2. The Auto Industry Transformation: Dimensions of Change

In the past 30 years, the motor vehicle has undergone a remarkable evolution. The personal passenger vehicle is now the most high-tech purchase most households will ever make: today's cars contain more computer chips and lines of software code than the first vehicles launched into space.

These days, the pace of vehicle technology change is accelerating, particularly in response to changes in consumer taste and expectations, higher safety standards, and the drive toward a low-carbon future embodied in more aggressive government fuel economy standards and more stringent greenhouse gas emissions rules. When considering changes in automotive technology that support the "greening" of automotive transportation, most people think first about advanced powertrains—including hybrids, plug-in hybrids, battery electrics, advanced internal combustion engines and advanced diesels—and secondly about alternative fuels, including renewables such as biofuels, solar and hydrogen.

Changes in materials and forming aimed at producing lighter weight and safer vehicles also contribute to a greener vehicle fleet requiring less fuel to propel. Increasing electronics, software and controls, and technology content enables many fuel-saving technologies as well, including navigation assistance to reduce idle time and traffic congestion and the many sensors, actuators and controls that are used to optimize vehicle performance for fuel economy. This section will review the advances in motor vehicle technology, provide possible timelines for implementation of the technologies, and examine the implications for the workforce needed to research, develop, engineer and manufacture these products.

While specific skill[4] sets are in demand in each of the three technology areas covered in this chapter, vehicle producers and suppliers across the board have told us they want more out of their engineering workforce than technical skill and competency. The industry needs engineering and technical employees who can consider the interaction of vehicle systems and can work to optimize solutions more broadly.

This need for systems thinking, as well as the truly global nature of this industry, means that individuals who work in research, development and engineering must also possess the "soft skills" that enable cross-cultural communication, collaboration and teamwork. On the hourly side, production and skilled trades workers must adapt to an increasingly fast cadence of new product, process and technology introductions. These workers, too, must possess communication and teamwork skills that enable problem solving and continuous improvement in process and quality systems.

2.1 Powertrain and Fuels

Perhaps the most noteworthy change occurring within the automotive industry is the reemergence of the electric vehicle (EV). The development of alternative forms of energy storage (primarily batteries) is rapidly progressing, but the internal combustion engine (ICE) may remain the dominant technology for the next decade and beyond. Significant technological innovations are necessary for the cost of electric vehicles to fall dramatically. Absent these innovations, the business case for EVs remains challenging. In addition, the ICE is a moving target. Respondents to a recent Center for Automotive Research (CAR) survey agreed that, even at $2.50 per gallon, half of gasoline

[4] This report uses the term "skill" in several different and significant ways. Skills or skill sets can refer to a broad range of requirements for an occupation, from interpersonal competencies to hours of experience in an apprenticeship to advanced academic training. In this sense, the term "skills" is something of shorthand for all occupational requirements. Skill can also be used in a stricter sense as the capacity to do a particular activity, e.g., the capacity to un-jam the photocopier, irrespective of whether one is support staff or company CEO. A skill set can describe a collection of capacities that are similar and related to a particular job. An occupation may require several skill sets, in addition to educational attainment or experience, to be performed well. Unless otherwise stated, skills or skill set refers to the broad understanding of the requirements for an occupation.

engines sold in 2015 may be at least 20 percent more efficient than similar 2009 engines.[5] Automakers are constantly finding ways to improve the overall efficiency of traditional engines, further lowering the cost and economy targets that electric vehicles must reach to be viable in the marketplace.

Table 1: Projected U.S. Market Share of Alternative and Advanced Powertrain Types, 2011 and 2015

	$2.50/gallon		$6.00/gallon	
	2011	**2015**	**2011**	**2015**
All Gasoline (Includes Hybrid Electric and Plug-In Hybrid Electric Vehicles)	96.5%	93.8%	95.0%	89.0%
Dedicated Gasoline	91.5%	83.8%	89.0%	69.0%
Hybrid Electric Vehicle	5.0%	10.0%	6.0%	20.0%
Diesel	3.0%	5.0%	4.0%	7.5%
Battery Electric Vehicle	0.1%	1.0%	0.5%	2.5%

Source: CAR/*Specialty Equipment Market Association* (SEMA)

Gauging future powertrain market volumes is exceptionally challenging. CAR recently surveyed 17 powertrain experts from vehicle manufacturers, powertrain suppliers and powertrain engineering services firms. Most of the respondents had engineering backgrounds and were selected based on their wide range of expertise in both technical and market factors. **Table 1** summarizes their forecast for 2011 and 2015 at two gasoline price options—$2.50 per gallon and $6.00 per gallon for the years 2011 and 2015. For the brief duration of this forecast, the internal combustion engine will remain the dominant power source.

As with other vehicle systems, government policy has had an important role in powertrain development. Policy has played, and will continue to play, an important role in setting targets for powertrain technology development. Through the establishment of future corporate average fuel economy (CAFE) standards and other actions, there are numerous avenues by which policy can impact powertrain development. Policy mandates will drive the pace of continued technological development in the powertrain arena, but it is the shape and form of innovations that have the most potential to initiate drastic changes in the skill set required of workers. The technology path is uncertain, and vehicle manufacturers and suppliers are developing multiple technology solutions, requiring a wide range of technical skills.

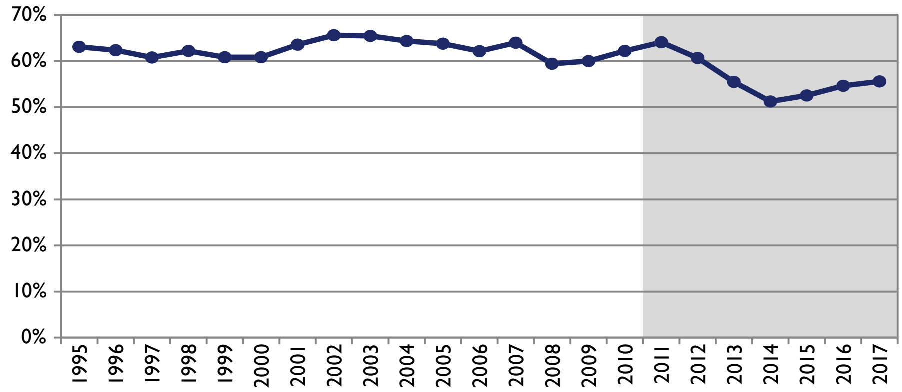
A number of unique skill sets are emerging as essential to the continued development of powertrain technology and the future of the industry. These skills include increased emphasis on chemical, electronic, software and coatings expertise, but the most critical skills cited were those of systems engineers that relate to the increased connectedness and integration of the various vehicle systems. Many engineering positions will require integration of more than one discipline in the future (e.g., engineers with mechanical expertise will require some knowledge of electronic systems that will interact and possibly control the mechanical systems in a vehicle). There will be few automotive engineering positions requiring mastery of only one discipline. It is clear that educators will need to turn out engineers that are cross-trained system thinkers, regardless of their specific core discipline.

While changes in powertrain development are resulting in substantial changes in the requisite skills and competencies of engineers, those same changes are having a lesser impact on the skill requirements for production workers. The powertrain itself may become more green or complex, but the manufacturing of these advanced powertrains will not change significantly. In most powertrain production facilities, working on advanced technologies requires only a few hours more training than would be needed for any new product introduction. However, since modern vehicle manufacturing plants increasingly utilize lean manufacturing concepts and team organization, production workers need the critical thinking and communication skills formerly

[5] Brett C. Smith, Zachery Adams and Jennifer Wong, *Powertrain Forecast and Analysis: What is Coming and What Are the Implications for the Specialty Equipment and Performance Aftermarket Industry* (Ann Arbor: The Center for the Automotive Transportation, August 2009); Brett C. Smith and Chris Powers, *Automotive Powertrain Forecast, U.S. Market 2011 and 2016* (Ann Arbor: The Center for Automotive Research, 2007).

associated with at least some postsecondary education. For hourly workers, technologies, processes and jobs will continually evolve; workers will need to keep learning and adapt their skills to meet these new challenges. Educators at all levels must deliver lifelong learners: problem solvers who are able to communicate effectively.

Figure 1: Michigan, Indiana and Ohio Engine Production as a Percent of Total U.S. Engine Production, 1995-2010 and 2011-2017 Forecast



Source: IHS Global Insight, Inc.

As powertrain technologies advance, the locations of powertrain production and the requisite employment in these plants may shift. The tri-state region of Indiana, Michigan and Ohio represented 62.2 percent of total U.S. traditional engine production in 2010 (see **Figure 1**). It is possible that new vehicle propulsion systems will be produced outside the region and/or that advanced technologies may require fewer workers to produce the same number of propulsion systems. In either event, a large-scale displacement of traditional engine production by alternative technologies puts the tri-state region's powertrain employment at risk.

2.2 Materials and Forming

The need to make vehicles lighter with the intent of improving vehicle fuel economy is the primary driver of development and changes in the realm of automotive materials. This process, often referred to as vehicle lightweighting or mass reduction, has been advancing for a number of years. Recent improvements in vehicle lightweighting have primarily been achieved through use of advanced grades of steel, the dominant material in the modern automobile. The development of new alloys with increased strength-to-weight ratios, combined with the relatively low cost of steel, has contributed to its prevalence. With the prolonged entrenchment of steel as an automotive material, an expansive infrastructure dedicated to steel production, supply, forming and joining has been built up over the years. Coupled with the development of a vast workforce knowledge base, economies of scale have developed further contributing to the dominance of steel in the automotive industry. While there are many situations where steel is the preferred material in terms of cost and performance, aluminum, magnesium and composites can be cost competitive and technologically superior in other instances. Vehicle lightweighting focuses on finding the optimal combination of materials to achieve the desired vehicle weight reductions.

Although the introduction of new materials may at first appear to be a minor alteration, developing a thorough understanding of material interactions and material performance under extreme conditions is no small task for any automaker. Currently, the adoption of new materials is impeded by risks of performance issues and the lack of a complete body of knowledge necessary to produce reliable simulation models to predict potential problems. Given the need for durability, safety and sustained performance, changes in vehicle materials require thorough research, development and testing.

In addition to the need to develop complete knowledge of a given material, automakers face additional challenges before large-scale utilization of a new material can take place. The processes to form and join new materials may require development to reach the cycle times required to assemble high-volume vehicles, as well as capital investment in new tooling and manufacturing equipment. The ability to develop a regionalized supply base plays a major role in the adoption of new materials for vehicle lightweighting.

In order to establish regionalized supply, an adequate local knowledge base must exist, along with general stability in the supplier sector. For example, Japan is currently the hub of carbon fiber production and technology across the world. In Washington, a long history with the aerospace industry has supported development of both a knowledge foundation and a supply base that could be leveraged for the expanded use of carbon fiber within the automotive industry. Additionally, China is currently the largest supplier of magnesium in the world. Given China's extensive domestic needs, supply chain risks exist due to potential export restrictions that may be imposed. This potential disruption in the supply base limits the adoption of this metal in the automotive industry. **Table 2** shows the projected change in vehicle content of various lightweight materials. These new materials will be added at the expense of mild strength steels, although advanced and ultra-high-strength steels will continue to comprise a large portion of motor vehicles.

Despite the challenges facing the widespread adoption of various materials for vehicle lightweighting, the push to increase vehicle fuel economy without compromising vehicle size continues to increase. Optimizing material use for minimal vehicle weight means automakers and suppliers need engineers with expertise in finite element analysis (FEA), materials science and metallurgy. The challenge of balancing competing objectives such as cost, manufacturability and performance will require systems engineering and systems thinking to arrive at the optimal combination of materials. In addition, a compartmentalized approach to vehicle design and manufacturing will not be possible, requiring management and corporate structures that enable a more systems-oriented approach to new vehicle development.

Unfortunately, the U.S. workforce lags in the fundamentals of material science and metallurgy. While there are only a few domestic metallurgy programs focused on lightweight materials, Europe and Asia have a much more extensive background in these fields.

Table 2: Increase in Material Content from 2009 to 2020

Material	Change in Vehicle Content by 2020 (lbs. increase)
Advanced and Ultra-High-Strength Steel	350
Aluminum	31 to 70
Magnesium	10 (130 to 350 possible)*
Plastics and Composites	25

* N. Lutsey, "Review of Technical Literature and Trends Related to Automobile Mass-Reduction Technology," Institute of Transportation Studies, University of California, Davis, Research Report UCD-ITS-RR-10-10, 2010.

Source: R. Schultz, et al., "Metallic Material Trends for North American Light Vehicles," 2009.

Advances in vehicle lightweighting will require very little additional training for production workers that is over and above standard new product training. Industry expectations are that production workers are willing to continue to acquire new skills, and that they have the ability to participate in problem solving, continuous improvement and other team-based endeavors. While there is an increasing need for employees with a background in advanced lightweight materials, it will not necessarily result in a net increase in employment. Many employees will be able to shift their skills from traditional materials to advanced lightweight materials through continuous learning. The tri-state region of Indiana, Michigan and Ohio is equipped to shift toward manufacturing research and development and computer-aided engineering of advanced lightweight materials. However, the tri-state region may lose out in metallurgy and basic chemistry jobs that have a stronger base in Europe and Asia.

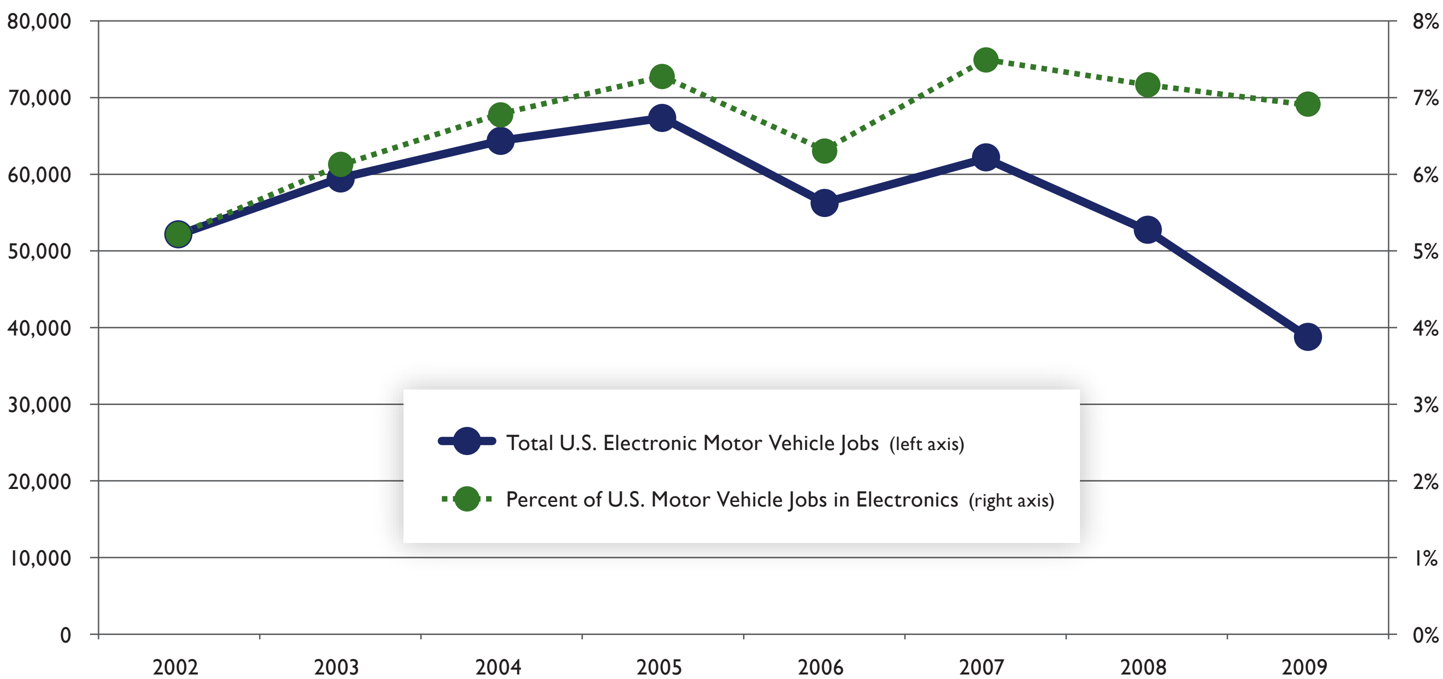
2.3 Electronics, Software and Controls

The amount of electronic content in vehicles has increased at a rapid rate since the 1970s, and this trend is expected to continue. Presently, electronics account for about 25 percent of a vehicle's value; that figure is expected to climb to 40 percent or more in the next five to 10 years. This growth in electronics content has also had an effect on employment to date. As shown in **Figure 2**, even though total U.S. employment in motor vehicle electronics has declined since 2005, U.S. motor vehicle electronics employment as a percentage of total U.S. motor vehicle employment has shown a net upward trend since 2002.

Electronics are a part of nearly every major vehicle system, including those that are mechanical in nature; electronic content is particularly critical for sensors and actuators, powertrain and transmission controls (especially as electric drive systems become more prevalent), vehicle safety systems, infotainment systems and vehicle communications, as well as the overall vehicle electrical architecture. Through power electronics, smart sensors, electronic control units (ECUs) and other components, vehicle electronics contribute significantly to a vehicle's improved fuel economy and reduced emissions. In addition, emerging electronic systems, such as those associated with connected vehicle systems (vehicle-to-vehicle and/or vehicle-to-infrastructure wireless communication), enable drivers to navigate more efficiently and avoid traffic congestion. They also take advantage of enhanced situational awareness to provide drivers with feedback on how to optimize green driving or directly control operation of the powertrain to achieve a similar outcome. All these developments can contribute significantly to the improved environmental performance of motor vehicle transportation.

Electronic content is increasing in response to the technical demands of increasingly complex vehicle systems, as well as consumer demand for a more personalized driving experience and the ability to access information and entertainment options instantaneously. The integration of electronic systems will be required to support more on-board applications, and the vehicle's electronic architecture must be consolidated due to increasing electronic content and faster data transmission. Because ECUs are expensive, vehicle manufacturers will integrate them across functional systems and incorporate more powerful, dual-core processors into the vehicle's electronic architecture. The industry will face increasing demands for ensuring the cyber-physical security of the vehicle. Needs will increase for electronic system validation and certification, as well as analysis of interactions between systems.

Figure 2: U.S. Motor Vehicle Electronics Employment, 2002-2009



Source: Bureau of Labor Statistics

To support growth in vehicle electronics, software and controls, the industry will demand more electrical and electronic engineers, as well as those with expertise in radio frequency technology, computer science, software engineering and cyber security.

Components such as the CAN bus (and FlexRay) will facilitate this interaction and communication between vehicle systems.[6] The "head unit" of a vehicle, which houses the radio, music, temperature controls, navigation and other systems, will be increasingly significant as more technological functionality is added (e.g., the ability to interface with third-party consumer electronics, such as smart phones). The vehicle aftermarket will play an important role in making communications available on existing vehicles and expanding the range and capability of electronic technologies available to consumers.

To support growth in vehicle electronics, software and controls, the industry will demand more electrical and electronic engineers, as well as those with expertise in radio frequency technology, computer science, software engineering and cyber security. As electronic technologies become more integrated, employers will also require candidates trained in a systems approach to the integration of these electronics throughout the vehicle. The workforce will need to understand the whole system, not just individual, autonomous pieces of the system. Although increased demand for employees with these skills may require a major transformation of automotive industry skill sets, the end result may not be a net increase in motor vehicle employment. The tri-state region of Indiana, Michigan and Ohio is poised to benefit from the research and development, design, engineering and systems integration side of the business, but will face stiff competition from other regions of the global automotive industry that are stronger in electronics manufacturing (particularly producers in Europe and Asia).

Driven by the opportunity to create a more environmentally friendly product, the automotive industry is undergoing a far-reaching change. While the pace and completeness of the change is uncertain, it is clear the change will impact job skill requirements. It is also apparent the tri-state region has an opportunity to take advantage of this changing vehicle landscape. Whether it can reap the benefits of the change in many ways depends upon creating a well-trained and effective green workforce. This report has identified technologies, skills and the associated opportunities to help the region's workforce trainers proactively prepare.

[6] CAN bus stands for Controller Area Network. This network consists of multiple micro-controllers that communicate with each other to direct electronic actions within the vehicle. The "bus" refers to the wire or cable platform through which the micro-controllers transfer information. FlexRay is a newer and more robust version of CAN.