CNG and LNG: What’s Best for Your Fleet?
A Westport and Clean Energy Webinar
Your Natural Gas Experts

- John Howell
  - Senior Director, Marketing
  - Westport OnRoad Group

- Jim Harger
  - Chief Marketing Officer
  - Clean Energy Fuels
Today’s Discussion Topics

- The case for natural gas as a vehicle fuel
- 7 factors to consider in choosing the right fuel
- CNG / LNG comparison
- Fueling considerations
- Application considerations
- Payback analysis
WHY NATURAL GAS
Why Natural Gas?

- More and more fleets across North America are switching to natural gas.
- Every day there’s another announcement of companies that have decided to transition.
- Key reason is economics:
  - Natural gas is less expensive than diesel or gasoline.

To optimize savings, fleets must consider the right factors to make the best decision:
- Type of engine system
- Type of fuel
- Type of fuel storage

---

UPS Ramps Up Natural Gas Investment

UPS (NYSE: UPS) today announced it has expanded its alternative-fuel fleet with the purchase of 220 liquefied natural gas (LNG) vehicles, with 140 of them set to be fueling stations in Florida. The new additions will bring the transportation company’s total number of LNG vehicles to 1,000. UPS has been operating LNG vehicles in the U.S. since 2008.

UPS, the world’s largest package delivery company, has been committed to reducing its carbon footprint and improving the sustainability of its operations for more than a decade. The company is committed to using renewable energy sources and alternative fuels to help reduce its environmental impact and meet future sustainability goals.

“LNG is a good alternative to petroleum-based fuel for long-haul delivery fleets as it is abundant and produces reduced emissions at less cost. At UPS, we are helping to knock down some of the biggest hurdles to broad market acceptance of LNG in commercial transportation by continuing to establish vehicle demand, fuel and maintenance infrastructures.”

---

Westport
7 Factors for an Informed Fuel Decision

1. Vehicle Type and Application
   - LNG / CNG differences and advantages

2. Duty Cycle
   - Range, speed, idle time

3. Combined Weight
   - Payload, storage tank weight

4. Hours of Service
   - Drive, idle, down time

5. Fuel Cost
   - Savings vs. diesel and gasoline

6. Fleet Fueling Needs
   - Refueling cycles

7. Fueling Infrastructure
   - Availability on your routes
CNG / LNG - the Distinction

- CNG and LNG are simply two different ways natural gas is stored
- There is no such thing as an “LNG engine” or a “CNG engine”
  - It’s not engine type that differentiates LNG and CNG, it’s how the fuel is stored and supplied to the engine
  - Both are delivered to the engine as a gas
LNG / CNG - Storage

- Natural gas in its cryogenic liquid form
- Stored at -260F (-162 C) at atmospheric pressures

- Pressurized natural gas
- Stored at pressures of 3,000 (non-North America standard) to 3,600 psi (North America standard)
Both CNG and LNG are less dense forms of energy than petroleum-based liquid fuel.
- NGVs need to have larger fuel tanks to store the same amount of energy.

Source: US Energy Information Administration
LNG / CNG - Energy Density

- Relative to one gallon of diesel:
  - LNG = 1.7 DGE
  - CNG = 3.8 DGE

- Energy density is an important factor you need to consider when choosing a natural gas vehicle.
CNG and LNG

FUELING CONSIDERATIONS
CNG Fueling Considerations
**Compressed Natural Gas - the Basics**

- Good for light, medium, and some heavy duty applications
  - <250 miles/day
- Natural gas delivered by gas company pipeline
- Gas is dried, compressed & stored at 4,500 psi and dispensed to vehicle at 3,600 psi

- Dispensed at similar rate to gasoline (5-8 gpm)
- Stored in cylinders onboard the vehicle
  - Gallon/Gallon for OTR, CNG weighs 4X compared to LNG

---

*Image of a Natural Gas dispensing station*
CNG Time Fill

- CNG provides a “complete fill” because we can dissipate heat over time
  - 3 to 6 hour fill period
- Lowest cost installation
  - Best value
CNG Fast Fill

- High heat gain during fueling
  - >20% loss of storage

- Large capital investment
  - $5 million for 4 lanes dispensing at >10 gpm each
    - ½ acre of land

- Plus utility services
  - NG supply, 100 psi minimum
  - >2MW electrical demand
    - 2,500+ HP
    - $30,000/month demand charge

- >2X compared to LNG
CNG Station Reality

- The majority are not “truck friendly”!
LNG Fueling Considerations
Liquid Natural Gas - the Basics

- Heavy-duty vehicles
  - >250 miles/day, 5-7 days/week operation

- Pipeline gas cooled to -260 F (liquefaction)
  - Adds $0.50 to $0.75/DGE

- Dispensed at 15+ DGE/minute

- Delivered in cryogenic trailer to the LNG station & stored in cryogenic tanks
  - OTR transportation can impact price compared to pipeline transport (CNG)
LNG Fast Fill Fueling

- Transparent to diesel fueling
- Stations can be expanded without utility constraints
- Store 2X energy/volume as CNG
- Single/Dual LNG cryogenic tank(s)
  - Gallon/Gallon for OTR applications with 120+ DGE, LNG weighs ¼ of CNG
- Don’t use it, you lose it
  - 7 day shelf life
- Higher FET and sometimes SET compared to CNG
  - Sales tax (some states)
CNG / LNG
APPLICATIONS
Consider Your Application

- Choosing between LNG and CNG is really about the spectrum - at either end the choice is relatively fixed.
Fueling Options Widen in the Middle

*bus & vocational trucks*

**CNG** is a good option for:
- Refuse and transit using fast or time fill
- Medium duty applications < 300 miles per fill

**Cold LNG** is a good option for:
- Long driving range requirements
- 8.9L to 12L engines hauling up to 80,000 lbs
Your Fleet’s Duty Cycle is Important

- Helps you evaluate:
  - How much energy your vehicles require
  - How often vehicles will need to be refueled

- Consider:
  - Number of hours a vehicle is in use per day
  - Number of hours a vehicle is driven per day

- LNG is an attractive solution if your fleet vehicles are in constant operation and need to be refilled quickly.

LNG needs to be used within 5 days to avoid tank venting.
The weight difference between CNG and LNG is dependent on the amount of fuel being stored.

- **Diesel**: 15 Gal.
- **LNG**: 26 Gal.
- **CNG**: 58 Gal.
Ask Yourself...

- How much tank weight can you afford?
  - A Westport LNG tank providing 60 DGE’s of storage capacity weighs 1,100 lbs when full
  - CNG tank packages providing 60 DGE of fast fill storage capacity typically weighs 1,600 lbs

- How much space will the tank require?
  - LNG tanks are typically mounted with standard diesel tank brackets
  - CNG pressure vessels are typically packaged in steel racks
# NG Tank(s)
## Storage Capacity and Weight Impact

<table>
<thead>
<tr>
<th>LNG Tanks Nominal Size (Gal)</th>
<th>Effective Size (Gal)</th>
<th>Effective Diesel Gallon Equivalents (DGE)</th>
<th>Dry Weight (lbs)</th>
<th>Wet Weight (lbs)</th>
<th>Diesel Weight (lbs)</th>
<th>NET Weight (NG - Diesel)</th>
</tr>
</thead>
<tbody>
<tr>
<td>119</td>
<td>102</td>
<td>60</td>
<td>495</td>
<td>850</td>
<td>1,025</td>
<td>(175)</td>
</tr>
<tr>
<td>150</td>
<td>128</td>
<td>75</td>
<td>620</td>
<td>1,065</td>
<td>1,150</td>
<td>(85)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>CNG Tanks Configuration</th>
<th>Nominal Size (DGE)</th>
<th>Effective Size (DGE)</th>
<th>Dry Weight (lbs)</th>
<th>Wet Weight (lbs)</th>
<th>Diesel Weight (lbs)</th>
<th>NET Weight (NG - Diesel)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2 Tanks – Rail Mount</td>
<td>82</td>
<td>62</td>
<td>1,200</td>
<td>1,575</td>
<td>1,050</td>
<td>525</td>
</tr>
</tbody>
</table>

**Notes:**
1. LNG tanks have a vapor space that reduces effective storage volume in converting from nominal to effective.
2. 1.7 gallons of LNG = 1 DGE = 1 gallon of diesel on an equivalent energy basis.
3. CNG tanks have heat of compression during fueling and residual fuel at low pressure in converting from nominal to effective.
4. Diesel Weight includes diesel tank, equivalent amount of diesel fuel + DPF + SCR + Urea Storage with solution.
5. DPF + SCR + Urea Storage with solution is 550 lbs (industry standard).
Consider Your Fleet’s Fueling Needs

- Return to base fleets are good candidates for CNG
  - You can install infrastructure to fuel at base using fast fill or time fill

- Time fill is an attractive fueling method that is less costly and complex
  - Does not require a storage system
  - Compressor is smaller and less expensive
  - Attractive option for fleets that are idle overnight, like refuse and school buses

- Fleets that operate around the clock need a fast fill option
  - Public or private
Cost of CNG/Gallon is a function of Station Investment.

The graph illustrates the relationship between Cost/GGE and Gallons Per Minute (GPM). The costs per gallon range from $1.40 to $2.50, and the GPM values range from 1 to 10.
Impact of Hours of Service at the Pump

| Gallons Per Minute (GPM) | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9  | 8  | 7  | 6  | 5  | 4  | 3  | 2  | 1  |
|-------------------------|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| 14                      |  6 |  7 |  8 | 10 | 11 | 13 | 16 | 17 | 20 | 22 | 24 | 27 |    |    |    |    |    |    |    |    |    |    |    |    |    |    |
| 17                      |  6 |  7 |  9 | 10 | 12 | 14 | 16 | 17 | 21 | 23 | 25 | 28 |    |    |    |    |    |    |    |    |    |    |    |    |    |    |
| 20                      |  6 |  7 |  9 | 11 | 12 | 14 | 16 | 17 | 21 | 23 | 25 | 28 |    |    |    |    |    |    |    |    |    |    |    |    |    |    |
| 23                      |  6 |  8 |  9 | 11 | 13 | 15 | 18 | 19 | 23 | 25 | 28 | 30 |    |    |    |    |    |    |    |    |    |    |    |    |    |    |
| 26                      |  6 |  8 | 10 | 12 | 14 | 16 | 19 | 20 | 24 | 26 | 29 | 32 |    |    |    |    |    |    |    |    |    |    |    |    |    |    |
| 29                      |  7 |  8 | 10 | 12 | 14 | 16 | 19 | 20 | 24 | 26 | 29 | 32 |    |    |    |    |    |    |    |    |    |    |    |    |    |    |
| 32                      |  7 |  9 | 11 | 13 | 15 | 17 | 19 | 20 | 24 | 26 | 29 | 32 |    |    |    |    |    |    |    |    |    |    |    |    |    |    |
| 35                      |  8 |  9 | 12 | 14 | 15 | 17 | 19 | 22 | 23 | 28 | 31 | 34 |    |    |    |    |    |    |    |    |    |    |    |    |    |    |
| 38                      |  8 | 10 | 12 | 15 | 16 | 17 | 20 | 23 | 25 | 29 | 32 | 35 |    |    |    |    |    |    |    |    |    |    |    |    |    |    |
| 41                      |  9 | 10 | 13 | 16 | 17 | 21 | 23 | 24 | 29 | 31 | 34 | 37 |    |    |    |    |    |    |    |    |    |    |    |    |    |    |
| 44                      |  9 | 11 | 14 | 17 | 19 | 22 | 26 | 29 | 32 | 35 | 42 | 46 |    |    |    |    |    |    |    |    |    |    |    |    |    |    |
| 47                      | 10 | 12 | 15 | 18 | 20 | 22 | 26 | 29 | 32 | 35 | 42 | 46 |    |    |    |    |    |    |    |    |    |    |    |    |    |    |
| 50                      | 11 | 13 | 16 | 19 | 21 | 24 | 26 | 29 | 32 | 35 | 42 | 46 |    |    |    |    |    |    |    |    |    |    |    |    |    |    |
| 53                      | 12 | 14 | 17 | 21 | 23 | 26 | 28 | 32 | 35 | 38 | 45 | 51 |    |    |    |    |    |    |    |    |    |    |    |    |    |    |
| 56                      | 13 | 15 | 19 | 23 | 25 | 28 | 30 | 35 | 38 | 45 | 51 | 56 |    |    |    |    |    |    |    |    |    |    |    |    |    |    |
| 59                      | 14 | 17 | 21 | 25 | 28 | 33 | 39 | 42 | 50 | 56 | 61 | 67 |    |    |    |    |    |    |    |    |    |    |    |    |    |    |
| 62                      | 17 | 21 | 26 | 31 | 35 | 42 | 49 | 52 | 63 | 69 | 76 | 83 |    |    |    |    |    |    |    |    |    |    |    |    |    |    |
| 65                      | 20 | 24 | 30 | 36 | 40 | 48 | 56 | 60 | 71 | 79 | 87 | 95 |    |    |    |    |    |    |    |    |    |    |    |    |    |    |
| 68                      | 23 | 28 | 35 | 42 | 48 | 56 | 65 | 69 | 83 | 93 | 102 |111 |    |    |    |    |    |    |    |    |    |    |    |    |    |    |
| 71                      | 28 | 33 | 42 | 50 | 56 | 67 | 78 | 83 | 100 |111 |122 |133 |    |    |    |    |    |    |    |    |    |    |    |    |    |    |
| 74                      | 35 | 42 | 52 | 63 | 68 | 83 | 97 | 104 |125 |139 |153 |167 |    |    |    |    |    |    |    |    |    |    |    |    |    |    |
| 77                      | 46 | 56 | 69 | 83 | 93 |111 |130 |139 |167 |185 |204 |222 |    |    |    |    |    |    |    |    |    |    |    |    |    |    |
| 80                      | 69 | 83 |104 |125 |139 |167 |194 |208 |250 |278 |306 |333 |    |    |    |    |    |    |    |    |    |    |    |    |    |    |
| 83                      | 139 |167 |208 |250 |278 |333 |389 |417 |500 |556 |611 |667 |    |    |    |    |    |    |    |    |    |    |    |    |    |    |

A 42 hour difference per year per truck
Natural Gas Fueling

INFRASTRUCTURE
North American Infrastructure

- CNG is more publicly available than LNG
- CNG stations must be near a pipeline network
  - Concentrated in California, New York, Utah, Oklahoma, Arizona, Texas, Colorado
- LNG can be hauled long distances from the liquefier while remaining economical
- About 150 LNG stations would provide fueling coverage along all of the major interstate trucking routes
  - At 300 mile intervals

230 LNG
NUMBER OF PUBLIC STATIONS PLANNED TO OPEN IN 2013
More CNG / LNG Stations Open Every Month
PAYBACK ANALYSIS
# The Advantage of Natural Gas Prices

## April 2013 Overall Average Fuel Prices on Energy-Equivalent Basis

### National Average Price:

<table>
<thead>
<tr>
<th>Fuel Type</th>
<th>GGE</th>
<th>DGE</th>
<th>Per Million Btu</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gasoline</td>
<td>$3.59</td>
<td>$4.01</td>
<td>$31.13</td>
</tr>
<tr>
<td>Diesel</td>
<td>$3.58</td>
<td>$3.99</td>
<td>$30.99</td>
</tr>
<tr>
<td>CNG</td>
<td>$2.10</td>
<td>$2.34</td>
<td>$18.21</td>
</tr>
<tr>
<td>LNG</td>
<td>$2.18</td>
<td>$2.45</td>
<td>$19.00</td>
</tr>
<tr>
<td>Ethanol (E85)</td>
<td>$4.66</td>
<td>$5.20</td>
<td>$40.40</td>
</tr>
<tr>
<td>Propane</td>
<td>$3.77</td>
<td>$4.20</td>
<td>$32.65</td>
</tr>
<tr>
<td>Biodiesel (B20)</td>
<td>$3.75</td>
<td>$4.19</td>
<td>$32.52</td>
</tr>
<tr>
<td>Biodiesel (B99-B100)</td>
<td>$4.23</td>
<td>$4.72</td>
<td>$36.65</td>
</tr>
</tbody>
</table>

* April 2013 Clean Cities Alternative Fuel Price Report*
### Sample Business Case: CNG

#### 10 Pick-up truck order (Westport WiNG™ Ford F-250)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average life of the truck</td>
<td>5 years</td>
</tr>
<tr>
<td>Mileage per truck (annual)</td>
<td>30,000</td>
</tr>
<tr>
<td>Fuel economy</td>
<td>15 mpg</td>
</tr>
<tr>
<td>Incremental cost</td>
<td>$9,500*</td>
</tr>
<tr>
<td>Gasoline price</td>
<td>$3.46/gallon</td>
</tr>
<tr>
<td>CNG price</td>
<td>$1.29/GGE</td>
</tr>
<tr>
<td>Fuel cost savings per truck per year</td>
<td>$4,344</td>
</tr>
<tr>
<td>Payback</td>
<td>26 months**</td>
</tr>
<tr>
<td><strong>Total fuel cost savings over fleet lifecycle</strong></td>
<td><strong>$ 217,200</strong></td>
</tr>
</tbody>
</table>

* * All pricing to be confirmed with Ford dealer
** ** Subject to mileage
Sample Business Case: LNG

- **10 truck order (Westport 15L and Paccar Class 8 truck)**

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Average life of the truck</td>
<td>5 years</td>
</tr>
<tr>
<td>Mileage per truck (annual)</td>
<td>120,000</td>
</tr>
<tr>
<td>Fuel economy</td>
<td>6 mpg</td>
</tr>
<tr>
<td>Incremental cost with 53 DGE’s (single tank)</td>
<td>$65,000*</td>
</tr>
<tr>
<td>Diesel price</td>
<td>$3.95/gallon</td>
</tr>
<tr>
<td>LNG price</td>
<td>$2.45/DGE</td>
</tr>
<tr>
<td>Fuel cost savings per truck per year</td>
<td>$30,000</td>
</tr>
<tr>
<td>Payback</td>
<td>2.2 – 2.5 years**</td>
</tr>
<tr>
<td>Total lifecycle fleet savings</td>
<td>$850,000</td>
</tr>
</tbody>
</table>

* All pricing to be confirmed with Paccar dealer

** Subject to duty cycle and displacement
Questions?

For more information, please contact:

**John Howell**
Senior Director of Marketing, Westport
jhowell@westport.com

**James Harger**
Chief Marketing Officer
jharger@cleanenergyfuels.com