

US Heavy-Duty Vehicle High Efficiency Technology Suppliers

An Industry Segment Spanning America



CALSTART Industry White Paper

July 2016



PREFACE

This report was researched and produced by CALSTART, which is solely responsible for its content. The report was researched primarily by Stephanie Yu with assistance from CALSTART technical and member service staff and written by Stephanie Yu and Bill Van Amburg, who also provided oversight.

Information developed from the Innovators Roundtable and its resulting Synthesis findings document were part of collaboration between CALSTART and Environmental Defense Fund (EDF).

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EXECUTIVE SUMMARY

Based on an initial scan and geo-mapping of industry activity, the United States has a dynamic high efficiency technology supplier sector for heavy-duty trucks and buses. These suppliers and manufacturers are capable of providing a diverse range of fuel saving systems and components for heavy-duty vehicles and are active throughout the nation, with facilities established in 80 percent of the states. The companies include truck and bus original equipment manufacturers (OEMs), full system suppliers to the OEMs, mid-level component suppliers, and innovative technology developers.

While not a comprehensive assessment, this scan has identified a rich supplier network. From a preliminary survey of 255 sector companies, these technology suppliers were identified to be

operating from 535 manufacturing and development sites across 40 states in all regions. Mapping shows the broad reach as well as key centers of activity in this sector. These centers are generally focused around the heavy-duty manufacturing regions of the upper Midwest



states, technology hubs in California and the Pacific Coast, technology innovators in the East Coast including Massachusetts, New York, and manufacturers in the Carolinas, and a corridor from Alabama and Georgia through Tennessee, Indiana and Ohio.

These companies were further segmented into ten different technology categories covering the range of components that can provide greater efficiency to medium and heavy-duty vehicles. These include advancements in current diesel engines including waste heat recovery and reduced accessory loads, more advanced combustion designs, more efficient transmissions and full powertrains including hybridization, low rolling resistance tires, advanced aerodynamics, efficient drivelines, light-weight materials, intelligent vehicle control systems, and alternative fuels including full electric drive.

These are the core findings of the whitepaper, **US Heavy-Duty Vehicle High-Efficiency Technology Suppliers**. CALSTART undertook the initial survey to better understand the breadth and innovation of this sector. To achieve this, it researched and assembled a “living” database of the companies which could make the technologies needed to achieve increasingly stringent fuel economy and carbon emissions standards and the geographical spread of those companies. These companies, categorized by key, high level technology categories of activities and by location, were identified and then entered into

a data base which captures the core important data about them. This database was then used to generate a graphical, map-based depiction of their location by type of technology.

This supplier map is being used to better understand the range of the industry via a first level survey of capabilities and location that visually depicts the capabilities of and showcases the high efficiency heavy duty industry. Over time, companies will be encouraged to provide updated information and new companies will be included in the database as a living assessment. The interactive map can be found on the CALSTART web site (www.calstart.org).

The technologies being developed and produced by this industry sector are becoming a competitive advantage for the United States. According to several assessments, the US heavy-duty truck industry is now producing the most efficient trucks in the world, partly due to the drivers of current and future fuel economy regulations. With increasing global pressure to reduce carbon and fuel use in transportation, this can translate into economic and export opportunity.

While the suppliers and manufacturers in the high efficiency sector are not monolithic and reflect a variety of approaches and opinions on the future, most are concerned with the shape of future fuel economy and carbon regulations and the impact these can have on their business. In particular, technology innovators are greatly worried about reducing the risks involved in making continued investments in efficiency. Based on findings from parallel work CALSTART performed with the Environmental Defense Fund (EDF) and other stakeholders, innovators have identified a range of key issues that can support or hinder their continued success and growth. Primary among the issues which can assist was a desire for clear, strong, and long term efficiency regulations to de-risk investment. Innovators also highlighted the need for regulations to be inclusive of innovation technology by not setting rules or test processes aimed only at current components and technologies, and to be mindful of and provide regulatory credit to the multiple stages at which fuel-saving technologies are added to a vehicle.

1. INTRODUCTION AND BACKGROUND

US Heavy-Duty Vehicle High-Efficiency Technology Suppliers is a high-level white paper that captures an overview glimpse of a dynamic American supplier industry. This industry segment is expanding to support technologies and products needed to provide required steady improvements in fuel efficiency for the nation’s medium- and heavy-duty trucks and buses.

Developed to better quantify the growing US industry segment needed to achieve current and emerging fuel efficiency regulations, CALSTART has identified more than 500 manufacturing and development sites located in 40 states through this first high-level scan to examine the existing potential for both high-value jobs and American technological leadership.



Figure 1: Full Map of High Efficiency Heavy Duty Vehicle Technology Companies from Preliminary Listing

This white paper is by no means a comprehensive study and listing of such supply companies; it was primarily designed as a first overview scan of this industry to outline its geographic reach and technology scope. CALSTART desired to outline the current state of the industry by capturing an initial view of some of the key companies in it, identifying their locations and technology focus, and highlighting any regional hotspots.

To hone its approach to the issue, CALSTART segmented the companies included in the report by categorizing them according to the key classifications identified by federal agencies and industries as important technology sets for achieving fuel efficiency gains. These categories are: Engines and Accessories; Advanced Transmissions (including hybridization); Aerodynamics; Drivelines; Tires and Rolling Resistance; Idle Reduction; Weight Reduction; Intelligent Controls; Alternative Fuels; and (Full) Electrification.

While other categories were considered, the scope of this white paper focused on these primary areas. Some companies only fit in one specific category; several larger firms developing or providing products across several categories were counted in multiple. This is reflected in the database. Representative companies were first identified via existing industry contacts or research before being categorized based on their technology focus areas. Their relevant development and manufacturing locations were then identified and mapped, as described in the *Companies by Technology and Region* section. Not all company facilities were mapped; the locations noted appeared most relevant to their high efficiency products.

As a result, there are, as of this writing, 255 individual companies operating from 535 mapped locations representing supplier development or manufacturing sites. The icons used to map these sites are color-coded for each technology category. The database is interactive: each icon is linked to basic information captured in the database, and selecting that icon provides users with information on the specific company involved at that site, its description, and technology focus.

Going forward, this document and its geo-mapped database is intended to continue as a living research asset for capturing and eventually further quantifying this high efficiency segment. Companies will be encouraged to provide updated or new information on their locations, focus, and activities.

Need and Value of Industry Segment

While customer desire for reduced fuel use is a fundamental driver for heavy-duty efficiency technologies, a more consistent and comprehensive motivator for this growth currently derives from fuel economy standards both currently in place and new ones to be enacted by the United States Environmental Protection Agency (EPA) and the National Highway Transportation Safety Administration (NHTSA). The standards require steady reductions in fuel consumption and carbon emissions from on-road medium and heavy-duty trucks, buses, and vocational vehicles.

The newest set of federal heavy-duty vehicle efficiency rules, known as “Phase II”, will build off earlier requirements established in 2014 and add continuing reduction goals for the 2021 – 2027 period.

The on-going regulations have set the heavy-duty vehicle industry on a course to shoulder its share of carbon reductions needed to address global climate change. The rules place the largest fuel-using segment, Class 8 line-haul tractor-trailers, on a path to achieve a roughly 40 percent reduction in fuel use by 2027 compared to a 2010 baseline. This reduction “slope” is nearly on track with the long term reduction path that international climate scientists recommend for eventually achieving climate stability¹ (see Figure 2). An 80 percent reduction in carbon and overall greenhouse gas (GHG) emissions by 2050 will require continuing and steadily declining GHG emissions over the next three or more decades.

¹ IPCC, 2014: Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, R.K. Pachauri and L.A. Meyer (eds.)]. IPCC, Geneva, Switzerland, 151 pp.

Efficiency in transportation is a critical component of the climate battle. Transportation in the United States accounts for nearly 30 percent of GHG emissions and represents an even higher percentage in certain states and urban regions. Just in California alone, transportation represents roughly 40 percent of climate change emissions. The medium- and heavy-duty sector represents about 23 percent of the nation’s transportation-related GHG contribution overall², and due to the growth in shipping and goods movement, it is the fastest growing transportation sector. Current projections show it representing a growing percentage of transportation’s climate impact over the coming decades.

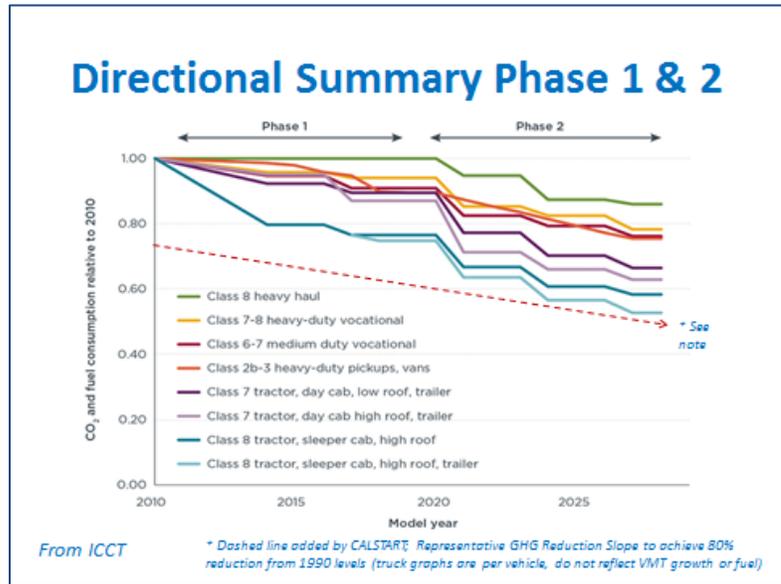


Figure 2: Directional Summary of CO₂ and Fuel Consumption Reduction by Vehicle Weight Class Relative to 2010

Achieving needed reductions will require continuing growth of innovative technology suppliers capable of providing systems and components that can achieve steadily increasing efficiency. This conclusion drives the importance of understanding the capabilities of these companies, their diversity and location, and how to nurture their success.

Rules addressing climate change can have other beneficial impacts for both the users of the technology and for US technology leadership and competitiveness. A recent report by CALSTART, *Higher Fuel Economy – Working for Fleets (2015)*, found that fleets using trucks achieving the levels of reduction being proposed under federal rules could see positive economic paybacks based on their resulting fuel savings. While results varied by type of truck, technologies used, and the future price of fuel, reducing fuel use can directly benefit vehicle operators and eventually end consumers.³

Another recent data set showcases a remarkable trend in overall efficiency leadership. While European heavy-duty trucks have long been considered the “gold standard” for efficiency compared to all other regions, North American trucks have reversed that trend in this decade and arguably become the most efficient in the world.⁴

² U.S. Environmental Protection Agency. 2014. Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990–2012. EPA 430–R–14–003

³ Higher Fuel Economy – Working for Fleets, CALSTART, 2015

⁴ Todts, William. “America’s Challenge to European Truck Supremacy.” EurActiv.com. N.p., 02 July 2015. Web. 7 July 2016.

While comparing European and North American routes, speeds, and loads make drawing concrete conclusions a challenge, the general trend lines are intriguing. Most notably, when North America adopted truck fuel economy rules and sent long term signals requiring compliance with those rules, truck efficiency increased faster than in other regions. Figure 3 depicts a graph illustrating observed changes and predictions in fuel economy in both European and North American trucks.

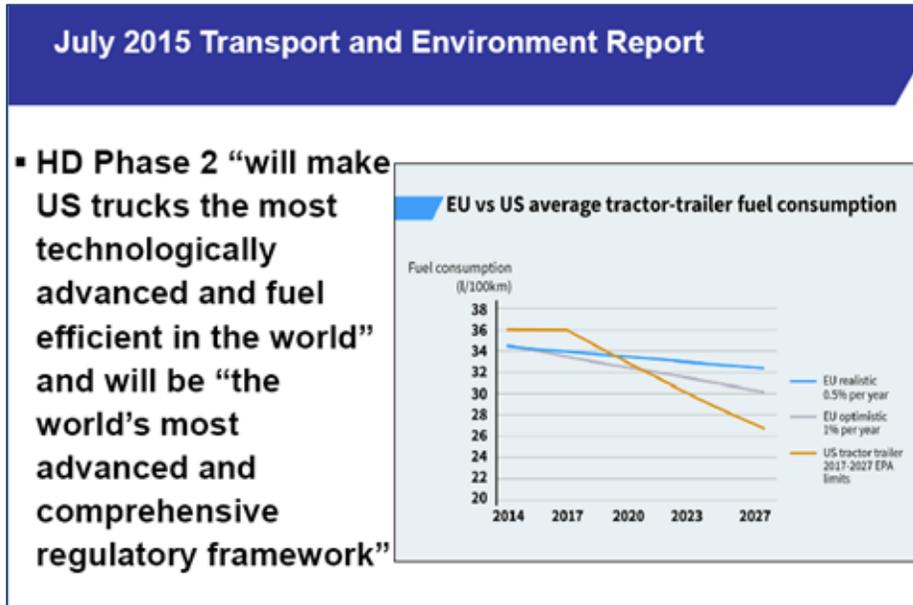


Figure 3: Changes and Predictions to Fuel Consumption for European and US Trucks from 2014-2027 (from EPA slide)

Finally, CALSTART recently convened an Innovators Roundtable of high efficiency suppliers, fleet users, and agencies in partnership with Environmental Defense Fund (EDF), the California Air Resources Board, the California Energy Commission and the South Coast Air Quality Management District.

The Roundtable was designed to understand

the status of technologies needed for higher levels of efficiency and considered their timing in the market, barriers to their commercial progress, and pathways forward. Findings highlighted in the Synthesis document included the industry’s ability to deliver efficiency beyond current regulations. A major concern was raised about setting standards that would limit innovation and make it difficult for non status quo products to be recognized. However, participants agreed that strong, long term fuel economy regulations would help reduce the risk of investment and development for suppliers.⁵ These needs of the innovative supplier community will be highlighted in the *Needs of Innovators* section.

⁵ Synthesis: Medium- and Heavy-Duty Innovators Roundtable, May 18, 2016, CALSTART & Environmental Defense

2. COMPANIES BY TECHNOLOGY AND REGION

The central findings of this white paper are the descriptions, categories, and location mapping of an initial set of companies identified as active, developing, and manufacturing high efficiency technologies for the medium- and heavy-duty vehicle industry.

This preliminary listing and mapping of high efficiency heavy duty vehicle technology suppliers includes 255 distinct companies. However, this is not an exhaustive list of all companies that produce high efficiency transportation technology in the United States, and smaller companies may not have been captured during this initial round of research. Similarly, this initial survey also does not include the broader supply chain for these companies. Supply chains further expand the impact of an industry segment, often involving a multiplier effect of more than five to one.

Nonetheless, it is salient that even as initially mapped the industry and its jobs impact more than 80 percent of the states in the nation – 40 of the 50. The 535 distinct points on the map include major offices or manufacturing sites for companies with multiple locations in addition to company headquarters. To avoid oversaturating the categories with every location for singular larger or international companies, not every satellite office for these companies was included. Several companies have been counted in more than one category based on the types of technologies they support. Each category of technology is represented by its own icon color and/or shape.



Figure 4: Full Map of High Efficiency Heavy Duty Vehicle Technology Companies from Preliminary Listing

Overall, the two states with the most companies were California (148) and Michigan (92). In California, activity was centralized in the Bay Area and in Los Angeles and San Diego. In Michigan, most of the companies were located in and around the Detroit region. While there are states not showing suppliers in this initial scan, the presence of this industry in almost every state suggests that neighboring states may experience spillover benefits supporting the full manufacturing supply chain.

We categorized high efficiency technology companies by their involvement in ten discrete technology segments. This categorization scheme was selected as it aligned with high level industry classifications as listed in the Notice of Proposed Rule Making (NPRM) by EPA and NHTSA as they developed their Phase 2 fuel economy rules. Those categories are:

- Aerodynamics
- Alternative Fuels
- Driveline
- Electrification
- Engine and Accessories
- Idle Reduction
- Intelligent Controls
- Tire/rolling resistance
- Transmission and Hybrid, and
- Weight Reduction

To compile this initial list, CALSTART staff began by categorizing companies already identified through its industry relationships and databases – including but not limited to CALSTART member companies – along with those identified or called out in federal high efficiency rules documents or programs, including the EPA SmartWay program. Additional research was then performed in several of the above listed categories to further identify companies not captured through the first assessments. Each identified company was entered into a database including a description of its technologies, location, primary technology categories, and contact information. An example is shown in Figure 5. Additional company locations are also labeled this way.

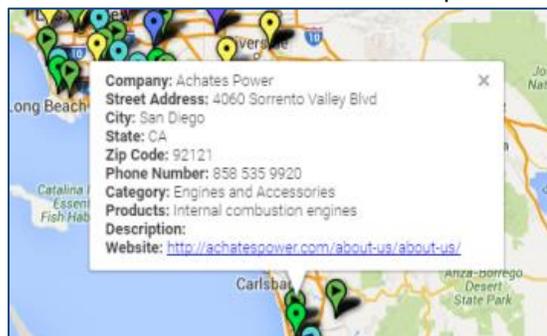


Figure 5: Example of Company Listing on High Efficiency Heavy Duty Technology Map

Major Category Breakdowns

Based on our initial research sampling, the companies supporting electric vehicles and infrastructure contributed to a sizeable part of our list. This certainly reflects the technology development focus of the last several years and the significant number of companies emerging in this space. We identified an initial 121 distinct addresses for companies that manufacture technologies that fell within the Electrification category. Other categories for which we discovered sizeable numbers were Alternative

Fuels (79), Transmission improvements including Hybrids (89), and Engines and Accessories (72). The area where we found the fewest contributors was Driveline technology (20), followed by companies producing technologies for Weight Reduction (24). Geographically, companies were spread across the United States, but there are clear focus regions or nodes for the industry, including a high percentage in the Midwest states, a strong showing on the East Coast and some Southern States, and a large node in California. The interactive map can be found on the CALSTART web site (www.calstart.org).

All the categories are well represented throughout the United States with the exception of companies producing Weight Reduction technologies, which are mostly focused on the eastern portion of the continental region. The Mountain region had consistently fewer companies/offices relative to the other regions. The following is an individual breakdown of findings for each category.

Aerodynamics

For the Aerodynamics category, we examined companies that developed products that reduce drag for powered heavy-duty vehicles and trailers. We identified 42 Aerodynamics companies. The spread across the continent was fairly uniform and companies and their offices were found generally throughout the continental United States.

Figure 6: Locations for Aerodynamics Companies



Alternative Fuels

While fuels are not specifically an efficiency technology, they can contribute to reducing carbon and are therefore an important category. For the Alternative Fuels category, we examined companies that supported alternative fuel vehicles, including but not limited to alternative fuel suppliers and alternative fuel vehicle components and systems. These fuels included biodiesel and biofuels, natural gas, fuel cells,

and compressed natural gas. Hybrid vehicles and engines were not included. We identified 79 Alternative Fuel companies, and the spread of these companies and their offices across the continent was fairly uniform. Many of these companies were concentrated in California in the Bay Area and in Los Angeles.

Figure 7: Locations for Alternative Fuel Companies



Driveline

For the Driveline category, we examined companies that support driveline improvement and efficiency. We identified 20 Driveline companies. While our identified group of Driveline companies and their offices was fairly small, they seemed to be concentrated in the northern Midwest in Michigan and in California in the San Francisco and Los Angeles areas.

Figure 8: Locations for Driveline Companies



Electrification

For the Electrification category, we examined companies that developed products to support electric vehicles - including battery cells, charging equipment, electric motors, and other electric vehicle support systems - and companies that manufactured electric vehicles. We identified 121 Electrification companies. The spread was fairly constant throughout the United States, though many companies were concentrated within California, the northern Midwest, and the East Coast.

Figure 9: Locations for Electrification Companies



Figure 12: Locations for Engines and Accessories Companies



Idle Reduction

For the Idle Reduction category, we examined companies that produced systems to reduce the time vehicle engines spent idling or the energy spent when vehicles idled. We identified 25 Idle Reduction companies. Most of these companies were concentrated in the northern Midwest along the Great Lakes region in Wisconsin, Illinois, Michigan, and Indiana.

Figure 13: Locations for Idle Reduction Companies



Intelligent Controls

For the Intelligent Controls category, we examined companies that developed systems that improved efficiency via vehicle safety systems, power management, navigation, and driver operations. We identified 38 Intelligent Controls companies. Many of these companies were in the Great Lakes region, with the majority operating in Michigan.

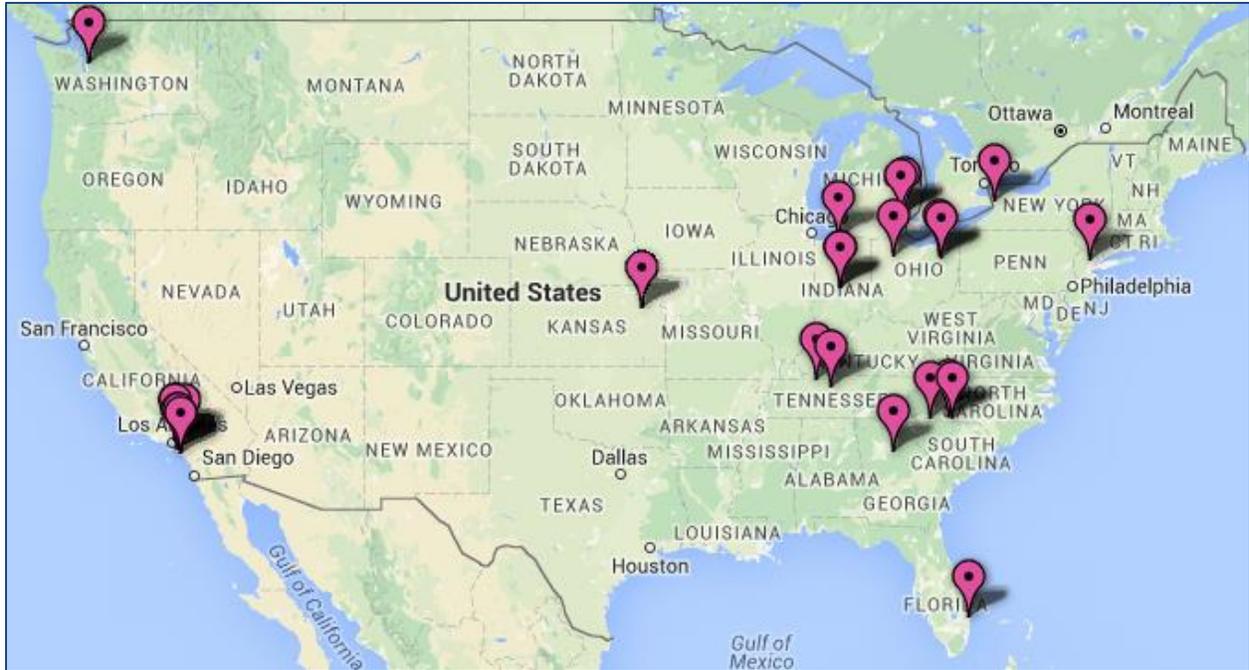
Figure 14: Locations for Intelligent Controls Companies



Tires and Rolling Resistance

For the Tires and Rolling Resistance category, we examined companies that produce, distribute, and develop tires with reduced drag. We identified 25 Tires and Rolling Resistance companies. These companies and their offices were found primarily on the West Coast in Washington and California (Los Angeles) and on the eastern part of the continent in Michigan, Indiana, Ohio, Tennessee, South Carolina, Kansas, Florida, New Jersey, and Georgia.

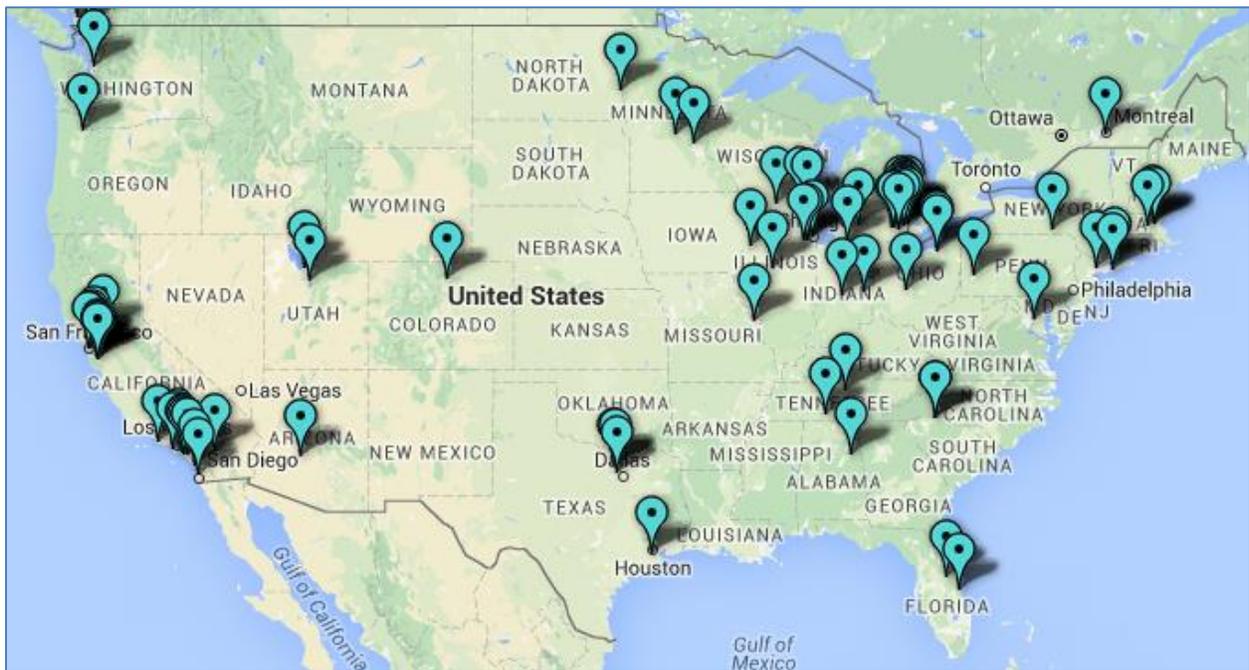
Figure 15: Locations for Tires and Rolling Resistance Companies



Transmissions, including Hybrids

For the Transmissions and Hybrids category, we examined companies that develop and produce powertrains, transmission components, and hybrid systems. We identified 89 Transmissions/Hybrids companies. Though modestly scattered throughout the continent, many of these companies were in Wisconsin, Illinois, and Michigan and California.

Figure 16: Locations for Transmissions and Hybrids Companies



Weight Reduction

For the Weight Reduction category, we examined companies that manufactured lightweight products and components for vehicles to reduce overall vehicle weight. We looked specifically at aluminum products for vehicles and identified 24 Weight Reduction companies. These companies and their offices were marked either in California or on the eastern side of the continent scattered in the Midwestern and Southern states with few in Maryland, Pennsylvania, and New York.

Figure 17: Locations for Weight Reduction Companies



Observations on the Scale of the High Efficiency Sector

While not the central focus of this white paper, CALSTART performed preliminary research to characterize the boundaries and size of the high efficiency technology sector based on the categories we highlighted. We consulted the United States Department of Labor’s Bureau of Labor Statistics database and examined the data in industry codes under the North American Industry Classification System (NAICS). While this database does not itemize professions to the level of specificity to match the categories of the high efficiency technology industry, understanding the general industries that these specific categories contribute to identifies which areas would see growth as the high efficiency technology sector advances.

Based on the Bureau of Labor Statistics, several subsectors encompass companies in the high efficiency technology market: Transportation Equipment Manufacturing, Motor Vehicle and Parts Dealers, Truck Transportation, Plastics and Rubber Products, and Fabricated Metal Product Manufacturing. All data mentioned was dated to May 2015.

While the employment within the high efficiency truck and bus technology industry is nested within these larger categories, support, and advancement of the high efficiency technology industry will subsequently lead to the further, continued growth of these broad industry classifications.

Within the Transportation Equipment Manufacturing subsector, the following industry groups would include companies in our categories: Motor Vehicle Manufacturing, Motor Vehicle Body and Trailer Manufacturing, Motor Vehicle Parts Manufacturing, and Other Transportation Equipment Manufacturing. Overall, following a decrease in employment in 2010, the Transportation Equipment Manufacturing sector has seen an increase in employment that appears to be plateauing.⁶ Within the Transportation Equipment Manufacturing industry, around **1,599,730 individuals** are employed.⁷

Relatedly, Motor Vehicle and Parts Dealers are under retail trade but include Automobile Dealers, Other Motor Vehicle Dealers, and Automotive Parts, Accessories, and Tire Stores. This category also had experienced a decrease in employment around 2010 but has since risen.⁸ Overall, around **1,909,020 individuals** are employed within the Motor Vehicle and Parts Dealers industry.⁹

Truck Transportation includes general freight and specialized freight industries in bus and truck mechanics and diesel engine specialists and delivery operations; like the previous subsectors, it has experienced an increase in employment since 2010.¹⁰ The Plastics and Rubber Products subsector includes all occupations involved in the production of plastic/rubber, though the specific Tire Builders profession had **17,710 employees** recorded in May 2015 located primarily in Ohio, Illinois, North and South Carolina, Georgia, and Alabama.¹¹ Our Weight Reduction category fit into the Fabricated Metal Product Manufacturing subsector, which has identified around **11,870 employees** within the Transportation and Material Moving Occupations field.¹²

The Bureau of Labor Statistic's Occupation Employment Statistics database also included general categories under which our high efficiency technology topics fell. Engine and Machine Assemblers (including motor vehicle parts manufacturing; engine, turbine, and power transmission equipment manufacturing; and motor vehicle manufacturing) has around **38,700 employees** with the highest percentage (7.14%) working specifically in engine, turbine, and power transmission equipment manufacturing.¹³ The Electrical and Electronic Equipment Assemblers industry includes companies assembling or modifying electric motors and batteries, which our Electrification category fits under; this industry employs **212,170 individuals** with 11.19% manufacturing semiconductors and other electronic components.¹⁴ Relatedly, Intelligent Controls fits under the Electronics Engineers (Except Computer)

⁶ "About the Transportation Equipment Manufacturing Subsector." U.S. Bureau of Labor Statistics. U.S. Bureau of Labor Statistics, n.d. Web. 08 July 2016.

⁷ "Transportation Equipment Manufacturing - May 2015 OES Industry-Specific Occupational Employment and Wage Estimates." U.S. Bureau of Labor Statistics. U.S. Bureau of Labor Statistics, n.d. Web. 08 July 2016.

⁸ "About the Motor Vehicle and Parts Dealers Subsector." U.S. Bureau of Labor Statistics. U.S. Bureau of Labor Statistics, n.d. Web. 08 July 2016.

⁹ "Motor Vehicle and Parts Dealers - May 2015 OES Industry-Specific Occupational Employment and Wage Estimates." U.S. Bureau of Labor Statistics. U.S. Bureau of Labor Statistics, n.d. Web. 08 July 2016.

¹⁰ "About the Truck Transportation Subsector." U.S. Bureau of Labor Statistics. U.S. Bureau of Labor Statistics, n.d. Web. 08 July 2016.

¹¹ "51-9197 Tire Builders." U.S. Bureau of Labor Statistics. U.S. Bureau of Labor Statistics, n.d. Web. 08 July 2016.

¹² "About the Fabricated Metal Product Manufacturing Subsector." U.S. Bureau of Labor Statistics. U.S. Bureau of Labor Statistics, n.d. Web. 08 July 2016.

¹³ "51-2031 Engine and Other Machine Assemblers." U.S. Bureau of Labor Statistics. U.S. Bureau of Labor Statistics, n.d. Web. 08 July 2016.

¹⁴ "51-2022 Electrical and Electronic Equipment Assemblers." U.S. Bureau of Labor Statistics. U.S. Bureau of Labor Statistics, n.d. Web. 08 July 2016.

industry that works on researching, designing, developing, or testing electronic components and systems for commercial, industrial, military, or scientific uses; they have recorded **135,390 employees**.¹⁵

¹⁵ "17-2072 Electronics Engineers, Except Computer." U.S. Bureau of Labor Statistics. U.S. Bureau of Labor Statistics, n.d. Web. 08 July 2016.

3. SELECTED PROFILES: HIGH EFFICIENCY INNOVATORS

Each company listed in the database is catalogued with basic profile information describing its product line, the technology categories in which it works, and location of its operations. This is accessible for all data points listed.

To further illustrate the diversity and geographic reach of the heavy-duty high efficiency supplier industry, we then identified and selected several companies to profile. These companies represent different technology categories and regions that showcased the various stages of development, technology approach, and market readiness of companies in the broader industry. While each is headquartered in a specific region of the country, most also have manufacturing or other facilities in others regions, showing the cross-linkages and multi-regional benefits of this sector.

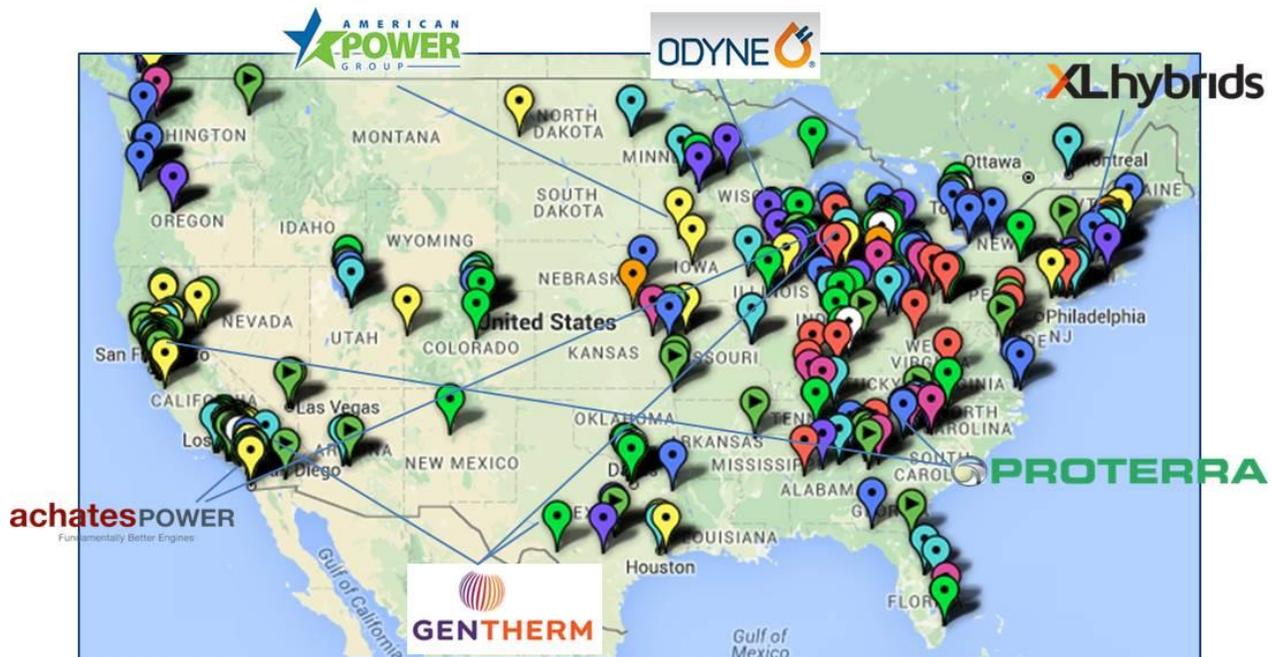


Figure 18: Locations for Selected Profiled Companies

These six companies profiled are purposely very different. However, they do share one key linkage in that they all represent cases which run counter to the conventional narrative about what solutions are coming forward in their segments. As a result, each also has some regulatory or other barrier to overcome or is overcoming to bring its technology to market. Interestingly, very few of these companies will actually receive credit for their contribution to increased fuel efficiency or carbon reduction under the draft Phase 2 rules as proposed.

Achates Power

Achates Power is working to modernize and commercialize a “better engine” that will significantly reduce greenhouse gas emissions while costing less than conventional diesel (or gasoline)



engines. Its Opposed-Piston Engines have unique proprietary cylinder and piston designs that reduce the amount of diesel fuel used per cycle to enhance engine efficiency by 10-30%, reduce oil consumption, and subsequently produce fewer emissions. While Achates Power's engine designs have initially focused on diesel combustion, assistance from the US Department of Energy has allowed the company to begin work on a gasoline engine to expand its markets. Achates Power is not an engine maker but an advanced engine design firm; it works with existing engine manufacturers to design opposed piston designs for their product line.

Located in San Diego, California, Achates Power began with extensive research and development on its engine design for around five years until its commercialized form was available to early adopters of the technology. One early adopter was the US Army, selecting Achates Power's technology to develop a next generation combat engine with greater power density; the US Army also plans to retrofit its older vehicles with modern engines. Achates's engine is compatible with the older vehicles and also offered a potential for cleaner, more efficient operation at a lower cost. Achates Power has also delivered system designs to engine makers in the stationary power sector.

While Achates Power has seen considerable progress in its business, it has also identified some barriers for further growth. Most of the funded grants offered for sustainable transportation target larger companies, while smaller, newer companies have a more limited pool of support. Furthermore, Achates's technology is still fairly young, despite demonstrating positive financial and environmental impact. In the absence of fuel price pressures, or sufficiently strong fuel efficiency requirements, companies have less incentive to examine higher efficiency engine technology. To assist a faster pace of adoption, Achates Power is seeking increased funding for demonstration projects to raise awareness and interest coupled with stronger fuel economy standards to motivate traditional manufacturers and users to more actively pursue high efficiency technology options.

American Power Group

American Power Group (APG), headquartered in Algona, Iowa, develops conversion systems that allow fleets to use natural gas fuel in conjunction with their diesel engines. APG describes its technology as a "user-friendly, transition technology" toward using increased levels of alternative fuel, as it does not change or modify the base OEM engine while allowing for dual fuel capabilities. Its Dual Fuel System currently focuses on diesel engines and can reduce the amount of diesel used by 50-60 percent by blending natural gas in the combustion process, thereby reducing greenhouse gas emissions while supporting domestic fuel sources, contributing to corporate sustainability goals and reducing annual fuel costs.



Prior to 2011, the Clean Air Act forbade any tampering with the original configuration of certified vehicles or engines, including alternative fuel conversions, to prevent modifications that could potentially increase emissions. After conversions were permitted for clean alternative fuel vehicles and engine conversions, APG was the first to gain the Environmental Protection Agency's (EPA) approval,

ultimately receiving 495 permits for its technologies. In 2015, APG's technologies were approved by the California Air Resources Board (CARB). Since 2011, the company has retrofitted over 600 trucks.

As California offered NOx reduction credits to improve air quality and had already developed a robust network of compressed natural gas (CNG) fueling stations, APG noticed a difference between their California market and the rest of the United States once CARB approved their technology. APG's system assisted California fleets with statewide emission reduction programs; states without these stringent policies did not have as much incentive to purchase the conversion system. APG identified other benefits and barriers its segment faces: the economic benefits are offered by the reduced cost of many alternative fuels, primarily natural gas; barriers stem from the limited availability and cost of tanks and equipment that are used for these fueling systems. Stronger national fuel economy policies and standards that target emissions would spread the growth APG saw in California onto a nationwide scale.

Gentherm

Though their thermal technology is used in multiple applications, Gentherm is best known for their automotive products. Headquartered in Michigan with North American offices in California, Texas, Ohio, Canada, and Mexico, this international company's range of applications includes seat comfort, interior comfort, thermal management, fans, and air moving devices. While providing a pleasant driving experience, these efficient climate control systems, built around technologies such as thermoelectric materials, support vehicle fuel efficiency and fuel economy when the vehicle uses less energy to regulate its interior environment. This aspect is even more critical for electric vehicles; when drivers use less of the vehicle's energy for thermal comfort, this conserved energy goes toward extending the range of the vehicle on a single charge.



Gentherm is also developing systems to capture waste heat from heavy-duty engine exhaust as well as thermal management of powertrain batteries. The solid state nature of their thermoelectric systems can greatly simplify the often complex technologies used to capture and reuse waste heat; their system also converts that heat directly into electrical energy. As the need for engine efficiency is combined with greater use of electricity aboard vehicles for operating accessories, idle reduction and the like, Gentherm's components – while perhaps more expensive on a per component basis, can cost-effectively contribute to a total vehicle system solution.

While much of Gentherm's focus has been on providing occupant climate comfort, it acknowledges the environmental benefits of its technology. Stronger fuel economy standards that Gentherm's products can address would help its business as manufacturers and users realize the additional benefits of their waste heat recovery and thermal comfort systems.

Odyne

Odyne's plug-in hybrid electric vehicle (PHEV) systems work for both medium and heavy duty trucks with multiple chassis



manufacturers and weight classes. The system's battery system produces the electric power for its electric motor and for the vehicle's air conditioning and heat, as well as for the tool systems and aerial devices which can be used with the vehicle's main engine is shut off, such as at work sites. The result of this hybrid structure includes lower operating costs, lower emission emissions, less noise pollution, and lower maintenance costs. Odyne has primarily focused on the work truck market, its product best for stationary work by reducing the amount of fuel needed during vehicle idling.

Currently headquartered in Wisconsin along with its production facility, Odyne was founded in 2001 with the goal of producing electric and hybrid electric propulsion systems for heavy-duty vehicles. In the recent past, the company has grown tenfold, attributing this growth to incentive programs that demonstrate its system's use and functions beyond its early adopters. As a result, Odyne has seen a boost in sales from more conservative fleets along with repeat sales from early adopters. Fleets who have purchased the hybrid systems have been motivated by the financial savings of switching to hybrid vehicles as well as seeing the emissions benefits of shutting off the engine during long work-site idling periods.

Despite its successes, Odyne notes that high initial purchase cost is still a major barrier to further growth. This price is expected to decrease once production volume of the system increases, but achieving this volume has been slow. So far, Odyne has noticed that demand is the highest in areas where emissions regulations are more stringent. However, current regulations have not helped the hybrid market significantly at the national level, as existing policies do not give enough recognition to the technologies used within a vehicle's system. Original equipment manufacturers do not have a stake in advocating for the smaller companies that contribute sub-component products like Odyne's hybrid system, which is often added at a later stage of manufacturing. The most effective policies that would best assist Odyne's business would include expanded definitions of the full manufacturing process for trucks and flexibility that acknowledges and gives credit to companies adding later-stage systems.

Proterra

Proterra is one of the prominent zero  **PROTERRA** emission vehicle manufacturers in the high efficiency technology market in the United States. Founded in 2004, the bus manufacturer offers fast charge and extended range batteries in its electric buses. Its electric buses provide significant improvements in fuel economy over diesel as well as zero emission tailpipe operations. Proterra buses also provide lower operating maintenance costs by running on electricity, which has historically more stable prices than fossil fuels. In addition to servicing US fleets, the majority of the components that go into Proterra buses come from domestic suppliers.

While Proterra has manufacturing locations on both the West and East Coasts, its corporate headquarters are now in California, which it has identified as its biggest potential market due to the sheer number of fleets and service area. Development of electrification technology and the climate change and air quality policies in the State have supported Proterra's growth. Funding from the California Air Resources Board and federal sources have helped increase initial transit agency

acceptance. Several large orders and demonstration projects in public transit fleets, including Foothill Transit and Southeastern Pennsylvania Transportation Authority (SEPTA), have helped bring Proterra and electric buses to greater national recognition; testing in King County in Washington has demonstrated Proterra buses' better fuel economy in real world route settings. Proterra's success and greater demand for its buses has allowed it to expand and create more jobs in the high efficiency technology market.

Proterra credits its market growth to federal and state funding that assisted fleets in purchasing their first electric buses and notes the value of financial assistance in trying new technology in fleets. Proterra is currently working to expand its scale to increase volume production. Stronger fuel economy and air quality standards would prompt more fleets to purchase cleaner buses like the ones that Proterra builds. It notes the importance of lesser known companies that contribute key component parts to this segment of the transportation sector. It predicts that the continued focus on and need for zero emissions will advance the electrification of the bus and truck sectors within the next decade.

XL Hybrids

XL Hybrid's system requires no significant vehicle modifications or changes to the internal combustion engine or transmission. Simply by adding an electric



motor, a small, advanced lithium-ion battery pack and control software, a vehicle becomes a hybrid that generates its own electricity through regenerative braking capabilities. With the addition of the hybrid system, vehicles with XL Hybrid's upfit use less fuel to operate and reduce their emissions. While relatively new in the high efficiency market, XL Hybrids has gone from selling its first powertrain two and a half years ago to becoming the company with the second largest deployment of electrified Class 2-6 vehicles in the industry. The relatively smaller batteries of the system coupled with a low entry price has allowed for a faster hybrid system adoption rate in the market. Government incentive programs have assisted in XL Hybrid's business growth as well, especially in Chicago and in Maryland. Based in Boston, Massachusetts, the company has been particularly active on the East Coast.

While incentivizing fleets and consumers to consider clean vehicle technology, stronger fuel economy standards alone will not be enough to support XL Hybrids and its peers in the high efficiency vehicle industry. Regulations must be more reflective of the real-world production process. Specifically, XL Hybrids believes third party upfitters need to be specifically acknowledged and given more flexibility in policies and legislation, as stronger fuel economy standards put pressure on larger original equipment manufacturers (OEMs) to develop technology. As third party upfitters work alongside OEMs by adding efficiency systems to their vehicles, regulators should acknowledge this collaboration between OEMs and smaller companies. XL Hybrids recommends implementing the same structure used in the passenger market for the commercial market where third party companies are included as part of a credit marketplace structure and have a recognized place at the table.

4. NEEDS OF INNOVATORS

As shown in the mapping exercise, the heavy-duty high-efficiency supplier sector is a diverse industry not only in terms of the technology it provides but also in its geographic reach across America. Simply by virtue of the ten different technology categories tracked, it is not a monolithic industry sector and its companies represent a range of views and opinions on the future.

Nonetheless, most companies are concerned about issues related to barriers to their investments in and development and introduction of their technology. Partly to understand these issues, CALSTART, together with the Environmental Defense Fund (EDF), organized and held a Medium- and Heavy-Duty Innovators Round Table on May 18, 2016. The day long session was co-convened with the California Air Resources Board, the California Energy Commission and the South Coast Air Quality Management District (SCAQMD) and was held at SCAQMD's facility.

The dialogue explored innovations that are advancing important U.S. leadership in new technologies as well as critical clean air and climate protections. The round table discussion format included four sessions, each co-moderated by a private sector representative and public or nongovernmental organization policy expert. The sessions were each designed to address key questions around the pace of new technology introduction, scalability, barriers to, and pathways forward for innovative technology. Moderators led participants through a collaborative and interactive discussion on each topic, engaging and capturing input from a broad cross-section of leading technology innovators in the medium- and heavy-duty industry.

The dialogue was intended to raise awareness about the development and deployment of advanced technologies that have important economic, climate, and clean air benefits. The round table dialogue also explored the context of the EPA and DOT Phase 2 greenhouse gas and fuel economy rulemaking and the important leadership of California, past, present and future, in driving the development and deployment of advanced technologies.

The core findings and takeaways from this Innovators Round Table (SYNTHESIS: Medium- and Heavy-Duty Innovators Round Table, May 18, 2016¹⁶) identified several key issues and barriers also echoed in the innovator profiles from the previous section. Most notably, the high level takeaways were these:

- **Technologies are available and in the pipeline**—There is a rich network of innovative companies in the United States with technologies available now in low volume or coming to market at scalable volumes over the next five years in the medium- and heavy-duty market. These technologies include systems and designs to increase engine efficiency, advanced transmission and powertrains, drive cycle and work site idle reduction, lower carbon fuels, intelligent routing, and powertrain control.
- **Successfully addressing risk is critical**—A key barrier—and also a key strategy for success for these technologies—is reducing risk at all steps in the commercialization process. This was

¹⁶ Synthesis: Medium- and Heavy-Duty Innovators Roundtable, May 18, 2016, CALSTART & Environmental Defense

referred to by several attendees as “de-risking” innovation. While it can involve many elements, the priority issues according to round table comments were: long-term, clear, and strong regulatory signals; better price signals in the market place for efficiency, whether via fuel price and/or new market models; increased co-funding of industry investment in product development to get over investment “humps”; and long-term, streamlined incentive support for accelerated fleet purchase (built on the model of HVIP vouchers in California).

- **Create a space for thriving innovation**—The marketplace does not like ambiguity and unclear goals. Strong signals, including robust regulatory requirements, shape the framework for successful long-term investment. Innovative technologies prosper best when clear long-term requirements are set. In an era when rapid technology improvement and innovation is necessary to meet global climate and urban emissions needs, innovators feared their offerings were less likely to break through to OEMs without such strong requirements.
- **American technologies are often reaching foreign markets first**—Innovation is often reaching the market faster in both Europe and Asia (particularly China and India) than in the United States. This is despite the fact that many of these innovations are coming from U.S. companies. Innovators reported this demand for innovative technologies is often driven by high fuel prices in Europe, a reduced burden and shortened process on certification, and industrial policy commitments in China. One innovator reported total time from concept to full certification of only nine months.
- **Smart regulations are needed**—The need for forward looking regulations was another important issue raised by innovators. There are concerns around “regulating the *status quo*”, described as setting standards and certification procedures that are crafted around and for incumbent technologies and may actually limit innovative technologies or approaches from “fitting” the rule structure.
 - This was particularly noted around engine technologies for Class 8 line-haul and for the multi-stage manufacturing process for vocational vehicles. Also given the importance of reducing idling in all phases of truck operations, the current draft regulations do not have a clear route for technologies that reduce work site engine use, measured in gallons per hour.
- **Commercializing innovative technology faster requires flexibility and fewer obstacles**—Innovators strongly encouraged regulators to build in flexibilities that encourage pathways to new innovation, and to reduce regulatory and certification barriers for innovation. The California Innovative Technology Regulation was cited as an example of possible approaches.

It is worth noting that many of these companies were smaller or mid-size firms but are of the class of companies bringing the next generation of technologies through the development and market introduction process. It is a vital class of companies to support as this group represents important drivers of the innovation pipeline of technologies transportation will require to meet steadily increasing requirements for fuel efficiency and carbon reduction.

5. CONCLUSIONS AND OBSERVATIONS

The United States has a diverse and growing supplier sector developing and producing high-efficiency and low carbon technologies for the medium- and heavy-duty vehicle market. These companies are found in all regions of the nation. Based on a preliminary scan performed by CALSTART, 255 individual companies were initially identified operating from 535 facilities in 40 states. Most of these companies are firms making complete components or systems, and the assessment does not generally include parts or materials companies in the broader supply chain.

These firms, which include vehicle manufacturers, component suppliers and technology developers, were further categorized by their activities across ten core technology categories important to producing current and future high efficiency trucks and buses. These technology groupings and the companies which are active in each can serve as a monitoring tool for assessing the growth and strength of different technology category supply chains.

This high-efficiency sector is a vital part of the US heavy-duty vehicle industry as the need for truck efficiency and carbon reduction increases globally. This technology capability is emerging as an area of American leadership and potential competitive advantage. Part of this advantage stems from fuel economy and carbon reduction standards for heavy-duty vehicles established in advance of other countries.

This sector is not monolithic and does not speak with one voice on all issues. However, the smaller and mid-size innovator firms in this sector do have specific concerns and strong ideas about what can help them invest, grow and succeed. Findings from a parallel project focused on innovators provide a sense of its critical issues for this sector going forward, which include:

- Making sure that strong, clear and long term regulatory signals on fuel efficiency are set. Innovators report this as the most critical element of reducing their risk of investing in and producing high efficiency technology products.
- Ensuring that regulations are not geared only to incumbent technologies and approaches, but are flexible in structure and testing to accommodate new and non-traditional technology.
- Similarly, with certification processes, develop approaches that reduce barriers to innovation by providing flexibility and reduced requirements to new and lower volume technologies to enter the market more quickly. Such approaches are being considered in California via its Innovative Technology Regulation (ITR).
- Provide a phased approach to help speed needed technologies to market, including funding for development and demonstration stages as well as streamlined funding for early market deployment. The California, Chicago, and New York “voucher” programs, which provide simple point of purchase buy-down funds for clean trucks and buses, were cited as the preferred approach.

While not a comprehensive assessment, this initial survey then establishes a useful framework for understanding the geographical reach of the industry, its focus areas and concerns. CALSTART intends to use the geo-map structure as a living document to update and track the progress of this sector over time and welcomes companies and stakeholders to provide additions and clarifications to provide further detail to the database.

6. APPENDIX

The appendix includes these two items:

Initial list of U.S. heavy-duty high-efficiency suppliers and their technology focus area

Initial list of 10 high-efficiency technology categories

Initial Listing: U.S. Heavy-Duty High-Efficiency Technology Suppliers

Company	Category
A&T Clutch Components	Aerodynamics
A123	Transmissions & Hybrids, Electrification
AC Propulsion	Electrification
Achates Power	Engines and Accessories
Actia Corp	Transmissions & Hybrids, Electrification
ADOMANI	Electrification
Advanced Power Products	Electrification
Aerofficient	Aerodynamics
AeroTech	Aerodynamics
Aerotech Caps	Aerodynamics
AeroVironment	Electrification
AeroVolution	Aerodynamics
Agron Bioenergy	Alternative Fuels
Airman	Aerodynamics
Airodyne	Aerodynamics
Alcoa	Weight Reduction
Allison Transmission	Transmissions & Hybrids, Idle Reduction
ALTe Technologies	Transmissions & Hybrids, Electrification
Altec Industries	Idle Reduction
Aluminum Precision Products	Weight Reduction
American Power Group	Alternative Fuels
American Transportation Products	Tires & Rolling Resistance
Artisan Vehicle Systems	Electrification
ATDynamics (subsidiary of Stemco)	Aerodynamics
Atlantic Great Dane	Aerodynamics
ATS Integrated Automated System	Aerodynamics
Aura Systems Inc.	Electrification
Auto Research Center	Aerodynamics, Tires & Rolling Resistance
Autocar	Engines and Accessories, Transmissions & Hybrids, Alternative Fuels, Engines and Accessories, Intelligent Controls
Autoliv	Engines and Accessories, Intelligent Controls
Avantechs Inc.	Aerodynamics
AVL Technical Center	Engines and Accessories, Transmissions & Hybrids, Electrification, Engines and Accessories
BAE Systems	Engines and Accessories, Transmissions & Hybrids, Electrification, Engines and Accessories
Ballard	Idle Reduction, Alternative Fuels, Electrification
Balqon Corporation	Electrification
Battery M.D. Inc	Electrification

Bauer's Intelligent Transportation	Transmissions & Hybrids
Bay Biodiesel	Transmissions & Hybrids
Bendix	Engines and Accessories, Intelligent Controls
Bergstrom Inc	Idle Reduction
Bluefire Renewables	Alternative Fuels
Bosch	Engines and Accessories, Transmissions & Hybrids, Electrification
Bravo Motor Company	Transmissions & Hybrids, Electrification
Brean Marketing, Inc.	Aerodynamics
Bren-Tronics, Inc	Electrification
Bridgestone	Tires & Rolling Resistance
Bus and Coach America	Electrification
BYD	Electrification
California Lithium Battery	Electrification
Calnetix	Transmissions & Hybrids
Capstone Turbine Corp	Engines and Accessories, Alternative Fuels
Caterpillar	Engines and Accessories, Transmissions & Hybrids, Alternative Fuels
CDTi	Transmissions & Hybrids
Cenergy Solutions	Transmissions & Hybrids
ChargePoint	Electrification
Chrysler	Alternative Fuels
Clean Air Power	Alternative Fuels
Complete Coach Works	Alternative Fuels, Electrification
Concord Minuteman Solutions	Alternative Fuels
Constellium	Weight Reduction, Engines and Accessories, Intelligent Controls, Electrification, Tires & Rolling Resistance
Continental	Engines and Accessories, Intelligent Controls, Electrification, Tires & Rolling Resistance
Cooper Tires	Tires & Rolling Resistance
Cummins Incorporated	Engines and Accessories, Alternative Fuels, Electrification
Daimler Trucks/Freightliner	Engines and Accessories, Intelligent Controls, Alternative Fuels
Dana	Driveline
Delphi	Engines and Accessories, Transmissions & Hybrids, Intelligent Controls, Electrification
Denso	Engines and Accessories, Transmissions & Hybrids, Intelligent Controls
Detroit	Engines and Accessories, Transmissions & Hybrids, Driveline
Dextero	Tires & Rolling Resistance
Dogpatch Biofuels	Transmissions & Hybrids
Dometic	Idle Reduction, Engines and Accessories
Downs Energy	Alternative Fuels

Drivelines Inc	Driveline
DRS Technologies	Electrification
Eagle Picher	Electrification
Eaton	Transmissions & Hybrids, Driveline, Intelligent Controls
Ebus	Electrification
EcoTech Fuels LLC	Alternative Fuels
Effenco	Transmissions & Hybrids, Idle Reduction
Efficient Drivetrains	Transmissions & Hybrids, Electrification
EIG America, Inc	Electrification
Ekostinger	Aerodynamics
Electric Vehicles International	Electrification
Electrovaya	Electrification
Emerald Automotive	Transmissions & Hybrids, Electrification
eMotors Electric Vehicles of Northern California	Electrification
EMP	Engines and Accessories
EnerDel	Electrification
eNow	Idle Reduction, Electrification
EPC Power	Electrification
EV Connect	Electrification
Fallbrook Technologies	Idle Reduction
Ficosa	Intelligent Controls
Fleet Engineers	Aerodynamics
Ford Motor Company	Engines and Accessories, Transmissions & Hybrids, Alternative Fuels
Freightliner Custom Chassis Corp	Transmissions & Hybrids
General Motors	Engines and Accessories, Alternative Fuels
General Tire	Tires & Rolling Resistance
Gentex	Intelligent Controls
Gentherm	Engines and Accessories
Giti	Tires & Rolling Resistance
Global ET	Intelligent Controls, Electrification
Golden Gate Petroleum	Alternative Fuels
Goodyear	Tires & Rolling Resistance
Greenkraft	Engines and Accessories, Alternative Fuels
Greenkraft Inc	Alternative Fuels
GreenTech	Electrification
GT Radial	Tires & Rolling Resistance
Hammond Air Conditioning	Idle Reduction
Hankook Tire	Tires & Rolling Resistance
Harris Corporation	Transmissions & Hybrids
Hino Trucks	Transmissions & Hybrids
Honeywell	Engines and Accessories
Horiba Instruments	Intelligent Controls
Huss Inc	Transmissions & Hybrids
Hydro	Weight Reduction
Hydrogenics USA	Electrification

Hydrophi Technologies	Alternative Fuels
HyGen Industries	Alternative Fuels
Hyundai Translead	Aerodynamics
Idle Free Systems	Idle Reduction
Impco	Idle Reduction, Alternative Fuels
IMPCO Technologies	Engines and Accessories
InventEV	Transmissions & Hybrids
Isuzu	Engines and Accessories, Alternative Fuels
Iteris	Intelligent Controls
ITM Power	Alternative Fuels
John Deere Electronic Solutions	Transmissions & Hybrids, Electrification
Johnson Controls	Engines and Accessories, Transmissions & Hybrids
Johnson Truck Bodies	Idle Reduction
K2 Energy Solutions	Electrification
Kaiser Aluminum	Weight Reduction
Kavlico	Engines and Accessories
Kenworth	Transmissions & Hybrids, Intelligent Controls, Alternative Fuels
Kinetics Drive Solutions	Transmissions & Hybrids, Driveline
Kingtec USA	Idle Reduction
Kodiak Innovations	Aerodynamics
Landi Renzo	Engines and Accessories, Alternative Fuels
Laydon	Aerodynamics
LG Chem	Transmissions & Hybrids, Electrification
Lightning Hybrids	Transmissions & Hybrids
Linamar	Engines and Accessories, Transmissions & Hybrids
Linde Group	Alternative Fuels
Loop	Transmissions & Hybrids, Electrification
Lytix	Intelligent Controls
MACK	Engines and Accessories, Alternative Fuels
Magna International	Engines and Accessories, Intelligent Controls
Magneti Marelli	Engines and Accessories, Transmissions & Hybrids, Intelligent Controls
Materia	Weight Reduction
Maxwell Technologies	Transmissions & Hybrids
Maxwell Transmission	Transmissions & Hybrids
Meritor	Transmissions & Hybrids, Driveline, Tires & Rolling Resistance, Intelligent Controls
Metalsa	Weight Reduction
Michelin	Tires & Rolling Resistance
Mobileye	Intelligent Controls
Morgan Olson	Alternative Fuels, Electrification
Motiv	Electrification

Navistar	Engines and Accessories, Intelligent Controls, Alternative Fuels, Transmissions & Hybrids, Idle Reduction, Electrification
Navitas	Transmissions & Hybrids, Idle Reduction, Electrification
Neapco	Driveline
New Eagle	Engines and Accessories, Transmissions & Hybrids, Electrification
New Flyer	Transmissions & Hybrids, Alternative Fuels, Electrification
NoseCone	Aerodynamics
Novelis	Weight Reduction
Nuvera	Electrification
NVIDIA	Intelligent Controls
Oberon Fuels	Alternative Fuels
Odyne	Transmissions & Hybrids, Idle Reduction
Omnitek Engineering	Alternative Fuels
Orange EV	Electrification
Pacific Ethanol	Alternative Fuels
Parker Hannifin	Transmissions & Hybrids
Peloton	Intelligent Controls
Pennex	Weight Reduction
Peterbilt	Engines and Accessories, Transmissions & Hybrids, Electrification
Phoenix Motorcars	Electrification
Pi Innovo	Engines and Accessories
Plug Power	Electrification
Proterra	Electrification
Quallion LLC	Electrification
Quantum Technologies	Transmissions & Hybrids, Alternative Fuels, Electrification
Ramos Oil Company	Alternative Fuels
Remy International	Transmissions & Hybrids, Driveline
Renasas Electronics	Driveline, Intelligent Controls, Electrification
Renewable Energy Group	Alternative Fuels
Ricardo	Transmissions & Hybrids, Driveline, Electrification
Ricconics	Aerodynamics
Ridge Corporation	Aerodynamics
Rio Tinto Aluminum	Weight Reduction
Rockford Drive Line	Driveline
SAFCeLL	Alternative Fuels
Saft	Electrification
Sandia National Labs	Engines and Accessories
Sapa	Weight Reduction
Schneider Electric	Electrification
Sevcon	Transmissions & Hybrids, Electrification

Siemens	Transmissions & Hybrids, Electrification
Sierra Energy	Alternative Fuels
Silver Eagle	Aerodynamics
Simbol Materials	Electrification
Slipstream Aerodynamics	Aerodynamics
SmartTruck	Aerodynamics
SOLUS	Aerodynamics
Southern California Gas Company	Alternative Fuels
Southern Company	Electrification
Spicer	Transmissions & Hybrids, Driveline
Springboard Biodiesel	Alternative Fuels
Sturman Industries	Engines and Accessories
Sumitomo Rubber USA	Tires & Rolling Resistance
Sumitomo Tires	Tires & Rolling Resistance
Sunspeed Enterprises	Electrification
Superior Industries International	Tires & Rolling Resistance
Sylvatex	Alternative Fuels
Syron Tires	Tires & Rolling Resistance
Taylor-Dunn	Transmissions & Hybrids
Tellus Technology	Tires & Rolling Resistance
Telogis	Intelligent Controls
Terex	Idle Reduction
Tesla	Electrification
The Green Station	Alternative Fuels
The Jankovich Company	Alternative Fuels
Thermo King	Idle Reduction
Thunderstruck Motors	Electrification
Tire Rack	Tires & Rolling Resistance
TrailerBlade	Aerodynamics
Transfer Flow Inc	Engines and Accessories
Transfoil Systems	Aerodynamics
Transportation Power	Electrification
Transtex	Aerodynamics
Trojan Battery Company	Electrification
TRW Automotive	Engines and Accessories, Transmissions & Hybrids, Intelligent Controls
Tula Technologies	Engines and Accessories
Turbonetics	Engines and Accessories
Unicell	Aerodynamics
Unique Technical Services	Transmissions & Hybrids, Electrification
UQM Technologies	Electrification
US Hybrid	Transmissions & Hybrids, Electrification
Utility	Aerodynamics
Valence Technology	Electrification
Valeo	Driveline, Intelligent Controls
VIA Motors Incorporated	Transmissions & Hybrids, Electrification
Visteon	Intelligent Controls

Wabash Composites	Aerodynamics
Waste Management	Alternative Fuels
WAVE	Electrification
Westport	Engines and Accessories, Alternative Fuels
Whole Energy	Alternative Fuels
Windyne	Aerodynamics
Woodward	Engines and Accessories, Alternative Fuels
Workhorse	Alternative Fuels, Electrification
Worthington Industries	Alternative Fuels
Wrightspeed	Transmissions & Hybrids, Electrification
XL Hybrids	Transmissions & Hybrids
Yokohama	Tires & Rolling Resistance
Zenith Motors	Electrification

Initial High Efficiency (low carbon) Heavy-Duty Vehicle Technology Categories

Main Categories	Tech included in Main Category	Initial Search terms for Category
Engine and Accessories (including waste heat recovery - WHR)	Advanced Engines, waste heat recovery, engine auxiliaries, electrified engine pumps/fans/components, aftertreatment systems, SCR, turbines	combustion optimization, turbocharging, engine friction and parasitic losses, exhaust aftertreatment, engine breathing system, engine downsizing, waste heat recovery (WHR), variable valve timing, opposed piston engines, transient control, cylinder deactivation, model based controls, electronic engine controls, high pressure rail, multiple event injectors, variable speed pumps, thermoelectric devices, variable speed water pump, variable displacement oil pump, high efficiency compressors, electric accessories, Advanced Lubricants, turbine engines, digital valves
Transmission and Hybrid	Automated Manual Transmissions (AMTs), automated transmission, Dual Clutch Transmissions (DCT), hybrids, hybrid electric, hybrid hydraulic, pneumatic hybrid, integrated starter generator (ISG) or alternator (ISA)	same as listed except add hybrid, mild hybrid, full hybrid, electric hybrid (HEV), hydraulic hybrid (HHV), pneumatic hybrid, dual clutch transmissions (DCT), Start-Stop Systems, idle stop, neutral idle, ultracapacitors, hybrid batteries, power batteries, hydraulic accumulators, pneumatic air tanks, ISG, ISA
Driveline	Axles, lubricants, bearings	6X2 Axles, low friction transmission, axle and wheel bearing lubricants, Advanced Lubricants, direct drive
Aerodynamics	Tractor aerodynamics, trailer aerodynamics	aerodynamic mirrors, front fairings, roof fairings, gap-reducing fairings, trailer skirts, boat tails, flow diffusers, side extenders, underbody devices, underbelly treatments, under trays
Tire/rolling resistance	Low rolling resistance (LRR) Tires and Tire Inflation systems	Tread material, tread design, tire inflation, wide based singles, double wide tires
Idle Reduction	Auxiliary Power Units (APUs), electric HVAC (heating, ventilation and cooling), worksite idle, electric TRUs (truck refrigeration units)	engine APU; battery APU; Thermal storage, battery air conditioning, fuel operated heaters, neutral idle, idle stop, workday idle, e-PTO, worksite idle, electric TRUs
Weight reduction	light weight materials	high strength steel, aluminum, thermo plastic materials, polycarbonate, composite materials, and Light Weight Wheels
Intelligent Controls	Intelligent controls (predictive cruise control)	Speed limiters, vehicle speed limiters (VSL), Predictive cruise control, vehicle platooning
Electrification	Full and partial driveline electrification (including Evs, PHEVs, Extended Range Evs, PEVs, Fuel Cell Evs), electric motors, power electronics, drive motor controllers, inverters, energy storage, fuel cells	Electric motors, permanent magnet (PM) motors, AC induction motors, switch reluctance (SR) motors, power electronics, DC-AC inverters, DC-DC converters, drive motor controllers, MOSFETS, energy storage, batteries, lithium ion (Li-ion) batteries, lithium polymer batteries, nickel metal hydride (NiMH) batteries, nickel cadmium batteries (NiCad), sodium sulfur (NaS) batteries, battery management systems (BMS), high voltage connectors/cables, fuel cells, fuel cell stack, fuel cell balance of plant
Alternative Fuels	fuel systems, fuel storage tanks, CNG tanks, LNG tanks, propane tanks, DME tanks	natural gas tanks, compressed natural gas (CNG), liquified natural gas (LNG), propane tanks, autogas, alternative fuel systems, fuel supply systems, DME tanks