PROVIDING HYDROGEN REFUELLING TO THE LIVERPOOL CITY REGION

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MARKET DEVELOPMENT MANAGER, CLEAN FUELS, BOC UK & IRELAND
The OLEV Hydrogen Bus and Filling Station Project
Bringing Hydrogen Refuelling to Liverpool

Mark Griffin
‘Delivering the Hydrogen Economy’
Wednesday 05 June 2019
Introduction to Linde

Facts and figures.

Our company.

100+
We serve our customers in over 100 countries worldwide

The Linde Group

~ 65,000 employees

Engineering Division

~ 7,000 employees

Around 65,000 employees deliver value to our customers every day

Our business.

4,000+
plants have been delivered by Linde around the globe

3,000+
air separation units have been built in more than 90 countries

1,000+
plants are operated by 10 Linde Remote Operating Centres worldwide

Our achievements.

55 million t
annual oxygen production capacity in liquid air separation units installed since 2010

2.5 million tonnes in CO₂ savings since 2006 as part of energy optimization in our air separation units

5,500 t
of oxygen produced by our largest single air separation unit per day

25,000 m²
is the heating surface of one of our col-wound heat exchangers

1,300 t
is the weight of one of our gigantic fully assembled cubebins

50%
of our research projects also aim to achieve an environmental benefit

1,000+
process technology patents bear testimony to our innovative powers

-50 °C to +40 °C
our plants withstand the most extreme climatic conditions

07/06/2019
Linde HRS Activity Globally

Europe
- 35+ public Linde H2 stations, 24 more in pipeline
- First H2 train project in Germany
- Various further H2 fleet projects: buses, car sharing, FLTs
- Power-to-H2: Mainz**, Berlin (Germany)

USA, esp. California
- H2 buses at AC Transit (CA, USA)
- FLT* at BMW Spartanburg (SC, USA)
- Public Linde H2 stations (CA, USA) (4 running, 4 in execution)

East Asia
- H2 bus projects (China)
- Component systems for 14 public H2 stations (Japan)
- 4 H2 stations for buses, taxis, passenger cars (Korea)

- Linde with strong project record globally with more than 100 HRS system installations in all H2 lead markets
- Net of HRS installations as demand foundation for Green H2 source investments

* FLT - fork lift trucks  ** Energy park Mainz, largest scale electrolysis system installation globally (6.3 MW installed capacity)
BOC UK hydrogen capability
Strong network and experience of refuelling activities

- Strong network of hydrogen plants
- Regional Operating Centre and Engineering team in Sheffield
Hydrogen supply options
Full range of solutions for trials and operational demands

<table>
<thead>
<tr>
<th>Volume</th>
<th>Cylinders</th>
<th>Tube Trailer or Liquid</th>
<th>Small on site production (SMR or electrolysis)</th>
<th>Large on site production plant (SMR)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-30kg/day</td>
<td>20-3,0000 kg/day¹</td>
<td>200-10,000 kg/day</td>
<td>10,000 kg/day plus</td>
<td></td>
</tr>
</tbody>
</table>

Ideal supply solution will depend on usage profile, duration, location and purity requirements
St Helens Hydrogen Overview

• No.2 H2 Plant commissioned in 1993

• Major refurbishment planned for 2020

• Bottom Fired furnace with 14 reformer tubes, Howar design

• H2 product:
  • Single pipeline customer
  • H2 trailers
  • H2 cylinders

• SMR process of High Temperature Shift, Pressure Swing Adsorption and H2 Compression, using a Natural Gas feed.

• Site team supported by the ROC (Remote Operating Centre) in Brinsworth

• Plant designed for capacity of 1600 Sm³/h with H2 purity of 99.999% (1700 Sm³/h with new reformer catalyst)
The H₂ bus refueling station in Aberdeen, Scotland supplies 10 Van Hool H₂ Buses, while maintaining a small footprint. The electrolyser can power up to 20 buses a day and are designed to extend to H₂ car dispensers.

**Key Information since opening in 2015**

- Over 90 tonnes of H₂ delivered since 2015
- Over 1,000,000 miles driven
- Average of 200-250 kg delivered nightly
- Station availability of 99.6%

<table>
<thead>
<tr>
<th>H₂ Supply</th>
<th>Compressor</th>
<th>Dispenser</th>
<th>Start of Operation</th>
</tr>
</thead>
<tbody>
<tr>
<td>3x Electrolyser</td>
<td>2x IC 90</td>
<td>2x 350bar Bus</td>
<td>2015</td>
</tr>
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</table>
BOC as part of a consortium bid involving Arcola Energy, Mersey Travel, Liverpool City Region and Aberdeen City Council have been awarded funding to build a HRS at BOC St Helens to refuel a fleet of 25 ADL Double-Decker Hydrogen Buses.

**Key Information of Planned Project**

<table>
<thead>
<tr>
<th>Hydrogen Supplied by the existing SMR plant</th>
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<td>Average daily demand of 500Kg per night</td>
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<tr>
<td>Project to be delivered in 2020</td>
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Thank you for your attention

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