The pathway has been prepared
Now is the time to implement zero emission fuel cell buses
Contributing to over 30% of greenhouse gas emissions transportation has a critical role to play in the decarbonisation of our economy.

This opens the door for the deployment of zero emission fuel cell vehicles. With large fleets, transit agencies and operators in Scandinavia are in the best position to accelerate the transition by replacing the conventional bus fleets with clean zero emission buses.

Scandinavia is at the forefront of the fight against climate change, committing to renewable energy further and faster than any other region in Europe. Denmark has adopted goals to reach 100 percent renewable energy by 2035 and to be completely free of fossil fuels by 2050. Denmark already generates 40 percent of its annual electricity demand from wind. Furthermore Sweden has declared that it will be one of the world’s first fossil-free welfare countries. Norway will ban the sale of all fossil fuel-based cars in the next decade.

All the three Scandinavian capitals are among the award winning cities of the European Green Capital Award with Oslo being the 2019 Green Capital.

The potential for greening urban mobility and the associated benefits are enormous. Fuel cell buses reduce the external environmental and health care costs of public transport. With lower noise levels and air quality improvement operators can benefit from a “green” and modern image, while reducing operating costs and improving passenger satisfaction.

Now is the time to make a move to fuel cell buses for public transit - zero emission fuel cell bus solutions are ready to be implemented in the public transport sector.

FCB OSLO18 will provide you with the information you need to start planning for the deployment of zero emission fuel cell buses in your area.
WHAT IS A ZERO-EMISSION FUEL CELL BUS?

A fuel cell bus is an electric vehicle that includes both a fuel cell generator and batteries working together seamlessly to provide an efficient zero emission bus without compromise in range or route restrictions.

Hydrogen fuel cell buses are battery fuel cell hybrid electric buses. They use hydrogen as the fuel source to generate electricity to power the electric drive and "recharge" the batteries.

The range of the fuel cell bus is determined by the amount of hydrogen stored onboard the bus.

The fuel cell generator generates electricity from hydrogen through an electro-chemical reaction producing only water and heat as by-products. Heat generated can be used for heating the bus cabin.

The batteries provide storage for regenerated energy from braking and peak power for the bus. There is no need to plug in the bus to recharge the batteries, as hydrogen stored in the bus provides the entire daily energy need of the bus.
WHICH FUEL CELL BUSES ARE AVAILABLE?

Fuel cell bus technology is increasing its presence in the public transportation industry, and more than 10 bus manufacturers are currently offering a fuel cell bus model. However, developments are constantly being made and we expect to see many new fuel cell buses in the future.

In the following, three examples from Solaris, Van Hool and Wrightbus are presented. They each offer a fuel cell bus as part of their zero emission bus product range.

The Solaris Urbino 18.75 fuel cell bus
In late 2014 Solaris introduced its first Urbino 18.75 articulated electric bus with hydrogen fuel cell range extender.

This innovative Solaris bus is equipped with 120 kWh batteries as the main energy provider to the drive system. The batteries are charged with a 85 kW fuel cell module provided by Ballard for a total range of 300 kilometers per day. The fuel cells are used only when 100% of output is required, which significantly increases their durability. The bus is quickly refuelled with hydrogen at the bus depot at the end of each day. At a length of 18.75 meters, this emission-free bus can be operated on even the most heavily used lines.

The bus has also won the Fuel Cell Award 2016 in the product and market category. Solaris is also developing a next generation 12-meter bus, which will be available in 2019.

Van Hool – A330 fuel cell bus
Van Hool is an independent Belgian designer- and manufacturer of buses, coaches and industrial vehicles. Van Hool has been building hydrogen buses for the American market since 2005 and for the European market since 2007. By now, Van Hool has produced 53 hydrogen buses for North America (21) and Europe (32).

Based on experiences with fuel cell buses for the American market, Van Hool has developed the first European hybrid fuel cell bus with the same passenger capacity as a diesel bus and with all modern comfort. Tests have
been conducted throughout Europe, which have proven the reliability of the fuel cell technology.

Van Hool has landed a significant contract with RVK Köln and WSW Wuppertal (Germany), to supply 40 hydrogen buses of the latest generation. This order consists of 30 fuel cell buses for Cologne and 10 for Wuppertal, making it the largest order for hydrogen-powered vehicles ever been placed in Europe. These high-tech vehicles will be built in the Van Hool factory in Koningshooikt, Belgium. The first buses will be delivered in the spring of 2019.

**Wrightbus – hydrogen fuel cell powertrain**

The Wright Group is a leading manufacturer of city buses for the UK and increasingly the global market. Wrightbus offers a comprehensive range of drivelines to meet operator’s needs, these include Micro Hybrid, Hybrid, and EV. In 2016 Wrightbus launched its new zero emission hydrogen fuel cell bus which is available in both single deck and double deck vehicle layouts.

The zero-emissions driveline technology from Wrightbus is developed with support from the British government’s Advanced Propulsion Centre (APC) under a grant for common platforms and assembly methods for Ultra Low Emission Buses.

Wrightbus’s fuel cell concept features an electric drive axle packaged to allow a full flat floor throughout the bus, a zero-emission heating and cooling system, the ability for overnight charging if the operator desires, and remote diagnostics.

<table>
<thead>
<tr>
<th>Solaris Urbino 18.75 fuel cell bus</th>
<th>Van Hool Fuel cell buses</th>
<th>Wrightbus Hydrogen Fuel Cell Bus</th>
</tr>
</thead>
<tbody>
<tr>
<td>Size</td>
<td>18.75m</td>
<td>12, 13, 18m</td>
</tr>
<tr>
<td>Battery power</td>
<td>120 kW lithium-ion-phosphate</td>
<td>80-120 kW lithium-ion-phosphate</td>
</tr>
<tr>
<td>Fuel cell power</td>
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<td>85-100 kW FCveloCity®-HD</td>
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<td>Hydrogen storage</td>
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<td>30-38 kg</td>
</tr>
<tr>
<td>Range</td>
<td>&gt;300 km with auxiliaries</td>
<td>&gt;300 km with auxiliaries</td>
</tr>
</tbody>
</table>

 BENEFITS OF DEPLOYING ZERO EMISSION FUEL CELL BUSES

Fuel cell buses provide zero emission transportation with no compromise in vehicle performance. Fuel cell buses are the only zero emission technology to offer full vehicle capability (grade ability, highway speeds, and long range) in all operating environments.

Fuel cell buses do a complete day’s work even on the most challenging routes and allow for a 1:1 replacement for conventional diesel, compressed biogas (CBG) or compressed natural gas (CNG) technologies. Therefore, fuel cell buses can be applied to all urban bus routes without compromise.

Benefits of implementing fuel cell buses include:

**GHG and NOx Reductions** - Fuel cell buses have zero tailpipe emissions. By using hydrogen produced from renewable energy sources, buses reach full carbon neutrality. One fuel cell bus fuelled with hydrogen from renewable energy sources will avoid approximately 122 kg of CO2 emissions for every 100 kilometres travelled compared to a conventional diesel bus.

**Range and route performance to match conventional buses** - Fuel cell buses operate over 450 km during an 18-hour shift on the road with a single 10-minute refuelling, and do not require any charging infrastructure along the route.

**Fast and scalable refueling** - Hydrogen refuelling stations at transit depots are built to be scalable, and a station can simply and cost-effectively increase its capacity from 10 to 100 buses by upgrading the compression and storage equipment and adding dispensers.
Flexible Vehicle Integration - Fuel cell power modules for transit buses are commercially available from 30 to 100 kilowatts, allowing bus manufacturers to offer a range of options to meet customer requirements. Fuel cell power modules can be integrated into any type of bus from 8m to 18m (articulated) including double decker buses.

Proven reliability – With millions of kilometres in commercial service, more than 15 years on the road in different environments and transit bus duty cycles, fuel cell buses have proven to meet operational requirements of transit agencies and bus operators.

Low maintenance costs - Fuel cell power module is based on solid state technology with few moving parts reducing maintenance cost. Fuel cell buses share over 90% of the parts with standard electric buses and have similar low cost maintenance.

“
I particularly enjoy driving a fuel cell bus because of the smooth ride without the noises and vibrations you have in a diesel bus. You feel more relaxed after your shift and in addition you know that you have done something good for the environment.

Bus driver at RVK, Cologne
HYDROGEN FUELLING INFRASTRUCTURE

A roll-out of hydrogen refueling stations and the supply of hydrogen is an important factor in the implementation of fuel cell buses. To secure a seamless 1:1 replacement with diesel buses, it is critical that refueling processes and operations are similar to conventional fuels.

Hydrogen is produced in large scale either on-site or trucked in from central production. The solution depends on the hydrogen demand and on physical surroundings. Refueling can be carried out at the depot as part of the normal procedure to prepare the buses for the next day of operation.

The H2Station® produced by NEL Hydrogen is a new generation of hydrogen refueling for fuel cell vehicles, offering fast and reliable refueling with long range according to international standards.

The hydrogen refueling systems can easily be customized to your needs. They are scalable and there are solutions for every hydrogen fuel cell vehicle. NEL Hydrogen can provide you with delivered hydrogen at a fixed price dispensed at pump over for example a 10-year period. The price of hydrogen includes all capital and operating costs, which means that there is no additional investment for the bus operator. A hydrogen fuel price of €5-6/kg is accepted as the target for the industry, as this is the level which allows parity with diesel costs for today’s buses.

Prices of €5-6/kg is already achievable and offered by NEL Hydrogen on a fixed price contract today. Fixed prices let operators and municipalities gain total clarity of the cost during the entire contract period. Thus, there will be no need to take increase in prices over time into account. Although the initial CAPEX investment of implementing fuel cell buses is higher than a comparable diesel solution, over time the fuel cell bus is from both environmental and economical perspective an attractive solution.
The price of fuel cell buses has decreased over the years as volumes have grown. Since the first deployments in the 1990s, purchasing costs for fuel cell buses have fallen by more than 75%.

Currently, the target price for a basic* 12m fuel cell bus is €650,000 as part of the next funded European deployment program. With volume purchases over 100 buses/year this price could start from 450,000€ or even lower beyond 2020. Aligning this price with the maintenance costs for fuel cell buses at €0.35 per kilometer, and being lower with volume increase, the fuel cell buses are very competitive to diesel buses.

Trials in cities around the world have demonstrated that fuel cell buses can cut emissions and noise pollution with no compromise in service. International commercial traction coincides with already strong uptake and deployment of hydrogen and fuel cell technologies by European transit operators in major cities including London, Aberdeen, Cologne, Hamburg and Oslo.

Through the JIVE project, over 300 new fuel cell buses will be on the road in Europe within the next three years and hundreds more in China, Korea and Japan.

Fuel cell buses are now ready to be deployed in large scale. The technology is ready, the price is affordable, and the time is now to make a move to fuel cell buses for public transit.

Municipalities and regions are establishing the public transport systems of the future. Fuel cell buses will help municipalities and regions to deliver zero emission public transport and meet the goal of a fossil free transport sector by 2050. This is done by including the implementation of fuel cell buses in the local public transport strategies and route tenders.

By engaging now this allows the municipalities to realize the benefits of fuel cell buses, to build-up their own knowledge and practical experience as well as taking responsibility for preparing the future of our public transport system.

*basic means without specific customer/PTA equipement.
THE PARTNERS
BEHIND FCB OSLO18

**Ballard Power Systems:** Ballard has established a sustainable leadership position in PEM (proton exchange membrane) fuel cell technology and products, currently providing solutions for backup power, material handling and heavy duty vehicles including bus, truck and train. www.ballard.com

**Nel Hydrogen:** Nel produces hydrogen production plants for industry and energy applications, hydrogen fueling stations for the transport sector, and power-to-gas/power-to-power solutions for the renewable industry. Nel has its roots from the hydrogen activities of Norsk Hydro, dating back to 1927. www.nelhydrogen.com

**Hexagon:** the technology group Hexagon Composites is a leading global supplier of composite cylinders and systems for gas applications. Hexagon is working with leading gas distributors, vehicle manufactures and system and component suppliers to be at the forefront of its industry. www.hexagon.no

**Agility Fuel Solutions:** Agility Fuel Solutions is the leading global provider of highly-engineered and cost-effective compressed natural gas, liquid natural gas, propane, and hydrogen fuel systems and Type 4 composite cylinders for medium- and heavy-duty commercial vehicles. www.agilityfuelsolutions.com

**Hydrogen Valley:** Hydrogen Valley is a non-profit business incubator acting as a driver in the hydrogen industry in Denmark. Hydrogen Valley conducts and assists in projects and activities which establish how hydrogen can advance the green transition of the energy system. This is done in close cooperation with companies, organizations and public authorities. www.hydrogenvalley.dk

**Norwegian Hydrogen Forum:** the non-profit organization, Norwegian Hydrogen Forum (NHF), was founded in 1996. NHF works to promote hydrogen-based value creation in Norway, and has members from industry, research, education and organizations. www.hydrogen.no
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Please do not hesitate to contact us if you have questions or you need advice on how to start planning for the deployment of fuel cell buses in your area.