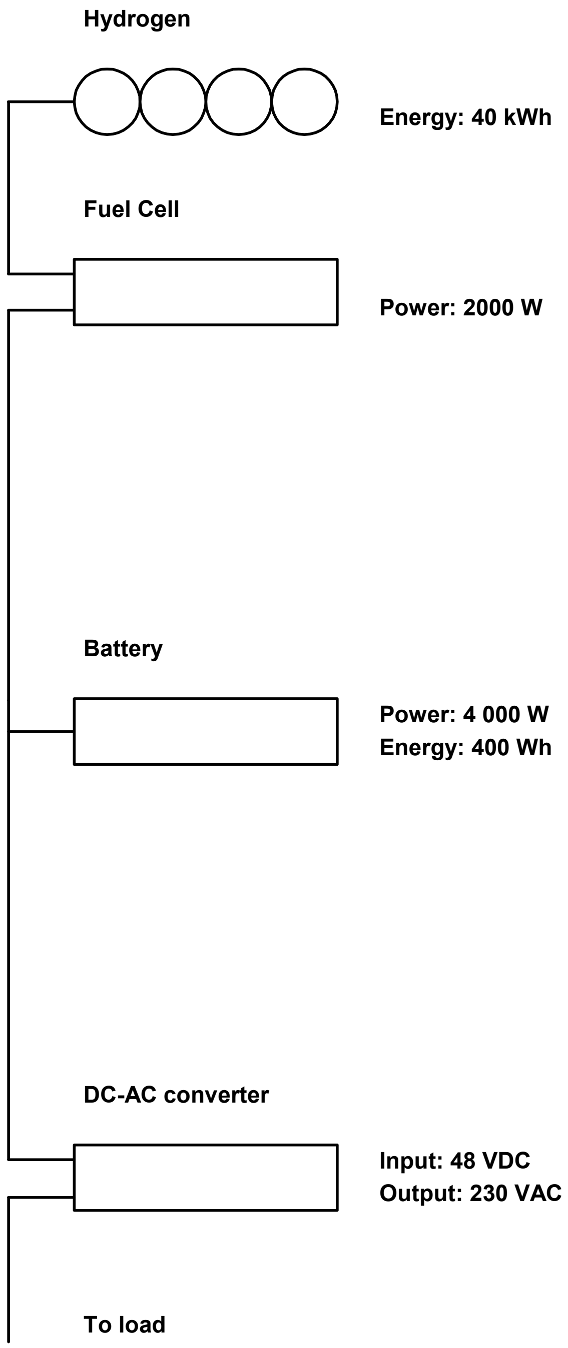
System architecture and dimensioning

Power and energy

The dimensioning of a fuel cell system starts by establishing the power and energy need.

What is the average power?
The fuel cell should have a power output that covers the need. Cellkraft fuel cells are available in different sizes from 50 W to 2000 W. Higher power can be obtained by connecting several units in series or in parallel. Power is usually measured in Watts (W).

How much energy must the system contain? How long time should the fuel cell be able to power the load? Energy is commonly expressed in terms of kilowatt hours (kWh). A standard gas cylinder (200 bar pressure, 50 liters volume) filled with hydrogen will correspond to 10 kWh_e. That means the cylinder can feed a fuel cell that delivers 1 kW electric power for 10 hours.



Battery or ultracapacitor

If the application has a need for high power for short times it is a good idea to dimension the fuel cell for the average need and then use a battery or an ultracapacitor to cover the peak power demand. The power buffer should then be dimensioned in the same way as the fuel cell. What is the difference between the peak power and the average power? This power need should be covered by the battery or ultracapacitor. It is then necessary to consider the length of the peak power demand and the time between the peaks to understand how much energy the power buffer must contain. Ultracapacitors could be an alternative to batteries if the load profile includes short periods or pulses of high power. Cellkraft offers systems based on different types of battery chemistries (Lead-acid, Li-Ion) or ultracapacitors.

There is a need for a small energy source for powering the start up of the fuel cell. If seamless power is of importance it is also necessary that this source can feed the load during the startup time of the fuel cell. Fuel cell systems are often hybrid systems because of these reasons, even if the load has a fixed power demand.

DC or AC Voltage

The application might require DC or AC voltage in a specific interval. If it is possible to use the raw DC voltage from the fuel cell no additional conversion is necessary. This means lower cost and higher efficiency. The fuel cell stack in itself has a rather wide voltage range. Maximum power could be achieved at a voltage about 50% of the zero-current voltage. The effective working interval of the fuel cell system is however more narrow. If the fuel cell is combined with a battery or ultracapacitor it is possible to get a quite well defined voltage from the system.

If the required voltage is different from the fuel cell voltage (higher, lower or more precise) a DC-DC converter is used.

If AC power is required a DC-AC inverter is connected to the fuel cell output.

> Cellkraft offers complete systems based on the building blocks described in this fact sheet.

Efficiency and hydrogen consumption

Efficiency

The efficiency of a fuel cell system is defined as the percentage of the fuel that is converted to electric energy. This is made by comparing the output electric energy with the consumed chemical energy. The common value of chemical energy is the lower heating value (LHV) of the fuel.

$$\frac{Electricity}{Fuel} = Efficiency$$

Hydrogen consumption

High efficiency means low hydrogen consumption. A fuel cell system that delivers 1000 W net power will consume hydrogen according to the table to the right.

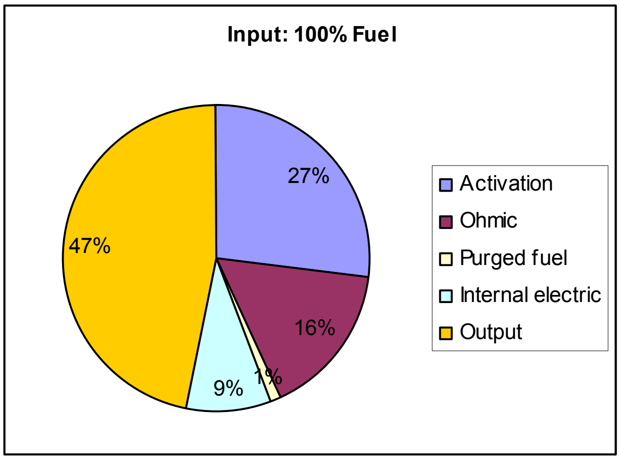
Efficiency (%)	Hydrogen (nl/min)	Hydrogen (g/h)
35	17,1	86,0
40	14,9	75,3
45	13,3	66,9
50	11,9	60,2

Efficiency and hydrogen consumption.

Why is the efficiency not 100%

All energy conversions will lead to a certain amount of degradation of energy quality. All input energy will not come out as output. Some of the energy will be lost as heat.

Fuel cell development work aims to maximise the output by minimising the losses. The losses could be traced to either the stack or the components of system. The fuel cell stack converts the chemical energy to electric energy. The electrochemical process and the conductance of current will however lead to losses and heat generation. These losses always increase at high current outtake. Stack design and operating conditions could be optimised to reduce the losses. There are two kinds of losses at system level: Fuel losses and electric losses. The fed hydrogen will be converted to electricity in the stack. Small amounts of hydrogen will however be purged out of the system. This fuel will represent a minor loss that must be considered when establishing the efficiency. The last thing to consider is the internal components of the system. They will consume some of the power delivered from the stack. Components like the air blower, cooling pump, cooling fans, valves and control circuits will support the stack and consume electric power. The net power delivered from the system will be slightly lower than the gross power from the stack, because of the internal consumption. The overall efficiency of the system takes all these losses into account.



Cellkraft S-1000 has an efficiency of 47 % at 1000 W net output. That corresponds to a hydrogen consumption of 12,7 nl/min.

Reliability and durability

Start-stop operation

Since February 2007 a test sequence is performed on two S-1000 units at a customer site. The sequence includes a start/stop operating cycle where the fuel cell is off three hours or six hours between starts. Up until September 2007 the fuel cell has performed more than 1000 such start/stop cycles with no significant degradation.

Reliability example #1

Continuous operation

Test cells operating at full power continuously is a method to explore the durability of the stack. Cellkraft has demonstrated operation of fuel cells in excess of 13 000 hours in lab tests. System components are carefully chosen to have life times exceeding 20.000 hours.

Reliability: example 1

The S-series is field tested to verify the characteristics. During the winter 2004 on a distant mountain top in the northern part of Sweden. Autonomous operation, internet monitoring and remote control was tested under varying ambient conditions. The fuel cell was in operation 24 hours a day – no supervision or maintenance.

Reliability example #2

Reliability: example 2

The system was installed 14th of February 2005. It is situated 20 meters from the seaside on the island Lidingö close to Stockholm. The system occupies 3 m^2 and the installation was less than 2 hours. The system is stand-alone with no physical connections to the surroundings. A GPRS-modem transmits information about the function of the system (Voltage, Current) and the energy content of the storage (kWh). The system was in operation during the winter 2005 and worked continuously.

Reliability: example 3

An S-series based system was shipped to Tasmania in the autumn of 2006 and installed on Antarctica by the customer spring 2007 by using the installation manual. After initial testing at the Australian Mawson base the system will subsequently be moved to Bechervaise Island (picture). Transport to and successful installation on Antarctica by a customer shows the robustness of the system in terms of installation.

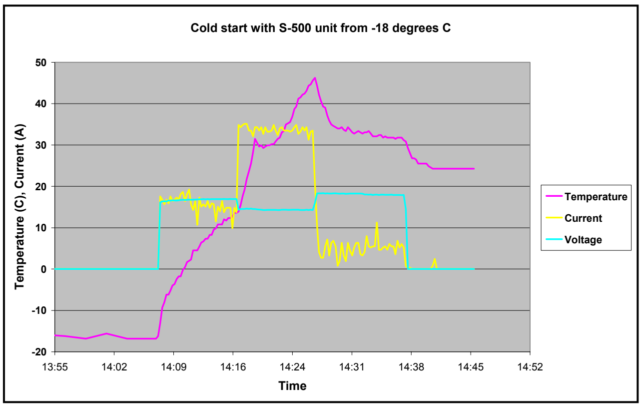
Reliability example #3

Cellkraft S-1000 has an expected lifetime of 15 years and 20 000 hours of operation.

Cold climate capability

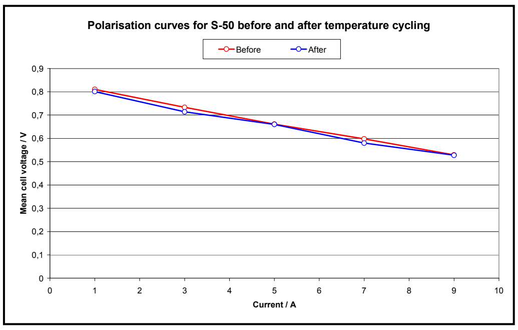
Start from subzero

Until some years ago it was common knowledge that the fuel cell stack would "turn into a block of ice" if the temperature dropped below zero degrees. Cellkraft was among the first to explore what was really happening. The Swedish Defence Material Administration actively asked for results considering fuel cells and cold climate and also supported the pioneer work. Based on the research work performed in 2004, hardware and software was developed to cope with subzero conditions. Today, cold climate capability is a unique characteristic of the S-series fuel cells. Cellkraft has developed a true cold climate capability, which means the stack actually starts from ambient temperature and heats itself. The stack is not insulated nor kept heated. This means there is no electrical consumption during standby for heating.



Thermal cycling

Cellkraft has put a large R&D effort into solving the cold climate issues with fuel cells. Among the result are numerous thermal cycles between running temperature and -30 °C without degradation.



Operation in subzero

Systems operating continuously have been operating for long periods of time in cold climate.

Location: Lidingö, Stockholm.

Fuel Cell: S-50 in IP55 class cabinet.
Power capacity: 50 W
Fuel storage: 12-tube hydrogen package
Energy capacity: 120 kWh
Temperature: Periodic < - 20° C.

The system was installed 14th of February 2005. It is situated 20 meters from the seaside on the island Lidingö close to Stockholm. The system consists of a Cellkraft S-50 unit installed in an outdoor cabinet and a 12-tube hydrogen package. This corresponds to 250 "car batteries" and will allow 100 days of continuous operation at 50 W load. The system is stand-alone with no physical connections to the surroundings. The test load consists of 3 halogen lamps. A GPRS-modem transmits information about the function of the system (Voltage, Current) and the energy content of the storage (kWh). The system was in operation during the winter 2005 and worked continuously. During some periods the temperature dropped below -20 °C that winter.

Cellkraft S-1000 starts and operates in -30 °C.