One hundred passengers and zero emissions

The first ever passenger vessel to sail propelled by fuel cells

Zemships – zero emission ships

The vision of a ship sailing without pollutant emissions has become a reality in Hamburg. In August 2008, the FCS Alsterwasser was the first inland passenger ship in the world to set off under fuel cell propulsion, and with hydrogen as its source of energy. The terminology FCS stands for Fuel Cell Ships. The vessel is run by ATG, and is initially due to sail up to 2010 on regular trips on the Alster, the inland lake at the heart of the city. The aim of this unique, EU-supported project is to test practical emission-free ship operation and to promote the use of this technology for maritime applications.

Until now, the maritime use of fuel cell technology has mostly been limited to military submarines and very small surface craft. Zemships is the first project in the world to integrate the process on board a passenger vessel. It combines two fuel cell systems with a 560-V lead gel battery pack. Both the systems were developed by Proton Motor and both have a peak output of 48 kW. The project is undeniably one of pioneering importance for inland shipping. One of the main tasks of the Zemships project is therefore to test the efficiency and practical performance of the fuel cell driven ship and the corresponding infrastructure required for filling up and storing hydrogen.

Hamburg – the gateway to the (eco)world

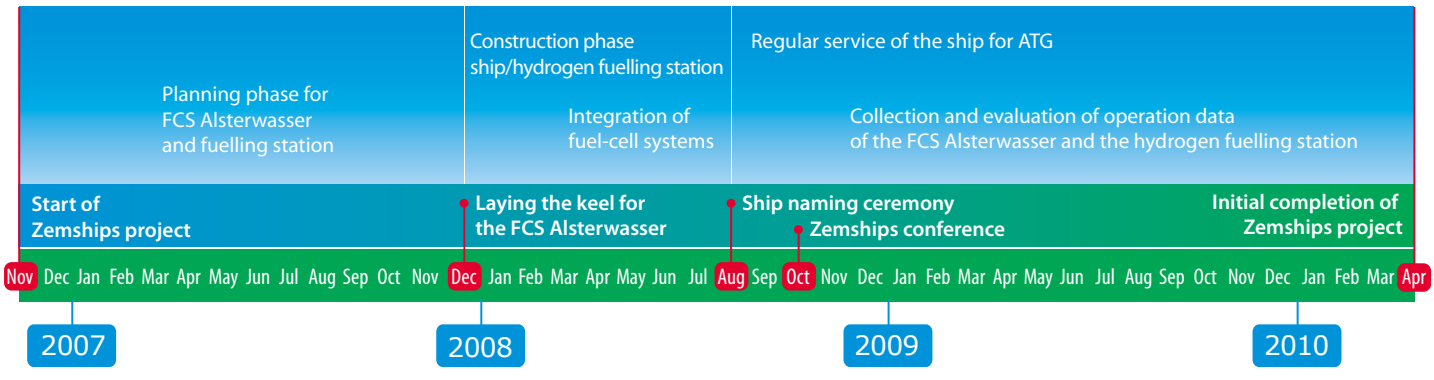
Hamburg has already gathered experience in the field of applied fuel cell technology. Indeed, the largest port in Germany has always played a pioneering role when it comes to climate protection. Ever since 2003 the Hamburger Hochbahn AG has been running fuel cell driven buses on regular bus routes, and currently has six such vehicles in service. It is hoped that the FCS Alsterwasser will help relieve the environmental burden on the city centre, for it serves an ecologically sensitive area of operation in this respect – the Alster lake, in the very midst of the metropolitan area of Hamburg.

Under the aegis of Hamburg's Department for Urban Development and the Environment, the following partners together developed the project Zemships:

- ATG Alster Touristik
- Germanischer Lloyd
- Hamburg University of Applied Sciences
- HOCHBAHN
- hySOLUTIONS
- Linde Group
- Proton Motor
- UJV Nuclear Research Institute

The FCS Alsterwasser is operated by ATG. The hybrid electro-fuel cell system has been developed by Proton Motor and has received a certification by GL. Responsible for the development and operation of the hydrogen fuelling station is the Linde Group.

People's expectations of the project are high – but so is the probability of its success. Growing costs for fuel and an ongoing interest in environmentally friendly propulsion systems have encouraged the demand for innovative fuel cell technology. The project is the awaited chance to bring a product onto the market that satisfies the need for efficient cutting-edge technology, and which simultaneously guarantees to conserve the ecology in the long term.



The consortium – competence times nine

Zemships was born of a consortium comprising nine companies and institutes. Every team of experts contributes its own particular know-how towards the success of the project. Clustering together competence has made it possible to help the innovative idea of an emission-free passenger vessel become reality. The following summarises who is responsible for what in the project:

ATG Alster Touristik GmbH, a HOCHBAHN subsidiary, is responsible for the design and building of the boat's hull, and for operating the FCS Alsterwasser.

Hamburg | Behörde für Stadtentwicklung und Umwelt

Hamburg's Department for Urban Development and the Environment was in charge of setting up the project and is now its central co-ordinator, with a special interest in protecting the ecologically sensitive lake and waterways in the city centre.

Germanischer Lloyd was responsible for surveying and certifying of the FCS Alsterwasser. The independent ship classification society GL in 2002 published the first-ever guidelines on the operation of fuel cell systems.

HOCHBAHN

Being a pioneer in climate protection, HOCHBAHN has gathered experience in the application of fuel cell technology. Being the largest local transport company of the City of Hamburg HOCHBAHN is responsible for press and public relations work connected with the Zemships project.

Hochschule für Angewandte Wissenschaften Hamburg
Hamburg University of Applied Sciences

Hamburg University of Applied Sciences (HUAS) is assisting in the project by making in-depth scientific analyses of the technical data it collects on the fuel cell excursion ship.

hySOLUTIONS Hamburgs Antrieb Wasserstoff

The City of Hamburg set up hySOLUTIONS for the development and application of fuel cells and hydrogen. Together with HOCHBAHN, the company is responsible for press and public relations work and for co-ordinating supplementary staff training for ATG personnel.

THE LINDE GROUP

The Linde Group is one of the leading gas and engineering companies in the world. It has built, set up and now operates the forward-looking hydrogen infrastructure for the Zemships hydrogen project. The company has set entirely new standards, thanks to its new innovative compression technologies.

PM PROTON MOTOR
Proton Power Systems plc Group

Proton Motor Fuel Cell GmbH is a specialist company for fuel cell and hybrid systems and responsible for the development, production and implementation of the FCS Alsterwasser's propulsion system.

UJV

The Czech Nuclear Research Institute, UJV, is responsible for producing and conceptualizing the mathematical blueprint of the ship's propulsion system.

The prototype – a trailblazer for an new, emission-free generation of vessels

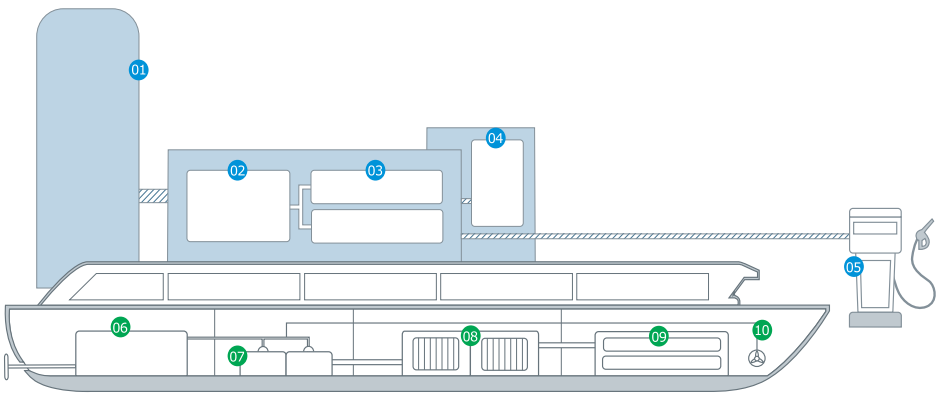
With a length of approx. 25 metres and a draft of around one, the vessel is standard size for an Alster steamer – in other words, a normal excursion ship, but with its own, built-in climate protection. Nevertheless, massive constructional and technological modifications had to be made to equip the FCS Alsterwasser with its environmentally friendly hybrid fuel cell system. Oortkaten, the shipyard for purpose-built vessels, and the engineers from Proton Motor actually managed to design the ship's hull so that there was room for all the special propulsion technology – and for up to 100 passengers.

This meant the FCS Alsterwasser had to be converted to fulfil the usual comfort requirements. Different furnishings, fittings and equipment all had to be accommodated on board, such as toilets and pantry. Also, the two fuel cell systems, the lead gel batteries and the hydrogen tanks had to be installed in an extremely confined space – safely, functionally and in compliance with the GL (Germanischer Lloyd) guidelines. At the same time, numerous electronic interfaces had to be considered and enough space left for the safety-related components necessary for the hydrogen supply. All these essentials demanded maximum efficiency on the part of the construction company and the engineers.

Top performance was also demanded of the fuel cell system, to propel the Alsterwasser's electric motor at 100 kW (ca. 130 horsepower). This is the first time ever that an inland passenger ship has been driven at a power of over 5 kW solely by fuel cells –

and with hydrogen as its single source of energy. To ensure that the power supply is continuous throughout a trip, up to 50 kg of the gaseous fuel can be stored in 350-bar pressure tanks on board the vessel, supplying it with enough energy for approx. three days in operation.

Besides electricity the only product emitted due to the chemical process inside the fuel cell is ecologically friendly water vapour. This is likely to be greeted by just as friendly reactions from passengers, who are assured an entirely emission-free, as well as low-noise trip on the FCS Alsterwasser. The prototype is the proof that it is possible to put technology of the future into everyday use – already today.



H_2 INFRASTRUCTURE

- 01 **LH_2 storage tank** (liquid hydrogen)
- 02 **GH_2 compressor** (gasenous hydrogen) 25 bar
- 03 **GH_2 main compressor** 450 bar, redundant ionic compressor
- 04 **Compressed GH_2 Storage**
- 05 **GH_2 dispenser** for the ZEMSHIP

ZEMSHIP

- 06 **Propulsion motor** 100 kW
- 07 **Hybrid system** Energy management & battery
- 08 **2 fuel cell systems** Proton motor, each 50 kW
- 09 **Hydrogen storage tanks** 350 bar
- 10 **Bow thruster** 20kW_{el}

The complete system

The propulsion system – systematic efficiency

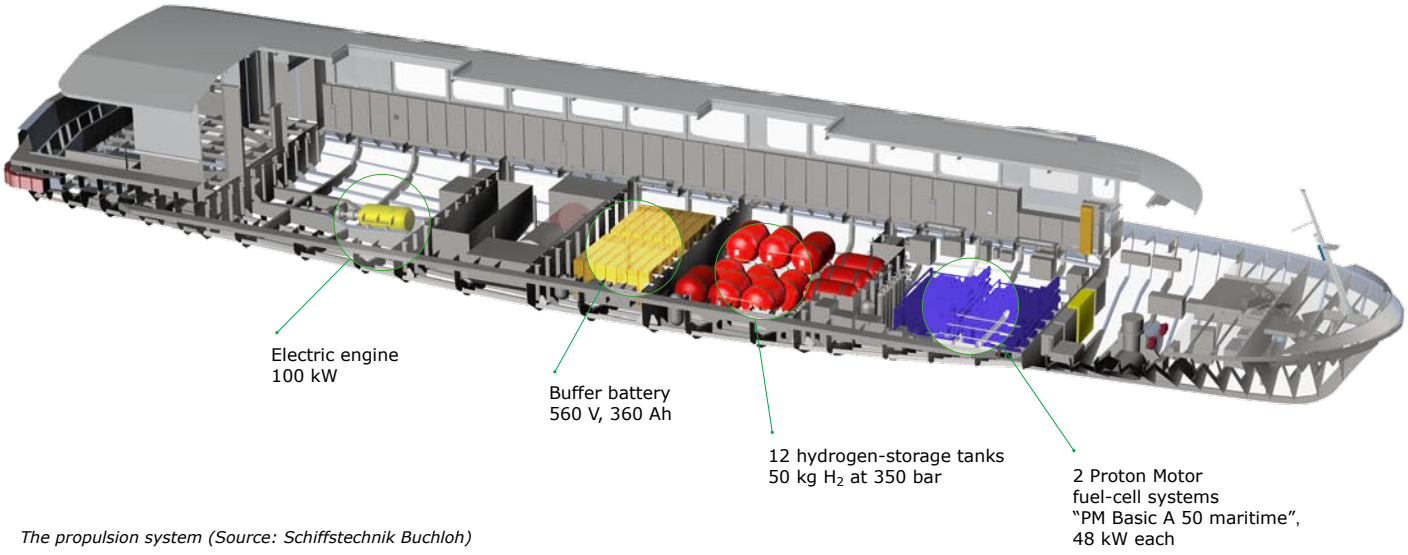
What is it exactly that makes the FCS Alsterwasser's fuel cell propulsion different from that of other ships? Proton Motor specially developed the fuel cell processes used, by which two separate systems are operated, each with a peak output of 50kW. They are of the 'PM A 50 maritime' construction series and intended for use on waterways subject to tidal influence. Not only are they particularly powerful, they are also extremely robust. The PEM (Proton exchange membrane) fuel cell system is liquid-cooled and suitable for various applications – in other words, the systems can be used on boats, and on ships of different sizes and power categories.

The Proton Motor fuel-cell system 'PM Basic A 50 maritime' is the very first application for this specific performance class with a certificate issued by GL. The electro-chemical fuel cell process is entirely pollutant-free. Furthermore, the new electro-hybrid fuel cell system ensures optimum fuel utilisation. This and its efficient mode of operation are yet another ecologically friendly aspect of the vessel. Due to the convenient fact that the system can run in partial-load or load-change mode, its effectiveness under normal operation is twice that of diesel propulsion. This means that the vessel uses just half the amount of fuel required by a standard fuel cell ship of the same size.

One essentially new feature, is that the fuel cell is assimilated into a hybrid system. The hybrid propulsion minimises the energy consumed by storing it temporarily in an integrated battery pack, which provides the electro-motor with energy, depending on the load transported. On the one hand, this demand-controlled energy management by battery is intended to guarantee operation at peak user hours; on the other, it lightens the load on the fuel cells while docking and casting-off procedures and so prolongs their life cycle substantially.

PM Basic A 50 maritime

Apart from having an intelligent energy management, the FCS Alsterwasser also has a low-energy water management system. It saves time, energy and work by moistening the external fuel cell membrane and re-filling de-ionised water. The project is undoubtedly a milestone in the fuel cell technology sector, and underpins the role of hydrogen as an alternative means to store energy.



The propulsion system (Source: Schiffstechnik Buchloh)

Hydrogen supplies – innovative compression

Innovative technology has also been used for the Zemships fuelling station infrastructure – with outstanding results. The Linde Group, which is responsible for engineering, assembling and commissioning of the hydrogen fuelling station, developed an entirely new process for the project, known as ionic compression. It is an ultra-new method, which compresses the gaseous hydrogen up to 450 bar – but without the use of mechanical pistons.

When a tank truck delivers the hydrogen, it is still in liquid form (liquified hydrogen, LH_2). This is stored at minus 253°C in a specially insulated tank (cryo-tank). Only when the FCS Alsterwasser is filled up the liquid hydrogen is evaporated. After that, the gas is compressed to an initial pressure of 25 bar by a rotary screw compressor.

Linde's patented ionic compressor is used during the second stage, when, through the use of an ionic liquid, the gas is compressed to a pressure of 290 bar – rising to 450 bar in booster mode. In order to store 50 kg of the GH_2, or gaseous hydrogen, storage tanks at a pressure of 350 bar are used on board the FCS Alsterwasser.

The new ionic compression process offers definite advantages over the standard piston compression method: quite apart from its extraordinary efficient process to supply the high quantities required, its most outstanding feature is the pureness of the hydrogen gas.

Unwanted contamination, which can readily occur when metal pistons are used for mechanical compression, is entirely avoided in the "clean" isothermal compression method. This causes a colossal noise reduction as a result (below 65 db(A)). Another important feature for the operation of the vessel is that the fuelling station is simple and quick to use. It takes just 12 minutes for the FCS Alsterwasser to fill up to 50 kg of compressed hydrogen (CGH_2). The fuelling station is also near Hamburg's city centre, on a branch of the Alster, at the HOCHBAHN's underground engineering depot.

All in all, the project can be said to be outstanding, not only due to its innovative fuel cell technology, but also because of the many new technological and engineering developments being made in the related infrastructure sector.

The FCS Alsterwasser can be seen as the debut of a new, emission-free, low-noise generation of vessels – and a worthwhile investment in the future.

Specification of the ship

Category of ship	Fuel Cell Ship – with an official operation licence for the habour area and a technical approval by GL.
Carrying capacity	up to 100 passengers
Length over all	25,46 m
Width of body	5,36 m
Height over waterline	2,65 m (2,30 m using the roof lowering device)
Tonnage displacement	72 tonnes fully loaded
Draft with passengers	1,33 m
Max. cruising speed	15 km/h
Materials	Steel and aluminium

Propulsion system

Type of fuel cell	Proton Motor PM 600 Proton-Exchange-Membrane (PEM)
Type of fuel cell system	Proton Motor "PM Basic A 50 maritime"
Number of fuel cell systems onboard	2
Fuel cell peak power	48 kW
Max. system efficiency	> 50 %
Fuel cell operating temperature	< 70°C
Total weight of single fuel cell system	ca. 500 kg
Size of single fuel cell system	2200 x 1100 x 900 mm
Buffer battery	Lead-gel Battery 560 V (7 x 80 V), 360 Ah
Type of electric motor	AC motor, (100 kW)
Storage of H_2	gaseous (GH_2) at 350 bar/15°C
Storage volume onboard	50 kg
Typical refuelling frequency	every 2 to 3 days

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zemships
ZERO EMISSION SHIPS

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