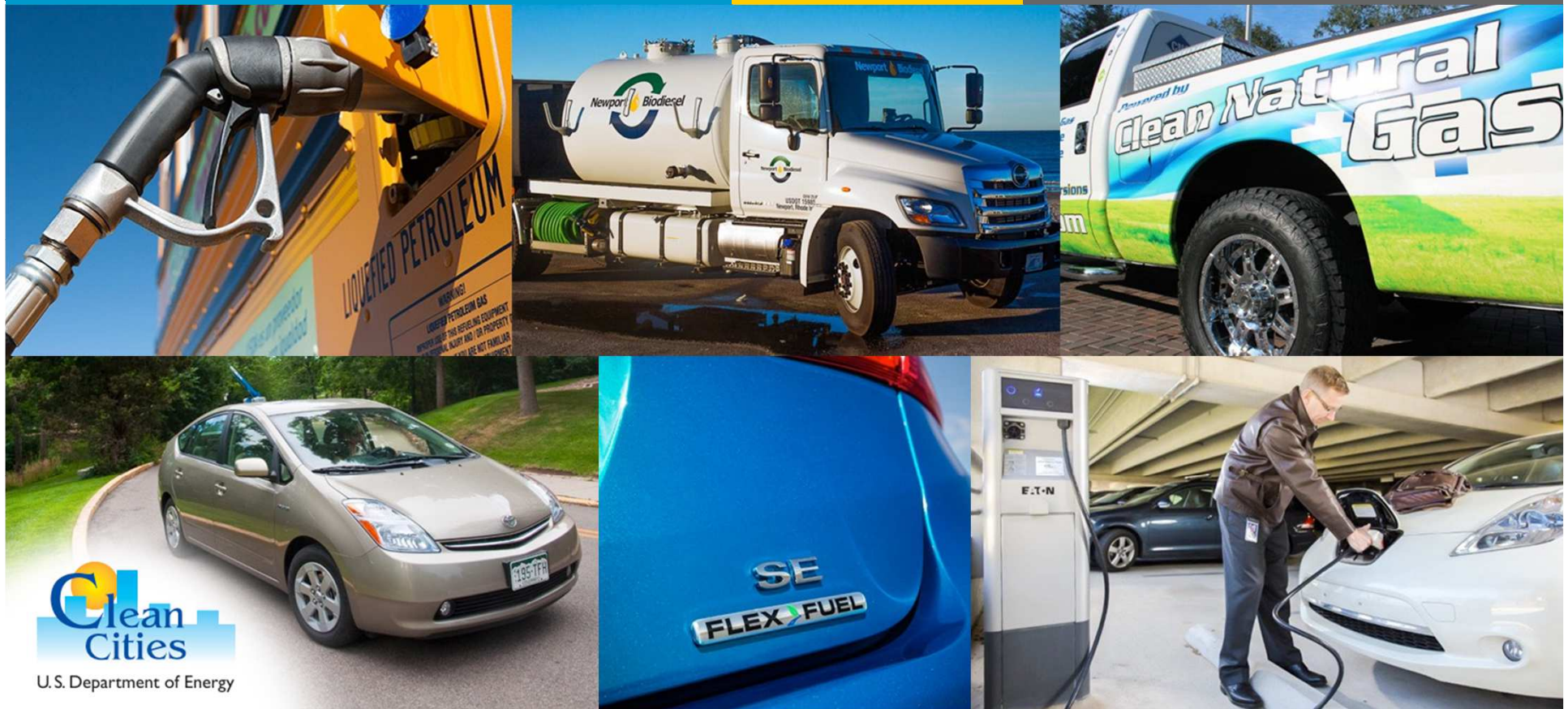


AFV TECHNOLOGY AVAILABILITY UPDATE

U.S. DEPARTMENT OF
ENERGY

Energy Efficiency &
Renewable Energy



Texas Clean Air Working Group
Volkswagen Settlement Workshop
January 17, 2018

Elizabeth Munger

Lone Star Clean Fuels Alliance (Central Texas)
Clean Cities Coordinator

**Technologies that meet VW
Environmental Mitigation Trust
eligibility requirements for actions
that will *reduce NOx emissions*.**

Sources

Environmental Defense - Chris Wolfe - VW Technology Spreadsheet

Clean Cities

Alternative Fuels Data Center

100 Clean Cities Coalitions Nationwide

4 Texas Coalitions

www.afdc.energy.gov

Alternative Fuel Vehicle information

National Alternative Fuel Station locator

AFLEET Calculator

Technical Experts

Vendor Contacts

Fleet-to-Fleet Experiences / Case Studies

Fleet Technology Workshops

Next Workshop: **April 5 - Transit & Shuttle Buses, DFW Clean Cities**

TBD: Port Trucks & Off-Road Equipment, Houston-Galveston Clean Cities

TBD: Refuse Haulers, Dump Trucks, & Cement Mixers- Lone Star Clean Fuels

TBD: School Buses

TBD: Delivery & other Freight Trucks

AFLEET Calculator Tool:



Alternative Fuel Life-Cycle Environmental and Economic Transportation (AFLEET) Tool

The Department of Energy's Clean Cities Program has enlisted the expertise of Argonne to develop a tool to examine both the environmental and economic costs and benefits of alternative fuel and advanced vehicles.

Argonne has developed the Alternative Fuel Life-Cycle Environmental and Economic Transportation (AFLEET) Tool for Clean Cities stakeholders using simple spreadsheet inputs to:

- estimate petroleum use
- air pollutant emissions
- cost of ownership of light-duty and heavy-duty vehicles
- greenhouse gas emissions

→ Updated August 2017: **Added low-NOx engine option for CNG, LPG and LNG medium & heavy-duty vehicles**

Available: <https://greet.es.anl.gov/afleet>

Currently Available Emissions Thresholds

Fuel Type	Available Emissions Certifications for Nitrogen Oxides (NO _x)
Diesel**	0.2 g/bhp-hr
Gasoline	0.2 g/bhp-hr
Natural Gas	0.2 g/bhp-hr 0.1 g/bhp-hr (50% Cleaner); ROUSH 6.8 L engine 0.1 g/bhp-hr (50% Cleaner); Cummins Westport 6.7 L engine 0.02 g/bhp-hr (90% Cleaner); Cummins Westport 8.9 L engine
Propane	0.2 g/bhp-hr 0.05 g/bhp-hr (75% Cleaner); ROUSH CleanTech 6.8 L V10 3V
Electric	N/A - Zero Emissions; Do Not Require Emissions Certifications

*****In-use research suggests that exhaust aftertreatment technologies used in diesel engines may not work properly in particularly low-speed duty cycles, leading to higher real-world emissions than what is certified.***

Key Considerations for Alternative Fuel Vehicles

- Return-to-Base Operations, Repetitive Route, or Pre-Set Geographic Operating Areas
- Higher Fuel Use -> Better Economics

Vehicle type	Fuel consumption
Regional/Long Haul Freight Trucks	18-22k DGE/year
Transit Buses	11-13k DGE/year
Refuse/Concrete Trucks, Plows	7.5-10k DGE/year
Municipal Sweepers	5-6k DGE/year
Shuttles	5.5-7.5k GGE/year
Local Goods/Services Delivery Vans and Trucks	7-10k DGE/year
School Buses	2.5-3k GGE/year
Utility Trucks, High-Mileage Pick-Ups	2-2.5k GGE/year

- Other Factors: Emissions; Sustainability; Lead by Example; Fuel Diversity

Port Cargo-Handling Equipment / Freight Switchers

Vehicle Technology	Example NOx Reduced (tons / year)	Example Cost (\$)	Other Considerations
Port Cargo-Handling Equipment (Forklifts w/ >8k lbs lift capacity, required) Repower/Replacement (all-electric + charging)	Ruber Tire Gantry (650-hp): 1.0 to 3.5 tons Yard Hostler (200-hp): 0.4 to 1.4 tons Forklift (72-hp): 0.3 to 0.7 tons	Electric RTG: \$250,000 to \$1.5M+ Electric Yard Hostler: \$150,000 to 250,000+ Electric Forklift: \$30,000+	+ Zero-emission projects + High horsepower, high annual usage equipment results in large NOx reductions + Significant community benefits
Freight Switchers (Pre-Tier 4 w/ >1000 hours/year, scrapage required) Repower/Replacement (diesel, CNG, hybrid, electric)	2 to 12+ tons <i>(potential for higher reductions for high usage T0/unregulated engines)</i>	\$1M+	+ Freight switchers can have very old engines (30-40 years) + Limited alternative funding available

Source: EDF "VW Eligible Activities Summary"

Ferries / Tugs

Vehicle Technology	Example NOx Reduced (tons / year)	Example Cost (\$)	Other Considerations
Ferries / Tugs (Unregulated/Tier 1/2 marine, scrapage required) - Repower (diesel to Tier 4 or upgrade to CMS/VEU, alt-fuel, hybrid, + install) - Repower (all-electric + charging, + install)	Tug (4000-hp): 18 to 30 tons	Tug (4000-hp): \$2M+	+ Vessels typically have 2 propulsion engines and 1-2 auxiliary engines + Limited alternative funding available
Ocean-Going Vessel (OGV) Shorepower (Equipment: cables, cable management systems, coupler systems, control systems, power distribution) - Shoreside costs	123 tons	\$5M+	+ Good option for frequent callers, such as cruise ships + Limited alternative funding available <i>Note: may also be a cost-effective option for tugs</i>

Source: EDF "VW Eligible Activities Summary"

Class 8 Freight/Waste/Dump & Port Drayage

Vehicle Technology	Example NOx Reduced (tons / year)	Example Cost (\$)	Other Considerations
Class 8 Local Freight/Waste/Dump Trucks & Port Drayage Trucks (1992-2009, scrappage required) -Repower / Replacement (diesel, CNG, hybrid, + install, all electric + charging + install)	0.2 to 1.0 ton	\$100,000 to \$125,000+	Community Benefits for projects where trucks travel in neighborhoods (e.g. drayage and waste haulers)

Source: EDF "VW Eligible Activities Summary

Class 8 Freight/ Port Drayage Trucks



- Autocar: CNG, LNG
- BYD Yard Truck: Electric
- Capacity Series: CNG, LNG
- Cargotec: CNG, LNG
- Freightliner: CNG, LNG
- Kalmar terminal: CNG, LNG
- Kenworth: CNG, LNG
- Mack Pinnacle: CNG, LNG
- Peterbilt: CNG, LNG
- US Hybrid drayage: Electric, Plug-in Hybrid Electric
- Volvo: CNG, LNG

Estimated 22 AFV Options in this Category

Waste Hauler



- Autocar: Hydraulic Hybrid, Hybrid CNG, Hybrid LNG
- Heil: CNG
- Mack TerraPro: CNG, LNG
- McNeilus: CNG, LNG

Class 4-8 School Bus, Shuttle Bus or Transit Bus

Vehicle Technology	Example NOx Reduced (tons / year)	Example Cost (\$)	Other Considerations
Shuttle or Transit Bus - Repower (diesel, alt-fuel, hybrid, all-electric) - Replacement (diesel, alt-fuel, hybrid, all electric)	Urban bus: 0.3 to 0.7 ton	Transit bus: \$400,000+	+ Public transit supports reduced congestion
Class 4-8 School Bus - Repower (CNG, diesel, LPG, hybrid, all-electric) - Replacement (CNG, diesel, LPG, hybrid, all electric)	School bus: 0.1 to 0.2 ton	School bus: \$125,000+	+ School bus projects have important health co-benefits for children + May reduce idling in neighborhoods & at schools - Alternative funding

Source: EDF "VW Eligible Activities Summary

Transit Bus

- **BYD: Electric**
- **Daimler Orion: CNG & Electric**
- **DesignLine Corp.: (Hybrid Electric & Hybrid/CNG)**
- **ENC Axess: CNG/LNG & Hybrid - Diesel Electric**
- **Foton America: Hybrid Electric/CNG**
- **Gillig (CNG & Hybrid - Diesel Electric)**
- **MCI Coach (CNG & Hybrid - Diesel Electric)**
- **New Flyer: CNG, Hybrid-Diesel Electric, Electric**



- **North America Bus Industries: Hybrid Electric/ CNG/LNG**
- **Nova Bus Hybrid - Diesel Electric & CNG**
- **Proterra Catalyst - Electric**

Class 4-8 School Buses

- **Blue Bird (Roush CleanTech):** CNG, Electric, Propane Autogas
- **Collins Bus:** CNG, Propane
- **IC (International) Bus:** Propane Autogas
- **Navistar:** Hybrid
- **Thomas Saf-T-Liner:** CNG, Propane, Hydraulic Hybrid, Hybrid-Propane, Hybrid Diesel



Estimated 20 AFV Options in this Category

Shuttle

- Blue Bird: CNG, Propane
- Champion Bus: CNG
- Ford, Hybrid-Diesel Electric
- Glaval: Hybrid Electric
- GMC: CNG, Propane
- Goshen: CNG, Propane
- Hometown Trolley: Propane, CNG
- Phoenix Motorcars: Electric
- StarTrans: Propane, CNG
- Thomas Built Saf-T-Liner: Electric
- Turtle Top Ford: CNG, Propane



Estimated 20+ AFV Options in this Category

Airport Ground Equipment (GSE)

Vehicle Technology	Example NOx Reduced (tons per year)	Example Cost (\$)	Other Considerations
Airport Ground Support Equipment (< Tier 4 CI, Uncert/>3.0 g/bhp-hr SI, scrapage required) - Repower (all-electric + charging, + install) - Replacement (all-electric + charging)	Baggage Tug (100-hp): 0.1 to 0.4 ton Aircraft Tug (500-hp): 0.6 to 2 tons	Electric Baggage Tug (100-hp): \$30,000+ Electric Aircraft Tug (500-hp): \$90,000+	+ Zero-emission projects + Projects could support both passenger and air freight operations - Alternative funding available

Source: EDF "VW Eligible Activities Summary

Class 4-7 Local Freight Medium-duty Trucks

Vehicle Technology	Example NOx Reduced (tons per year)	Example Cost (\$)	Other Considerations
Class 4-7 Local Freight ("Medium") Trucks (1992-2009, scrappage required) - Repower/Replacement (diesel, alt-fuel, hybrid, + install, all-electric + charging, + install) - Replacement/Replacement (diesel, alt-fuel, hybrid, all-electric + charging)	Class 4 (flat bed and stake trucks): 0.1 to 0.2 tons Class 7 (beverage): 0.1 to 0.2 tons	Class 4 (flat bed and stake trucks): \$60,000+ Class 7 (beverage): \$70,000+	- Typically lower mileage vehicles (~20k/year), with some exceptions - Alternative funding available

Available Medium-Duty Vehicles

- Ford: CNG, Propane
- Mitsubishi Fuso eCanter
- Isuzu NPR HD (LCF)
- Hino 195H
- BYD T5, T7: Electric
- FCCC S2G, MT45, MT55
- GM G4500
- Workhorse E-Gen Step-Van: Electric



Class 4-7 C/C platforms for upfitting

Estimated 20 AFV Options in this Category

Stations: Cost, Current Availability, Needs



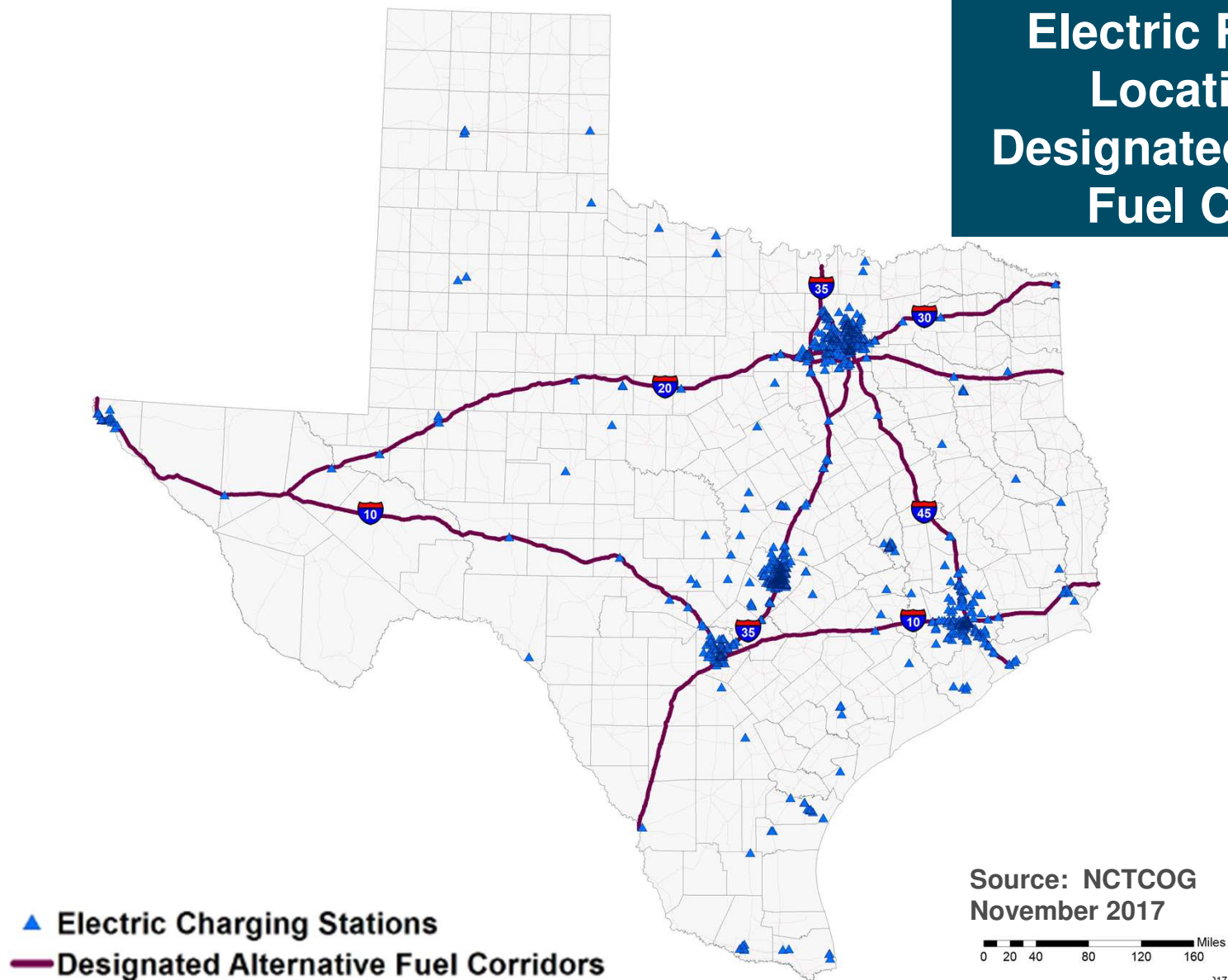
LD ZEV Supply Equipment - Electric Charging

Vehicle Technology	Other Considerations
<p>LD ZEV Supply Equipment (Mitigation Trust max use of up to 15% of funds, L1/2/fast charging equipment, H2 FC equipment w/ 70 MPa pressure)</p> <ul style="list-style-type: none">- Electrical vehicle supply equipment available to public (purchase/install/maint)- Other specific private applications (work place, etc.)	<p>Note: \$2.0 B is also being allocated through the ZEV Investment Commitment (detailed in Appendix C of the Partial Consent Decree for 2.0 L, 9/30/2016)</p>

Source: EDF "VW Eligible Activities Summary

Existing Alternative Fuel Network in Texas

Electric Recharging Locations and Designated Alternative Fuel Corridors



Electric Charging Stations

AC Level 1 Charging

2 to 5 miles of range per
1 hour of charging

AC Level 2 Charging

10 to 20 miles of range per
1 hour of charging

DC Fast Charging

60 to 80 miles of range per
20 minutes of charging

EVSE Unit Costs

EVSE Type (single port)	EVSE Unit Cost Range
Level 1	\$300-\$1,500
Level 2	\$400-\$6,500
DCFC	\$10,000-\$40,000

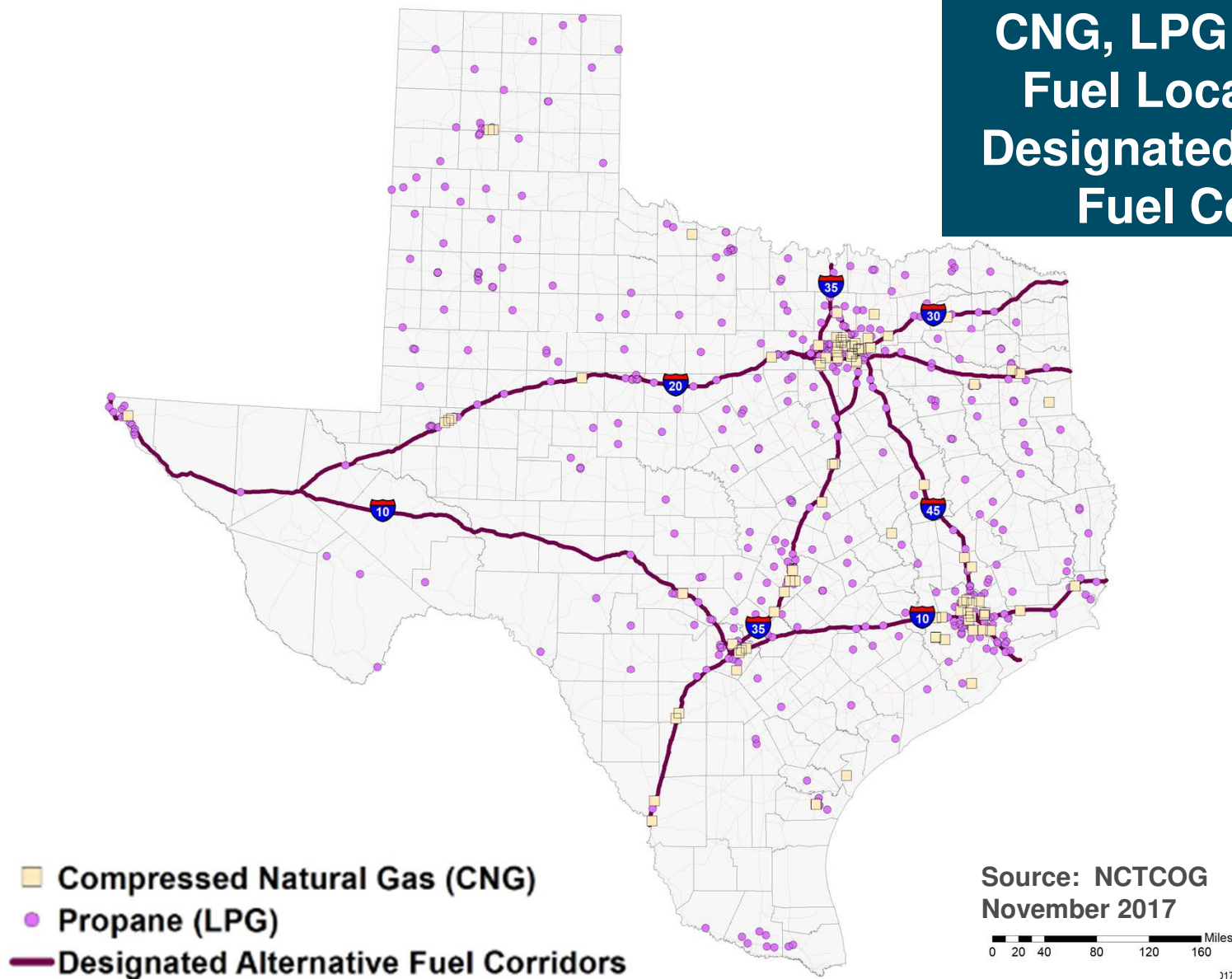
EVSE Installation Cost from ACEEE

Type of Charging	Installation Costs (\$)
Level I	\$100
Level II	\$1,000 to \$7,000
Level III (DC Fast Charging)	\$20,000 to 50,000

Sources: Costs Associated With Non Residential Electric Vehicle Supply Equipment: Factors to consider in the implemen
The American Council for an Energy-Efficient Economy (ACEEE) study “Plug-in Electric Vehicle
Challenges & Opportunities” Table 1-1.



Existing Alternative Fuel Network in Texas

**CNG, LPG Alternative
Fuel Locations and
Designated Alternative
Fuel Corridors**



Propane Autogas Refueling

Small Stations (Skid-Mounted)



Station Design	Approx. Daily Fuel Use*	Cost Range	Example Applications*
1,000-gal storage tank 1 single-hose dispenser	100–400 gal (If tank is filled every 2 weeks to 2 times/wk)	Purchasing New Equipment: \$45,000–\$60,000 <i>Initial Cost for Leasing:</i> <i>\$3,000–\$10,000</i>	3 school buses × 16 gal/day, 10 shuttle vans × 20 gal/day, or 30 taxis × 7 gal/day 
2,000 gal storage with twin 1,000-gal tanks 1 dual-hose dispenser	200–800 gal (If tank is filled every 2 weeks to 2 times/wk)	Purchasing New Equipment: \$60,000–\$70,000 <i>Initial Cost for Leasing:</i> <i>\$5,000–\$12,000</i>	20 school buses × 15 gal/day 30 shuttle vans × 18 gal/day 60 taxis × 7 gal/day, 65 delivery vans × 6 gal/day, or 



Source: Costs Associated With Propane Vehicle Fueling Infrastructure: Factors to consider in the implementation of fueling infrastructure (Technical Support) John Gonzales, National Renewable Energy Laboratory : 08/2014

Propane Autogas Refueling

Medium Stations

Station Design	Approx. Daily Fuel Use*	Cost Range	Example Applications*
12,000-gal storage tank 2 dual-hose dispensers	450–1,800 gal (If tank is filled with 1–3 transport loads/mo)	Purchasing New Equipment: \$120,000–\$145,000 <i>Initial Cost for Leasing:</i> \$15,000–\$50,000	35 school buses × 14 gal/day, 65 police cruisers × 7 gal/day, or 100 shuttle vans × 20 gal/day 
18,000-gal storage tank 3 dual-hose dispensers	900–2,400 gal (If tank is filled with 2–4 transport loads/mo)	Purchasing New Equipment: \$150,000–\$220,000 <i>Initial Cost for Leasing:</i> \$15,000–\$50,000	60 school buses × 16 gal/day, 70 shuttle vans × 20 gal/day, 100 school buses × 10 gal/day, or 150 taxis × 10 gal/day 

Large Stations

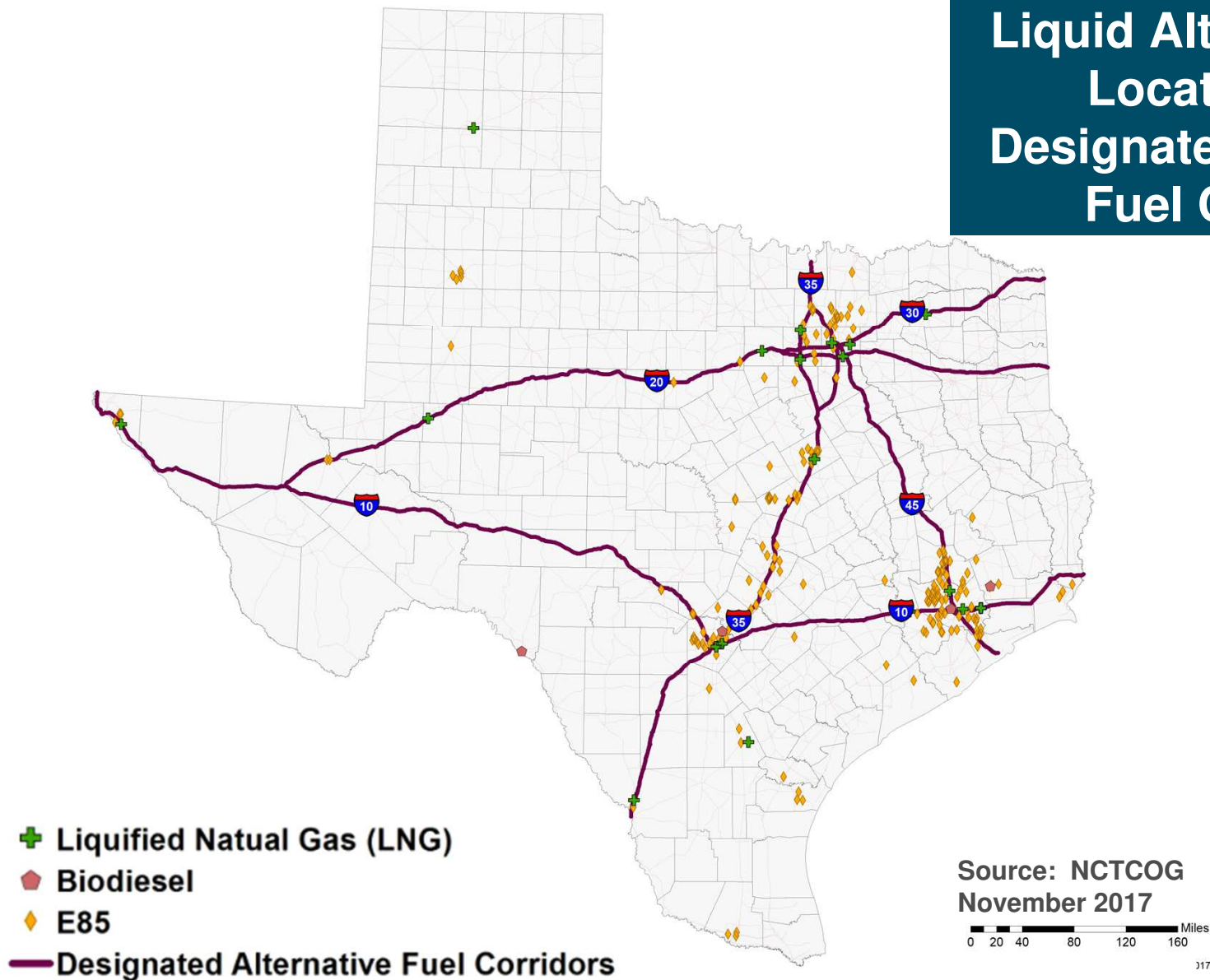
Station Design	Approx. Daily Fuel Use*	Cost Range	Example Applications*
30,000-gal storage tank 4 dual-hose dispensers	900–3,000 gal (If tank is filled with 2–5 transport loads/mo)	Purchasing New Equipment: \$225,000–\$300,000 <i>Initial Cost for Leasing:</i> \$15,000–\$50,000	70 shuttle vans × 20 gal/day, 100 delivery vans × 9 gal/day, or 250 school buses × 10 gal/day 

**Daily fuel use and fleet sizes for each tank size can vary substantially.*

Source: Costs Associated With Propane Vehicle Fueling Infrastructure: Factors to consider in the implementation of fuel



Existing Alternative Fuel Network in Texas

Liquid Alternative Fuel Locations and Designated Alternative Fuel Corridors



CNG Station - Small

Small Station (100–200 gge*/day)

Type	Cost Range	Example Applications	Assumptions
Fast-Fill 	\$400,000– \$600,000	Private fleet station serving: <ul style="list-style-type: none"> • 15–25 pickups/delivery vans fueling 7 gge/day or • 9–16 taxis/work trucks fueling 12 gge/day 	<ul style="list-style-type: none"> • One 40–75 scfm (19–24 gge/hr) compressor • 5–15 psi inlet gas pressure • 16,250 scf storage (129 gge) • One single-hose metered dispenser • Included installation costs are estimated at 65% of equipment costs
Time-Fill 	\$250,000– \$500,000	Private fleet station serving: <ul style="list-style-type: none"> • 10–20 school buses fueling 10 gge/night, • 5–10 refuse vehicles fueling 20 gge/night, or • 15–20 sedans/pickups fueling 7 gge/night** 	<ul style="list-style-type: none"> • One 20–50 scfm (10–24 gge/hr) compressor • 5–10 psi inlet gas pressure • 10 dual-hose posts • One time-fill panel; 10-hour fueling window • Included installation costs are estimated at 65% of equipment costs



*1 gge (gasoline gallon equivalent) = 126 scf (standard cubic feet)

**A time-fill station can accommodate more vehicles than hoses if the vehicles do not fuel every day.

Source: Costs Associated With Compressed Natural Gas Vehicle Fueling Infrastructure: Factors to consider in the implem

CNG Station - Medium

Medium Station (500–800 gge*/day)


Type	Cost Range	Example Applications	Assumptions
Fast-Fill 	\$700,000– \$900,000	<ul style="list-style-type: none"> Public retail station serving 50–80 light/medium-duty vehicles fueling 10 gge/day or Private fleet station serving 45–65 taxis fueling 12 gge/day 	<ul style="list-style-type: none"> One 180–300 scfm (86–143 gge/hr) compressor 30 psi inlet gas pressure 34,000 scf storage (270 gge) One dual-hose metered dispenser Included installation costs are estimated at 65% of equipment costs
Time-Fill 	\$550,000– \$850,000	Private fleet station serving: <ul style="list-style-type: none"> 50–80 school buses fueling 10 gge/night, 25–40 refuse trucks fueling 20 gge/night, or 75–80 sedans/pick-ups fueling 7 gge/night** 	<ul style="list-style-type: none"> One 100–175 scfm (48–83 gge/hr) compressor 30 psi inlet gas pressure 10–40 dual-hose posts One time-fill panel; 10-hour fueling window Included installation costs are estimated at 65% of equipment costs

*1 gge (gasoline gallon equivalent) = 126 scf (standard cubic feet)

Source: Costs Associated With Compressed Natural Gas Vehicle Fueling Infrastructure: Factors to consider in the implem

CNG Station - Large

Large Station (1,500–2,000 gge*/day)

Type	Cost Range	Example Applications	Assumptions
Fast-Fill 	\$1.2–\$1.8 million	<ul style="list-style-type: none"> Large retail station serving light- to heavy-duty vehicles such as delivery vans, work trucks, refuse trucks, class 8 tractors, and local fleets, or Airport station serving light- and medium-duty vehicles such as taxis, shuttle buses, and local fleets** 	<ul style="list-style-type: none"> Two 300–400 scfm (143–190 gge/hr) compressors 30 psi inlet gas pressure 55,000 scf storage (437 gge) Two dual-hose metered dispensers Included installation costs are estimated at 50% of equipment costs

*1 gge (gasoline gallon equivalent) = 126 scf (standard cubic feet)



Source: Costs Associated With Compressed Natural Gas Vehicle Fueling Infrastructure: Factors to consider in the implemen

For More Information

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