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What Fleets Need to Know About Alternative Fuel Vehicle Conversions, Retrofits, and Repowers

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This publication is part of a series. For other lessons learned from the Clean Cities American Recovery and Reinvestment (ARRA) projects, please refer to the following publications:

- *American Recovery and Reinvestment Act – Clean Cities Project Awards* (DOE/GO-102016-4855 - August 2016)
- *Designing a Successful Transportation Project – Lessons Learned from the Clean Cities American Recovery and Reinvestment Projects* (DOE/GO-102017-4955 - September 2017)

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Disclaimer

This document is not intended for use as a "how to" guide for individuals or organizations performing a conversion, repower, or retrofit. Instead, it is intended to be used as a guide and resource document for informational purposes only.

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Key Terms

Certificate – An authorization issued from the Environmental Protection Agency (EPA) or the California Air Resources Board (CARB) certifying that a converted or retrofitted vehicle or engine meets emissions standards for the given model year.

Conversion – A process that involves modifying an existing engine through the use of a conversion kit to run on a fuel (such as an alternative fuel) or power source (such as electricity) that is different from the one it was originally designed to operate on.

Conversion kit – Also referred to as a "conversion system," conversion kits are available to modify gasoline and diesel vehicles for operation on propane, compressed natural gas (CNG), electric, or hybrid power. The elements of the kit depend on the type of alternative power source selected, but typically involve the addition of fuel-specific supply lines, storage system components and controllers, and engine recalibrations or software adjustments to the electronic engine control system.

QSR/QVM – A qualified system retrofitter (QSR) or qualified vehicle modifier (QVM) is commonly referred to as an "upfitter" or "installer." These are companies with trained technicians who have met strict requirements in order to convert certain vehicles.

OEM – Short for original equipment manufacturer, OEM is a term collectively used to describe major vehicle manufacturers. This is not to be confused with a kit manufacturer, which makes the additional vehicle components necessary to complete a vehicle conversion or retrofit.

Repower – A process that involves removing a vehicle's original engine and replacing it with a new engine or power source (such as an electric drive system). Because new engine components and older vehicle engine compartments are not designed for one another, repowering a vehicle requires an engineered solution by a trained technician.

Retrofit – A process that involves making diesel emission system modifications. This is most commonly achieved through the addition of engine exhaust aftertreatment hardware such as diesel particulate filters (DPFs), diesel oxidation catalysts (DOCs), selective catalytic reduction (SCR), crankcase emission control devices, or other modifications that reduce emissions.

Introduction

Balancing multiple, often conflicting priorities within daily operations is a way of life for most fleet managers. There is constant pressure to minimize the costs associated with operating and maintaining vehicles while simultaneously reducing vehicle emissions and environmental impact. Compounding these factors, there is also the expectation that a requisite number of vehicles will be in service around the clock.

Although purchasing new and more fuel-efficient vehicles is not always an option, there are a myriad of ways that existing vehicles can be modified to use alternative fuels and other advanced technologies. Vehicle conversions and retrofit packages, along with engine repower options, can help fleet managers achieve emissions and environmental goals, often at substantially lower capital costs.

Fleet managers can set projects up for success from the start by selecting the appropriate technology for specific vehicle applications, determining infrastructure costs and options, understanding applicable regulations, and thoroughly vetting technology vendors who perform the modifications. Additionally, fleet managers can ensure they are receiving credible information and get access to technical assistance in the event of any unforeseen challenges by working with their local Clean Cities coalition (*cleancities.energy.gov/coalitions/*).

This Ford F250 pickup truck was converted to run on propane. *Photo by Dennis Schroeder, NREL 33407*

Pacific Gas and Electric chose to convert its heavy-duty trucks to run on natural gas to obtain the emissions benefits and engine performance it was looking for. *Photo from Pacific Gas and Electric, NREL 14921*

The City and County of Denver's vehicle fleet includes hydraulic hybrid refuse hauler trucks. This technology is ideal for stop-and-go trash collection operations. *Photo from Denver Fleet Management, NREL 17153*

Definitions and Technology Options

Knowing which conversion, retrofit, or repower technology is the best fit for a fleet starts with understanding each option.

Conversions

Conventional vehicles or engines can be modified through the use of a conversion kit to run on a fuel or power source that is different from the one it was originally designed to operate on. The process to convert a vehicle depends on the type of alternative power source selected, but typically involves the addition of fuel-specific supply lines, storage system components and controllers, and engine recalibrations or software adjustments to the electronic engine control system. See Table 1 for more information about the typical modifications required for various fuel types.

Conversion kits are available that modify gasoline and diesel vehicles for operation on propane, compressed natural gas (CNG), ethanol (E85), or hybrid power. Vehicles and engines can be converted to "dedicated" configurations so that they operate exclusively on one alternative fuel. They can also be converted to "bi-fuel" configurations that include two separate fuel systems—one for a conventional fuel and another for an alternative fuel. In this type of configuration, either fuel can be used by flipping a switch. Although U.S. Environmental Protection Agency (EPA) regulations refer to bi-fuel

Table 1. Conversion Requirements for Various Alternative Fuels and Advanced Technologies

Alternative Fuel Type	Conversion Requirements
Natural Gas	The addition of fuel storage system components, such as fuel cylinders and supply lines, and other hardware, like fuel-specific injectors.
Propane	The addition of fuel storage system components, such as fuel cylinders and supply lines, and other hardware, like fuel-specific injectors.
E85/Ethanol	Modifications throughout the fuel system and electronic engine control system, including a fuel supply system made of ethanol-compatible materials and the addition of sensors. Sensors are typically sold as an original equipment manufacturer (OEM) product, and the OEM is responsible for making the modifications.
Biodiesel	Not typically considered an aftermarket conversion, but may require certification if engine modifications are required to accommodate the use of biodiesel as a vehicle fuel. Refer to the vehicle's manufacturer warranty to confirm whether the engine and fuel systems are compatible with biodiesel.
Hybrid Electric Vehicle (HEV)	Conversion requirements vary substantially from manufacturer to manufacturer
Plug-in Hybrid Electric Vehicle (PHEV)	Increasing the OEM vehicle's energy storage capacity by replacing or adding capacity to the battery, adding on-board charging equipment that allows the vehicle to be plugged in to charge, and adjusting the OEM battery management system. The most common application converts HEVs to PHEVs.
Hydraulic Hybrid Vehicle	The addition of hydraulic pumps and motors.

configurations as "dual-fuel," the term dual-fuel typically refers to another type of configuration where two fuels are used simultaneously (such as in a heavy-duty natural gas vehicle that uses a small amount of diesel for ignition assistance).

Most companies that sell conversion kits are referred to as aftermarket equipment manufacturers, but there are several designations to be aware of when engaging a vendor for these products. When you purchase a new alternative fuel light-duty vehicle through a dealership, the conversion kit is installed by the system manufacturer or by a company designated as a qualified system retrofitter or vehicle modifier (QSR or QVM). These companies have met strict requirements in order to convert certain vehicles from an original equipment manufacturer (OEM). When converting an in-service vehicle, the work should always be completed by a trained technician associated with a QSR or QVM—also referred to as an upfitter or installer—who is authorized to install a particular conversion kit.

All vehicle and engine conversions must meet standards instituted by the EPA, the National Highway Traffic Safety Administration (NHTSA), and state agencies like the California Air Resources Board (CARB).

Often, fleets can take advantage of federal and state-level funding opportunities and incentive programs to offset the costs associated with alternative fuel conversions. Contact your local Clean Cities coordinator (*cleancities.energy.gov/coalitions/contacts*) and consult the Alternative Fuels Data Center's Laws and Incentives section (*afdc.energy.gov/laws*) to determine which opportunities may be available in your location.

Retrofits

"Retrofits" is a term most often used to describe diesel emission system modifications. Retrofit technologies consist of hardware options that can be added to further reduce emissions from certified diesel engines. Engine exhaust after treatment hardware is the most common retrofit and includes technologies such as diesel particulate filters (DPFs), diesel oxidation catalysts (DOCs), selective catalytic reduction (SCR), crankcase emission control devices, or other modifications that reduce emissions.

A retrofit may involve adding a parallel fuel system, which allows the vehicle to run on an alternative fuel and meet or exceed EPA emissions standards. The EPA's Tips for a Successful Diesel Retrofit Project (*bit.ly/2uiytRx*) offers step-by-step recommendations to assist fleet managers in avoiding common mistakes associated with retrofit projects.

Products are available for non-road and on-road heavy-duty diesel engines for a wide range of model years. Each retrofit device is verified for use with specific engines and configurations, so taking an inventory of your existing fleet is an important first step in any retrofit project.

Retrofit technologies must meet emissions standards established by the EPA and CARB, which are outlined in lists of verified diesel retrofit technologies maintained by the respective agencies at the EPA's Verified Technologies List for Clean Diesel page (*epa.gov/verified-diesel-tech/verified-technologies-list-clean-diesel*) and CARB's Verification Procedure - Currently Verified page (*arb.ca.gov/diesel/verdev/vt/cvt.htm*).

There are a number of local and national funding sources to support the purchase and installation of retrofit technologies. In particular, the EPA Clean Diesel Program (*epa.gov/clean-diesel*) provides support for projects that improve air quality by reducing emissions from diesel engines. This program includes grants and rebates funded under the Diesel Emissions Reductions Act (DERA).

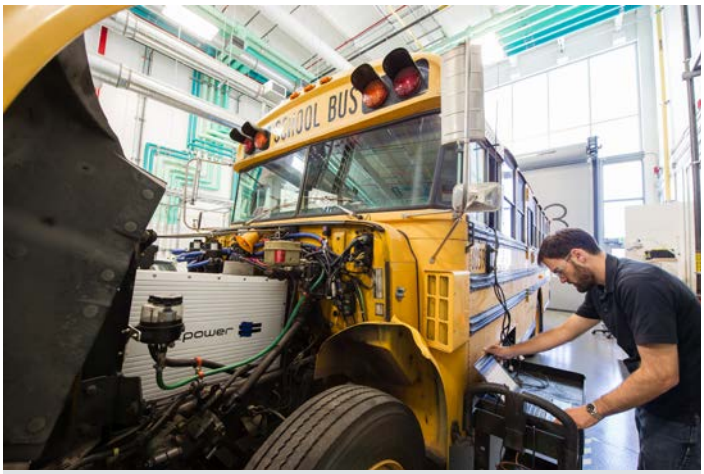
Repowers

A final option to consider, particularly with older vehicles, is repowering a vehicle. Repowering a vehicle consists of replacing an older engine with a new one that has been certified to meet cleaner emissions standards. However, while repowering a vehicle with a new engine may extend the life of the vehicle, reduce fuel consumption, and significantly reduce harmful emissions, a successful project requires an engineered solution by a trained technician. Because new engine components and older vehicle engine compartments are not designed for one another, repowering a vehicle often requires additional work, such as adding cooling system upgrades, installing emissions control devices, or altering the configuration of the engine compartment. Repowers are relatively expensive, so they are mostly performed on Class 7 and 8 trucks because their vehicle life is typically much longer than those of light- and medium-duty vehicles. Most heavy-duty engine manufacturers offer stock replacement engines, which are subject to emissions testing at the time of manufacture. More information on repowers, identifying a qualified technician, and obtaining technical assistance is available through the U.S. Department of Energy's Vehicle Technologies Office (*cleancities.energy.gov/technical-assistance/tiger-teams/*).

The Cummins Modular Aftertreatment System combines DOC, DPF, and SCR technology for meeting diesel engine emissions. *Photo courtesy of Cummins Engines*

Funding for engine repowers is available through many local and national sources, including the EPA Clean Diesel Program. See Table 2 for typical requirements related to the most common types of repowers.

Emissions Regulations



National Renewable Energy Laboratory researcher Andrew Meintz runs tests on a school bus that has been repowered with an electric motor. *Photo by Dennis Schroeder, NREL 38951*

The EPA has the authority to regulate vehicle emissions under the Clean Air Act (CAA) (*epa.gov/enforcement/air-enforcement*). As part of the regulations, light-duty vehicles and heavy-duty engines from OEMs must be certified to meet applicable emissions standards. Regulations are also in place to ensure that those emissions do not increase as a result of changes made to a vehicle or engine, including conversions, retrofits, and repowers. The CAA prohibits anyone from knowingly removing or rendering inoperative any device or design element installed on a certified vehicle or engine. These actions could be considered "tampering," a violation that carries a significant fine.

In the case of repowers, the engine and aftertreatment components have been certified to meet EPA emissions standards. Because conversions and retrofit systems modify an existing

Table 2. Repower Requirements for Various Alternative Fuels and Advanced Technologies

Fuel Type	Repower Requirements
Diesel*	Repowering a vehicle from diesel to diesel often requires an engineered solution, such as adding cooling system upgrades, installing emissions control devices, or altering the configuration of the engine compartment.
Electric Vehicle	The addition of an electric drive motor, traction battery, vehicle control system, cooling system, accessory drive systems, and chassis/body modifications
Natural Gas	The addition of a natural gas engine, fuel system, fuel tanks, cooling system, engine control system, and chassis/body modifications
Propane	The addition of a propane engine, fuel system, fuel tanks, cooling system, engine control system, and chassis/body modifications

**This may include biodiesel-compatible engines.*

system, EPA and CARB have developed regulations to prevent tampering.

These regulations specify that, so long as a system is compliant with EPA or CARB regulations, the manufacturer is exempt from the tampering prohibition for that particular system. Emissions standards are fuel neutral, which means that the same emissions requirements must be met regardless of which fuel or technology powers the engine or vehicle. So, vehicles with conversion kits must meet the same emissions standards that the original gasoline or diesel products first met.

Refer to the EPA's Alternative Fuel Conversion Vehicle and Engine website (*epa.gov/vehicle-and-engine-certification/vehicle-and-engine-alternative-fuel-conversions*) for the complete regulations, as well as compliance procedures and related information.

Manufacturers selling conversion kits for use in California must meet CARB requirements and obtain approval from CARB. EPA Certificates of Conformity or tampering exemptions are not required in California, nor will they take the place of CARB certification. For information on CARB procedures and requirements, visit the Certification of Alternative Fuel Retrofit Systems section of the CARB website (*arb.ca.gov/msprog/aftermkt/altfuel/altfuel.htm*).

Demonstrating Compliance

All conversion-kit manufacturers must prove that a given vehicle or engine conversion complies with EPA regulations (*epa.gov/vehicle-and-engine-certification/vehicle-and-engine-alternative-fuel-conversions*). This is established by an EPA or CARB Certificate of Conformity for the given engine family (see *Appendix B: EPA and CARB Certificates* on pp. 17-19). Fleet managers should request copies of EPA or CARB certificates and keep them on file with vehicle titles and other critical papers. Vehicle owners and fleet managers interested in converting vehicles must work with that conversion-kit manufacturer or an authorized representative. The actual conversion work must be performed by a trained technician at the company designated as a QSR or QVM by the kit manufacturer described above. Required demonstration and notification procedures differ based on the age of the converted vehicle or engine.

Both EPA and CARB require the installer to apply a Vehicle Emissions Control Information (VECI) label under the hood of the vehicle indicating that the vehicle and/or engine have been altered from their original configuration, but have slightly different requirements for information contained on the VECI label. For examples, see *Appendix A: Conversion and OEM VECI Labels* on p. 16.

New and Relatively New Vehicles and Engines

This category includes conversions that take place within a calendar year and not more than one year after the original model year of the vehicle/engine. Conversion-kit manufacturers must submit applications to the EPA, including test data, certification fees, and other information. Vehicles and engines in this category need an EPA or CARB Certificate of Conformity to qualify for an exemption from the EPA's tampering prohibition. The EPA or CARB then issues a certificate to verify that the appropriate regulations and requirements have been met.

Certificate documentation indicates the following:

- The original test group, as determined and provided by the manufacturer
- The evaporative emissions family
- The state(s) in which the test group is certified
- The "car line," which includes the model and engine size
- The model year of the vehicles included in the test group
- The emissions standards met.

A certificate is valid for the specified certification year (referred to as the Model Year at the top of the certificate). Certificates can be renewed. When they do expire, tampering exemptions remain in place as long as the conditions under which a certificate was issued do not change.

Intermediate Age Vehicles and Engines

This category includes conversions of vehicles or engines that are no longer "new or relatively new" but still fall within the EPA's definition of "useful life" (*bit.ly/2f3tG0Q*). Manufacturers of conversion kits within this category must demonstrate that the conversion meets emissions standards for the year in which the vehicle/engine was manufactured. The EPA does not issue certificates for this category but lists the compliant conversion kits online (*epa.gov/vehicle-and-engine-certification/lists-epa-compliant-alternative-fuel-conversion-systems*). Annual renewal is not required to maintain a tampering exemption.

Vehicles and Engines Outside Their Full Useful Life

This category includes conversions of vehicles or engines that are outside the EPA's definition of "useful life" (*bit.ly/2f3tG0Q*). Manufacturers must submit information verifying that the system is technically sound. As with the "intermediate age" category, the EPA does not issue certificates but publicly lists the compliant conversion kits as having satisfied the requirements. Annual renewal is not required to maintain a tampering exemption, as long as the conditions under which the exemption was granted do not change. Fleets should take note that some conversion kits are only certified for use on vehicles that are outside of useful life and it is illegal to install these kits onto new or intermediate age vehicles.

Considerations and Lessons Learned

Clean Cities has decades of experience in assisting fleets transitioning to alternative fuels. When pursuing the transition, it is important to understand the technology you are considering and partner with trusted resources to acquire accurate information. You should also conduct risk assessments and perform routine quality audits to ensure a successful result. Many principal investigators for past Clean Cities projects agree that, prior to engaging in a project, fleet managers should conduct their own research on project partners, technology suppliers, and equipment vendors to be certain that they are insured, reliable, and certified. It is also beneficial to establish and encourage open lines of communication among all project participants throughout the process. This way, if problems arise, they can be identified, addressed, and resolved quickly to keep projects on track and prevent costly repairs or safety incidents.

Selecting an Appropriate Conversion/Retrofit/Repower Option

The first step in the process of converting, retrofitting, or repowering a vehicle is to fully understand the attributes of the existing vehicle, the job that the vehicle is required to perform, and how the fuel or technology that you are considering for your conversion/retrofit/repower will impact the operation and performance of that vehicle. The cost of, and/or access to, public or shared-use infrastructure should also be considered, which is dependent on the type of fuel you choose.

The following list includes many of the items that should be considered prior to selecting a particular technology:

- **Fuel Properties** – Conventional fuels like diesel and gasoline have different properties than alternative fuels like propane or CNG that can cause them to behave differently inside an engine. For example, the combustion of natural gas and propane results in substantially higher temperatures.These fuels also have lower lubricating characteristics than that of traditional liquid fuels. For this reason, many OEMs offer specially designed engine packages known as "gaseous-prep" or "prep ready" packages. These engines include hardened intake and exhaust valves and valve seats, and high-temperature-tolerant materials that allow engines to perform well using gaseous fuels. In fact, many fleets routinely purchase "prep-ready" engines for their added durability, even if they use conventional fuels. When considering a move to

Pro Tip
When considering a move to gaseous fuels, a "prep ready" engine will help to prevent engine damage from the higher temperatures and lower lubricity associated with gaseous fuels.

Depending on the application and installation, extra storage tanks may displace cargo capacity, as seen in this Ford Transit taxi (pictured with its protective tank cover open for demostration purposes) that was converted to CNG. *Photo by Margaret Smith, NREL 18210*

gaseous fuels, it is imperative to ensure that the engines are "prep ready" to prevent engine damage from the higher temperatures and lower lubricity associated with gaseous fuels.

- **Driving Range** – While nearly 23,000 alternative fuel stations are available to the public across the country, with steady growth over the past decade, some regions of the country have greater access to certain fuels than others. The fuel economy for alternative fuels varies based on the energy density of the specific fuel, along with factors such as road grade, climate, and vehicle loading. It is important to understand which alternative fuels are available in your area and ascertain that fueling infrastructure for your chosen fuel is conveniently located along the route that your fleet drives. In many cases, a vehicle conversion can be customized to your specifications by appropriate tank sizing or the addition of extra fuel tanks to meet driving range requirements. To find fueling stations in your area, see the Alternative Fueling Station Locator (*afdc.energy.gov/locator/stations/*).

Pro Tip
Before choosing an alternative fuel, it is important to know that fueling infrastructure for your chosen fuel is conveniently located along the route that your fleet drives.

- **Cargo Capacity** – In the case of conversions and retrofits, additional equipment is often added to the vehicle as part of its modification. Careful consideration should be given to the placement of new equipment on an existing vehicle chassis to ensure sufficient space is available that does not interfere with the job the vehicle needs to perform. For example, extra storage tanks can increase driving range, but the placement of these tanks and their additional weight may displace cargo capacity. Similarly, the chassis of a very old diesel vehicle may not have sufficient space or strength to accommodate the quantity of equipment necessary for a modern diesel emission system or the heavy batteries associated with an electric vehicle conversion.

Pro Tip
Careful consideration should be given to the placement of new equipment on an existing vehicle chassis to ensure sufficient space is available that does not interfere with the job the vehicle needs to perform.

- **Space for New Engines and Components** – In the case of repowers, a new engine and its associated components are installed in a space that was originally designed for the old engine, which likely had fewer external components. In particular, new engines typically require extra cooling, which is often in the form of additional radiators and additional heat shielding, both of which take up more space in the engine compartment. In addition, the various attachment points for fuel lines and storage tanks, additional components, and the interface between the engine and transmission will require an engineered solution to ensure that the new engine footprint can work in an old vehicle body and chassis.

Pro Tip
Repowering a vehicle will require an engineered solution to ensure that the new engine footprint can work in an old vehicle body and chassis.

- **Drive-Cycle and Duty-Cycle** – The attributes of certain fuels make them better candidates for certain types of driving. Understanding what type of driving and work a vehicle will experience can help determine which fuel offers the greatest return on investment. For example, hybrid vehicles tend to perform well in stop-and-go city driving where the regenerative braking system has more opportunities to charge the hybrid battery. Performing a hybrid conversion on a vehicle that drives primarily at highway speeds and encounters little stop-and-go traffic may not achieve the advertised and desired fuel economy benefits.

Pro Tip
Understanding what type of driving and work a vehicle will experience can help determine which fuel offers the greatest return on investment.

- **Crashworthiness** – Any equipment that was not part of the vehicle's original configuration has the potential to impact its performance in an accident. Vehicle conversions that require the addition of heavy battery systems

Pro Tip
Vehicle conversions that require the addition of new components may need to be safety crash tested and certified to comply with Federal Motor Vehicle Safety Standards (FMVSS) and other NHTSA regulations.

This CNG vehicle conversion facility is outfitted with a fuel-leak mitigation system. The system includes the in-wall exhaust fan shown in the upper right. *Photo by Amy Glickson, NREL 45006*

A technician at Redmark CNG Services in Colorado, a QSR/QVM upfitter, discusses the fuel system of a vehicle being converted to run on compressed natural gas. *Photo by Amy Glickson, NREL 44920*

or additional fuel tanks that may alter a vehicle's center of gravity, payload capacity, or handling characteristics may need to be safety crash tested and certified to comply with Federal Motor Vehicle Safety Standards (FMVSS) and other NHTSA regulations.

- **Emissions Compliance** – All manufacturers must prove that a given vehicle or engine conversion complies with EPA or CARB regulations. These regulations are in place to ensure that emissions do not increase as a result of changes made to a vehicle or engine. Unfortunately, not all aftermarket conversion companies subject their equipment to rigorous emissions testing and some market segments do not require full chassis emissions testing (only dynamometer testing of the engine itself). For these reasons, it is important to use EPA/CARB-certified conversion kits and to request emissions and compliance data directly from the manufacturer for market segments where full emissions testing is not required. This will help to ensure that the conversion/retrofit/repower system you select does not inadvertently increase tailpipe emissions.

Pro Tip
It is important to use EPA/CARB-certified conversion kits and to request emissions and compliance data directly from the manufacturer.

- **Facility Modifications** – Most fleet maintenance facilities are designed to service gasoline- and diesel-fueled vehicles. Facilities that maintain alternative fuel vehicles require additional safety measures that are designed to the characteristics of the different fuels. Gaseous fuels like natural gas are lighter than air and will therefore rise to the ceiling in the event of a gas release. Although some of the means of protection safety precautions are similar, the types and placement of building systems and protective equipment are different because of the different behavior of the fuels. For more information about CNG facility modification requirements, see the *Compressed Natural Gas Vehicle Maintenance Facility Modification Handbook* (*afdc.energy.gov/uploads/publication/cng_maintenance_facility_mod.pdf*).

Pro Tip
Most fleet maintenance facilities are designed to service gasoline- and diesel-fueled vehicles and require additional safety measures to service alternative fuel vehicles.

- **Vehicle Downtime** – The time required to perform an aftermarket conversion varies depending on the complexity of the system. If a fleet manager plans to convert vehicles that are currently in service, the installation of the equipment can result in vehicle downtime. Fleet managers should consider vehicle downtime in their planning and potentially convert vehicles incrementally so that a significant portion of the fleet is not out of service at any given time. Be sure to discuss installation time and scheduling with the manufacturer or QSR/QVM as necessary.

Pro Tip
Fleet managers should consider vehicle downtime in their planning and potentially convert vehicles incrementally so that a significant portion of the fleet is not out of service at any given time.

Vendor Selection

After carefully considering the factors above and selecting an appropriate conversion/retrofit/repower technology for your fleet, it is time to draft a request for proposal (RFP) or request for quote (RFQ) to select the vendor for your desired equipment. Fleet managers are encouraged to design RFPs and RFQs to include terms and conditions specific to systems installation, as this will help to ensure that installations are performed correctly,

safely, and to address any specialized fleet needs. These terms and conditions should carry over to any contracts signed with a manufacturer or QSR/QVM. A suggested best practice, particularly for fleet managers intending to convert a significant number of vehicles, is to incorporate an evaluation period. For example, a fleet would require a certain number of vehicles to be converted, allow time for your personnel to conduct independent testing and inspection as necessary, and proceed with the remaining conversions only when approved by the fleet manager.

Installations should be performed according to:

- Manufacturer guidelines
- Widely accepted industry practices
- National codes and standards
- Requirements that apply at the state or local levels
- Standard business certifications and internal guidelines and quality control procedures.

An additional best practice is to include periodic inspections as part of your contract with a vendor. This provides the opportunity for "spot checks" to be performed throughout the project and across several waves of installations to ensure continued installation quality and adherence to established procedures. If you do not have access to an in-house expert, consult with your local Clean Cities coalition to ensure you are receiving sound advice throughout the installation process.

If possible, a site visit to the installation facility is recommended in order to verify the information a vendor provided in the RFPs/RFQs, as well as to gather references and other details. This practice will also help to establish a face-to-face working relationship with the vendor.

Regardless of the type of conversion/retrofit/repower system or vendor that you select, the following items should be investigated prior to engaging them to complete your project:

- **Financial/Business Solvency** – A risk assessment should be performed to determine if the company is financially solvent. This may include requesting copies of business records such as tax returns, corporate banking statements, and insurance coverage directly from the potential partner. In addition, checking sources like the Better Business Bureau and credit rating services, and obtaining public records that reflect business licenses, pending lawsuits, bankruptcies, or court filings can provide good insight into a company's status. While this can be a time-consuming process, it is worthwhile to ensure that the company will have the capability to complete the project and be available for troubleshooting and warranty work once the vehicle conversions are complete.

Pro Tip
Risk assessments should be performed to ensure the company will have the capability to complete the project and address warranty issues once the conversions are complete.

- **References** – Sourcing a reference list of customers that the company has worked with in the past and reaching out to several of them to discuss their experience in working with the company can be very informative. Be sure to ask references about things such as vehicle performance and reliability, in addition to customer service considerations, such as their level of responsiveness to inquiries. Lack of responsiveness or a high degree of staff turnover may be indicative of problems.

Pro Tip
Be sure to ask references about things such as their vehicle's performance and reliability, in addition to customer service considerations, such as the company's level of responsiveness to inquiries.

- **Trained Personnel** – It is recommended that work be performed by licensed technicians authorized by the system manufacturer. Manufacturers should provide a comprehensive training program and detailed documentation to their own technicians, as well as employ QSR/QVM-certified technicians to ensure that the equipment and components are installed properly. Successful installation of a conversion/retrofit/repower system is highly dependent upon the skills, training, and attentiveness of the person performing the work. Always inquire about the training and qualifications required of the system installers. Technicians installing the equipment and components should be experts in the fuel or technology they are working with to ensure that systems are installed correctly and with all the relevant safety factors and best practices taken into account.

Pro Tip
Always inquire about the training and qualifications required of the system installers.

This kit allows a gasoline-powered vehicle to be converted to run on CNG. *Photo by Amy Glickson, NREL 44909*

- **Adherence to Procedures** – Installation of a conversion/retrofit/repower system requires a set of written procedures to certify that the process is performed in a safe, proper, and repeatable manner. Vendors of these systems should be able to provide their procedures and describe how they guarantee that their technicians are following the procedures during each installation.

> **Pro Tip**
> Ask to see a set of written procedures to certify that the process is performed in a safe, proper, and repeatable manner.

- **Inventory Control Measures** – Conversion kits include many, often very small components. Some of these components, such as fuel tanks, require careful handling and storage to prevent damage. Inventory control measures are important to certify all pieces of a conversion kit are accounted for and in good condition. It is also important to keep components together to prevent technicians from pulling from more than one conversion kit at a time, which can result in incomplete boxes of parts by the time they get to the end of the project. A good inventory control system includes multiple levels of sign-off between the vendor, the installer, and the customer to ensure quality. It is important to make sure that all of the small washers, fittings, and hoses are kept together from the point that the system is delivered to the facility until it is installed on the vehicle. Furthermore, it is important to store fuel tanks properly to prevent dents, dings and/or rust that can seriously impact the structural integrity and safety of the tank.

> **Pro Tip**
> Inventory control measures are important to certify all pieces of a conversion kit are accounted for and in good condition.

- **Warranty** – In most cases, it is advantageous to work directly with an OEM because of their ability to offer assurances that the technology will work seamlessly with the original vehicle. OEMs may also be able to provide a warranty coverage that ensures the longevity of the system.

  Aside from OEMs, there are a number of aftermarket companies that provide alternative fuel conversions. The optimal scenario in this case is to choose an aftermarket system offered by a QSR/QVM. Using either an OEM or QSR/QVM's system is highly encouraged. Companies considered a QSR/QVM work hand-in-hand with the OEM to ensure compatibility with the underlying vehicle systems and are able to install the systems without voiding manufacturer warranty.

> **Pro Tip**
> If using the products and services from non-OEM, non-QSR/QVM, be extra cautious to ensure you understand how the system works, how it impacts your vehicle's OEM warranty, and how to find continued support for your vehicles in the event that the original supplier goes out of business.

  There are also a number of independent vendors who may not work in collaboration with OEMs to develop and/or certify their products. If using the products and services from a vendor that is not an OEM or QSR/QVM, be extra cautious to ensure you understand how the system works, how it impacts your vehicle's OEM warranty, and how to find continued support for your vehicles in the event that the original supplier goes out of business.

- **Service and Maintenance Requirements** – Conversions, retrofits and repowers introduce new equipment onto the vehicle and it is important for fleets to understand how this equipment can impact critical service, maintenance and inspection requirements.

  Fleets should request a written list of items installed onto each vehicle, including any components that have specific inspection and maintenance requirements and/or expiration dates. For example, CNG fuel tanks have unique inspection requirements and an end-of-life expiration date. The tanks must be inspected at regular intervals, after accidents, or when there is suspected damage. It is also critical to know the end-of-life date of the CNG fuel tank to ensure that it is taken out of service and properly decommissioned at the end of its life. To prevent having to remove and replace tanks, fleets should confirm that any tanks installed on the vehicle will last for the entire expected service life of that vehicle.

> **Pro Tip**
> Fleets should obtain a written list of items installed onto the vehicle by vendors, including any components that have specific inspection and maintenance requirements and/or expiration dates.

Technical Assistance

Despite following all of the guidance described above, fleet managers can sometimes experience unexpected challenges with conversion/retrofit/repower projects. In the event of an unforeseen issue with a project, there are many resources available to help get projects back on track.

Direct consultation with the manufacturer of the conversion/retrofit/repower equipment should always be a fleet's first course of action in the event of a problem. The manufacturer can assess the product for manufacturing defects and/or recalls and perform an investigation into whether installation was performed to established quality standards. In the event that further assessment is required, the manufacturer is in the best position to troubleshoot its own technology and, depending upon the extent of the issue, institute changes system-wide to prevent them in the future.

If a manufacturer is unwilling or unable to address safety or performance issues, or provide warranty coverage, assistance is available through the Clean Cities Technical Assistance Project (Tiger Teams) (*cleancities.energy.gov/technical-assistance/tiger-teams/*). Tiger Teams is a group of highly skilled experts from national laboratories and industry that can provide on-the-ground consultation to tackle difficult technical and market challenges that exhaust local resources. With many years of hands-on experience with these technologies, Tiger Teams experts work with fleet operations staff, fuel providers, fueling equipment suppliers, vehicle conversion companies, and equipment and vehicle manufacturers to assist with all phases of alternative fuel projects. Fleet managers are encouraged to contact their local Clean Cities coordinator, who can connect them with Tiger Teams assistance.

Conclusion

Conversion, retrofit, and repower options provide fleet managers with alternative fuel and advanced vehicle options, in addition to those offered by OEMs. With proper education and planning, fleet managers can make certain their chosen technologies are compliant with applicable safety and emissions standards, make informed decisions about which products are best suited to their particular operations, and ensure quality installations.

References

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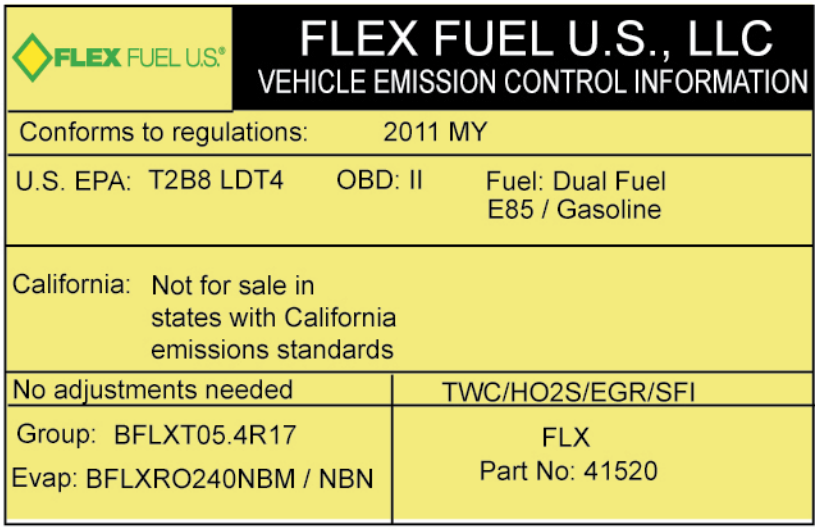
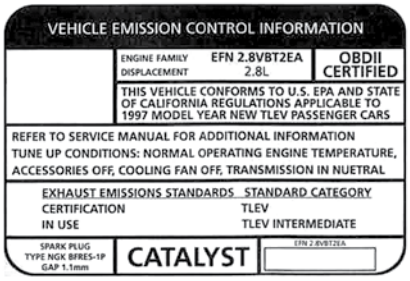
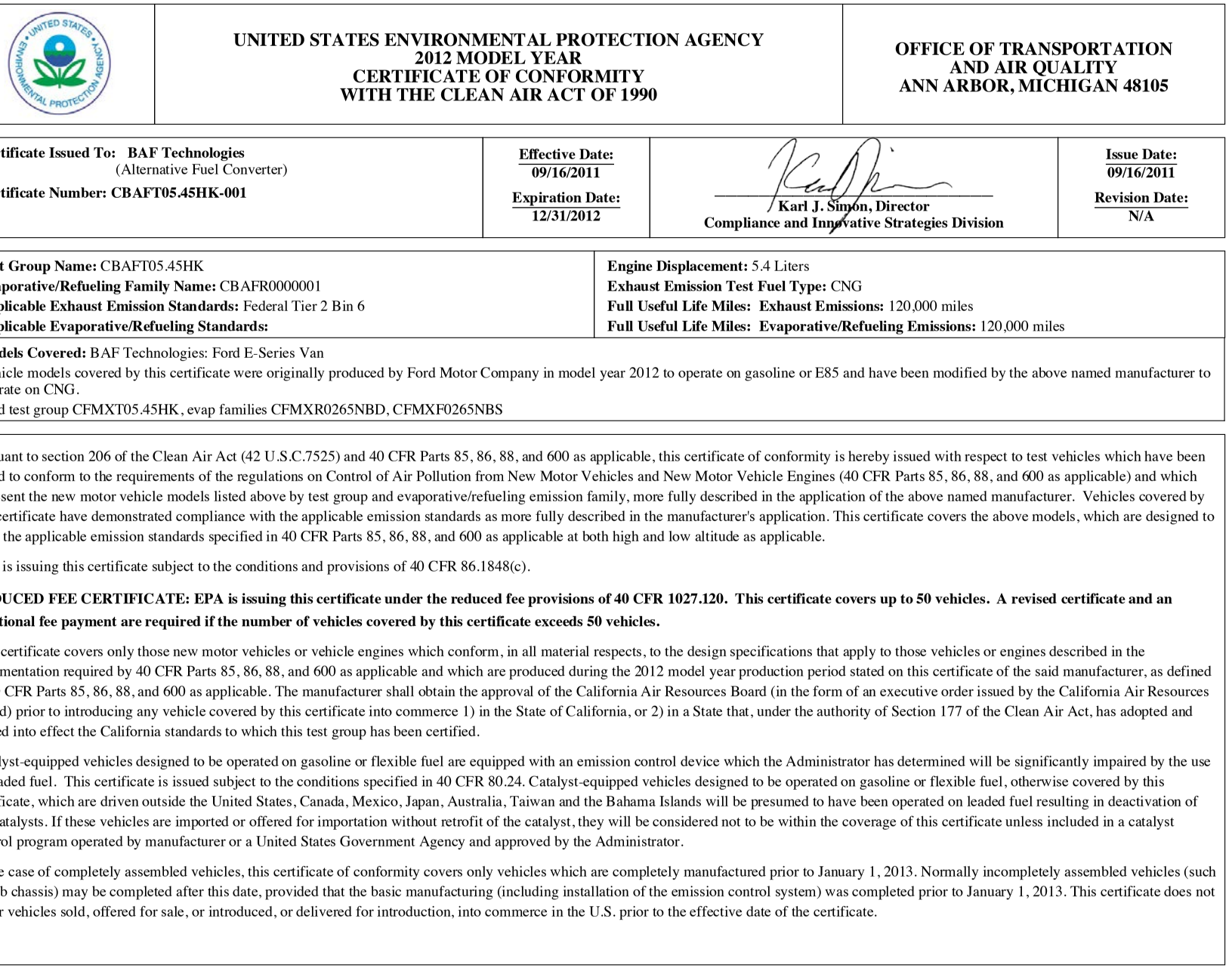
Appendix A: Conversion and OEM VECI Labels

BAF A CLEAN ENERGY COMPANY		***Vehicle Emission Control Information***
2327 Beatrice Street, Dallas, TX 75208 (214) 231-1450		MY 2012
U.S. EPA: LDT1 T2B2	OBD: FED	Fuel: CNG
CNG 2.0L - Test Group: CBAFT02.01DW		EVAP: **CBAFR0000001**
ECS: TWC, HO2S, EGR, SFI		NO ADJUSTMENTS
CNG System Compliant Only When Installed On The Following Vehicles:		
OEM 2012 - Gasoline Test Group: CFMXT02.01DW		**EVAP: CFMXR0125NBB**
This clean alternative fuel conversion system has been certified to meet EPA emission standards.		
This vehicle has been equipped with a clean alternative fuel conversion system designed to allow it to operate on a fuel other than the fuel it was originally certified to operate on.		
CNG System Installed By:		
CNG System Installer Address:		
CNG System Installation Date:	/ /	CNG Fuel Capacity: 12 - 16 GGE
CNG System Installation Mileage:		*Form #: C-TC-FED*
This conversion was manufactured and installed consistent with the principles of good engineering judgment and all U.S. EPA regulations.		





Examples of two conversion Vehicle Emissions Control Information (VECI) labels (top, middle) and one original equipment manufacturer (OEM) VECI label (bottom). Conversion VECI labels must be placed under the vehicle hood near the OEM VECI label. *Images from BAF Technologies, Flex Fuel U.S., and the California Air Resources Board*



UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
2012 MODEL YEAR
CERTIFICATE OF CONFORMITY
WITH THE CLEAN AIR ACT OF 1990

OFFICE OF TRANSPORTATION
AND AIR QUALITY
ANN ARBOR, MICHIGAN 48105

Certificate Issued To: **BAF Technologies**
(Alternative Fuel Converter)

Certificate Number: CBAFT05.45HK-001

Effective Date: 09/16/2011

Expiration Date: 12/31/2012

Karl J. Simon, Director
Compliance and Innovative Strategies Division

Issue Date: 09/16/2011

Revision Date: N/A

Test Group Name: CBAFT05.45HK
Evaporative/Refueling Family Name: CBAFR0000001
Applicable Exhaust Emission Standards: Federal Tier 2 Bin 6
Applicable Evaporative/Refueling Standards:

Engine Displacement: 5.4 Liters
Exhaust Emission Test Fuel Type: CNG
Full Useful Life Miles: Exhaust Emissions: 120,000 miles
Full Useful Life Miles: Evaporative/Refueling Emissions: 120,000 miles

Models Covered: BAF Technologies: Ford E-Series Van
Vehicle models covered by this certificate were originally produced by Ford Motor Company in model year 2012 to operate on gasoline or E85 and have been modified by the above named manufacturer to operate on CNG.
Ford test group CFMXT05.45HK, evap families CFMXR0265NBD, CFMXF0265NBS

Pursuant to section 206 of the Clean Air Act (42 U.S.C.7525) and 40 CFR Parts 85, 86, 88, and 600 as applicable, this certificate of conformity is hereby issued with respect to test vehicles which have been found to conform to the requirements of the regulations on Control of Air Pollution from New Motor Vehicles and New Motor Vehicle Engines (40 CFR Parts 85, 86, 88, and 600 as applicable) and which represent the new motor vehicle models listed above by test group and evaporative/refueling emission family, more fully described in the application of the above named manufacturer. Vehicles covered by this certificate have demonstrated compliance with the applicable emission standards as more fully described in the manufacturer's application. This certificate covers the above models, which are designed to meet the applicable emission standards specified in 40 CFR Parts 85, 86, 88, and 600 as applicable at both high and low altitude as applicable.

EPA is issuing this certificate subject to the conditions and provisions of 40 CFR 86.1848(c).

REDUCED FEE CERTIFICATE: EPA is issuing this certificate under the reduced fee provisions of 40 CFR 1027.120. This certificate covers up to 50 vehicles. A revised certificate and an additional fee payment are required if the number of vehicles covered by this certificate exceeds 50 vehicles.

This certificate covers only those new motor vehicles or vehicle engines which conform, in all material respects, to the design specifications that apply to those vehicles or engines described in the documentation required by 40 CFR Parts 85, 86, 88, and 600 as applicable and which are produced during the 2012 model year production period stated on this certificate of the said manufacturer, as defined in 40 CFR Parts 85, 86, 88, and 600 as applicable. The manufacturer shall obtain the approval of the California Air Resources Board (in the form of an executive order issued by the California Air Resources Board) prior to introducing any vehicle covered by this certificate into commerce 1) in the State of California, or 2) in a State that, under the authority of Section 177 of the Clean Air Act, has adopted and placed into effect the California standards to which this test group has been certified.

Catalyst-equipped vehicles designed to be operated on gasoline or flexible fuel are equipped with an emission control device which the Administrator has determined will be significantly impaired by the use of leaded fuel. This certificate is issued subject to the conditions specified in 40 CFR 80.24. Catalyst-equipped vehicles designed to be operated on gasoline or flexible fuel, otherwise covered by this certificate, which are driven outside the United States, Canada, Mexico, Japan, Australia, Taiwan and the Bahama Islands will be presumed to have been operated on leaded fuel resulting in deactivation of the catalysts. If these vehicles are imported or offered for importation without retrofit of the catalyst, they will be considered not to be within the coverage of this certificate unless included in a catalyst control program operated by manufacturer or a United States Government Agency and approved by the Administrator.

In the case of completely assembled vehicles, this certificate of conformity covers only vehicles which are completely manufactured prior to January 1, 2013. Normally incompletely assembled vehicles (such as cab chassis) may be completed after this date, provided that the basic manufacturing (including installation of the emission control system) was completed prior to January 1, 2013. This certificate does not cover vehicles sold, offered for sale, or introduced, or delivered for introduction, into commerce in the U.S. prior to the effective date of the certificate.

Figure 3: An example of an EPA Certificate of Conformity for BAF Technologies. *Image from BAF Technologies*

California Environmental Protection Agency AIR RESOURCES BOARD	ROUSH INDUSTRIES INC.	EXECUTIVE ORDER A-344-0019 New Passenger Cars, Light-Duty Trucks and Medium-Duty Vehicles

Pursuant to the authority vested in the Air Resources Board by Health and Safety Code (HSC), Div. 26, Part 5, Chap. 2; and pursuant to the authority vested in the undersigned by HSC Sections 39515 & 39516 and Executive Order G-02-003;

IT IS ORDERED AND RESOLVED:
That the following exhaust and evaporative emission control systems produced by the manufacturer are certified as described below. Production vehicles shall be in all material respects the same as those for which certification is granted.

MODEL YEAR	TEST GROUP	VEHICLE TYPE	EXHAUST EMISSION STANDARD CATEGORY	USEFUL LIFE (miles)		INTERMEDIATE IN-USE COMPLIANCE (*=N/A or full in-use; A/E=exh. / evap. intermediate in-use)		FUEL TYPE
				EXH / ORVR	EVAP	EXH	EVAP	
2011	BRIIT05.45HS	MDV: 8501-10000# GVW	"LEV II" Super Ultra Low Emission Vehicle (LEV II SULEV)	120K	150K	*	*	Liquefied Petroleum Gas

No.	ECS & SPECIAL FEATURES	EVAPORATIVE FAMILY (EVAF)	DISPLACEMENT (L)
1	2TWC, 2HAFS,2HO2S, SFI, OBD(P)	BRIIF0265LPG	5.4
*	*	BRIIR0265LPG	
*	*	*	
*	*	*	

See the Attachment for Vehicle Models, Evaporative Family, Engine Displacement, Emission Control Systems, Phase-In Standards, OBD Compliance, Emission Standards and Certification Levels, and Abbreviations.

BE IT FURTHER RESOLVED:
That the exhaust and the evaporative emission standards and the certification emission levels for the listed vehicles are as listed on the Attachment. Compliance with the 50° Fahrenheit testing requirement may have been met based on the manufacturer's submitted compliance plan in lieu of testing. Any debit in the manufacturer's "NMOG Fleet Average" (PC or LDT) or "Vehicle Equivalent Credit" (MDV) compliance plan shall be equalized as required.

BE IT FURTHER RESOLVED:
That for the listed vehicle models, the manufacturer has attested to compliance with Title 13, California Code of Regulations, (13 CCR) Sections 1965 [emission control labels], 1968.2 [on-board diagnostic, full or partial compliance], 2035 et seq. [emission control warranty], 2235 [fuel tank fill pipes and openings] (gasoline and alcohol fueled vehicles only), and "High-Altitude Requirements" and "Inspection and Maintenance Emission Standards" (California Exhaust Emission Standards and Test Procedures for 2001 and Subsequent Model PC, LDT and MDV).

BE IT FURTHER RESOLVED:
The test group listed in this Executive Order is certified conditionally on the manufacturer providing test data to determine the greenhouse gas (GHG) emissions for the listed test group, expressed in grams per mile of carbon dioxide-equivalent (g/mi CO2-e), as required in section E.2.5.2 of the California Exhaust Emission Standards and Test Procedures for 2001 and Subsequent Model Passenger Cars, Light-Duty Trucks, and Medium-Duty Vehicles, as amended August 4, 2005 (the Test Procedures). Manufacturer shall provide the required data within 45 days after the date of the Executive Order unless (a) an extension is granted by the Executive Officer, or (b) the manufacturer demonstrates to the satisfaction of the Executive Officer that it is exempt from determining GHG emissions for the listed test group under section E.2.5.3 (Intermediate Volume Manufacturers) or E.2.5.4 (Small Volume Manufacturers) of the Test Procedures. Failure to comply with the certification requirement to determine the GHG emissions for the listed test group may be cause for the Executive Officer to revoke the Executive Order. Vehicles in the revoked Executive Order shall be deemed uncertified and subject to penalties authorized under California law. Notwithstanding the requirement therein, the manufacturer is not required to determine GHG emissions for any medium-duty vehicles in the listed test group that are not medium-duty passenger vehicles.

Vehicles certified under this Executive Order shall conform to all applicable California emission regulations.

The Bureau of Automotive Repair will be notified by copy of this Executive Order.

Executed at El Monte, California on this 18 day of March 2011.

Annette Hebert, Chief
Mobile Source Operations Division

Figure 4: An example of a California Air Resources Board approval certificate for Roush Industries *Image from Roush Industries*

California Environmental Protection Agency
AIR RESOURCES BOARD

ROUSH INDUSTRIES INC.

EXECUTIVE ORDER A-344-0019
New Passenger Cars, Light-Duty Trucks and Medium-Duty Vehicles

ATTACHMENT

EXHAUST AND EVAPORATIVE EMISSION STANDARDS AND CERTIFICATION LEVELS

(For bi-, dual- or flexible-fueled vehicles, the STD and CERT in parentheses are those applicable to testing on gasoline test fuel).

CH4=methane; **NMOG**=non-CH4 organic gas; **NMHC**=non-CH4 hydrocarbon; **CO**=carbon monoxide; **NOx**=oxides of nitrogen; **HCHO**=formaldehyde; **PM**=particulate matter; **RAF**=reactivity adjustment factor; **2/3 D** [g/test]=2/3 day diurnal+ hot-soak; **RL** [g/mi]=running loss; **ORVR** [g/gallon dispensed]=on-board refueling vapor recovery; **g**=gram; **mg**=milligram **mi**=mile; **K**=1000 miles; **F**=degrees Fahrenheit; **SFTP**=supplemental federal test procedure

NMOG FLEET AVERAGE [g/mi]		NMOG @ RAF=* CH4 RAF = *		NMOG or NMHC STD [g/mi]	CO [g/mi]		NOx [g/mi]		HCHO [mg/mi]		PM [g/mi]		Hwy NOx [g/mi]	
CERT	STD	NMOG CERT [g/mi]	NMHC CERT [g/mi]		CERT	STD	CERT	STD	CERT	STD	CERT	STD	CERT	STD
*	*													
	@ 50K	*	*	*	*	*	*	*	*	*	*	*	*	*
	@ UL	0.039	*	0.100	2.5	3.2	0.02	0.1	2	8	*	0.06	0.04	0.2
	@ 50°F & 4K	0.043	*	0.200	1.7	3.2	0.02	0.1	4	16	*	*	*	*

CO [g/mi] @ 20°F & 50K			NMHC+NOx [g/mi] (composite)		CO [g/mi] (composite)		NMHC+NOx [g/mi] [US06]		CO [g/mi] [US06]		NMHC+NOx [g/mi] [SC03]		CO [g/mi] [SC03]	
			CERT	STD	CERT	STD	CERT	STD	CERT	STD	CERT	STD	CERT	STD
CERT	*	SFTP @ * miles	*	*	*	*	*	*	*	*	*	*	*	*
STD	*	SFTP @ * miles	*	*	*	*	*	*	*	*	*	*	*	*

Evaporative Family	3-Days Diurnal + Hot Soak (grams/test) @ UL		2-Days Diurnal + Hot Soak (grams/test) @ UL		Running Loss (grams/mile) @ UL		On-Board Refueling Vapor Recovery (grams/gallon) @ UL	
	CERT	STD	CERT	STD	CERT	STD	CERT	STD
BRIIF0265LPG	0.38	1.00	0.33	1.25	*	0.05	*	*
BRIIR0265LPG	0.38	1.00	0.33	1.25	*	0.05	*	*
*	*	*	*	*	*	*	*	*

y vehicle; ECS= Emission Control System; STD= Standard; CERT= Certification; onal-LEV; ULEV=ultra-LEV; SULEV=super-ULEV; TWC=3-way-catalyst; r; HO2S=heated O2S; AFS/HAFS=air-fuel-ratio sensor / heated-AFS; EGR=exhaust SFI=sequential MFI; TBI=throttle body injection; DGI=direct gasoline fuel injection; stic; DOR=direct ozone reducing; prefix 2=parallel; (2) suffix=series; CNG/LNG=

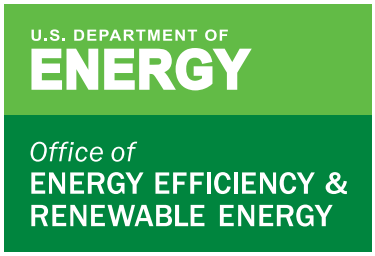
* = not applicable; UL=useful life; PC=passenger car; LDT=light-duty truck; MDV=medium-dut LVW=loaded vehicle weight; ALVW=adjusted LVW; LEV=low-emission vehicle; TLEV=transiti ADSTWC=adsorbing TWC; WU=warm-up catalyst; OC=oxidizing catalyst; O2S=oxygen senso gas recirculation; AIR=secondary air injection; PAIR=pulsed AIR; MFI= multiport fuel injection; TC/SC= turbo/super charger; CAC=charge air cooler; OBD (F)/(P)=full/partial on-board diagnos compressed/liquefied natural gas; LPG=liquefied petroleum gas; E85="85%" Ethanol Fuel;

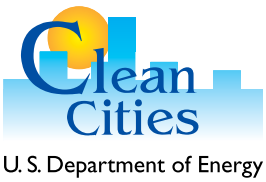
E MODELS INFORMATION

2011 MODEL YEAR: VEHICL

E	ECS NO.	ENGINE SIZE (L)	INTERMEDIATE IN-USE COMPLIANCE (*=N/A or full in-use; A/E=exh. / evap. intermediate in-use)		PHASE-IN STD.	OBD II	MAKE	MODEL	EVAPORATIVE FAMILY
			EXH	EVAP					
5	1	5.4	*	*	*	Partial	ROUSH	E150 CLUB WAGON PROPANE	BRIIR0265LPG
5	1	5.4	*	*	*	Partial	ROUSH	E350 CLUB WAGON PROPANE	BRIIR0265LPG
5	1	5.4	*	*	*	Partial	ROUSH	E150 VAN PROPANE	BRIIR0265LPG
5	1	5.4	*	*	*	Partial	ROUSH	E250 VAN PROPANE	BRIIR0265LPG
5	1	5.4	*	*	*	Partial	ROUSH	E350 VAN PROPANE	BRIIR0265LPG
5	1	5.4	*	*	*	Partial	ROUSH	E350 CUTAWAY PROPANE	BRIIF0265LPG

Figure 4 continued





For more information, visit: cleancities.energy.gov

Clean Cities Technical Response Service
800-254-6735 · *technicalresponse@icfi.com*

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