Independent assessment of the benefits of supplying gas for road transport from the Local Transmission System

Technical summary report

Cadent

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LTS-connected stations bring emissions savings and a stronger financial case vs. MP-connected stations, especially for stations serving hundreds of vehicles

Summary of key messages

• The CNG station in Leyland, the UK first station connected to the Local Transmission System (LTS), was monitored for over a year to benchmark its environmental and economic parameters.
• Leyland dispensed over 900 tonnes of CNG in a year of operation, operating at an average of 3% of its total capacity.
• EMISSIONS BENEFITS:
  – An LTS-connected station offers a **79% reduction in specific station emissions** (emissions related to the station operation, namely electricity use) compared to an MP-connected station.
  – Dedicated gas vehicles refuelled at Leyland bring an **84% reduction in Well-to-Wheel CO₂, compared to diesel vehicles**, thanks to the accredited biomethane supply.
  – For vehicles using 100% fossil fuel natural gas, the Well-to-Wheel emissions savings for those using an LTS-connected station, compared to those using an MP-connected station would be 6%. The Well-to-Wheel savings compared to equivalent diesel vehicles would be 12-15%.
• FINANCIAL CASE:
  – The payback period for an LTS-connected station equivalent to the Leyland station was estimated as **6.3 years** assuming that the loading of the station would increase to 75% over a 10-year period (equivalent to serving 470 trucks).
  – The payback period for an equivalent capacity **MP-connected station was estimated to be around 2 years longer**, due to the higher capital costs as well as higher operating costs (an MP station requires more electricity to compress gas).

CNG: Compressed Natural Gas; LTS: Local Transmission System (carries gas between 7bar and 70bar); MP: Medium Pressure (carries gas between 75mbar and 2bar)
The LTS connected CNG station at Leyland was monitored for over a year to benchmark its environmental and economic parameters.

The study aims to provide evidence on the performance of CNG refuelling technology

- Natural gas is a market-ready alternative fuel solution to reduce CO₂ emissions from HGVs, which currently account for 15% of greenhouse gas emissions from UK transport (and 4% of the UK’s total GHG emissions)\(^1\). However, natural gas leakage and increased energy use during Well-To-Tank stages can negate the benefits of the reduced CO₂ content of natural gas relative to diesel.

- Connecting a filling station to the Local Transmission System (as is done at Leyland) reduces two key components of the Well-To-Terminal stages – leakage from the distribution network system and emissions due to energy use for gas compression.

- Element Energy was appointed to independently monitor the Leyland station financial and technical performance over a full year. Data collection started in March 2016, using a data collection protocol developed with Cadent (then National Grid) and CNG Fuels (the station operator). Data was collected for 14 months (March 2016 to April 2017, inclusive).

Source pictures: CNG Fuels
OPERATION: Leyland has dispensed over 900 tonnes of CNG in a year of operation, operating at an average of 3% of its total capacity

Summary of station operation to date

• The LTS-connected CNG filling station at Leyland has now been in operation for over 16 months, starting in February 2016. Since the start of the monitoring period in March 2016, the monitored dedicated gas vehicles using the station have covered over 1 million km.
• The station has the capacity to provide 30,000 tonnes of CNG per year (around 80 tonnes per day). It could serve up to 600 dedicated gas HGVs.
• From March 2016 to May 2017 (14 months) the station dispensed 1,028 tonnes of CNG, refuelling 13 dedicated gas vehicles and also several dual fuel vehicles. This represents an average station loading of 3% over this time period.

Timeline of operation

Official station opening and monitoring begins

March 2016

Two dedicated CNG vehicles with 200 bar tanks using the station

Station is supplied with 100% biomethane (covered by Renewable Transport Fuel Certificates)

September 2016

Ten new dedicated CNG vehicles with 250 bar tanks using the station

March 2017

Source pictures: CNG Fuels
EMISSIONS BENEFITS: 1) An LTS-connected station offers a 79% reduction in specific station emissions compared to an MP-connected station

**Specific station emissions**

- Some of the “well-to-wheel” emissions associated with using CNG as a transport fuel come from the electricity used to compress the gas from 14-30bar (at the connection point) to around 290bar, and to dispense the gas at the refuelling station: the *specific station emissions.*

  - The specific station emissions have been calculated for Leyland, using the half-hourly electricity consumption at the station and the half-hourly electricity grid carbon intensity. Over March 2016 to April 2017, specific station emissions averaged at 1.0 gCO$_2$eq/MJ gas.

  - This represents a **79% reduction** in specific emissions compared to a modelled MP-connected station, estimated at 4.8 gCO$_2$eq/MJ gas (for the same UK grid emissions intensity).

  - This reduction is due to the higher pressure of LTS gas compared to MP gas, and the lower need for compression for use as a vehicle fuel.

*Compression accounts for 80-90% of the daily electricity consumption.*
EMISSIONS BENEFITS: 2) Dedicated gas vehicles refuelled at Leyland bring an 84% reduction in Well-to-Wheel CO$_2$, compared to diesel vehicles

Well-To-Motion emissions (gCO$_2$eq/km) by station connection (LTS versus MP) and source of natural gas (fossil versus bio):

- Since September 2016, Leyland has been supplied with 100% biomethane; on a WTW basis, CNG vehicles refuelling at Leyland have **84% lower emissions than equivalent diesel vehicles**, and 9% lower emissions than vehicles using biodiesel from used cooking oil (UCO).

- For vehicles refuelling with fossil fuel natural gas at a similar LTS-connected station, the WTW emissions saving vs. diesel vehicles would be 12%, and the WTW emission saving compared to vehicles using an MP-connected station with 100% fossil fuel natural gas would be 6%.

*Emissions from combustion are calculated assuming the consumption of 11.7 MJ/km (0.26kg/km) for CNG vehicles and 9.65 MJ/km (0.27l/km) for diesel vehicles.

UCO: Used cooking oil; See full report for details on the calculations.
EMISSIONS BENEFITS: 3) New fleet of 250 bar gas trucks operate at higher efficiencies and can operate over longer distances

Comparison of new 250 bar trucks with the 200 bar vehicles (which have provided most of the data)

- Over the 14 months monitored, the average efficiency of the two CNG vehicles using the station (with 200 bar tanks) was 11.7 MJ/km (0.26 kg/km).
- The annual distance travelled by the 200 bar vehicles was comparable to that of equivalent diesel vehicles.
- In March 2017, a new fleet of ten CNG trucks (with 250 bar tanks) was introduced.
- Performance data shows that the 250 bar trucks can travel further and at greater efficiencies than the 200 bar vehicles.
- The efficiency improvement brings the WTW emissions reduction for fossil CNG compared to diesel from 12% to 15%.

<table>
<thead>
<tr>
<th>Period</th>
<th>Average fuel consumption</th>
<th>Average daily distance</th>
</tr>
</thead>
<tbody>
<tr>
<td>03/2016 – 04/2017</td>
<td>11.7 MJ/km</td>
<td>535 km</td>
</tr>
<tr>
<td>03/2017 – 05/2017</td>
<td>11.9 MJ/km</td>
<td>556 km</td>
</tr>
</tbody>
</table>

Average annual distance: 187,500 km

Compared to 200 bar vehicles*:
- 3.5% reduction in fuel consumption
- 25% increase in daily distance

Efficiency improvements bring incremental reductions to WTW emissions; in addition, the capability to travel further on a single tank allows more diesel journeys to be replaced.

*Comparison is over the same time period, to remove the impact of different weather conditions on performance. Values are averaged for the two 200 bar vehicles and for the ten 250 bar vehicles.
EMISSIONS BENEFITS: 4) Dedicated gas vehicles refuelling with natural gas could bring 15% reduction in WTW CO₂, compared to diesel vehicles.

Well-To-Motion emissions (gCO₂eq/km) by station connection (LTS versus MP) and source of natural gas (fossil versus bio):

200 bar trucks, March 2016 - May 2017 (14 months of data)

- Diesel (average bio-fuel blend)
- Fossil Natural Gas, LTS
- Leyland (100% bio-methane, LTS)

250 bar trucks, March 2017 - May 2017 (2 months of data)

- Diesel (average bio-fuel blend)
- Fossil Natural Gas, LTS (higher truck efficiency)
- Leyland (100% bio-methane, LTS, higher efficiency trucks)

*Emissions from combustion are calculated assuming the consumption of 11.7 MJ/km (0.26kg/km) for CNG vehicles and 9.65 MJ/km (0.27l/km) for diesel vehicles.

*Emissions from combustion are calculated assuming the consumption of 11.3 MJ/km (0.25kg/km) for CNG vehicles (a 3.5% improvement from 11.7 MJ/km) and 9.65 MJ/km (0.27l/km) for diesel vehicles.
FINANCIAL BENEFITS: 1) The capital costs for LTS-connected stations can be lower than for an equivalent-capacity MP-connected station

Capital costs for LTS-connected and MP-connected CNG stations with equivalent capacity:

<table>
<thead>
<tr>
<th></th>
<th>LTS station</th>
<th>MP station</th>
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</thead>
<tbody>
<tr>
<td>Assumed capital costs</td>
<td></td>
<td></td>
</tr>
<tr>
<td>of the CNG station</td>
<td>435</td>
<td>2,000</td>
</tr>
<tr>
<td>capable of refuelling</td>
<td></td>
<td>1,965</td>
</tr>
<tr>
<td>625 trucks/day (in £k)</td>
<td></td>
<td>2,932</td>
</tr>
</tbody>
</table>

The MP station requires significantly higher compressor power to achieve the same flowrate as the LTS station

Assuming 200m pipeline for connection

**Connection cost** – companies that carry out MP connections require accreditation, but the process is fairly generic, although specialist labour is required. An LTS connection is not generic and is highly complex – there is no competition at the moment and the overheads on labour are very high.

**Pipeline costs** – pipes for LTS connections are significantly more expensive because high grade stainless steel is normally used instead of low density polyethylene for MP connections.

Sources: CNG Services / Element Energy (figures based on recent tenders and National Grid input)
FINANCIAL BENEFITS: 2) The payback period for an LTS-connected station is 2 years shorter than for an MP-connected station with similar loading.

Payback period for equivalent LTS-connected and MP-connected CNG stations:

- The payback period for an LTS-connected station equivalent to the Leyland station was estimated as 6.3 years (undiscounted cash flow), assuming that the loading of the stations would increase to 75% over a 10-year period (equivalent to serving 470 trucks).
- The payback period for an equivalent MP-connected station was estimated to be around 2 years longer, due to the higher capital costs as well as higher operating costs (an MP station requires more electricity to compress gas, and incurs more frequent compressor maintenance events).

Opex is higher for MP station due to higher expenditure on electricity and maintenance (due to higher compressor utilisation).
LTS-connected stations can increase the emissions benefits of CNG trucks, and could offer an improved business case for stations serving hundreds of vehicles

Recommendations to maximise the financial and emissions benefits of LTS-connected stations:

• The high cost of making an LTS connection is a barrier towards further roll-out of CNG stations connected to the LTS; benefits compared to MP-connected stations only apply to high capacity stations. The following can help to reduce the cost of making a new connection:
  – Opening the LTS connection to competition is likely to increase the efficiency of the entire process and may help to minimise the connection costs going forward
  – The choice of a location close to the LTS pipeline will reduce the additional cost for the connection pipeline
• The CNG station network requires only a few additional stations in a short term in order to:
  – Cover the entire UK, including Scotland and Wales
  – Reinforce the existing refuelling infrastructure in the Midlands and London regions to ensure that the CNG HGVs have an alternative option for refuelling (e.g. in case that one of the stations is out of order)
• A significant number of stations will be required on a medium term (20 years) to support uptake of CNG vehicles – the number of stations will have to increase from 15 stations at the moment (only one connected to LTS) to around 85 stations connected to LTS by 2035.
• A high uptake of CNG stations can increase the uncertainty in daily gas demand and may require an additional gas network flexibility. This can be achieved by installing sufficiently large ground storage at the stations – up to 25% of the expected daily gas demand.
## Summary of operational and performance parameters for the Leyland refuelling station

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
<th>Assumptions / measured data</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maximum station capacity</td>
<td>80 tonnes/day</td>
<td></td>
</tr>
<tr>
<td>Connection pressure</td>
<td>14bar-30bar</td>
<td></td>
</tr>
<tr>
<td>Range of dispensing pressure</td>
<td>200bar - 250bar</td>
<td></td>
</tr>
<tr>
<td>Maximum compression pressure</td>
<td>290bar</td>
<td></td>
</tr>
<tr>
<td>Ground storage capacity</td>
<td>4 tonnes</td>
<td></td>
</tr>
<tr>
<td>Well-to-terminal emissions of CNG vehicles refuelling at Leyland</td>
<td>112 gCO$_{2eq}$/km</td>
<td>100% RTFO certified bio-methane (9.6gCO$_{2eq}$/MJ); 11.7 MJ/km</td>
</tr>
<tr>
<td>Terminal-to-tank emissions of CNG vehicles refuelling at Leyland</td>
<td>14 gCO$_{2eq}$/km</td>
<td>Specific station emissions 1 gCO$<em>{2eq}$/MJ gas (based on electricity usage and UK grid mix March16-April 17); gas distribution 0.2 gCO$</em>{2eq}$/MJ gas (Element Energy analysis); consumption 11.7 MJ/km</td>
</tr>
<tr>
<td>Well-to-wheel emissions of CNG vehicles refuelling at Leyland</td>
<td>140 gCO$_{2eq}$/km</td>
<td>Well-to-terminal emissions as above; methane slip 13 gCO$<em>{2eq}$/km (LowCVP for DfT, 2017); 1 gCO$</em>{2eq}$/km for combustion of biomethane (BEIS, GHG Conversion Factors for Company Reporting, 2016)</td>
</tr>
<tr>
<td>Well-to-wheel emissions savings of CNG vehicles refuelling at Leyland, compared to diesel vehicles</td>
<td>84%</td>
<td>As shown above and below</td>
</tr>
<tr>
<td>Average fuel consumption of CNG trucks</td>
<td>11.7 MJ/km</td>
<td>Articulated dedicated gas truck</td>
</tr>
<tr>
<td>Average fuel consumption of diesel trucks</td>
<td>9.65 MJ/km</td>
<td>Articulated diesel truck (data from the Waitrose fleet)</td>
</tr>
<tr>
<td>Station capex</td>
<td>£1.97 million</td>
<td>Includes connection costs</td>
</tr>
<tr>
<td>The payback period for an LTS-connected station equivalent to the Leyland station</td>
<td>6.3 years</td>
<td>Undiscounted cash flow. Loading of station increases to 75% over a 10-year period (equivalent to serving 470 trucks)</td>
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