MAY 2017
IP: I7-05-B

REPORT

SUPPLYING INGENUITY II:
U.S. SUPPLIERS OF KEY CLEAN, FUEL-EFFICIENT VEHICLE TECHNOLOGIES

Authors' note:

The first edition of "Supplying Ingenuity: U.S. Suppliers of Key Clean, Fuel-Efficient Vehicle Technologies" was published in 2011, just as a new generation of light-duty vehicle fuel economy and GHG standards were being implemented and standards for 2017–2025 were under debate. The report found hundreds of automotive suppliers already investing in and manufacturing new technology in anticipation of an extended trajectory of fuel economy improvement. The near collapse of the automotive industry and its supply chain was still a recent memory, and plants that faced closure were getting new investment to build advanced engines and components and more-efficient cars and trucks.

Today, with those Phase I standards for model years 2012–2017 fully and successfully implemented, Phase II standards underway, and the final years of the standards (2022–25) under debate, some of the same authors and researchers have come together to publish "Supplying Ingenuity II" and to again take stock of advanced vehicle component and technology manufacturing in America. The progress to date—for American vehicles, American manufacturing, and American jobs, as well as for the environment, energy security, and consumer savings—has been significant, but there is still more to be done.

–May 2017

Front page photo of Chevrolet Bolt EV used with permission from General Motors. Photo of pickup truck courtesy of BlueGreen Alliance.

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Executive Summary

Over the past decade, the U.S. automotive industry has demonstrated that we can bring back American jobs and manufacturing and enhance industry competitiveness and profitability. American workers are building world-leading, popular vehicles that save consumers billions at the pump, enhance energy security, and cut pollution.

Commonsense clean car and fuel economy standards, coupled with actions to rebuild U.S. manufacturing, have been integral to this success. Standards have spurred added investment in American innovation and manufacturing. Today's domestic supply chain has grown increasingly innovative and robust and manufactures globally competitive vehicles. As a result, the industry has brought back more jobs and better-secured jobs for the future.

Strong long-term standards have been critical and remain essential to continued automotive recovery, to ongoing innovation and job growth, and to a further strengthening of the manufacturing sector as a whole.

This report investigates the real companies and jobs in this sector today. Our research finds more than 1,200 U.S. factories and engineering facilities in 48 states—and 288,000 American workers—building technologies that reduce pollution and improve fuel economy for today's innovative vehicles, from family sedans to long-haul tractor trailers.

Nine states (Michigan, Indiana, Ohio, Tennessee, Kentucky, California, Alabama, North Carolina, and South Carolina) each count 10,000 or more manufacturing and engineering jobs building fuel-efficient technologies, and half of U.S. states count fuel-efficient technology jobs in the thousands. Building clean vehicle technology is a local issue for at least 335 congressional representatives and 96 senators.

More than 1,200 U.S. factories and engineering facilities in 48 states—and 288,000 American workers—are building technology that improves fuel economy for today's innovative vehicles.

FIGURE ES I: SUPPLIERS OF FUEL-EFFICIENT VEHICLE TECHNOLOGY—MORE THAN 1,200 FACILITIES NATIONWIDE

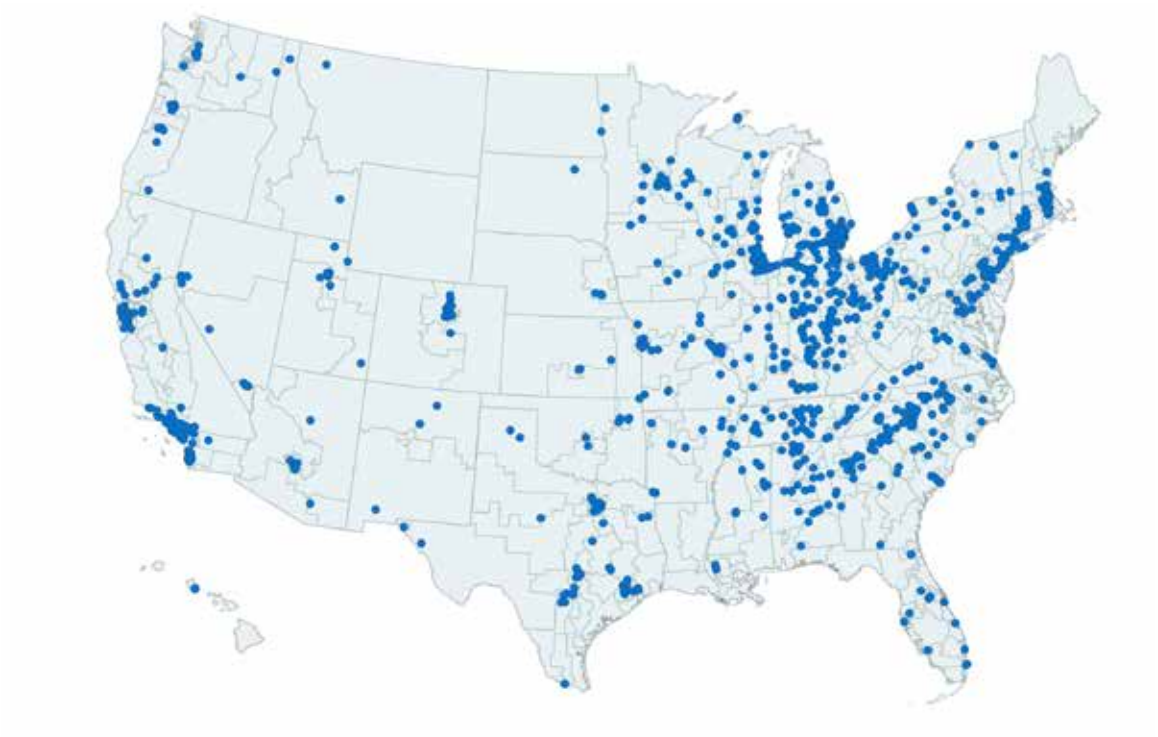
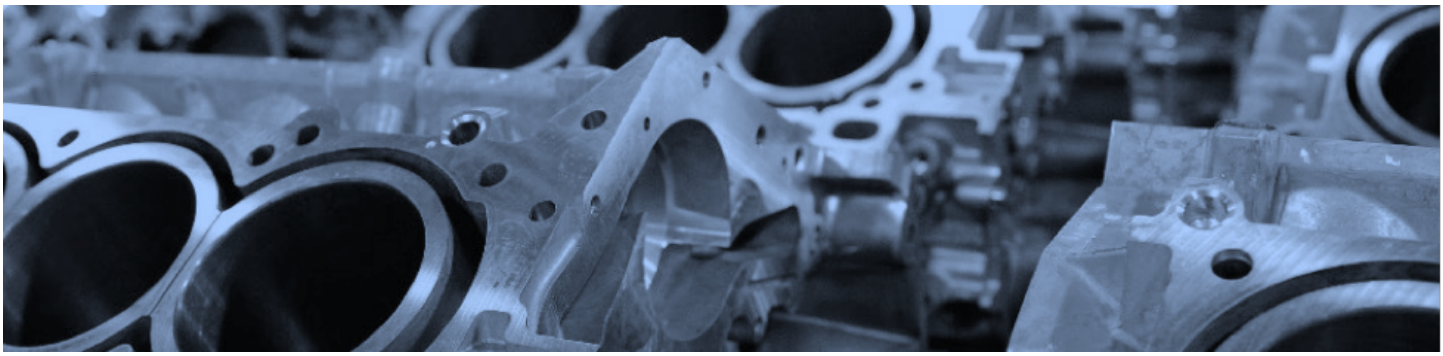


TABLE ES I: TOP 10 STATES BY EMPLOYMENT BUILDING CLEAN, FUEL-EFFICIENT VEHICLE TECHNOLOGY

State	Employment
U.S. TOTAL	**288,594**
Michigan	69,593
Indiana	32,725
Ohio	27,838
Tennessee	16,455
Kentucky	15,319
California	14,776
Alabama	13,439
North Carolina	12,355
South Carolina	11,535
Illinois	9,904

Securing today's jobs and continuing to create new ones across the industry depend on keeping up the pace of domestic innovation, investment, and manufacturing under strong, long-term standards. Today's automotive sector provides a powerful example of how we can simultaneously meet the nation's environmental, economic, and job-creation goals. For decision makers who are serious about continuing this progress, the following actions are critical:

- **Sustain robust clean vehicle and fuel economy standards.** An ongoing trajectory of improvement in GHG emissions and fuel economy supports investment, innovation, and job growth. Strong, long-term standards help position the domestic industry as a global leader and strengthen its competitiveness and economic stability. By contrast, stepping back from these standards puts jobs at risk.
- **Improve and enforce tax, trade, and manufacturing policies** to spur manufacturing in America, reward reinvestment in domestic manufacturing and the U.S. workforce, and enhance—rather than degrade—labor and environmental standards globally.
- **Strengthen labor standards, workers' rights, and regulations that protect worker safety and health on the job.** These standards are necessary to ensure that new and existing jobs in automotive technology manufacturing deliver family-supporting wages, decent benefits, and good working conditions.



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2017: Supplying Ingenuity II

Over the past decade, the U.S. automotive industry has demonstrated that we can bring back American jobs and manufacturing and enhance industry competitiveness and profitability. American workers are building world-leading, popular vehicles that save consumers billions at the pump, enhance energy security, and cut pollution.

Commonsense clean car and fuel economy standards, coupled with actions to rebuild U.S. manufacturing, have been integral to this success. They remain critical to continued automotive recovery, to strong innovation and job growth, and to continuing to strengthen the manufacturing sector as a whole.

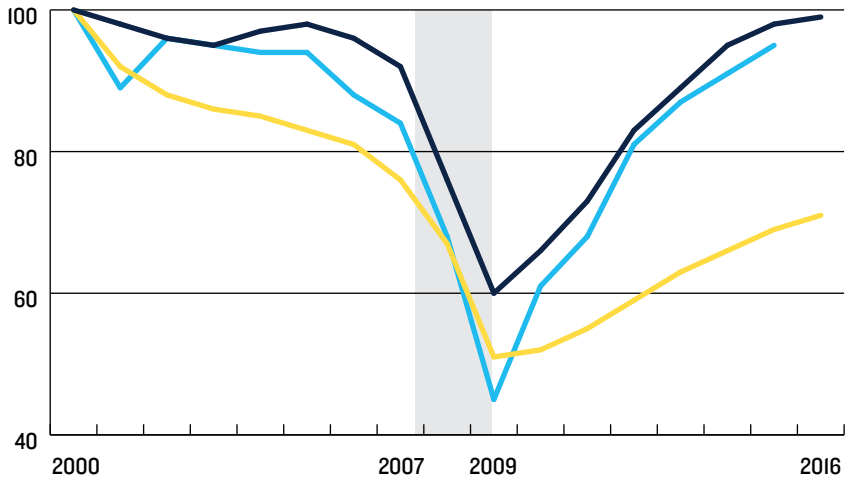
I. THE CONTEXT: ONGOING AUTOMOTIVE INNOVATION AND INVESTMENT IS DRIVING U.S. MANUFACTURING RECOVERY

A successful domestic automotive industry is critical for preserving U.S. jobs and creating new ones. Since the 2008–2009 recession, the auto industry has recovered, adding nearly 700,000 retail and manufacturing jobs, while simultaneously meeting steadily tightening emissions and fuel economy standards and capturing the market benefits of new leadership in innovation.[1]

Today the automotive industry directly employs nearly three million Americans at auto dealerships and in manufacturing. Nearly one million Americans work in motor vehicle and motor vehicle components manufacturing—the single largest segment of American manufacturing. In turn, these manufacturing jobs indirectly support millions of additional jobs throughout the economy.[2]

Since 2009, the auto sector has brought back more than 300,000 manufacturing jobs—accounting for nearly 40 percent of all net jobs added in U.S. manufacturing since the recession. To be clear, the industry hasn't yet regained the thousands of manufacturing jobs lost in the decade before the recession. But the past seven years have constituted the first period of sustained growth in automotive manufacturing jobs—and in U.S. manufacturing jobs as a whole—since 1999.[3] Job growth in the vehicles sector, as shown in Figure 1, has been a key driver of a gradual U.S. manufacturing recovery. Sustaining this trajectory will require strong ongoing commitment to investment in domestic innovation, advanced manufacturing, and a skilled workforce.

FIGURE I: A FOCUS ON BOTH DOMESTIC MANUFACTURING AND TECHNOLOGY LEADERSHIP WILL BE CRITICAL TO ONGOING JOB GAINS



US Vehicle Sales (% of year 2000)

Motor Vehicle & Parts Manufacturing Employment (% of year 2000)

US Vehicle Production (% of year 2000)

Recession: Dec 2007 - June 2009

Selected Vehicle Manufacturing States	Motor Vehicle & Parts Manufacutring Jobs Today (January 2017)	Change Since Recession Low (June 2009)
Michigan	168,300	+72,100
Indiana**	117,400	+48,300
Ohio	97,600	+32,500
Kentucky	61,100	+26,100
Alabama	39,400	+17,600
U.S. Total*	946,700	+323,400

*State data is not seasonally adjusted. US Total data is seasonally adjusted.
**Indiana total includes motor vehicle bodies and trailers.
Sources: Employment, US Bureau of Labor Statistics. Sales, Auto Alliance. Production, DOT RITA.

Standards Have a Been a Critical Part of the Automotive Recovery

Over the same period that the auto industry has brought back jobs and seen a dramatic return to profitability and record sales, the industry has also successfully implemented national fuel economy and greenhouse gas (GHG) standards across all types and sizes of vehicles—saving consumers money and transforming what Americans and the world drive.

Rapid automotive innovation under the standards has also aided in the industry recovery itself, boosting the growth of a robust automotive supply chain and enhancing job gains across the industry.

Commonsense, long-term targets have provided the certainty—and competitive level playing field—needed to invest in developing and manufacturing new clean and efficient technologies while continuing to improve performance, safety, connectivity, and other vehicle attributes important to consumers. The experience of the past decade shows that rapid innovation and new vehicle content have brought additional investment to retool and rebuild the automotive sector and added labor hours to manufacture and integrate technology into a new generation of vehicles.[4] Sound manufacturing policies, such as low-interest retooling loans, have complemented fuel-efficiency improvements to help ensure that investments to design and manufacture advanced technologies took place in America.[5]

In addition, efficient advanced vehicles perform strongly in domestic and global markets and help secure jobs at home.[6] Gas price spikes were once notorious for creating disruptive shifts in auto market preferences, production, and jobs, sending customers fleeing to more efficient and often foreign-made vehicles when prices were high. The availability of more efficient vehicles of all sizes means fewer consumer and production shifts with respect to gas price volatility, while fuel economy leadership eliminates any incentive to shift to vehicles built for markets overseas. Efficient, low-emission fleets are also compatible with tighter standards set in Europe and Asia, allowing automakers to build global vehicle platforms and significantly reduce costs.

Americans continue to want more from their vehicles while spending less at the pump, and they have consistently shown strong support for improving vehicle efficiency.[7] Under standards promulgated in 2010 (for 2012–2016) and in 2012 (for 2017–2025), automakers are on track to dramatically improve fuel economy from an average real-world figure of 22 miles per gallon (mpg) in 2011 to more than 36 mpg in 2025 (under federal rules, these real-world ratings translate to 28 mpg and 51 mpg in regulatory language, respectively).[8]

Under the new generation of smartly structured fuel economy and GHG standards that began implementation in 2011 the requirements for each manufacturer are based on the size of the individual vehicles and the mix of cars and trucks produced each model year by that manufacturer. Each size of vehicle must make gradual but steady progress although the mix of vehicles can shift. Thus, even during times of low gas prices, automakers have been able to comply with the standards even as sales of larger vehicles, such as SUVs and pickups, increase. Big fuel savings in popular vehicles—such as crossovers and pickup trucks—have translated into record-high fuel economy in vehicles of all sizes, big pollution reductions, record sales, and strong profitability.[9]

Ongoing innovation and investment in advanced, clean, and fuel-efficient vehicle technology and manufacturing across the sector have been critical to economic gains made by the industry to date and will be equally critical to sustaining this progress in years to come.

In the following sections, this report looks at the role that hundreds of thousands of American workers at thousands of American factories and engineering facilities play in building the new automotive technology that makes these gains possible.

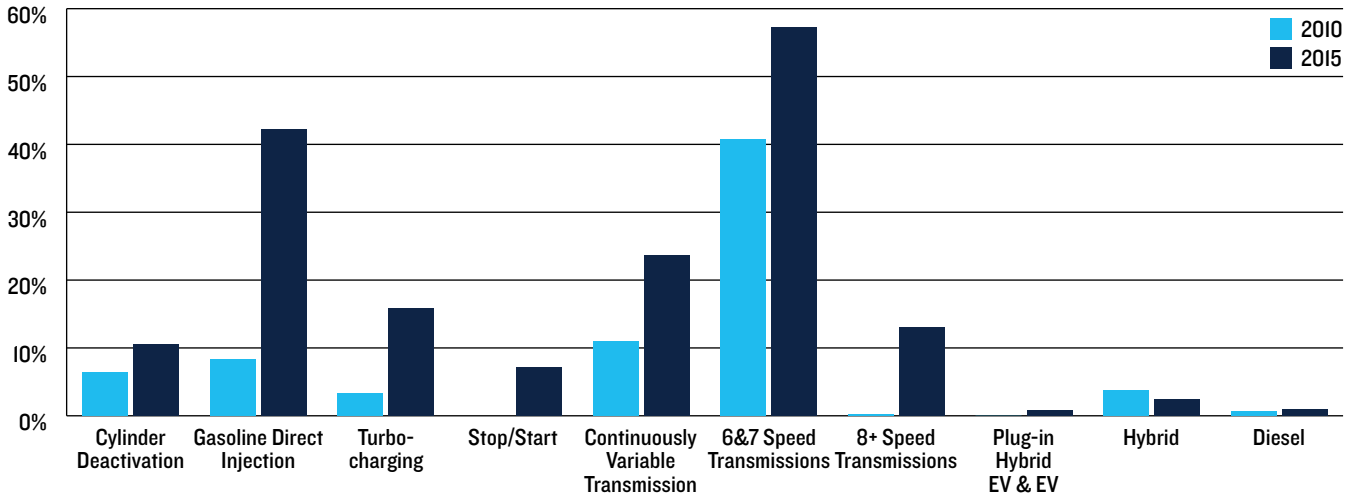
II. SUPPLIER INNOVATION IS CRITICAL TO FUEL ECONOMY AND ECONOMIC GAINS

A single vehicle typically has thousands of components built by dozens to hundreds of companies across the United States and around the globe.[10] These components determine a vehicle's performance, safety, connectivity, fuel savings, and many other features.

Since 2011, the auto industry has impressively met—and in many cases exceeded—fuel-economy and GHG standards as familiar cars, SUVs, and trucks have become significantly more efficient. Achieving these gains is a result of innovation and investment and the work of hundreds of thousands of workers at companies that make vehicle components and materials.

A variety of innovative technologies have been deployed across vehicles to cut pollution and improve fuel efficiency, as shown in Figures 2 and 3. These technologies include advanced gasoline and diesel engines and transmissions, including components like turbochargers; hybrid and electric propulsion technology; lightweight body, frame, and component materials and improved aerodynamics; efficient ancillary systems, such as electric power steering; and many more. These technologies are saving consumers billions at the pump, and they often provide additional benefits, such as improved handling, performance, comfort, and payload capacity.[11]

FIGURE 2: CLEAN AND FUEL-EFFICIENT TECHNOLOGY ADOPTION[12]



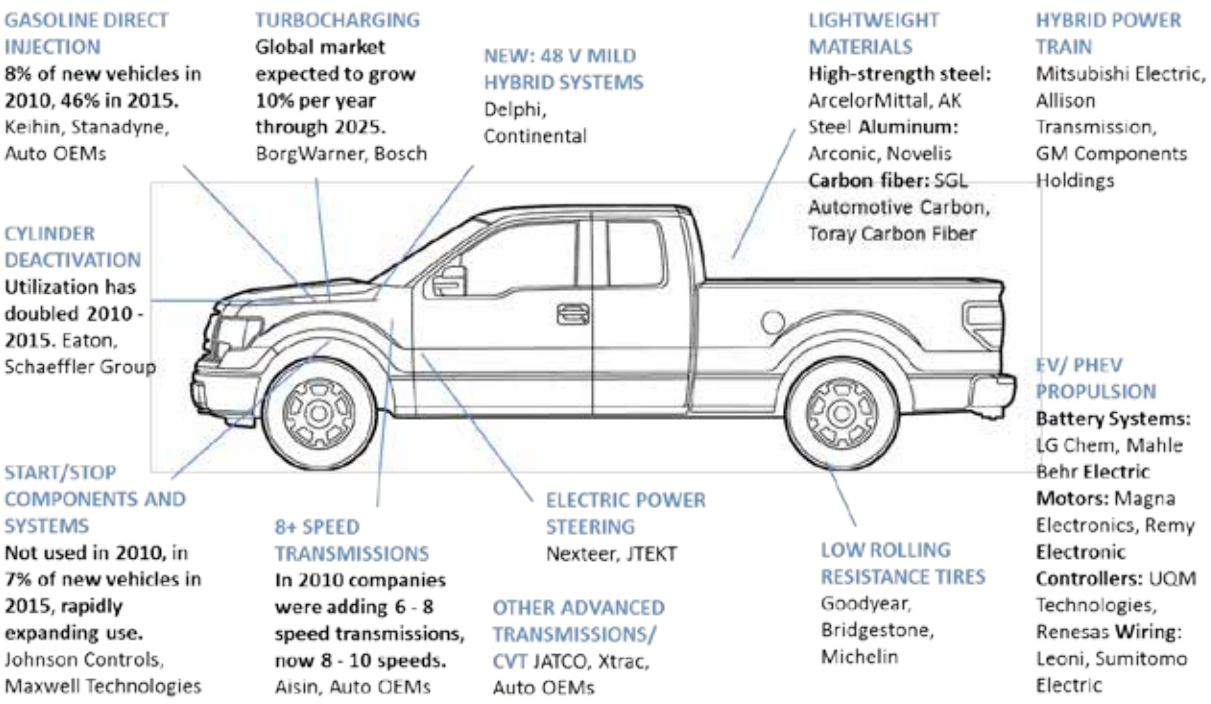
Source: US EPA Light-Duty Automotive Technology, Carbon Dioxide Emissions, and Fuel Economy Trends: 1975 Through 2016 (November 2016)

Our 2011 "Supplying Ingenuity" report found that suppliers were already manufacturing a first round of new components and technology to meet the 2012 standards.[13] Today we see many of the same companies—and new ones—building the next generation of advanced technology.

The July 2016 comprehensive technical assessment by the U.S. Environmental Protection Agency (EPA), the National Highway Traffic Safety Administration (NHTSA), and the California Air Resources Board (CARB) found that advanced conventional technologies—both those identified in 2012 and others that had not been anticipated—have been adopted more rapidly than expected at the time of the original rulemaking, and that the industry is on track to meet 2025 standards at reasonable cost.[14]

Figures 2 and 3 and the case studies throughout this report illustrate the technology changes underway and examples of companies in the U.S. supplying these advancements to automakers.

FIGURE 3: EXAMPLES OF U.S. MANUFACTURERS OF FUEL EFFICIENCY TECHNOLOGY



Note: Many additional U.S. manufacturers produce each of these technologies. Indicators of growth are drawn from agency, industry, and press reports.

It's important to note that while numerous companies are already producing fully electric or plug-in hybrid electric vehicles, the National Academy of Sciences and federal agencies estimate that the U.S. auto fleet needs only a very small percentage of electric or hybrid vehicles in order to meet the standards.[15,16] As a result, the bulk of technology innovations deployed between now and 2025 are likely to involve advancements in conventional powertrains, lightweight materials, and integration of hybrid or electric components into gasoline vehicles.

While large numbers of electric vehicles (EVs) are not required to meet federal fuel economy and greenhouse gas standards, robust development, deployment, and manufacture of EVs are an important complement to the standards, and faster-than-expected deployment of EVs could make the standards easier to meet. Currently, EV research, development, and technology deployment are aiding efforts to meet standards as technologies developed for EVs cross over into applications—such as start-stop technology and regenerative braking—that make conventional vehicles more efficient. In addition, there have been recent increases in domestic battery and electric drive component manufacturing. Continuing this progress will be important to building U.S. jobs as the industry grows globally.

Our analysis shows hundreds of thousands of Americans at work engineering and manufacturing these new technologies today in facilities all across America.

III. SUPPLYING INGENUITY: U.S. MANUFACTURING OF CLEAN AND FUEL-EFFICIENT VEHICLE TECHNOLOGY

While innovation to build the next generation of vehicles reaches into virtually every part of the auto industry in some way, our analysis looks only at those workers and facilities designing, engineering, manufacturing, and assembling the types of components and technologies specifically identified by the EPA and NHTSA as contributing to meeting efficiency, GHG reduction, and energy security goals.

Our analysis found more than 1,200 facilities in 48 states—and 288,000 American workers—making the components and materials that go directly into improving fuel economy today.

The companies analyzed in this report, whose locations are shown in blue in Figure 4, include facilities wholly focused on fuel efficient technology as well as those for whom this technology is part of a larger product line. The facilities we discuss in this report are part of an integrated automotive supply chain that includes many additional facilities nationwide building other components and parts and assembling all these technologies into the increasingly fuel-efficient cars, SUVs, and trucks in showrooms today. (More detail on the types of companies included can be found in the methodology section of this report.)

FIGURE 4: SUPPLIERS OF FUEL-EFFICIENT VEHICLE TECHNOLOGY—MORE THAN 1,200 FACILITIES NATIONWIDE

The companies analyzed here develop and produce the full range of technologies that improve fuel economy and cut GHG emissions, from lightweight automotive steel and aluminum to advanced engines and transmissions to electric motors and batteries—and many more. They range from facilities owned by major automakers and suppliers and employing thousands of people, to small, locally owned manufacturers with just a few employees. Facilities are shown by technology type in Appendix C.

Hundreds of these companies are clustered in the industrial heartlands of the Midwest and Southeast and in California and Texas, but there is notable advanced component and technology manufacturing in almost every state east of the Mississippi and in growing clusters in the North and Southwest.

What's more, innovation is taking place across all the major types of technology we reviewed in every region. For example, while Indiana has long been a leader in heavy-truck manufacturing and is host to diesel engine and heavy-duty transmission innovators, it is also home to innovation in hybrid and electric-drive technology. California is seeing growth in auto assembly; steel mills in Ohio are bringing back jobs developing and producing cutting-edge automotive materials; Texas is producing the components that make SUVs cleaner and more fuel efficient; and South Carolina is building advanced gasoline engine technology and electric buses.

Our analysis finds more than 288,000 workers employed at facilities that engineer and manufacture fuel-efficient technology. This is equivalent to around one-third of total motor vehicle manufacturing employment in the United States.

Manufacturing advanced vehicle technology is an important driver of manufacturing and job growth in many states. In Michigan and Indiana alone, clean and fuel-efficient technology manufacturing employs more than 100,000 Americans. Seven additional states each count 10,000 or more manufacturing and engineering jobs building fuel-efficient technologies, and half of U.S. states count fuel-efficient technology jobs in the thousands. Building clean vehicle technology is a local issue for at least 335 congressional representatives and 96 senators. Employmer in clean and fuel-efficient vehicle technology is shown for the top 20 states in Table 1, and for all 50 states in Appendix B.

Compared with our 2011 report, this study finds two and a half times as many facilities and almost twice as many jobs connected to clean and fuel-efficient vehicle manufacturing.[17] Looking qualitatively at the companies found in both studies, we see firms continuing to innovate and grow, reinforcing a larger industry trend in which innovation and recovery throughout the supply chain has been transformative.

TABLE I: TOP 20 STATES BY EMPLOYMENT BUILDING CLEAN, FUEL-EFFICIENT VEHICLE TECHNOLOGY

State	Employment	Number of Facilities
U.S. TOTAL	**288,594**	**1,238**
Michigan	69,593	224
Indiana	32,725	78
Ohio	27,838	80
Tennessee	16,455	40
Kentucky	15,319	32
California	14,776	175
Alabama	13,439	29
North Carolina	12,355	46
South Carolina	11,535	35
Illinois	9,904	44
Missouri	7,708	27
Pennsylvania	7,515	31
Texas	6,687	57
Wisconsin	6,318	27
New York	6,090	36
Minnesota	4,398	18
Mississippi	3,175	11
Arkansas	2,805	10
Georgia	2,359	22
West Virginia	2,321	3

FIGURE 6: FUEL EFFICIENT TECH EMPLOYMENT BY STATE: LARGEST BUBBLE REPRESENTS 70,000 WORKERS

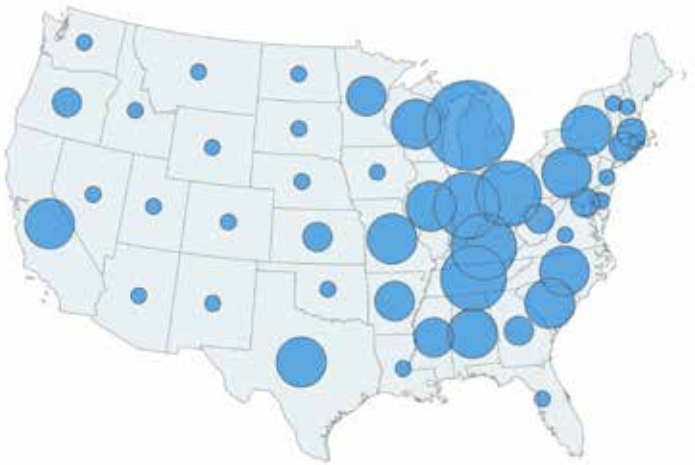
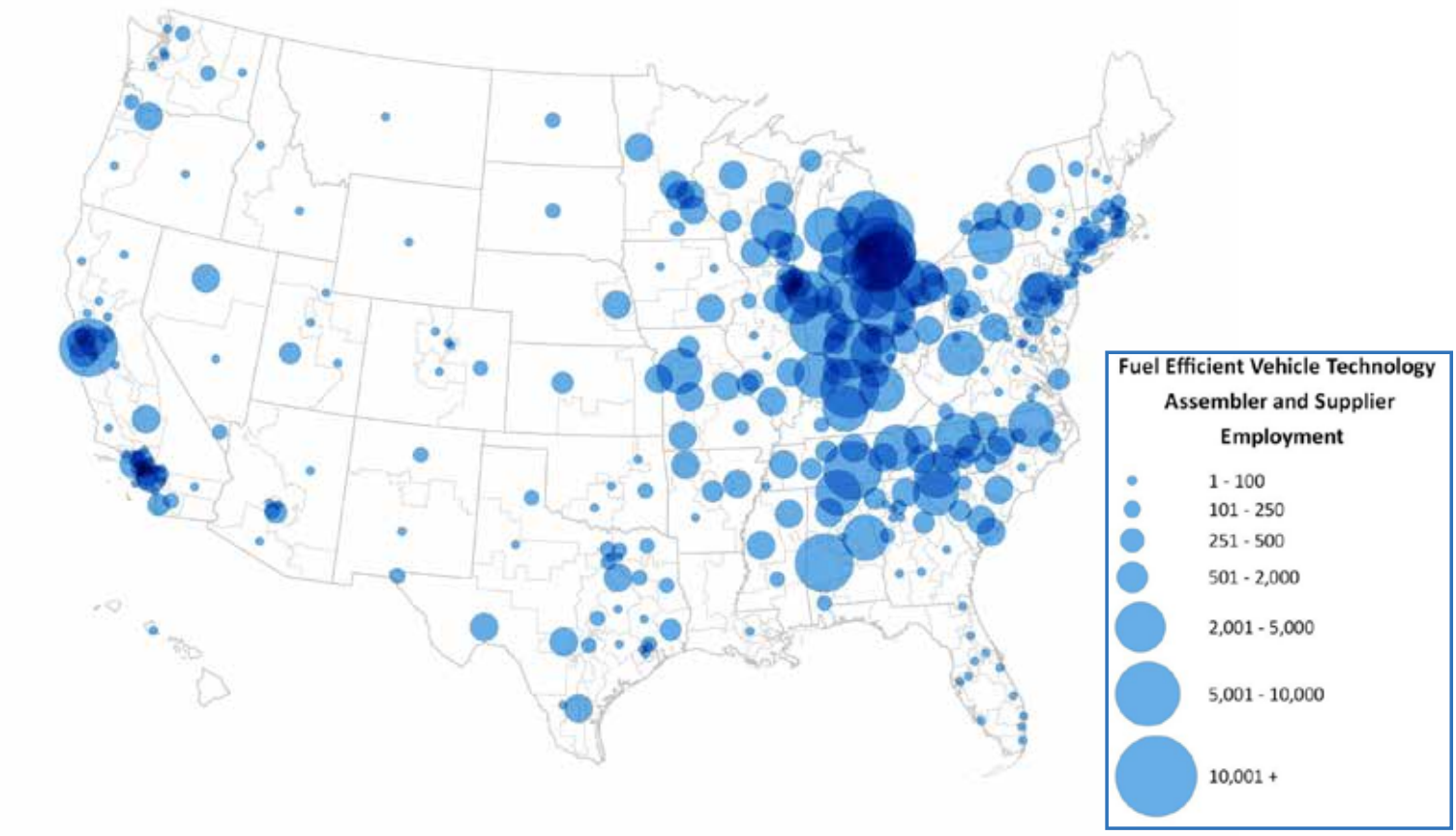


FIGURE 7: FUEL-EFFICIENT VEHICLE TECHNOLOGY EMPLOYMENT BY CONGRESSIONAL DISTRICT



VEHICLES PROVIDE A HISTORY OF SOUND, BIPARTISAN, BROADLY SUPPORTED STANDARDS ACHIEVING EMPLOYMENT, ECONOMIC, AND ENVIRONMENTAL GOALS

Today's vehicle standards are rooted in bipartisan agreement in the 2007 Energy Bill—the Energy Independence and Security Act (EISA). This legislation put fuel economy regulation on a new path and ensured that the nation could simultaneously meet obligations to cut greenhouse gas emissions under the Clean Air Act. In conjunction with requiring agencies to set a new generation of much more stringent standards, Congress made several smart choices that remain part of the standards today. It required a flexible, competitively neutral standard that adjusts along with the market and consumer preferences for smaller or larger vehicles. By encouraging fuel economy and emissions improvement across all sizes of vehicle, it also spurred broader innovation and greater consumer benefits.

In 2007, when Congress passed EISA to increase fuel economy standards, it also recognized that attracting and retooling U.S. automotive manufacturing facilities would be critical to ensure that current and future jobs in automotive technology would stay and grow in the United States. Congress established manufacturing loan programs at the U.S. Department of Energy (DOE), which helped vehicle manufacturers build and retool U.S. factories and retain and add tens of thousands of domestic jobs. These loans remain available to automotive and component manufacturers today. In addition, when automakers faced bankruptcy in 2009, Congress approved auto recovery loans that were critical to retaining the automotive supply chain in the United States—and that were repaid by a resurgent industry. And while job recovery has been relatively strong, there has been increasing focus by the press and stakeholders in recent years on disparities in wages, benefits, and labor, health, and safety standards across parts of the industry.[24] Opportunities remain to do more to bring back good jobs and grow auto sector manufacturing in America.

Since 2010, the two federal agencies (EPA and NHTSA) and the state of California have developed and implemented tighter standards through a process that has repeatedly engaged stakeholders and conducted deep technical analysis. This rigorous process has further provided a systematic framework for reviewing and addressing technical and market developments and changes as they arise while meeting environmental and economic goals. The result is a national program of sound rules that jointly meet state and federal fuel efficiency and GHG reduction regulatory obligations, with a decade of broad support from industry, labor, environmental, and consumer groups.

IV. MAINTAINING THE MOMENTUM: JOB GROWTH DEPENDS ON ONGOING AUTOMOTIVE INNOVATION, INVESTMENT, AND MANUFACTURING IN AMERICA

Overall economic conditions are critical to the health of the automotive industry. The automotive recovery of the past decade could not have happened without an overall economic rebound. But the recovery of U.S. automotive jobs and manufacturing was enhanced by clean vehicle and fuel-efficiency standards that promoted innovation, and by policies that encouraged domestic reinvestment in manufacturing the next generation of technology.

Looking forward—with the economy largely recovered and sales already high—sustaining existing jobs and continuing to create new ones will depend more than ever on retaining a domestic edge in innovation and manufacturing, with ongoing fuel economy, technology, and manufacturing leadership across the vehicle fleet. By contrast, stepping back from vehicle standards and smart manufacturing investments will retard progress and put jobs at risk.

Since 2010, studies have predicted that fuel economy standards would create jobs above and beyond business-as-usual automotive investment.[18] They argued that standards would drive direct manufacturing job growth as a result of enhanced investment in developing, manufacturing, and incorporating the additional automotive technology necessary to improve fuel efficiency. Studies also showed that the amount of job growth resulting from automotive innovation is deeply dependent on what share of that new technology is not just invented but actually built in the United States.[19] In addition, studies have found that jobs are created indirectly as households and businesses spend less on gasoline, with fuel savings going into other spending categories, such as retail and food.[20]

Today we're seeing these predictions of growth play out in practice across the country in companies like those we identify in this report.

In addition:

- **Companies are investing more.** Over the past decade, automakers and suppliers have invested more than $100 billion in American factory expansion and retooling, a figure that appears to significantly exceed investment in American auto factories before the recession—during a comparable period of high sales but industry stagnation.[21]
- **The industry is increasingly resilient.** Where the industry was once blindsided by volatile oil prices, in recent years the wider range of domestically manufactured fuel-efficient vehicles of all sizes has helped keep domestic sales strong as gas prices rise and fall. As fuel efficiency improves, the American automotive sector is increasingly insulated against gas price volatility. A recent report by automotive market analysts found that implementing strong standards through 2025 insulates automakers and suppliers against risks to market share and profits should gas prices rise.[22]
- **The automotive sector has led manufacturing job growth.** Since the recession, job growth in the auto industry has preceded and exceeded growth in other manufacturing sectors and has been a bright spot for several industries otherwise negatively impacted by adverse global trade agreements.[23]

Across the automotive supply chain, American manufacturing is proving that it can compete and lead while keeping hundreds of thousands of Americans hard at work.

NEXTEER AUTOMOTIVE—SAGINAW AND AUBURN HILLS, MICHIGAN

FUEL-EFFICIENT ELECTRIC POWER STEERING

Nexteer Automotive is a global supplier of steering and driveline systems, well known for its fuel-saving electric power steering (EPS). Traditional power steering systems rely on the vehicle's engine to power a pump and maintain hydraulic pressure to control movements of the steering system.[25] EPS eliminates steering from the engine load—and therefore saves fuel—by using an electric motor to finely manage steering controls. In addition, because EPS operates independent of the engine, it can provide responsive, efficient power steering for vehicles with all types of powertrains—from today's advanced internal-combustion-engine pickup trucks, to hybrids, to increasingly electrified vehicles that may lack a conventional engine to drive a traditional power steering system.[26]

Our 2011 "Supplying Ingenuity" report featured Nexteer for its early investment in EPS to aid automakers in meeting the 2012–2016 fuel economy and GHG standards. The subsequent growth in EPS demand helped the century-old company, which had faced bankruptcy in 2009, to rebuild.

In 2011 Nexteer employed 3,700 workers at its Saginaw, Michigan, facility.[27] By 2015 it was the largest employer in Saginaw County, with a workforce of workforce of 5,200 in Saginaw and a new global headquarters in Auburn Hills, Michigan.[28] Locally the company has invested more than $500 million in upgrading the Saginaw facility, has an annual payroll of $290 million, and makes $80 million in purchases in the local Great Lakes Bay counties annually.[29,30] Nexteer's overall EPS production doubled between 2013 and 2016—the year it produced its 40 millionth EPS system—and accounts for 62 percent of the company's revenue.[31]

In keeping with tightening vehicle pollution and fuel efficiency standards, Nexteer continues to innovate. It has moved to new materials to reduce the weight of its steering systems, optimized EPS to deliver sufficient power and responsiveness to meet the needs of a wide range of vehicle types and classes, and worked to integrate advanced steering systems with more fully electrified and autonomous vehicle systems.

ADVANCED AUTOMOTIVE MATERIALS

Lighter vehicles consume less fuel than heavier vehicles of the same size, reducing greenhouse gas emissions and saving consumers fuel and money.[39] Innovation in lightweight materials—not only for body and structural materials but also for subcomponents—is happening across the industry to meet auto sector and consumer demand for improved performance, safety, and emission-reduction.

HIGH STRENGTH STEEL: ARCELORMITTAL
Cleveland, Ohio, and other locations nationwide

Parts of ArcelorMittal's sprawling integrated steel mill in Cleveland have been operating since 1913. But the mill was mothballed in 2008–2009 at the height of the recession, and its future was in doubt.[40] Today, despite pressure on domestic materials producers from Chinese overcapacity and other stressors, the plant employs more than 1,900 people and is one of the most productive steel facilities in the world.[41] Key elements of this success, says local management, include successful innovation to produce advanced lightweight and high-strength steels for the auto industry and a strong partnership with the United Steelworkers Local 979.[42,43]

ArcelorMittal is one of the world's largest steel producers. Globally it devotes approximately 30 percent of its research and development funding to advanced automotive solutions and produces 60 varieties of advanced and high-strength steels.[44,45] These advanced steels are also 10 times stronger than counterparts just 20 years ago.[46] In Cleveland, the company sped its product development to keep up with change in the industry, and it recently upgraded its hot dip galvanizing line to produce high-strength, lightweight steel with tailored coatings for automotive customers.[47]

High-strength, lightweight sheet steel like that produced in Cleveland and in Burns Harbor and Indiana Harbor, Indiana, often flows to ArcelorMittal's facilities like those in Tennessee, Ohio, and Michigan, where workers make tailored blanks (semifinished parts made from steels with different properties) designed in a coengineering process with major automakers. The parties collaborate to identify lightweighting opportunities from the early stages of vehicle development through production, achieving substantial weight reduction while also optimizing safety and other performance criteria.[48] ArcelorMittal is currently investing $83 million in a new subsidiary facility for tailored blanks outside Detroit, near General Motors' Detroit–Hamtramck assembly plant.[49]

AUTOMOTIVE ALUMINUM: ARCONIC
Alcoa, Tennessee; Davenport, Iowa; and other locations nationwide

Automakers have steeply increased their demand for aluminum as they look to make vehicles and components safe and lighter in weight. Increased automotive orders have spurred major suppliers like Arconic to upgrade and expand their facilities while at the same time catalyzing innovation in related components and processes throughout the supply chain.

For example, Arconic recently invested $275 million and created 200 new jobs to increase production of automotive-grade aluminum sheet at its rolling mill in Alcoa, Tennessee.[50] Arconic also spent $300 million to upgrade its Davenport, Iowa, facility where that aluminum is customized—using a novel process—to facilitate bonding between aluminum automotive components.[51] Arconic is now rolling out an entirely new Micromill™ casting process that greatly speeds the production of automotive aluminum sheet and results in material that is even lighter, stronger, and more formable.[52]

Meanwhile, at its Kansas City plant, Ford added 900 workers and invested $1.1 billion to retool to utilize aluminum more broadly in its pickup trucks.[53] Investments included new robotics—new technology that replaced spot-welding with state-of-the-art rivets and adhesives. The company also carried out thousands of hours of training so workers could use the new technology. The resulting trucks are 700 pounds lighter, more powerful, and 17 percent more fuel efficient than their predecessors.

CARBON FIBER: SGL AUTOMOTIVE CARBON FIBERS
Moses Lake, Washington

Drawn in part by affordable, low-emitting hydroelectric energy, a joint venture between SGL Group and BMW established this facility in 2011 to produce carbon fiber threads for BMW's i-Series electric vehicles, the first mass-produced cars to rely extensively on lightweight carbon fiber for their structure.[54] Moses Lake exports more than 9,000 tons of carbon fiber thread every year to processing and assembly facilities in Germany. With $300 million invested and more than 150 employees, the facility has the largest production capacity of any carbon fiber maker in the world.[55,56]

In 2014 the state of Washington committed funds to train workers at local colleges in advanced manufacturing techniques to aid growth of a cluster of carbon fiber producers in the state.[57] A new advanced-composites research facility funded by Lamborghini recently opened in Seattle.[58] The state is now home to companies representing the full life cycle of composites production—from research to recycling—and serving demand for innovative materials from the automotive, aerospace, and other industries.[59]

V. POLICY RECOMMENDATIONS

Over the past decade, America has done much to reverse a devastating decline in a core industry, returning it to competitiveness and growth while at the same time achieving major environmental, consumer, and energy security gains. Sustaining this trajectory is critical in order to maintain and create automotive jobs and to continue to bring back manufacturing employment nationwide. To get this job done, the following policies should be a priority.

- **Effective, long-term, smartly structured fuel economy and GHG standards remain central** to robust advanced technology investment, innovation, and job growth—as well as to preserving the competitiveness of the domestic industry. In March 2017, the Trump administration opened a review of EPA's January determination that model year 2022–2025 standards, set in 2012, remained appropriate. NHTSA is expected to begin its previously scheduled fuel economy rulemaking in 2018. As the agencies do their reviews, they should recognize that a weakening of standards could stifle innovation and put industry manufacturing and job gains at risk. **Federal standards must maintain a sound ongoing trajectory of improvement on GHG emissions and fuel economy if they are to meet both their environmental and their economic goals.**
- Continued job growth in the auto industry—as in U.S. manufacturing as a whole—depends not only on technological leadership but on **national trade, tax, and economic policies that support reinvestment in American factories and workers**. These must improve, rather than degrade, labor and environmental standards globally. In addition, federal investments and incentives that spur domestic advanced technology manufacturing, innovation, demonstration, and deployment (such as the DOE's Advanced Technology Vehicles Manufacturing Loan Program) should be sustained and enhanced.
- **Strengthening labor standards, workers' rights, and regulations that protect worker safety and health on the job** are critical to ensure that jobs manufacturing the next generation of automotive technology are good jobs that deliver family-supporting wages and decent benefits and working conditions.

Together, these core policies that bolster fuel economy, domestic manufacturing, and good jobs can ensure that American workers and communities prosper while inventing and building the clean and fuel-efficient vehicle technologies that save consumers money and protect our environment.

A strong economy depends on securing today's advanced manufacturing and jobs while leading the world in building jobs in the emerging technologies of tomorrow. Every day, the companies and workers profiled in this report, and those across the automotive industry, are proving that America can get this job done.

Let's keep driving forward.

FORD CLEVELAND ENGINE—BROOK PARK, OHIO

A DECADE OF ADVANCED ENGINE INVESTMENT

Ford's Cleveland Engine plant in Brook Park, Ohio, has been building engines for familiar Ford vehicles since 1952. Today the plant is a key producer of Ford's EcoBoost family of engines.

Long-term fuel efficiency standards and the stability ensured by multiyear labor agreements with the United Auto Workers have enabled a pipeline of domestic reinvestment in globally competitive advanced technology and advanced manufacturing at Brook Park and similar Ford facilities across the country.

Ford's EcoBoost engine has been a central piece of its effort to improve fuel economy and cut GHG emissions across its vehicles. By combining a smaller engine displacement with advanced turbocharging, gasoline direct injection, and variable valve timing, these engines provide better fuel economy as well as equal—and often greater—power and performance.[32] After introducing the line in 2009, Cleveland Engine has produced more than one million EcoBoost units. Not surprisingly, more than 60 percent of F-150 pickup truck buyers have chosen an EcoBoost engine since the option became available to them in 2011.[33]

In recent years, Ford has made a string of investments to increase production capacity for EcoBoost and to secure and add jobs. In 2010, with the assistance of the DOE's Advanced Technology Vehicles Manufacturing Loan Program, Ford invested $155 million in early EcoBoost production.[34] This and similar investments across the company became the basis for dramatic growth, and the loans were paid back early. In 2013 Ford invested nearly $200 million in the plant and added 450 jobs to produce a 2.0-liter version of the EcoBoost engine that previously was supplied by a European facility.[35,36] In 2016 Ford announced a $145 million upgrade—securing 150 jobs—to produce the newest 3.5-liter EcoBoost.[37]

Overall, Ford spent $10.2 billion between 2011 and 2015 to retool domestic assembly and component facilities, and the latest investment at Brook Park is part of an additional $9 billion commitment over four years laid out in the company's 2015 agreement with the United Auto Workers, which includes plans for three engine upgrades at Brook Park.[38]

VI. ACKNOWLEDGMENTS AND METHODOLOGY

This report is based on research carried out by Baum & Associates, the BlueGreen Alliance (BGA), and the Natural Resources Defense Council (NRDC). This report updates a 2011 report, "Supplying Ingenuity," released by NRDC, the National Wildlife Federation, and the United Auto Workers, and is based on research by many of the same individuals.

Lead authors of this report are Zoe Lipman, director of the Vehicles and Advanced Transportation program at BGA, and Luke Tonachel, director of the Clean Vehicles and Fuels Project, part of the Energy and Transportation program at NRDC. Lead researchers include Alan Baum of Baum & Associates and Erin Daly, Roxanne Johnson, and Michelle Manson of BGA. We also thank industry expert Dan Luria for his review, as well as numerous others who provided key insights and input.

As in our earlier report, the suppliers detailed in this study provide technologies that contribute to improved vehicle fuel efficiency and lower GHG emissions, as identified by the EPA, NHTSA, CARB, and the National Academy of Sciences, in various assessments identifying technology likely to be used to meet fuel economy and GHG standards through model year 2025. Also included are suppliers of fuel-efficient technologies for medium- and heavy-duty vehicles.

A supplier database was developed by BlueGreen Alliance, Baum & Associates, and NRDC using a variety of primary sources, including:

- Baum & Associates' North American Automotive Production Forecast
- Baum & Associates' U.S. Electric Vehicles Sales Forecast
- BlueGreen Alliance's Visualizing the Clean Economy Transit & Rail Database
- BlueGreen Alliance's Visualizing the Clean Economy Automotive Database
- Databases and industry listings of automotive and related technology suppliers and facilities
- Internet research

Research also included press reports and information gathered through direct contact with companies.

Our data include facilities wholly focused on fuel-efficient technologies, systems, or components as well as those for whom these technologies are one part of a broader product line. The vast majority of these facilities are factories manufacturing advanced vehicles, components, or materials, but we also include design and engineering facilities. To calculate our employment estimate, we include 100 percent of employment at facilities wholly focused on fuel-efficient technology, and estimate a percentage of employment for facilities focused on a broader range of activities.

APPENDIX A

Suppliers mapped for this report produce the following technologies that improve vehicle fuel efficiency and/or reduce pollution.

Product Category	Products
Advanced Gasoline Internal Combustion Vehicles, Engines, and Components	Engine assembly, camless valve actuation, cylinder deactivation, exhaust treatment, gasoline direct injection, turbochargers, variable valve lift, and variable valve timing.
Aerodynamics and Auxiliaries	Aerodynamic fittings, cooling systems, electric, water and fuel pumps, auxiliary power units, low-energy lighting, and lightweight fuel tanks.
Alternative Fuel Systems	Fuel cells, propane and natural gas propulsion components.
Batteries	Materials, separators, cells, and packs for traction and start-stop system batteries.
Diesel Engine Vehicles	Engines, turbochargers, injectors, electronic fuel pumps, and after-treatment systems.
Electronics	Electronic braking, compressors, control modules/controls/controllers, capacitors, charging systems, motors, and power steering. Also high-efficiency alternators, inverters, power splitters, sensors, stop/start systems, starter/generators, and wiring systems—including specialized wiring harnesses.
Hybrids and Plug-In Electric Vehicles	Traction motors, regenerative braking systems, battery cooling systems, vehicle assembly, and vehicle conversion.
Infrastructure	Home charging stations, public charging stations, and battery materials recycling.
Materials	Aluminum, carbon fiber, high-strength steel, lithium supply, magnesium, and rare earth metals supply.
Tires	Fuel-efficient, low-rolling-resistance tires.
Transmission	Six-speed (or more) transmissions, automated manual transmissions, continuously variable transmissions, and dual-clutch transmissions.

APPENDIX B

Number of facilities and employees building clean and fuel-efficient vehicle technology, by state (all 50 states)

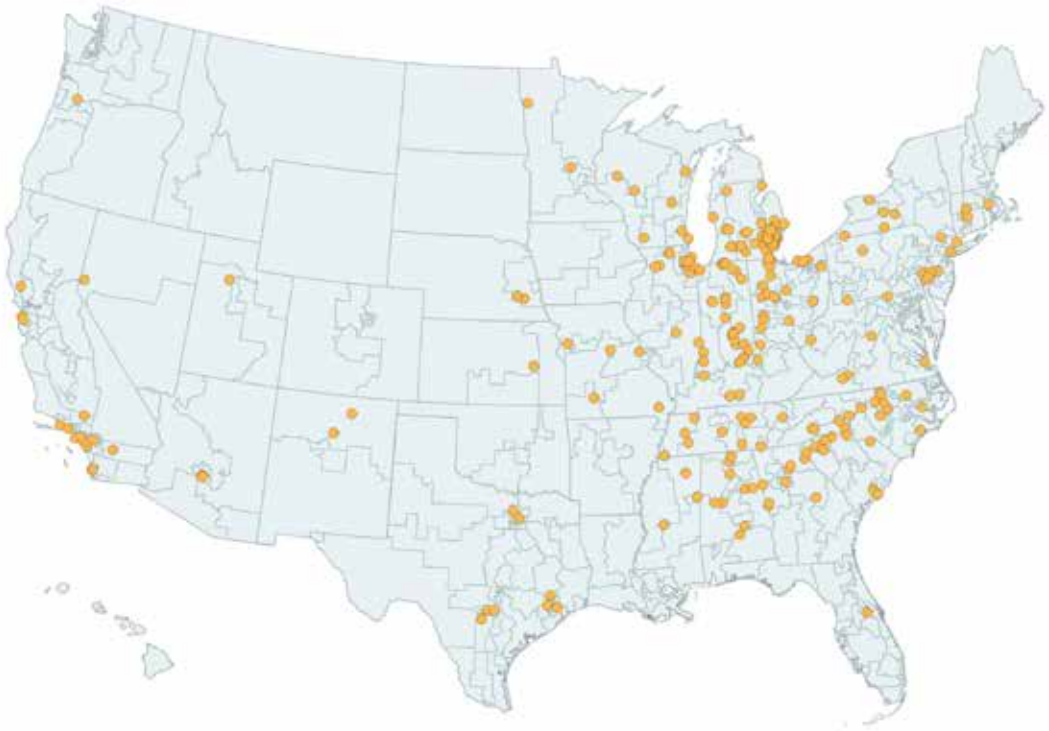
State	Employment	Number of Facilities
U.S. TOTAL	**288,594**	**1,238**
Michigan	69,593	224
Indiana	32,725	78
Ohio	27,838	80
Tennessee	16,455	40
Kentucky	15,319	32
California	14,776	175
Alabama	13,439	29
North Carolina	12,355	46
South Carolina	11,535	35
Illinois	9,904	44
Missouri	7,708	27
Pennsylvania	7,515	31
Texas	6,687	57
Wisconsin	6,318	27
New York	6,090	36
Minnesota	4,398	18
Mississippi	3,175	11
Arkansas	2,805	10
Georgia	2,359	22
West Virginia	2,321	3
Connecticut	2,253	16
Kansas	2,085	5
Maryland	1,675	9
Massachusetts	1,171	24

State	Employment	Number of Facilities
Oregon	1,156	15
Nebraska	983	4
Virginia	958	21
Nevada	726	11
Iowa	588	7
Arizona	557	11
Washington	482	9
Utah	435	8
Florida	299	13
Colorado	295	20
New Jersey	261	9
Oklahoma	249	7
Vermont	200*	2
North Dakota	200*	1
South Dakota	150*	1
Rhode Island	148	5
New Mexico	115	4
Idaho	100*	2
Wyoming	100*	1
Louisiana	60*	2
New Hampshire	20*	2
Montana	20*	1
Delaware	10*	1
Hawaii	10*	2
Alaska	--	--
Maine	--	--

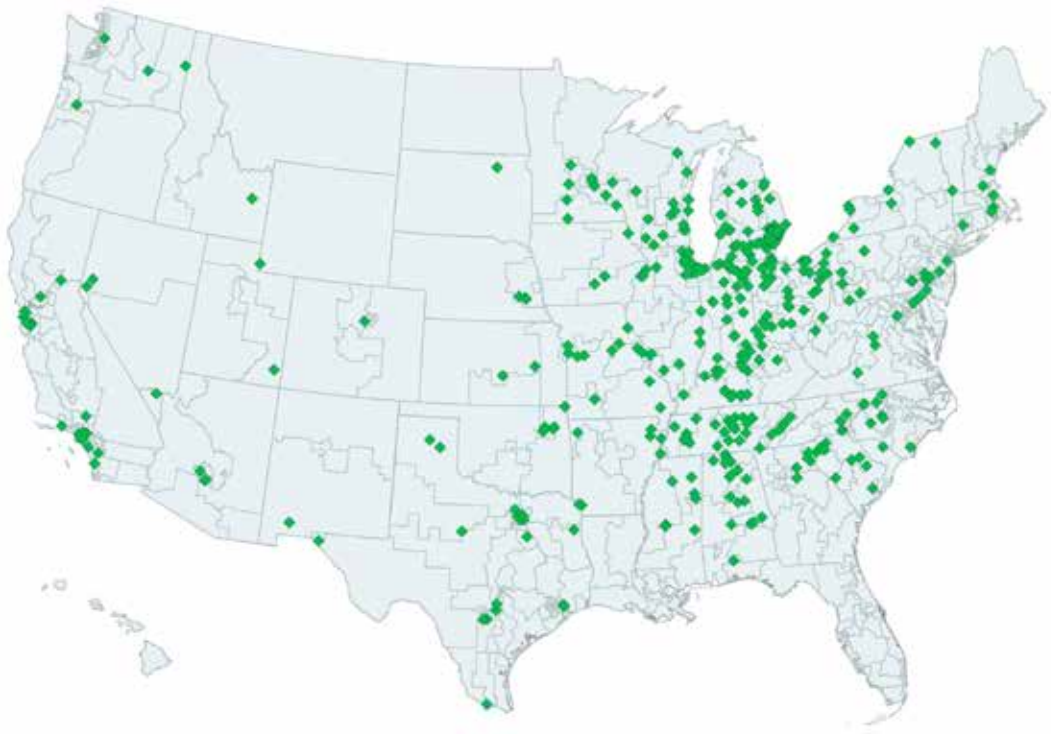
*Employment totals are rounded for states with fewer than 3 facilities listed

APPENDIX C:

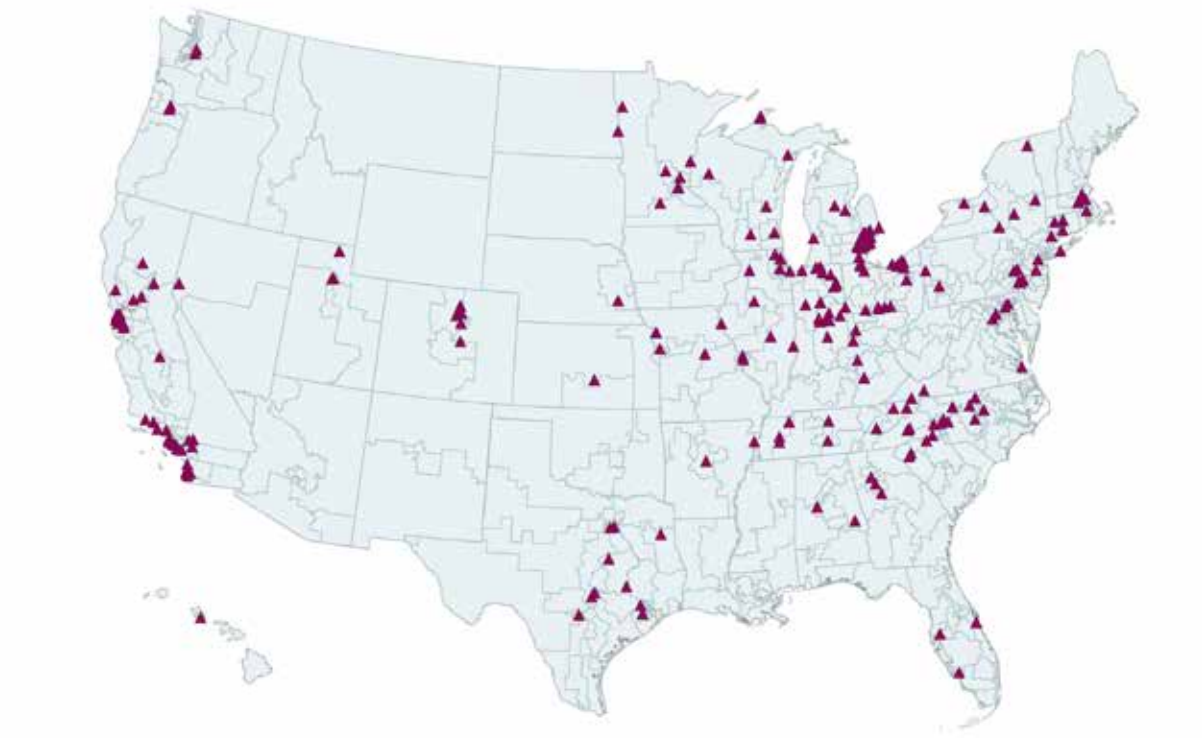
FACILITIES NATIONWIDE, BY TECHNOLOGY TYPE: ADVANCED GASOLINE OR DIESEL POWERTRAIN TECHNOLOGY



FACILITIES NATIONWIDE, BY TECHNOLOGY TYPE: ADVANCED MATERIALS AND COMMON COMPONENTS



FACILITIES NATIONWIDE, BY TECHNOLOGY TYPE: HYBRID, ALTERNATIVE FUEL, AND NATURAL GAS VEHICLE TECHNOLOGY



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