Fuel Cell Backup Power

An attractive value proposition for zero emission backup power in Scandinavia
Backup Power for Scandinavia
Executive Summary

Wireless and fiber broadband communication is rapidly expanding, which makes our world increasingly connected and power outages severely problematic. Today, telecommunication is critical in terms of growth, innovation and disruptions across many industries. Reliable, robust and cost-effective backup power solutions for communication networks, including fibre broadband, are therefore vital to ensure critical infrastructure availability during unexpected power outages.

As providers of some of the fastest and most widespread broadband connections in the world, Scandinavian countries have a strong need for backup of active systems. Telecom fiber broadband networks have become a critical part of the countries’ infrastructure and it is—often mission-critical to have a reliable backup generator if the electric grid fails or other issues bring down the power sources temporarily. Furthermore, in today’s world, there is a focus on bringing down costs while also using sustainable and green technologies. This is where hydrogen fuel cell backup power comes in.

Hydrogen fuel cell backup power systems convert the chemical energy contained in hydrogen and air into stable DC power. This process produces reliable backup power with a wide temperature operating range, allowing the systems to function normally in temperatures as low as -40 °C with the ‘cold climate kit’.

Because fuel cell backup power systems are scalable, from 500W to 60kW or even higher, there are no risks in terms of future changes to power requirements or new regulations. Should legislation change and more hours of backup be required, it is simple to add more hydrogen bottles on site. Should power needs increase or reduce, the modularity of the system allows power modules to be added or removed to meet site requirements. In Denmark, there currently is no legislation that enforces a minimum requirement for minimum backup time, however such legislations exist in both Norway and Sweden. When there are systems running for over ten years, providing millions of hours of backup time, clearly the technology has successfully proven it critical network sites.
Reliable, cost-effective backup power systems for critical infrastructure, powered by renewable hydrogen
Introduction

As the world becomes more and more digital, the increasing dependency on critical infrastructure for communications is becoming vital. New European requirements are in place, making it necessary for energy companies to have 24 hours of backup on both their communication networks and transformer stations, which will require reliable and cost effective extended backup solutions.

Scandinavia is at the forefront of technology development with some of the world’s fastest and widespread communication networks that must be secured and protected. Some countries are taking this task to heart by increasing the duration of backup time requirements for critical infrastructure set by new legislation.

As a matter of fact, the Nordic countries are above the EU average in terms of broadband connections. The EU average in 2017 was approximately 85%, with 97% of Danish citizens, 95% of Swedish citizens and 94% of Finnish citizens having access and, 85% (2016) of Norwegian citizens having broadband access.

This means that there is an increasing focus on the importance of reliable critical infrastructure, resulting in an increasing amount of new legislations. For example, in Norway the Forsterket Ekom project has set-up requirements of 72+ hours of backup time on critical sites in 423 cities.

As a whole, Norway is moving toward longer backup times due to critical power interruptions in the past. Similarly, Swedish legislation will be introduced with requirements of 12-24 hours of backup time for the fiber broadband networks in 2020. Currently, the backup time requirements in Sweden depend on the amount of connections in each area, oscillating between 2 and 24 hours. In Denmark, legislation has not been issued; however, most fiber broadband operators as well as the Tetra network are already using fuel cell solutions to provide the reliable extended backup required for such critical sites.
Today, batteries and diesel generators are widely used for backup power all over the world. Diesel generators are suitable for high power and long backup time requirements, but suffer from high CAPEX and OPEX as well as generally low reliability.

In contrast, batteries are better suited for sites that require shorter backup time and less power, but batteries are sensitive to their environment, which often shortens their expected lifespan leading to lower reliability. Another challenge for batteries is weight and volume, particularly for high energy demands.

Fuel cell backup systems complement diesel generators and batteries as a reliable and flexible solution that provide significant benefits for many critical sites where either battery or diesel generator solutions are not optimum.

In addition, fuel cell backup power systems offer a more sustainable alternative with no emissions, no harmless substance use and an existing recycling process for the fuel cell stack.

From a financial perspective, each backup power technology option provides an attractive solution based on the site power requirement and the back-up time as visualized below.
For typical site with 8 hours of backup power requirements and 8 kW of power load, the comparison of key parameters is shown below:

<table>
<thead>
<tr>
<th>Solution CAPEX</th>
<th>DIESEL GENERATOR</th>
<th>BATTERIES (VRLA)</th>
<th>FUEL CELLS</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>500,000 NOK</td>
<td>400,000 NOK</td>
<td>350,000 NOK</td>
</tr>
<tr>
<td>Average annual OPEX</td>
<td>50,000 NOK</td>
<td>25,000 NOK</td>
<td>12,000 NOK</td>
</tr>
<tr>
<td>Reliability</td>
<td>85-95%</td>
<td>98-99%</td>
<td>99.99%</td>
</tr>
<tr>
<td>Weight</td>
<td>300kg + 10kg tank</td>
<td>2000kg</td>
<td>150kg + 120kg H2 tank</td>
</tr>
<tr>
<td>Upgrade cost (5kW extra load)</td>
<td>4-500,000 NOK</td>
<td>2-300,000 NOK</td>
<td>140,000 NOK</td>
</tr>
<tr>
<td>Space (width x height x depth)</td>
<td>Separate room + tank</td>
<td>Indoor: 180x170x60</td>
<td>Indoor: 60x190x60 + tanks: 90x160x60</td>
</tr>
</tbody>
</table>

8kW / 8 hours example

For these applications, fuel cell solutions have the lowest cost, the highest reliability, the simplest maintenance, the smallest space requirement, and the lowest weight. Especially when more than six hours of backup is required and down to three hours for sites with >15 kW power requirements. Fuel cells have a lifetime of 15 years and are scalable, therefore investment in fuel cell power systems is safeguarded as increase in power requirement or backup time is easily achievable.

Fuel cell solutions are highly flexible. As fuel cell systems come in building blocks of 1.7 kW or 5 kW modules, upgrading to higher power is easily done by adding a module, where upgrading to longer backup time is easily done by adding additional hydrogen storage. The individual power modules can also be easily re-deployed to other sites.

When choosing a backup power solution, fuel cell systems become particularly attractive for sites with a power need less than 25 kW and with a backup time requirement of more than 3-6 hours. The lower the energy required in the application, the more competitive batteries become. The higher the energy required, the more competitive diesel generators become. A financial comparison for your site could easily be done by using the Ballard Business Case Tool. (click on link)
Hydrogen has traditionally been used as an industrial gas, widely available from gas companies and distributed in pressurized steel cylinders, bundles of steel cylinders or hydrogen tanks.

During the last 5 years, hydrogen has also become widely used as a fuel for source for fuel cell cars, buses and for power generators, including backup power systems. Such uses are growing rapidly. The wider use of hydrogen has increased hydrogen availability and fostered new composite storage cylinders and new logistic concepts.

Today, hydrogen is commercially available in different packaging from several suppliers and distributors across Europe at the point of use.

In the Nordic countries, companies like AGA, Strandmollen and Woikoski are setting up depots to support the installation of backup power systems. Central depots can hold large quantities of hydrogen and local depots located near the fuel cell backup power sites hold sufficient amounts of hydrogen to support predefined response time.
In Denmark, hydrogen has been used for backup power since 2007. As a result, today there is a network of hydrogen depots across the country to support more than 400 sites. The hydrogen logistics concept has continually been improved over time, and is now a proven concept for the past 10 years. The concept can easily expand into any Nordic region.

Today, transportation of hydrogen is shifting to composite bottles, which reduces the weight and eases the handling (all cost analysis in this paper are based on composite bottles). Composite bottles come at a small premium to steel bottles.

Using an example site with 8 kW of power consumption and 8 hours of required power backup time; the table below shows the weight comparison (in kilograms) between hydrogen bottles to be handled and diesel and batteries.

<table>
<thead>
<tr>
<th></th>
<th>DIESEL GENERATOR</th>
<th>BATTERIES (VRLA)</th>
<th>FUEL CELLS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Power density (kg/kWh)</td>
<td>1</td>
<td>20</td>
<td>1.5</td>
</tr>
<tr>
<td>Avg. annual logistics (to site in kg)</td>
<td>40</td>
<td>300</td>
<td>40</td>
</tr>
<tr>
<td>1 hour of outage (kg)</td>
<td>8 *</td>
<td>0</td>
<td>20</td>
</tr>
<tr>
<td>Full (8h) outage (kg)</td>
<td>64</td>
<td>0</td>
<td>100</td>
</tr>
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</table>

*Full diesel storage needs to be changed every 5 years

8kW / 8 hours example

The cost of hydrogen is almost negligible for backup power systems, as the duration of power outages is generally very short. A full 8 hour outage as illustrated above will usually cost on 200-300 NOK of hydrogen gas.

Transportation, handling and storage of hydrogen is well defined according to safety standards and is completely safe. This is also highlighted by the increasing number of fuel cell buses and cars on the road that are fueled using hydrogen across Europe.
Fuel cell backup power systems provide low cost, flexible backup power with the highest reliability. Hundreds of systems have been in operation for over ten years without any issues, continuously ensuring that the end-customers stay connected even when the grid supply has failed.

The duration of backup power delivered could easily be increased by adding more hydrogen cylinders to the systems on site and options include indoor or outdoor enclosures, and a ‘cold climate kit’ for operation as low as -40°C without compromise in operation.

Lower cost backup power with no compromise in price, performance or reliability.
Low Cost
Lower CAPEX compared to battery and diesel generators for 6+ hours of backup power.
Attractive OPEX due to the system’s long lifetime (>15 years) and low maintenance requirements.
Remote capacity & functional testing, 5-year service intervals, predictive maintenance and no discharge tests.
Comprehensive service packages that covers the FCgen®-H2PM system’s lifetime.

Flexible Solutions
The FCgen®-H2PM module is designed to support critical infrastructure. It fits into a standard 19-inch rack. The modular and scalable design from 0.5kW to 60kW allows multiple systems to be coupled in parallel to meet site power requirements. The system supplies backup power for both DC and AC equipments.
The modules’ low weight, compact size, and ability to be integrated with existing power equipment reduce siting issues and facilitate future relocation.
Ballard’s comprehensive service offer includes optional on-site support, partner training, and a start-up package.

No Risk
The FCgen®-H2PM is a future-proof investment.
Fuel cell backup power modules are solid state power generators with few moving parts and no degradation in standby mode regardless of temperature. The FCgen®-H2PM system has unique built-in predictive maintenance features and automated self-testing.
Ballard Power Systems has 10 years of experience with systems in operation on critical infrastructure sites with 99.99% reliability. Ballard offers a service warranty of up to 15 years.

Environmentally friendly
Recycling: The system uses recycled materials and all parts are recycled or reused in future systems
Zero-emission operation with no harmful or toxic substances, waste or fuel
The modularity equals easy scale to fit and upgrade of the solutions

PRODUCT PORTFOLIO

<table>
<thead>
<tr>
<th>TECHNOLOGY</th>
<th>FCgen® – H2PM 1.7 kW</th>
<th>FCgen® – H2PM 5.0 kW</th>
</tr>
</thead>
<tbody>
<tr>
<td>MAXIMUM POWER kW</td>
<td>1.7 kW</td>
<td>5.0 kW</td>
</tr>
<tr>
<td>PARALLEL OPERATION</td>
<td>12 modules can be coupled for systems with up to 60 kW power output</td>
<td></td>
</tr>
<tr>
<td>DIMENSIONS, cm</td>
<td>45 x 63 x 36</td>
<td>50 x 57 x 62</td>
</tr>
<tr>
<td>WEIGHT</td>
<td>40 kg</td>
<td>75 kg</td>
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</table>
A fuel cell backup power system converts chemical energy (hydrogen and air) into regulated DC power.
Backup Power Systems

Fuel Cell Backup Power Systems are a cost effective, environmentally friendly, easy to install and reliable power generators that convert chemical energy (hydrogen and air) into regulated DC power, providing up to 60 kW of reliable backup DC power on demand.

The intended application of this system is backup power for critical infrastructure networks like telecom, optical fiber and emergency communication.

The thousands of systems installed and millions of hours of backup power provided validate fuel cell technology and the maturity of Ballard’s FCgen®-H2PM system. The fuel cell backup power solution consists of:

- Fuel cell module (DC and AC output options)
- Integrated ultra-capacitor module or external battery
- Master system controller (for multiple module interconnection)
- Module casing (such as a 19” rack or outdoor enclosure or shelter with integrated hydrogen storage)

The duration of backup power delivered can easily be increased by connecting more hydrogen storage cylinders to the systems on site. Solutions are scalable and options include an indoor or outdoor enclosure and a ‘cold climate kit’ for operation as low as -40°C.

Hydrogen offers a much higher energy density compared to traditional electrical storage systems such as batteries. Delivery of hydrogen can be compared with diesel delivered on site in terms of weight and volume, but the fuel cell system is smaller and lighter compared to a diesel generator — and it could be installed indoor in a shelter or building.
Eniig Energy Group

In 2007, Ballard Power Systems Europe A/S provided the first commercial solution into service on the fiber-optic broadband network operated by the Danish power company Eniig. The FCgen®-H2PM fuel cell backup power system was offered to Eniig for its reliability and flexibility and this promise has been kept throughout the years.

Since the initial installations were rolled out through 2007, Eniig has continued to increase the number of fuel cell backup power systems as their network expanded. Today, approximately 90 Ballard FCgen®-H2PM units have been installed across Denmark.

The fuel cell backup power units ensure that more than 170,000 Danes can surf the internet at breakneck speed even during a power grid failure as the backup power systems will automatically and seamlessly switch on. More importantly, businesses and public institutions such as hospitals can rely on stable internet to support their critical data traffic.
Denmark’s public safety network, SINE

In 2009, the Danish public safety network, SINE, needed a new backup power solution. The SINE network is used by Danish government authorities, including the police and regional emergency services such as rescue preparedness, ambulance and fire-fighting services.

In 2009, Ballard developed customized integrated fuel cell systems inside an outdoor cabinet that were deployed across Denmark.

Backup for approximately 120 critical radio stations was secured and these systems have been continually operating and serviced by Ballard since.

The SINE case also highlights the proven reliability of fuel cell backup power solution. The SINE deployment shows that fuel cell backup power systems have proven to be available 99.99994% of the time (average) and with average reliability is 100%.

![](image)

Real life numbers showing the reliability and availability of the SINE fuel cell systems.

This means that the Danish public safety network is securely backed up by an environmentally friendly solution that has kept the radio communications network up and running during power outages during the past ten years.
Similar to batteries and diesel generators, a fuel cell backup system needs auxiliary equipment to be functional on site when it is deployed as a complete solution. Special equipment has been developed and the best partners in the industry have been selected for those components of the complete solution.

Fuel cell modules are usually mounted in a 19” indoor rack with air ducts for external air. If needed the fuel cell modules could be packaged in outdoor cabinet.

Hydrogen is necessary to generate electricity. It comes in steel or composite cylinders that are placed in standard cabinets, usually outside the building/equipment room. Gas companies like AGA, Strandmollen and Woikoski are today offering a large variety of solutions for storage bottles and the logistics behind suiting fuel cell backup power system deployments.

For power management, a rectifier is needed to provide 48V DC. Any rectifier could be used, but Eltek equipment has been optimized for fuel cell system operation. If other voltage levels are required a DC/DC or DC/AC (inverter) solution could be provided.

The design, installation and commissioning of fuel cell power backup solutions is becoming simple with easily customized solutions to meet specific site or customer requirements. Such activities could undertaken by operators or trained technicians and installers, or by Ballard team. Often, Ballard is involved in the first installations to build capabilities with engineers and installers and to support service personnel. Ballard offer a comprehensive training program for technicians who have not previously worked with fuel cell solutions.

Ballard provides various comprehensive and flexible service packages to meet expected system life time. A 10 year full service and warranty package is often chosen, as it provides a “no worries” option and fully utilizes the benefits of fuel cells from a robustness and lifetime perspective.
Reliable and flexible fuel cell backup power solutions are ready to meet your network requirements.
Fuel cell backup power system pricing has decreased considerably as volumes have grown. Since the first deployments in 2007, the technology has become more competitive on several fronts — particularly when it compares to incumbent technology at longer runtimes and higher power.

In general, fuel cell installation cost is determined by the kilowatt (kW) load that is needed on site. Increasing the duration of backup power (or kWh) is relatively inexpensive, as it only requires to increase the amount of hydrogen storage on site. For instance, an installation with a 2.4 kW load and 24 hour backup is only 2-3% more expensive than a 2.4 kW and 12 hour backup installation.

Furthermore, add-ons can be chosen to complete the solution, including an indoor or outdoor enclosure and a 'cold climate kit' for operation as low as -40°C.

While understanding the capital investment cost of a backup system is one important element, getting the full picture of operating cost (OPEX), lifetime cost, and total cost of ownership (TCO) is critical when making long term investment on network critical infrastructures.
Distinctive aspects of fuel cell backup power systems include long lifetime and minimal maintenance. With high efficiency, low standby power consumption, external hydrogen storage with minimal indoor footprint and preventive maintenance only every five years, fuel cell backup power systems have very low operating costs compared to incumbent solutions. In particular, the aspect of minimal maintenance is of value as it significantly lowers operating cost and thus the total cost of ownership.

Maintenance of the systems is done automatically, which means that no one needs to go to the sites removing costly site visits. Hydrogen is readily available at the site and trained service personnel only need to go when a scheduled service check is required, or when the hydrogen bottles need to be changed if the system reports an issue during the automatic self-tests.

Fuel cell systems do not degrade over time, even while in standby mode. FCgen®-H2PM fuel cells are rated to provide 4,000+ hours operating time over a 15+ year lifetime.

Companies investing in fuel cell systems will transfer current high operation costs of current solution into capital costs and asset investments, improving operating results.
Proton exchange membrane (PEM) fuel cell technology generates clean electricity from hydrogen to power a range of applications, while emitting nothing but water. Fuel cells are an environmentally friendly alternative to polluting internal combustion engines and batteries containing toxic materials, such as lead acid. PEM fuel cells contain no poisonous or hazardous materials that can impact the environment upon disposal.

With years of fuel cell manufacturing experience, Ballard has developed industry leading processes that minimize energy intensity and environmental impact during production. At the end of a product’s life, processes ensure efficient recovery of precious metal catalyst and minimize waste entering the landfill.

The products are designed to meet rigid environmental requirements, restricting the use of hazardous substances in electrical and electronic equipment.

Ballard offers a refurbishment program for fuel cell stacks that have reached the end of life. The customer returns the fuel cell stack to Ballard, where the MEA is replaced while plates are re-used. The returned MEA is then sent to a 3rd-party for recovery of precious metals. This process will typically save customers up to 30% when they purchase a new fuel cell stack. The majority of the remainder of components in a fuel cell stack are recycled using ordinary recycling processes.

A fuel cell back-up power systems include also electronics, pumps, valves, hoses and metal for housing and frames as the main components, which are all commonly used components that can easily be recycled and meet standard regulations, such as WEEE for general recycling.
With more than a decade in operation, fuel cell backup power and the hydrogen industry is now mature.

A reliable European supply chain has emerged that provides fuel cell components, training, support and hydrogen to companies throughout Europe.

A number of commercial solutions for production, delivery, storage and dispensing of hydrogen are available from different suppliers in order to meet the specific site requirements of operators.
Conclusion

With millions of hours of operation with a reliability of 99.999% proven the past ten years, fuel cell backup power systems are the futureproof and flexible solution that will allow customers to increase the power and relocate systems at any time.

The technology and infrastructure is ready now with robust hydrogen supply chain. And it is needed now, as new legislations increasing backup requirements will lead to significant additional costs for those installing battery or generator solutions. Using fuel cell solutions will reduce upgrade cost by adding only more hydrogen bottles or fuel cell power modules to increase backup time and power.

Our fuel cell backup power solutions allow operators of critical infrastructures to harden their networks and improve customer satisfaction with:

**Low Cost**
- Low CAPEX, particularly for 6+ hours of backup power.
- Attractive OPEX due to the long lifetime (>15 years) and low maintenance requirements.
- Remote capacity & functional testing, 5-year service intervals, predictive maintenance and no discharge tests

**Flexible Solution**
- The modular and scalable design from 0.5kW to 60kW (and above for special requirements) allows multiple systems to be coupled in parallel to meet site power requirements. The system supplies backup power for both DC and AC with possible customization for higher output. The modules’ low weight, compact size, and ability to be integrated with existing power equipment reduces siting issues and facilitates future relocation.

**No Risk**
- The FCgen®-H2PM is a future-proof investment. The module has few moving parts, no degradation in standby mode regardless of temperature, built-in unique predictive maintenance features and automated self-testing.

Please do not hesitate to contact Ballard Power Systems Europe A/S if you want to know more about our FCgen®-H2PM fuel cell backup power solutions.
Appendix

Case Study – Assumptions

- System Design Parameters*
  - Batteries – 5 kWh/h +70% extra capacity → 17 kWh battery per 2 hours
  - Fuel Cell Systems – 2 hydrogen bottles per 2 hour
- Economic Parameters
  - Cost data from literature (reports), suppliers, users, and IFE (data base)
  - Sensitivity analysis w.r.t. specific costs, lifetime, etc.
- Method
  - Net Present Value (NPV) calculations; i = 3 %, n = 10 and 15 years
  - Excel Spreadsheets

*Sources: Battery, Hydrogen, and Fuel Cell Technology suppliers

Battery System – Parameters

<table>
<thead>
<tr>
<th>System category</th>
<th>Battery Activated Power (kW)</th>
<th>System 1</th>
<th>System 2</th>
<th>System 3</th>
<th>System 4</th>
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<tbody>
<tr>
<td>Hours of back-up</td>
<td>2 4 24 48 72</td>
<td>2 4 24 48 72</td>
<td>2 4 24 48 72</td>
<td>2 4 24 48 72</td>
<td>2 4 24 48 72</td>
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<tr>
<td>Capacity needed (kWh)</td>
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<td>2,000</td>
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<tr>
<td># of Batteries (Battery capacity 1.5 kWh)</td>
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<tr>
<td># of strings (4 batteries in each string)</td>
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Hydrogen Fuel Cell System – Parameters

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<tr>
<th>System category</th>
<th>FC Reactor Power (kW)</th>
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<th>System 2</th>
<th>System 3</th>
<th>System 4</th>
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<tr>
<td>Hours of back-up</td>
<td>2 4 24 48 72</td>
<td>2 4 24 48 72</td>
<td>2 4 24 48 72</td>
<td>2 4 24 48 72</td>
<td>2 4 24 48 72</td>
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<tr>
<td># of H2 bottles necessary</td>
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<td>1</td>
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<tr>
<td># of bottles (50 kg/bottle)</td>
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<td>10,000</td>
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<tr>
<td>Sum CAPEX</td>
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