Heavy-Duty Alternative Fuel Engines

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Alternative Fuel Options

Non-Petroleum Based:

- Gaseous Fuels (Spark Ignition):
  - » Natural Gas, Propane, Hydrogen, Hythane (NG + H_2)
- Liquid Fuels (Compression Ignition):
  - » Methanol, Ethanol, Biodiesel, Di-Methyl Ether (DME)
- Dual-Fuels (Compression Ignition):
  - » Diesel and Gaseous Fuels

Petroleum Based:

- Reformulated Diesel and Gasoline

Dedicated Spark-Ignited Gaseous Fuel Products

- Diesel-based platforms with following exceptions:

INCLUDE	EXCLUDE
Gaseous Fuel System	Diesel Fuel System
Gaseous Fuel ECM	Diesel ECM
Gaseous Fuel Piston & Rings	Diesel Piston & Rings
Spark Plugs	Diesel Injectors
Spark Ignition Cylinder Head	Diesel Cylinder Head
Water-cooled Wastegate Turbo	Diesel Wastegate Turbo
Ignition System	
Exhaust Oxygen Sensor	

Engine and Vehicle Fuel Systems

- Dedicated Flexible Engines:
  - maintain performance / emissions with fuel composition tolerance:
    - » electronic lean-burn closed-loop control (oxygen sensor)
    - » Cummins designed sub-systems (electronics, ignition, air / fuel)
  - CNG or LNG - maximum vehicle fuel system range:
    - » 60 psig minimum (L10G & C8.3G; 50 psig min. B5.9G)
  - tailor for other gaseous fuels - HD-5 Propane specification
    - » 35 psig minimum B5.9LPG (for cold ambients - less than 10 deg F)
- Vehicle Fuel Systems:
  - SAE J2343 “Recommended Practices - LNG-Powered Heavy-Duty Trucks
  - buses and other vehicle applications in process by AFV Industry
- Medium- & Heavy- Duty NGV Availability Bullentin
  {GRI 1/98 revision (773-399-8239)}

B5.9G NGV OEM Availability

School / Shuttle / Transit

AutoSan (Poland)
Blue Bird
Boyertown Mfg.
Champion Coach
Chance Coach
Collins
Dennis Specialty (UK)
El Dorado National
Goshen Coach
MASA (Mexico)
Metrotrans
North American Transit
Neoplan (Germany & NA)
Optare (UK)
Orion Bus
Specialty Vehicles
Thomas Built
Trolley Enterprises
Van Hool (Belgium)

Medium-Duty Truck

ERF (UK)
Freightliner FL 50/60/70
Leyland - DAF (UK)
Thomas (FR)

Refuse

Athey - sweeper
Crane Carrier
Elgin - sweeper
ERF (UK)
Johnston - sweeper
Tymco - sweeper

Industrial

Hoist Liftruck
Ottawa - yard spotter
SISU (NA) - yard spotter

Chassis

Freightliner Custom
Spartan Motors

B5.9G NGV OEM Availability - LPGV Potential

School / Shuttle / Transit

AutoSan (Poland)
Blue Bird
Boyertown Mfg.
*** Champion Coach**
*** Chance Coach**
Collins
Dennis Specialty (UK)
*** El Dorado National**
Goshen Coach
MASA (Mexico)
Metrotrans
North American Transit
Neoplan (Germany & NA)
Optare (UK)
Orion Bus
Specialty Vehicles
Thomas Built
Trolley Enterprises
Van Hool (Belgium)

Medium-Duty Truck

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Industrial

*** Hoist Liftruck**
*** Ottawa - yard spotter**
SISU (NA) - yard spotter

Chassis

*** Freightliner Custor**
*** Spartan Motors**

*** Denotes B5.9LPG Availability**

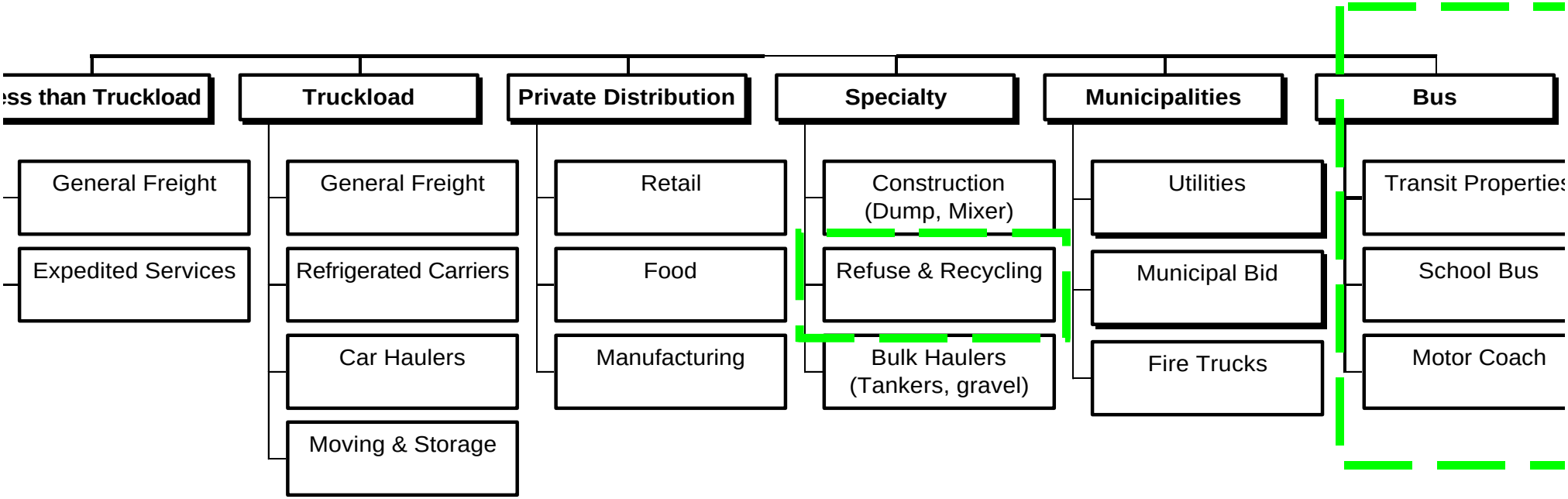
C8.3G NGV OEM Availability

School / Shuttle / Transit	Refuse	H.D. Truck
Berkhof (Netherlands)	Crane Carrier	ERF (UK)
Blue Bird	Dennis Eagle (UK)	Iveco (Aust)
Cespel (Hungary)	Ponticelli (FR)	Freightliner
Dennis Specialty (UK)	Seddon Atkinson (UK)	
El Dorado National		
Neoplan (Germany & NA)		
NABI		
New Flyer		
Nova Bus / TMC		
Orion Bus		
Thomas Built		

L10G NGV OEM Availability

Transit / Coach	Refuse	H.D. Truck
Gillig	Crane Carrier	Freightliner
Neoplan (Germany & NA)	Peterbilt	Kenworth
NABI	Volvo	
New Flyer		
Nova Bus / TMC		
Orion Bus		

Target Markets - North America



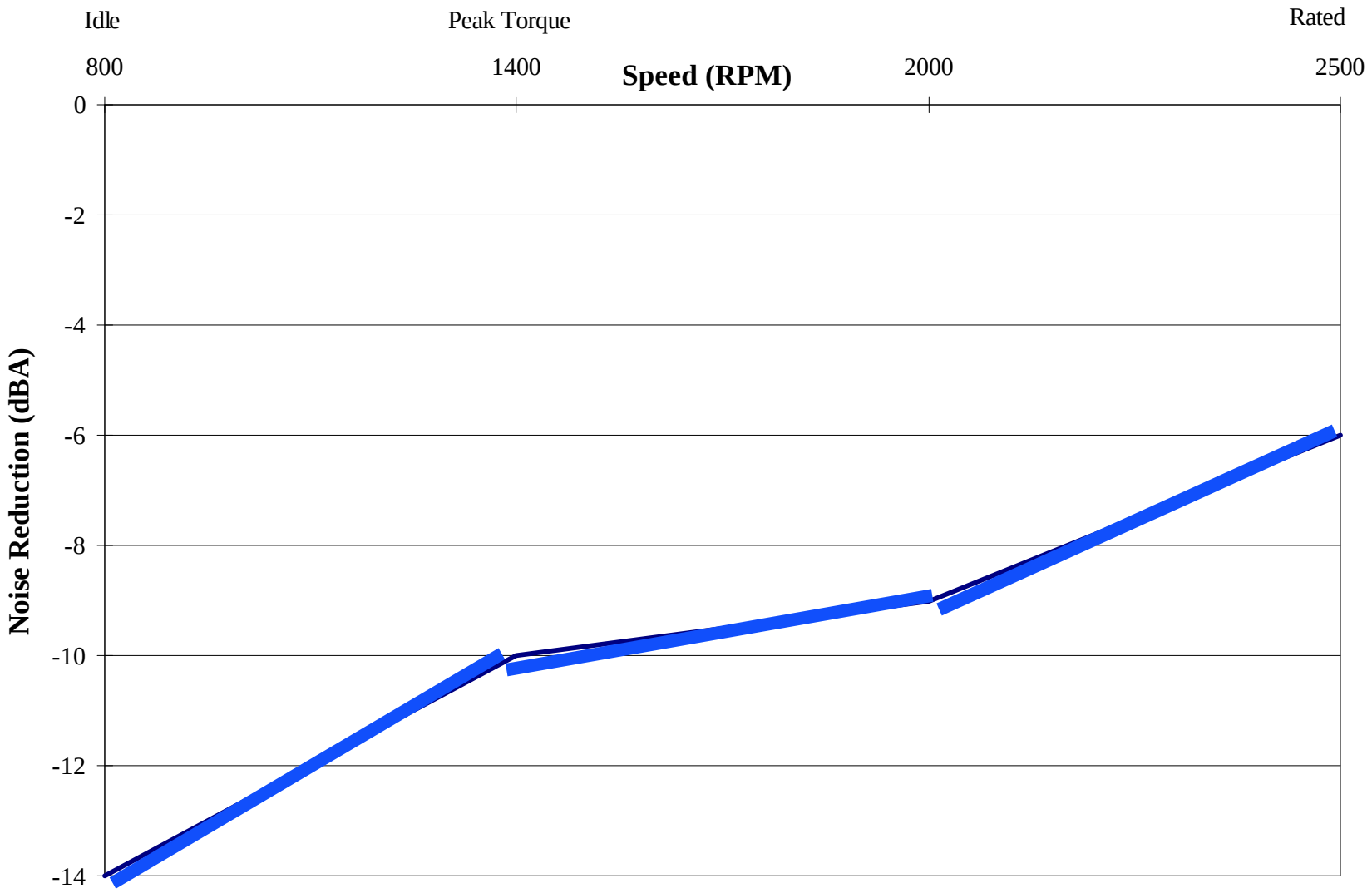
Exceptions:

* High visibility municipal parcel delivery market (i.e., USPS, UPS).
* Truckfleets which consume large amounts of fuel could find LNG an economically viable as "clean fuel corridors" are established.
* Fuel Suppliers / Transporters (i.e., LPG) likely will find their respective fuel economically attractive.

Heavy-Duty Transit Bus Experience

- Heavy-duty bus OEM availability:
  - » vehicle fuel system integration and application / powertrain match critical
- 2600 engines in revenue service with over 120M miles (194M km) experience in bus and truck applications
- Engine durability equivalent to or greater than diesel:
  - » engines with over 270k miles (436,000 km)
  - » extended bottom-end overhauls and oil drain intervals
- L10G-powered fleet example: Pierce Transit - Tacoma, WA (2/98)
  - » 30 240Hp engines with 7.9M miles (13M km; 1992 vintage)
  - » 28 260Hp engines with 5.3M miles (8.6M km; 1994 vintage)
  - » 15 280Hp engines with 532k miles (0.9M km; 1997 vintage)
  - » 50 275Hp C8.3G buses for 1998 delivery
- Engine emissions and NVH significantly less than diesel; fuel consumption higher than diesel (duty cycle dependent)

B5.9 Noise - Spark Ignition versus Diesel



Heavy-Duty Truck Experience - Raley's

- Production Kenworth T800 L10-300G LNG powered tractors
- Eight trucks in service since May 1997 with three M11-330E diesel control tractors (also two B5.9G LNG yard spotters)
- 280k miles total (64k highest, 37k lowest); 4.2k mi./mo. avg. (4/98)
- In-use tests show significantly reduced NOx and PM emissions compared to diesel; HC and CO would be similar to diesel with aftertreatment (SAE Paper #981392)
- Initial vehicle reliability less than diesel (* resolved):
  - » * ECM software calibration (i.e., idle stability)
  - » * vehicle interface (footpedal)
  - » * misfire (ignition module)
  - » * drivability (EGO sensor)
  - » performance (limited to 66k GVW - less torque than diesel)
  - » vehicle LNG fuel system

Alternative Fuels Product Strategy

- Comparative Advantage - 1998 Deliverables:
  - higher power ratings: B5.9G and C8.3G
  - EPA ULEV / LEV and CARB Optional Low NOx emissions certifications for complete product line (automotive and bus)
  - closed crankcase ventilation system (EPA)
  - enhanced reliability and durability
- Volume Growth:
  - North America: centrally-fueled nonattainment urban fleets
  - International: U.K., Western & Central Europe, Egypt, S.E. Asia, Australia, Mexico, South America
- Product Issues:
  - cost reduction: integrated full authority engine control module
  - higher engine fuel economy (R&D on-going)
  - higher Hp products: requires substantial volumes

1998 Heavy-Duty Emissions Certifications

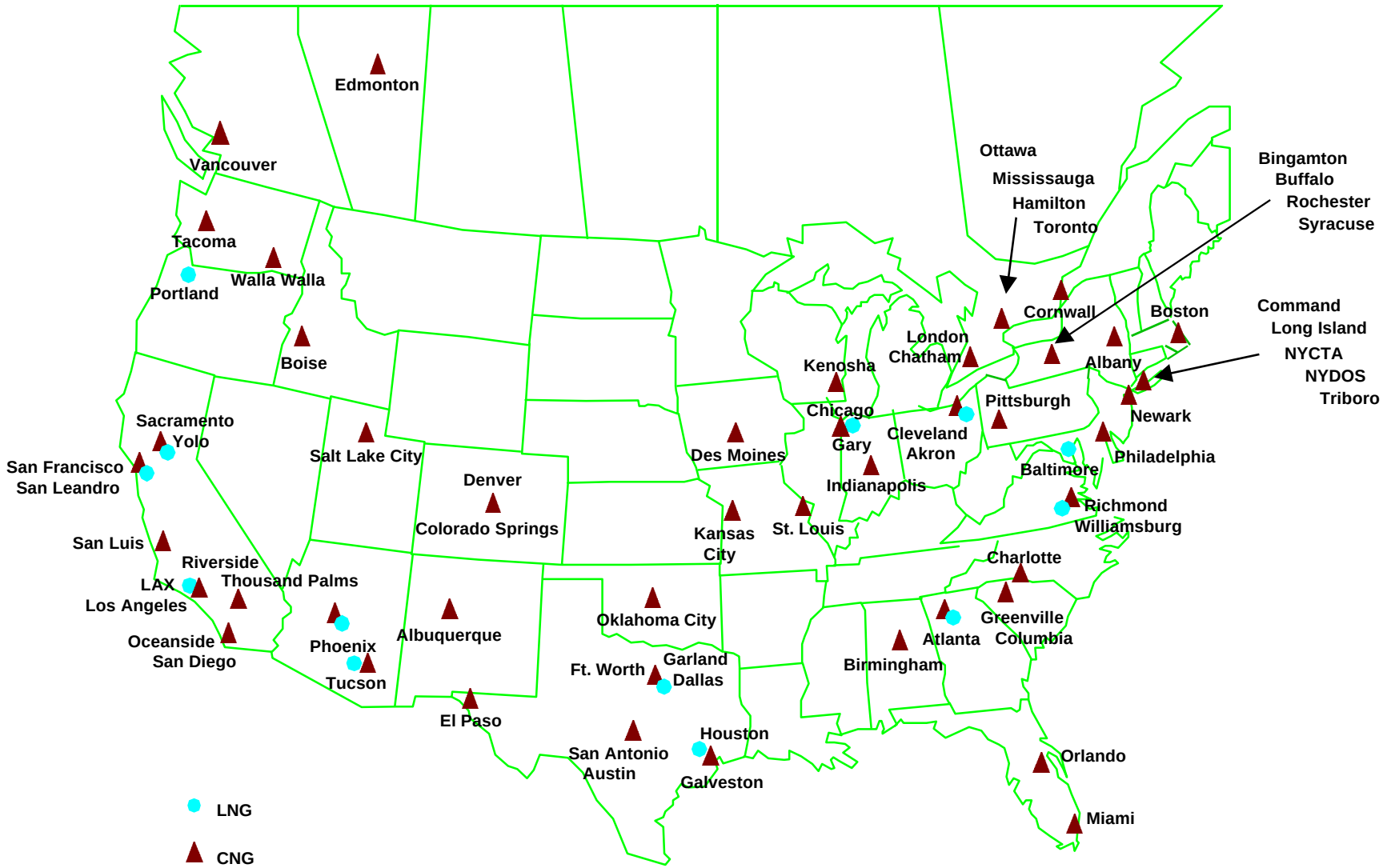
Engine	Catalyst	Applications	Emissions Certification (g/bhp-hr)	
			EPA CFFV	CARB (Low NOx)
B5.9G	Y	All	ULEV	HD (2.5)
B5.9G	N	All	LEV	HD (--)
B5.9LPG	Y	All	LEV	HD (2.5)
C8.3G	Y	Automotive	ULEV	HD (2.5)
C8.3G	N	Automotive	LEV	HD (--)
C8.3G	Y	Urban Bus	LEV*	HD (2.5)
L10G	Y	Automotive	ULEV	HD (2.0)
L10G	N	Automotive	LEV	HD (--)
L10G	Y	Urban Bus	ULEV	HD (2.0)

* ULEV certification expected 2Q98

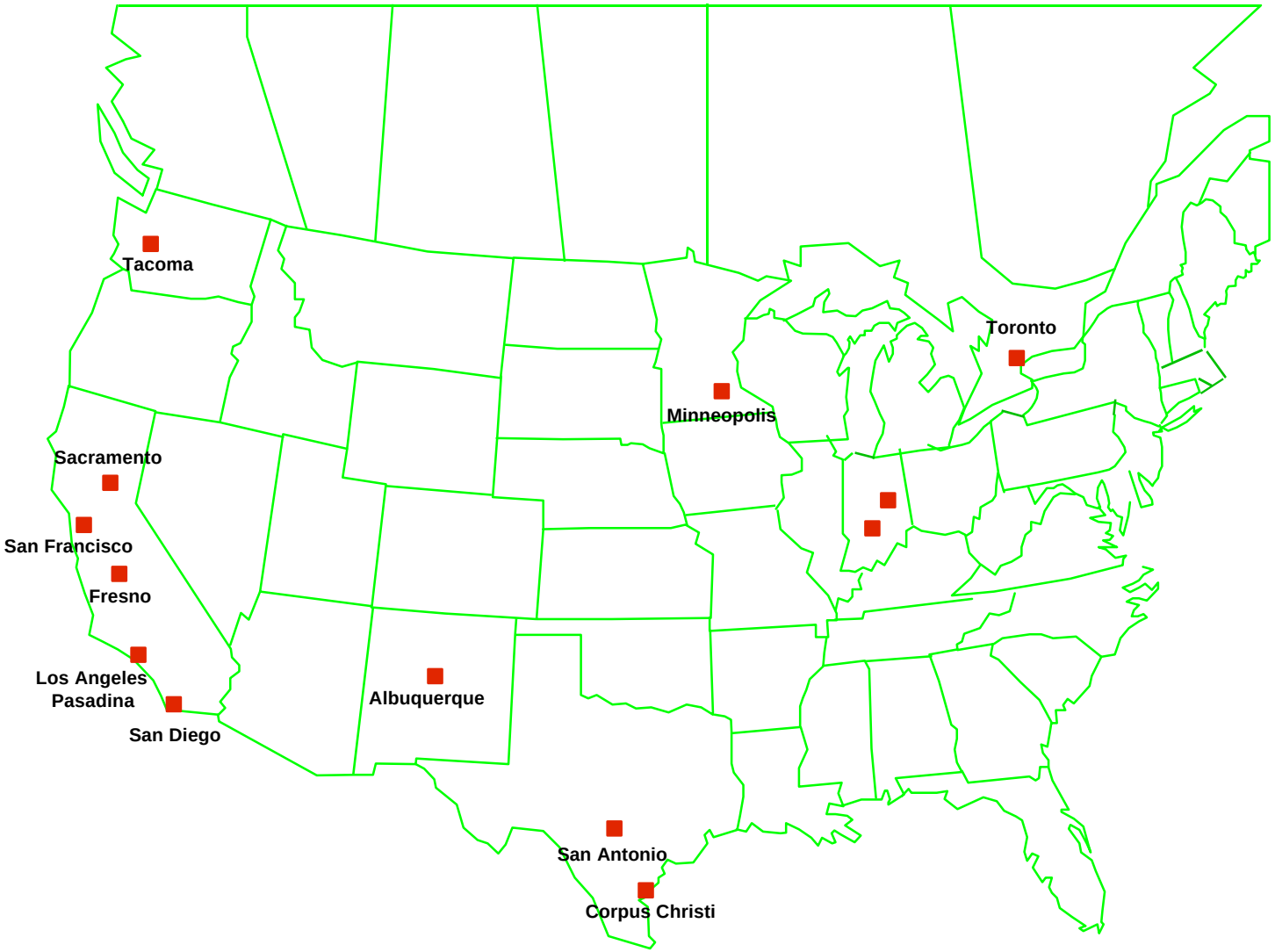
Alternative Fuel (CNG / LNG / LPG) Products

ENGINE PLATFORM	RATED POWER (Hp @ rpm)	TORQUE PEAK (ft-lb @ rpm)	AVAILABILITY STATUS
B5.9G	230 @ 2800	500 @ 1600	NOW
	195 @ 2800	420 @ 1600	NOW
	150 @ 2500	375 @ 1500	NOW
B5.9LPG	195 @ 2600	420 @ 1600	NOW
C8.3G	275 @ 2400	750 @ 1400	NOW
	250 @ 2400	660 @ 1400	NOW
L10G	280 @ 2100	900 @ 1300	NOW
	300 @ 2100	900 @ 1300	NOW
	325 @ 2100	900 @ 1300	2Q99

Natural Gas Fleet Locations



B5.9LPG Engine Locations



B5.9LPG

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Consolidated Natural Gas
Gas Technology Canada
NYSERDA

LPG

NREL / DOE
Propane Vehicle Council
SCAQMD
Natural Resources Canada
Propane Gas Assoc. of Canada
Superior Propane

FOR MORE INFORMATION, CONTACT:

1) Cummins Web Page

(http://www.cummins.com/bus/altfuels.html)

2) Local Cummins Distributor / Dealer

3) Jim (JL) Branner, Jr. - Alternate Fuels Group

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