely with existing production processes • Conduct outreach to businesses within the market to understand the demand for the components, target customers, and potential competitors • Identify a list of customers/OEM and/or vendors to collaborate with going forward • Assess the feasibility of producing the new component(s) (e.g., includes risk assessment). Feasibility should also consider whether to develop the product internally or acquire a business with the necessary capabilities (make or buy)
	3. Collaborate with customers on design/bid on opportunities	• Identify bids of interest • Consider activities to strengthen bid award chances/competitiveness: Research bidding best practices and strengthen relationships with applicable suppliers • Bid on opportunities to produce the component(s)
	4. Complete resource planning[44]	• Determine the resources required (e.g., raw materials, machinery, labor)
	5. Complete preliminary budget, funding, and financing plan[45]	• Identify potential sources of funding (e.g., loans, investors, grants) • Prepare financial projections to understand future profitability potential
	6. Secure funding	• Set aside funds available to support future development • Apply for and secure necessary financing like loans. Includes confirming customers/OEMs and/or vendors that will support future development
Design	1. Review customer/ OEM specification and quality standards	• Engage customers/OEMs to obtain component specification and quality documents
	2. Design the manufacturing process (i.e., align volume with capability)	• Collaborate with customers/OEMs to: • Design manufacturing processes for the component • Identify any upgrades/improvements needed to existing processes or equipment
	3. Review and update prioritization (if needed)	• Incorporate insights from design efforts into overall prioritization efforts. Update the opportunity's overall prioritization where needed. Suspend efforts if needed.
	4. Begin customer/OEM and/or vendor contracting efforts	• Begin negotiation, selection, and contract development with new customers/OEMs and/or vendors

42 Refer to sections 3.A.i and 3.A.ii for information to help identify potential new customers and opportunities in the xEV space.
43 Refer to sections 3.B.i and 3.B.iii for information to help prioritize opportunities identified.
44 Refer to section 4.B for steps to consider when preparing the workforce for a business transition.
45 Refer to section 3.B.ii for considerations when thinking about resourcing cost/investment needs. Refer to section 4.A for an overview of financial strategies used, questions to consider when thinking about the financial strategy most applicable, and resources that can support financing efforts.

Pre-production	1. a. Procure equipment (through vendors)	• Review machinery or equipment compatibility with existing systems • Procure any new machinery or equipment for pilot execution from vendors
	b. Engage customers/OEMs	• Engage with customers/OEMs for raw materials and components • Negotiate contracts and ensure quality standards
	2. a. Prepare the facility	• Modify or expand facilities to accommodate new production lines • Ensure compliance with safety and regulatory standards
	b. Complete workforce planning	• Hire and train additional staff if necessary • Develop training programs for existing employees on new processes
	3. Execute the pilot	• Create prototypes, can be in batches, to test new processes and equipment • Identify and resolve any issues or bottlenecks
	4. Provide sample materials or components to customers/ OEMs to complete quality assurance testing (PPAP) if industry remains automotive)	• Collaborate with customers/OEMs to conduct rigorous testing to ensure the component meets intended specifications and quality standards. If not possible, suspend development efforts.
	5. Improve process and production plans (if needed)	• Collaborate with costumers/OEMs where needed to ensure quality standards (include refining component specifications, processes, or equipment). This should result in prioritized improvement opportunities
	6. Finalize customer/OEM and/ or vendor contracts	• Complete contract development with customers/OEMs and/or vendors that will enable production
Production	1. Ramp-up production	• Collaborate with customers/OEMs where needed to: • Increase production volume in line with market demand • Monitor performance and efficiency during the ramp-up
	2. Execute early warning quality system	• Monitor and analyze quality data in real time to detect and address early defects • Conduct root cause analysis for defects and implement corrective actions • Collaborate with suppliers to ensure material quality and maintain feedback loops for continuous improvement
	3. Track supply chain to ensure timely material delivery	• Coordinate with companies in the component production supply chain to ensure timely material delivery
	4. Conduct continuous improvement activities (if needed)	• Collaborate with customers/OEMs where needed to: • Implement continuous improvement practices to optimize production • Review and refine manufacturing processes regularly • Work to refinance contracts based on how the overall business risk changes
Post-production	1. Complete project assessment	• Collaborate with customers/OEMs where needed to: • Conduct a thorough review of the project to assess outcomes • Identify successes, challenges, and areas for improvement
	2. Socialize findings	• Prepare detailed reports for staff and customers/OEMs on the project's performance, insights, and areas for improvement to inform future projects
	3. Complete sustainability analysis	• Ensure that the new component's production is sustainable long-term • Monitor resource usage and environmental impact
	4. Ramp-down contracts/ perform end of life inventory management (if needed)	• Complete all paperwork and processes to close contracts with customers/ OEMs and/or vendors are no longer needed
	5. a. Conduct training (ongoing)	• Continue training programs to keep staff updated on best practices
	b. Monitor performance (ongoing)	• Track key performance indicators (KPIs) for the new component regularly • Adjust strategies to maintain optimal production levels

Appendix B: Job Quality Self-Assessment Questionnaire

These questions are based on the Good Jobs Principles, and can be used in concert alongside other job quality assessment tools such as the Baldridge Job Quality Toolkit.

1. **Pay:** Do you pay at or above the average prevailing wage for your area? Do you pay above-median wages for all your firm's job classifications in your region? If not, why not? What parts of your business model limit your ability to pay above-median wages, and can those factors be addressed as part of a product conversion process?
2. **Skills and Career Advancement:** Career advancement is especially important to today's younger workers: in a recent manufacturing workforce survey, roughly two-thirds of workers under the age of 25 reported that training and career pathway opportunities were motivating factors to remain at their current employer, exceeding the overall respondent average by nearly 25 percentage points.

   How many years do your workers stay in a particular role, on average? Do you frequently promote from within your firm? What opportunities are available for production line workers to increase their skills and move into new roles? Do you offer on-the-job training, such as through apprenticeship and apprenticeship readiness programs? Do your workers report that they feel they have advancement opportunities at your firm? Of particular importance: what new skillsets will new potential production lines require, and do you have current workers who would want to learn these skills and advance accordingly?
3. **Benefits:** Healthcare coverage, paid vacation, and paid sick leave are increasingly standard fare for manufacturing roles at all levels (both hourly and salaried workers). Workers also want childcare support, disability insurance, and retirement security, and they can increasingly get these benefits in industries that compete with lower-skill manufacturing roles, such as in warehousing and retail sectors. Do you offer both hourly and salaried workers benefits that are competitive with manufacturing peers and other industries? What benefits do your workers note as most important for their well-being and job satisfaction? What opportunities are there to partner with community organizations or service providers who can help augment your offerings and connect workers to helpful resources?
4. **Organizational Culture:** Do workers feel like they are respected and safe at work? Do they feel like the firm takes care of them and cares about their well-being? Do they respect their direct supervisors? Can they raise safety or job quality concerns without fear of harassment or termination? What structures for voice and feedback do workers have?
5. **Job Security and Working Conditions:** Predictable job schedules, long-term employment, and safe and healthy working environments are critical for worker retention and performance. What percentage of your workforce are permanent employees, rather than temporary or contractor hires? Do your workers know their schedules an appropriate amount of time in advance? Are workers generally taking on the number of work hours they want? Are you quick to share your health and safety records with potential employees?
6. **Empowerment and Representation:** Union representation can help SMMs to attract and retain workers. For example, the 2023 US Energy & Employment Jobs Report indicate union employers were nearly 20 percentage points less likely (29% vs. 48%) to indicate that it was 'very difficult' to find workers for open positions. Furthermore, recent research provides evidence that job satisfaction, worker productivity, and retention are higher for firms in which a higher rate of workers are represented by unions or covered by collective bargaining / project labor agreements (Doucouliagos et al, 2020). Has your workforce sought to organize? How has your firm's management reacted?
7. **Recruitment and Hiring:** Hiring in today's manufacturing labor market requires creativity, and new recruitment and workforce partnerships can help. Does your HR department feel empowered to try new things when it comes to recruiting? Do you hire for demonstrable skills, rather than unnecessary educational or credential requirements? Do you have relationships with your local universities, community colleges, trade schools, and workforce development boards? What more would you need from these partners in order to hire more of their program graduates?
8. **Diversity, Equity, Inclusion, and Accessibility (DEIA):** Do all your workers feel equally respected and protected at work? Are there discrepancies in your retention and advancement rates across groups? Do you have policies in place that allow diverse workers to thrive in your workplace, including for individuals with disabilities, justice-involved individuals, and women? This is often fundamental to expanding your recruitment pool, increasing overall retention, and filling skill gaps.

Appendix C: Federal Manufacturer Assistance and Workforce Development Programs

Agency	Program Name	Focus Areas and Eligibility	Description
General Manufacturer Assistance Programs			
Department of Energy	Industrial Training and Assessment Centers (ITAC)	SMM Energy Efficiency; Product Conversions (Pilot); Workforce Training	ITACs provide no-cost assessments to help SMMs identify opportunities to improve energy performance, productivity, smart manufacturing improvements, workforce development, recruitment and training. They are also a source of rigorously-trained clean energy and manufacturing students and workers. The ITAC network recently announced three centers (at Purdue University, University of Michigan, and the University of Illinois) that will focus specifically on helping automotive suppliers apply the concepts in this report.
Department of Commerce	Manufacturing Extension Partnership (MEP) Centers	SMM Business Strategy; Manufacturing Innovation; Process Improvement; Lean Manufacturing; Supply Chain; Talent Recruitment; Workforce Training	Every state has at least one MEP Center. Overseen by the Department of Commerce, MEP centers are federal and private industry collaborations that help SMMs with a variety of services. Assistance may include business growth ideas and strategy, recruiting or reskilling employees, implementing lean manufacturing techniques, pivoting production lines to new industries, adopting technology to help improve productivity and finding suppliers and other services. These centers provide hands-on and low-cost assistance to SMMs but do not provide grants or loans. Learn more about the MEP workforce programs in particular here.
Small Business Administration	Small Business Technical Assistance Programs	Small Business Support; Business Strategy; Financing; Product Strategy; Operations	Small Business Technical Assistance Programs from the Small Business Administration provide localized training and resources to small businesses. Companies can receive tailored business advisory services and technical assistance to help promote small business growth and expansion, access to capital, feasibility analysis, marketing, management improvement, financial management and increased productivity and innovation. https://www.sba.gov/local-assistance/resource-partners
Targeted Manufacturer Business Strategy Support			
Department of Commerce	Minority Business Development Agency's Advanced Manufacturing Centers	Diverse-Owned Business Support; Manufacturing Innovation; Process Improvement	The Advanced Manufacturing Centers offer targeted, industry-focused assistance to minority manufacturers that aim to employ new technologies to increase the number of "Made in America" products for sale. Centers provide low-cost services (typically linked to revenue) and are open to all minority businesses but with a particular focus on those with revenues exceeding $500,000.

Department of Labor	Rapid Response Solutions and Layoff Aversion Technical Assistance	Business Strategy; Distressed Business Support	The Department of Labor oversees rapid response solutions for businesses that can provide customized, on-site services at your company to (1) help growing companies access the resources they need to continue to be successful and (2) respond to announcements of layoffs and plant closings by quickly coordinating services and providing immediate aid to companies and their affected workers.
Manufacturing Workforce Development			
Department of Labor	Registered Apprenticeships and Registered Apprenticeship Intermediaries for manufacturing	Workforce Development; Training Program Design; Apprenticeships	Department of Labor-funded organizations that help stand-up skilled trades apprenticeship programs for SMMs. The Department of Labor manages the Registered Apprenticeship program—a structured way for companies to support career development for their employees. With a Registered Apprenticeship program at their company, workers know in advance the blend of classroom instruction and on-the-job training they need to complete to enter designated jobs or receive promotions. The federal Office of Apprenticeship, and apprenticeship offices across the country, are available to help companies evaluate if Registered Apprenticeship is right for them. Field staff can also provide technical assistance in setting up an apprenticeship.
Department of Labor	State/Local Workforce Development Boards and American Job Centers	Workforce Development; Recruitment and Hiring; Incumbent Worker Training	The Department of Labor oversees a network of 2,400 American Job Centers across the country, which provide a full range of assistance to job seekers. American Job Centers are operated by local Workforce Development Boards, which direct government funding to workforce development programs in your community. • For workers, the centers offer training referrals, career counseling, job listings, and similar employment-related services. • For businesses, the centers provide an array of screening and referral tools, including electronic job postings and fairs, use of private interview space, background checks and customized screening, and regular referrals of qualified candidates. Many businesses work with American Job Centers to find diverse candidates. Although most public workforce training opportunities are for unemployed / underemployed individuals, many states and local areas also support incumbent worker training as a critical facet of their regional economic development strategy. DOL has granted states flexibility in decisions about training dollars for incumbent workers. Different states have made different decisions about whether they will support such training, which high-growth industries are eligible, and yearly limits. To learn more about programs in your state and whether your company may qualify, visit your local American Job Center, talk to the local Workforce Development Board, or visit your state workforce agency.

Department of Labor	Partnership amongst Manufacturing Extension Partnerships, Manufacturing USA Institutes, and Public Workforce System	Workforce Development; Recruitment and Hiring; Incumbent Worker Training	This guidance document talks about the benefits of collaboration between the public workforce system, the manufacturing extension partnership (MEP) Program and the Manufacturing USA Network of Institutes. The purpose of this Training and Employment Notice is to encourage workforce system collaboration and strategic partnership with the U.S. Department of Commerce's Manufacturing Extension Partnership program and the Manufacturing USA network of institutes to provide assistance and support to manufacturing firms, particularly small and medium-sized manufacturers, to prepare a skilled workforce to support economic growth while preserving and creating jobs. This document provides examples of what these partnerships can look like.
Department of Labor	Sector Strategy Framework	Job Quality; Workforce Development	A central repository focused on developing a sector framework for a community or region within manufacturing. Sector strategies are a critical model for addressing workforce and talent development needs at a regional scale, while advancing career opportunities in good jobs and promoting economic mobility for workers, job seekers, and learners. Sector strategies represent an industry-driven, community-supported, and worker/learner-focused approach—a proven model that engages industry with workforce partners to address workforce development needs effectively.
Department of Labor	GoodJobs.Gov	Job Quality; Workforce Development	A central repository for job quality, equity, and worker empowerment resources produced by DOL and the Good Jobs Initiative. This website also hosts the Departments of Commerce and Labor's shared Good Jobs Principles, which outline the essential elements of a quality job (see Appendix B).
Department of Labor	High-Road to the Middle Class program	Job Quality; Workforce Development	The High Road to the Middle-Class program has a map of training programs "that implement demand-driven workforce strategies advancing job quality, equity, and worker voice—that can train America's infrastructure, clean energy, and manufacturing workforce."
National Science Foundation	Advanced Technological Education (ATE) Program	Workforce Development; Technician Training	Supports partnerships between two-year institutions of higher education, other academic institutions, industry and other entities to improve the education of technicians in science and engineering
Department of Energy	Battery Workforce Challenge	Batteries; Energy Storage	This program consists of BattChallenge, BattForce, BattSTEM and BattAcademy. BattChallenge is a 3-year collegiate program that has launched. BattForce will address reskilling / upskilling vocational and transitional workers. BattSTEM is youth and HS education activities and BattAcademy will be cloud based to deliver training.
Department of Energy	Battery Workforce Initiative	Batteries; Energy Storage	A Department of Energy-led, Department of Labor-supported initiative that provides National Guideline Standards for new Registered Apprenticeships for battery machine operators.

Appendix D: Federal Capital Programs

Many of these programs and others are included in the White House's 2023 Resource Guide for Auto Suppliers and 2024 Climate Capital Guidebook, which provides a compilation of U.S. Government resources for startups and small businesses supporting the transition to a renewable energy future.

Agency	Program Name	Project or Deal Size	Program Description and Eligibility	Point of Contact
U.S. Department of Agriculture	Business & Industry Loan Guarantees	Loans up to $25 million per borrower; interest rates are negotiated between the lender and borrower and rates may be fixed or variable	Projects must be in rural areas of less than 50,000 residents. Eligible uses include business conversion, enlargement, repair, modernization, or development. Eligible borrowers include for-profit or non-profit businesses, cooperatives, and individuals engaged or proposing to engage in a business.)	Your local Rural Development office
U.S. Department of Agriculture	Rural Energy for America Program	USDA-guaranteed loans up to 75% of total eligible project costs and a maximum of $25M; renewable energy system grants for up to 50% of total eligible project costs up to $1M; energy efficiency grants of up to 50% of total eligible project costs up to a maximum of $500,000. Loan terms are available up to 40 years with rates negotiated between the lender and borrower.	Eligible entities include small businesses located in eligible rural areas of less than 50,000 residents that meet Small Business Administration size standards. Eligible projects include the purchase and installation of renewable energy systems, such as biomass, geothermal for electric generation or direct use, hydropower below 30 megawatts, hydrogen, small and large wind or solar generation, ocean generation; the purchase, installation, and construction of energy efficiency improvements.	Your USDA State Coordinator
Small Business Administration	Small Business Investment Company	Varies but generally between $1M to $10M of equity investments or loans; interest rates are capped by the Small Business Administration and vary by fund	A Small Business Investment Company is a privately owned investment company that leverages funds raised by private investors with Small Business Administration-guaranteed debt to provide det and equity financing to small businesses. Eligible projects vary by fund but could include: advancing companies from prototype to production; using follow-on equity investment and private debt to scale technologies for broader commercial applications; and integrating innovative technology developments into established businesses to secure supply chains. Of special note: Leveraging the Small Business Investment Company program, Monroe Capital intends to launch its "Drive Forward" Fund to provide lower cost capital for small- and medium-sized auto manufactures to refinance, grow, and diversify their businesses; as of November 2024, the fund has not yet launched but will appear in the Small Business Investment Company directory once live	Consult the SBIC directory

Small Business Administration	504 Loan Program	Up to $5M generally; or up to $5.5M per loan for certain energy or manufacturing projects; interest rates are pegged to an increment above the market rate for 10-year U.S. Treasury issues	Long-term, fixed-rate loans issued by Small Business Administration-qualified lenders to small businesses to support capital expenditures for fixed assets, such as real estate or equipment. Maturity is generally 20 or 25 years for real estate; 10 years for machinery and equipment; and 10, 20, or 25 years based upon a weighted average of the useful life of the assets being financed. Small businesses are those with a tangible net worth of less than $15M; average net income of less than $5M after federal income taxes for the two years preceding the application; and/or fall within SBA size standards. 504 loans require a personal guaranty for owners with at least 20% ownership stake and have some limitations when combining with other federal programs.	504Questions @sba.gov Find your Certified Development Company here
Small Business Administration	7a Loan Program	Up to $5M for lenders to guarantee loans; lenders and borrowers negotiate the interest rate but it cannot exceed the SBA maximum of a base rate plus 3.0% for loans of greater than $350,000	Small Business Administration-guaranteed loans for purposes such as acquiring, refinancing or improving real estate; short- and long-term working capital; refinancing current business debt; purchasing and installing equipment; purchasing furniture and supplies; changing of ownership; multiple purpose loans. Terms of 10 years or less unless the useful life of the project exceeds that window, in which case up to 25 years. Small businesses are those with a tangible net worth of less than $15M; average net income of less than $5M after federal income taxes for the two years preceding the application; and/or fall within SBA size standards.	SBA District Offices can provide in-person or virtual assistance; SBA Resource Partners can also help small businesses
Export-Import Bank of the United States	Make More in America Initiative	No maximum; generally, loans of $10 million to $80 million; interest rates depend on the risk of the project and duration of the loan and are negotiated between the borrower and lender; on top of the interest rate, EXIM charges a risk-adjusted premium, ranging from 0.9–3.15%	Direct loans and loan guarantees to finance capital investments that will facilitate exports and create jobs (includes renewable energy, energy efficiency, energy storage, and critical minerals as priority areas). Projects include metals production and battery manufacturing as well as plant construction and expansion. Financed projects must have an export nexus of 15% for small businesses, transformational export areas, and climate-related transactions. For reasonable assurance of repayment, the Export-Import Bank generally requires a minimum three-year revenue-producing history and proven debt service capacity. Loans cannot exceed 40% of the tangible net worth of the borrower.	Domestic. Finance @exim.gov
Export-Import Bank of the United States	Working Capital	No maximum; generally, loans of more than $1 million	Loan guarantees to support the working capital needs of U.S. exporters and suppliers of exporters (includes renewable energy, energy efficiency, energy storage, and critical minerals as priority areas) Point of Contact: Request a free consultation here; a list of delegated authority lenders can be found here	

Department of Energy	Domestic Manufacturing Conversion Grants—For Small and Medium Manufacturers	Award size varies depending on state programs—recommended amounts $250,000 to $2M	Grant awards to the states of Michigan, Ohio, Indiana, Tennessee, Kentucky and Illinois to aid small- and medium-sized manufacturers with ICE-to-EV retooling; as of October 2024, states are currently developing plans to implement their programs	State governments in each eligible state
Department of Energy	Advanced Technology Vehicle Manufacturing Loan Program	No statutory minimum or maximum; usually $100M or more for up to 80% of project costs; interest rates are set at U.S. Treasury rates of comparable maturity for the term of the loan with no credit spread	Direct loans to support the manufacture of eligible advanced technology vehicles and qualifying components. Eligible projects must manufacture eligible advanced technology vehicles or components; build new facilities, equip/modernize/expand existing facilities, or engineer integration related to the manufacturing of eligible vehicles or components; have a reasonable prospect of repayment; and demonstrate that the applicant has sufficient funds to carry out the project.	Atvmloan@hq.doe.gov for a no-fee, no-commitment consultation
Department of Energy	ITAC Implementation Grant	Grant awards are up to $300,000 per manufacturer (covering one or multiple projects), at a 50% cost share. Other federal funds cannot count toward the applicant's share.	Grants to help SMMs implement recommendations made by ITAC or Onsite Energy Technical Assistance Partnership assessments, or equivalent assessments qualified by DOE. Eligible entities are small and medium-sized manufacturers with fewer than 500 employees and less than $100M in annual revenue.	info@ energywerx.org
Department of Defense	Office of Strategic Capital—Loan and Loan Guarantee Program for Critical & Emerging Technologies	Structured, long-term direct loans of $10–150 million. Senior secured on financed assets.	Designed to support domestic manufacturing in 31 specific technology areas critical to national security, including advanced manufacturing, battery storage, edge computing, hydrogen generation and storage, sensor hardware (including microelectronics), and more. The interest rate is based on the U.S. Treasury comparable to the loan maturity, plus a risk premium. The program can offer sculpted repayment schedules to match borrowers' anticipated revenues and expenses, to include longer tenors, which allow for capitalization of equipment cost and associated expenses over the useful life of the financed assets. The loans can be combined with private equity, corporate debt, grants, and other funding sources. The deadline for Phase 1 applications is February 3, 2025. Contact: OSC.Loan.Application@osc.mil	

Appendix E: Industry Credential and Certification Programs

Organization	Technology/ Industry	Description
ToolingU	Various	ToolingU is a workforce division of the SME (Smart Manufacturing Experience) non-profit industry association. They offer programs in machining, welding, smart manufacturing, stamping, assembly and others. Both on-line and instructor led programs are available with certifications from SME, Amazon Web Services (AWS), Manufacturing Skill Standards Council (MSSC), National Institute for Metalworking Skills (NIMS), and Smart Automation Certification Alliance (SACA).
National Coalition of Certification Centers	Various	This website lists company sponsored certifications across a wide array of industries, including manufacturing, with welding, health and safety, and digital literacy as separate categories.
Credential Engine	Various	Credential Engine is a non-profit dedicated to bringing a central repository for credentialing programs across a variety of industries. The database is searchable by keyword and by location.
Smart Automation Certification Alliance	Smart Manufacturing; Automation; Industry 4.0	This non-profit has a mission to develop and deploy certifications in modular industry 4.0. Certificates are categorized by Associate, Specialist and Professional.
Advanced Robotics for Manufacturing (ARM) Institute	Robotics	This website and database has overviews of robotics careers, links to open roles and links to training programs. The site is sponsored by Advanced Robotics for Manufacturing (ARM), a Manufacturing USA Institute. There are 16,000 robotics training programs incorporated, many of which are endorsed by ARM and member organizations. Programs go from microcredentials up to degree programs. Programs are searchable by location and skills (e.g., at the time of writing, there are 8 aggregated programs in Ohio with a total of 178 skills).
CyMANII	Cybersecurity	CyMANII is the Manufacturing USA Institute for cybersecurity. The San Antonio-based hub supports manufacturers by providing hands-on training in secure smart manufacturing. CyMANII's four workforce training elements are a learning library, hybrid learning, a mobile training vehicle, and the C4M hub.
ReMADE	Circular Economy	ReMADE has 80+ hours of circular economy training available online and on demand, including short courses, certificates and webinars. Training is available for members of ReMADE as well as non-members. Categories include design for Re-X, manufacturing materials optimization, recycling & recovery and metals.
International Ground Source and Heat Pump Association	Heat Pumps	The International Ground Source and Heat Pump Association trains installers, designers and inspectors of geothermal systems.
ASHRAE Professional Development Trainings	Energy Management; HVAC	The American Society of Heating, Refrigeration and Air-Conditioning Engineers (ASHRAE) has on-line and instructor led courses in topic areas relevant to heating and cooling. This resource is aimed at recent engineer graduates and technicians who want to know more about the systems they are working on.
Hydraulic Institute	Heat Pumps; Manufacturing Systems	The Hydraulic Institute has fee-based training opportunities as well as free tools, such as DOE sponsored MEASUR.

Appendix F: State-Specific Programs

This Appendix provides a list of programs in states with a high concentration of automotive manufacturing. This list may not be exhaustive, and only covers a subset of states. We encourage SMMs to connect with their state programs to identify state and local resources and programs available to them. Your state-specific Manufacturing Extension Partnership (MEP) may be the best place to start for help navigating various state resources and programs.

State	Programs
Michigan	• The state's Education & Training website links to a wide variety of educational and workforce development programs available throughout the state, including Michigan Training Connect (MiTC), which provides state approved training for individuals with an Individual Training Account. • The state's Industry & Business website outlines the *Sector Strategies Employer-Led Collaborative Initiative* (SLC), which identifies industry-focused employment and training programs for agriculture, construction, energy, manufacturing, IT, and others. Emphasis is placed on recruitment, training and retention, as well as identifying critical occupations or emerging occupations, determining potential skills and training gaps among the workforce, plus assessing and re-designing training or K–12 curricula to address occupational skill requirements. • Another service available to Michigan businesses is Going PRO Talent Fund, which provides funds via the Michigan Works! Network (MWAs). The fund covers employers' costs to define training needs and develop an appropriate training plan. The locations of MWAs can be found here. • The Michigan Manufacturing Technology Center has a series of classes to support industry in Michigan, particularly small- and medium-sized enterprises. Training includes Cybersecurity, Industry 4.0, Lean Principles, Quality Management, Six Sigma and Supply Chain. • The EV Jobs Academy is rolling out training programs for the xEV industry in Michigan. Michigan received $237 million through the State Small Business Credit Initiative (SSBCI). The Michigan Strategic Fund and the Michigan Economic Development Corporation run five credit support programs and one venture capital/equity program. Businesses can locate participating lenders and investors using the U.S. Treasury Lender map. Michigan SSBCI also offers small business technical assistance services through a network of nine local service providers, and the state was awarded a Small Business Opportunity Program (SBOP) grant to establish the Auto Supplier Transition Fund, which will provide $9 million to small automotive manufacturers and suppliers in Michigan access to capital and services to participate in EV and other expanding supply chains. • The Office of Apprenticeship in Michigan provides technical support to program sponsors, answers questions about the apprenticeship model, along with a range of other services to businesses.
Indiana	• Indiana's Department of Workforce Development has multiple programs for job seekers including certifications and grants for tuition free programs. Certificates in Advanced Manufacturing range from CNC machinist to welder to production technician. Each year, Indiana selects industries to promote and publishes certifications aligned with the promoted industries. For 2024, the selected industries include electronics technicians, variable frequency drives, hydraulic maintenance, and structural sheet metal assembly. • Indiana Career Explorer has search function for job seekers/workers to search skills training programs with 1,000+ manufacturing training programs in Indiana. • Purdue University MEP operates manufacturing training bootcamp programs. for current or future manufacturing workers • Indiana received $99 million through the State Small Business Credit Initiative (SSBCI). The Indiana Economic Development Corporation (IEDC) is managing one credit support program, and Elevate Ventures is managing an equity program. Indiana SSBCI offers small business technical assistance services through the IEDC and a network of partners. Businesses can locate participating lenders and investors using the U.S. Treasury Lender map. • Tecumseh Area Partnership, Inc. d/b/a Region 4 Workforce Board. This initiative will develop and implement a newly formed Regional Electric Vehicle Manufacturing Partnership (REV) and provide training for individuals to access good paying jobs in the renewable energy sector focused on Electric Vehicles and Electric Vehicle Battery production. • The Office of Apprenticeship in Indiana provides technical support to program sponsors, answers questions about the apprenticeship model, along with a range of other services to businesses.

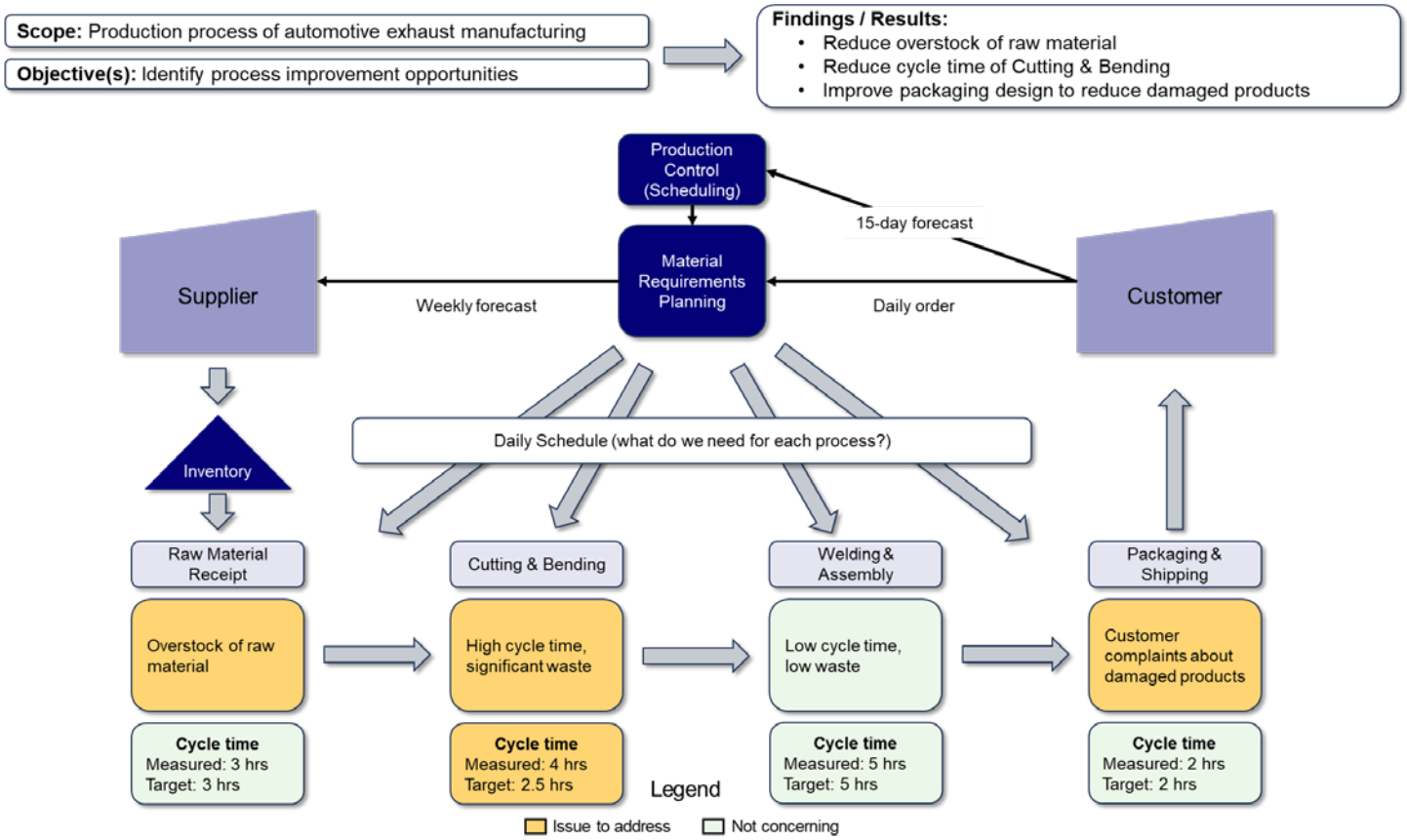
Kentucky	• The Kentucky Federation for Advanced Manufacturing Education (KYFAME) is an industry led partnership that includes manufacturers, educational and workforce institutions, and the state's cabinet for Economic Development to create a pipeline of skilled workers in the automotive space. • Kentucky's Community and Technical College System (KCTCS) offers a variety of manufacturing-specific academic programs including manufacturing electrical technology, engineering and electronics technology, and advanced manufacturing technician. The state boasts nearly 45K fabricators, 10K skilled electricians, and 5K machinists, to support its large automotive manufacturing footprint. • Kentucky received $117 million through the State Small Business Credit Initiative. The Kentucky Economic Development Finance Authority (KEDFA) manages two credit support programs, and the Kentucky Science and Technology Corporation and Keyhorse Capital manage two equity programs. Businesses can locate participating lenders and investors using the U.S. Treasury Lender map. • The State Apprenticeship Agency in Kentucky provides technical support to program sponsors, answers questions about the apprenticeship model, along with a range of other services to businesses.
Illinois	• Illinois' Environmental Protection Agency office has a dedicated program, "Electrify Illinois," that focuses on accelerating xEV deployment across the state. The program offers comprehensive incentives and a series of trainings and degree programs across the electric space. • The Illinois Technology and Manufacturing Association (TMA) offers trainings resources to fill in workforce knowledge gaps for small- and medium-sized manufacturers. • Illinois received $354 million through the State Small Business Credit Initiative (SSBCI). The Illinois Department of Commerce and Economic Opportunity (DCEO) is the administrator of the Advantage Illinois Loan Participation and Loan Guarantee Programs and INVENT venture capital program. DCEO and the Illinois Finance Authority (IFA) administer the Climate Bank Finance Participation Loan Program. Illinois SSBCI offers small business technical assistance services through DCEO and a network of partners. Businesses can locate participating lenders and investors using the U.S. Treasury Lender map. • The Office of Apprenticeship in Illinois provides technical support to program sponsors, answers questions about the apprenticeship model, along with a range of other services to businesses.
Ohio	• The Ohio Department of Development has workforce training programs and grants to support both industry and employment seekers. • The Ohio Department of Job and Family Services (ODJFS) is implementing the Charged Up project to replicate and scale regional career pathways in northeast Ohio to meet industry demand for a skilled electric vehicle manufacturing sector. ODJFS will partner with the Manufacturing Advocacy and Growth Network, the Mahoning Valley Manufacturers Coalition, and a network of education and training providers to prepare individuals to work in battery production facilities. • The list of 899 individual certificates available under TechCred ranges from abrasive fine finishing to fluid power systems to certified composites technician. • Ohio received $182 million through the State Small Business Credit Initiative (SSBCI). The Ohio Department of Development is the managing entity of two credit support programs and two equity programs. Ohio SSBCI offers small business technical assistance services through Ohio Development and their Minority Business Development Division. Businesses can locate participating lenders and investors using the U.S. Treasury Lender map. • The State Apprenticeship Agency in Ohio provides technical support to program sponsors, answers questions about the apprenticeship model, along with a range of other services to businesses.

Tennessee	• The University of Tennessee offers an Automotive Supply Chain Workforce Readiness Program that provides classroom education and hands-on training to upskill existing and train next generation of automotive workers in the state. • The Tennessee American Manufacturing Communities Collaborative has established a program to provide workforce development and training, research and innovation, & supplier network assistance for the 900+ automotive manufacturers across the state. • Tennessee received $116 million through the State Small Business Credit Initiative (SSBCI). The Tennessee Department of Economic & Community Development (TNECD) administers a credit support program, and the Tennessee Technology Development Corporation (LaunchTN) manages three venture capital programs. Tennessee SSBCI offers small business technical assistance services through the Tennessee Small Business Development Center at Middle Tennessee State University. Businesses can locate participating lenders and investors using the U.S. Treasury Lender map. • The State Apprenticeship Agency in Tennessee provides technical support to program sponsors, answers questions about the apprenticeship model, along with a range of other services to businesses.

Appendix G: Value Stream Mapping

Value stream mapping (VSM) is a lean-management method used to analyze and design the flow of materials and information required to deliver a product or service. By visualizing the entire process, from raw materials to delivery, suppliers can identify inefficiencies, bottlenecks, and waste, and develop strategies for improvement. VSM is often used in partnership with continuous improvement initiatives. To create a value stream map (see example) manufacturers generally follow a five-step process:

1. **Define the Scope and Objectives.** Clearly define the process or value stream to map (e.g., product line, service). Establish specific objectives like reducing lead time, improving quality, or identifying general process improvements (see example).
2. **Map the Current State.** List all process steps, including value-added and non-value-added activities. Then, gather data for each step, such as cycle time, lead time, and bottlenecks. Finally, visualize the data to create the value stream map
3. **Analyze the Current State.** Identify waste types (overproduction, waiting, transport, extra processing, inventory, motion, defects) by reviewing the VSM. Determine bottlenecks and areas for improvement.
4. **Design the Future State:** Create goals for a desired future state, including a desired future VSM. Outline what improvements will allow you to transition from the current to future state, including required resources and expected timelines.
5. **Implement and Monitor:** Work with your teams to implement changes from the future state map, measure impact, and adjust to sustain improvements

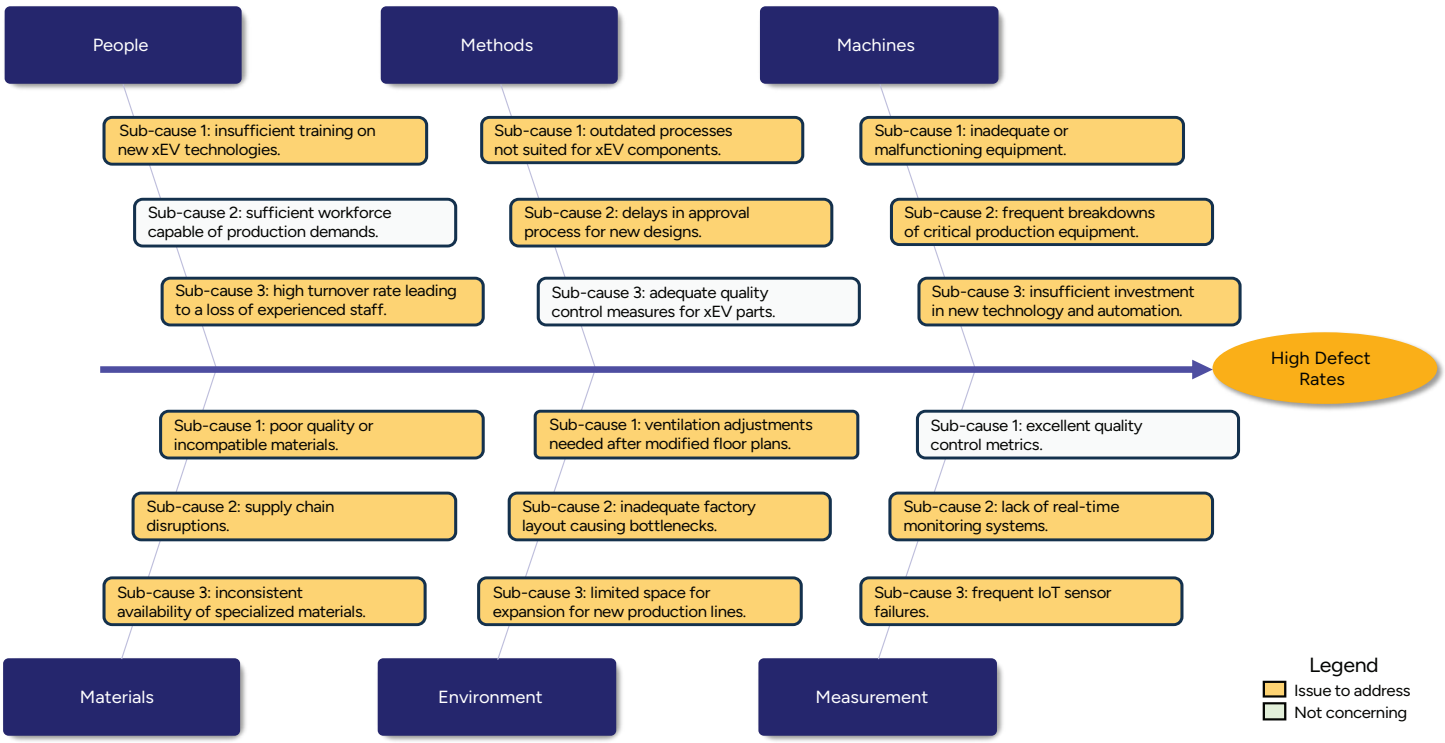


Appendix H: Fishbone Diagram

Also known as Ishikawa diagrams or cause-and-effect diagrams, fishbone diagrams are used to systematically identify and analyze the root causes of specific problems or inefficiencies within a given manufacturing process. By mapping out all possible causes of delays, bottlenecks, or waste, SMMs can develop targeted strategies to address the most critical concerns, streamline operations, and enhance productivity. Fishbone diagrams are often use in conjunction with continuous improvement initiatives (i.e., Kaizen).

The following provides instructions for creating a fishbone diagram (see example below):

1. **Define the problem** you are trying to address. This becomes the "head" of the fish.
2. **Identify major categories** of potential causes. Common categories in manufacturing include, but are not limited to:
    a. People (workforce skills, training, performance management)
    b. Methods (processes, procedures, workflows)
    c. Machines (equipment, tools, technology)
    d. Materials (raw materials, components, supplies)
    e. Environment (physical conditions, workspace, external factors)
    f. Measurement (data collection, metrics, analysis)
3. For each major category, **brainstorm potential causes** of the problem. These become the "bones of the fish."
4. A**nalyze** the potential causes to identify the most likely root causes. Prioritize these for further investigation and action.
5. **Develop** action plans to address the identified root causes, **implement** the solutions, and monitor their effectiveness.



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