Boatplan Stockholm 2025

Annex

Content

1 The new technology

Regulatory and economic factors tend to drive technology development. After decades of development, both battery technology and fuel cell technology have reached the commercialization phase, while regulatory demands for environmental and climate impacts have come into focus. Swedish companies have an opportunity here to export high-tech vessels and show how the transition to emission-free waterborne traffic in urban areas can be made with new technology.

1.1 Technology development - Powertrains

Green City Ferries (GCF) was established in 2013 with the aim of putting an electric passenger ship into service. The experience gained from this was then used in the development of the powertrain for BB Green, an EU-funded project to develop a fast emission-free vessel. The experience of the prototype could then be used in the development of a commercial vessel, charging station and a high-performance battery system.

2014 Supercharging
E/S Movitz, the world's first supercharged passenger ferry that can run for an hour and recharge in 10 minutes. The battery chemistry was Nickel-Metal-Hydride, which could stand heavy charge.

2016 Electric high-speed prototype BB Green
The world's fastest supercharged passenger ferry running at 30 knots only on batteries. Battery chemistry was the first marine application of lithium-titanium-oxide (LTO) chemistry.

2020 Emission-free fast commercial ferry BB Green 24
Continued battery development to reduced weight to increase range. To significantly increase the range, an alternative powertrain with fuel cells was developed.

The battery system in BB Green is a maritime application of Toshiba's LTO modules that have been in use in the automotive industry for over 10 years. GCF's sister company Echandia has been responsible for battery development and is continuing to increase both performance in terms of charging time and lifetime as well as safety of LTO batteries. At the same time, fuel cell systems are being developed as an alternative or complement. Much of the system and equipment is equal between battery and hydrogen operation, providing flexibility to convert.

The battery system on BB Green 24 is air cooled and can withstand charging with 6 C (e.g. charging 500 kWh battery with 3,000 kW in less than 10 minutes). The battery can be used at 80% Depth of Discharge (DoD) and the lifetime is up to 10 years. It is 3 times faster charging and 5 times longer lifetime than the equivalent NMC batteries which is the dominant battery chemistry in the maritime market. The disadvantage of LTO batteries stood clear in the development of BB Green. An LTO system weighed more than twice as much as an NMC system, which almost became a showstopper. A thorough product development led to a weight reduction of 40%, which lead to that LTO batteries with their high performance could be maintained for use in BB Green. In February 2020, the battery system received a type approval from DNV GL.

The charging stations consist of transformers, which take power from the high-voltage grid and transform to about 1,000 Volts. Charging connection can be made conductively from the top or from the side or using inductive charging from the side.

The development of hydrogen operation is ongoing, and delivery of such powertrain will be possible in 2022. So far, there is only the possibility of organizing the production and refuelling of hydrogen at Käppala. Initiatives have recently been taken to create green hydrogen production in the archipelago with wind and solar energy.

1.2 Technology development - Hull

The development of BB Green has taken 9 years from idea to finished concept. BB stands for Battery Boat, which 9 years ago was unthinkable for fast ships - even for slow! The project was financed mainly from the EU through FP7 and Horizon 2020 and was completed in 2019.

BB Green has an ASV hull (Air Supported Vessel) where a fan in the bow blows air into a large cavity under the vessel. A flap in the stern regulates the discharge. The air pressure on the large surface provides power to lift the ship about 40 cm out of the water. Three effects occur. The first is that less water needs to be moved, which reduces the need for propulsion power. The second is that the friction between hull and air is less than between hull and water, which also reduces the need for propulsion power. The third is that the energy losses in the form of wake wash are reduced and the prototype vessel makes only 16 cm high wake wash at 30 knots. This means that there is a possibility to get exemption from speed limitation.

From the above reasoning it is also understood that weight is important. The battery system was made lighter. The hull was built in carbon fibre which is 30 % lighter than aluminium hulls. The Navy corvette Visby is built in carbon fibre. Green City Ferries has taken advantage of this competence through our CTO, who led the development towards carbon fibre.

The prototype, which was built in Riga, has dimensions of 20 x 6 m, a capacity of 80 passengers and needs a power of 600 kW (Propeller + fan) to make 30 knots. During the development, 2000 tank tests were carried out with different models at SSPA in Gothenburg before the best dimensions could be determined. The extensive material and comparisons between theory and full-scale prototype makes it possible to scale-up the ship to larger dimensions with a tolerance of +/- 5 %.

1.3 Technology Development - BB Green 24

BB Green 24 is the commercial concept. The size 24 m x 7.2 m is a 20% scale-up of the prototype. The capacity is 147 passengers, which is a common size on the Norwegian market where about 100 high-speed catamarans are in service. Also New York and Seattle have it as a standard capacity. The top speed is 35 knots with 4 x 330 kW axial flux motors while at 25 knots cruising speed the energy consumption is 25 kWh/NM. The battery pack holds 490 kWh LTO batteries, which is enough for 40 min operation at 25 knots over a distance of 16 NM, but it increases at lower speeds. Charging at 3,000 kW takes 8 minutes (with 2,000 kW it takes 12 minutes). The fuel cell version has a normal range of 100 NM, but it can be increased by using larger hydrogen tanks.

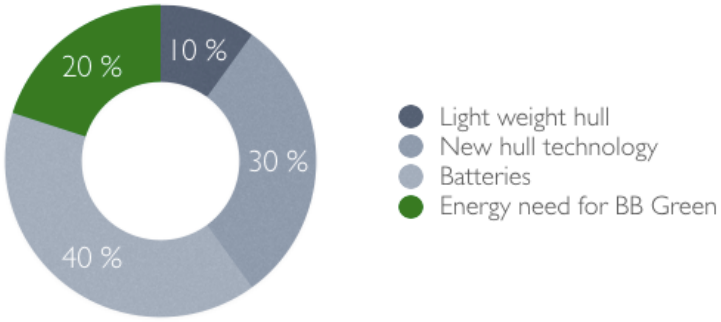
1.4 The new technology saves a lot of energy

BB Green combines light-weight hulls with ASV technology and battery systems into a vessel that consumes 80% less energy than modern diesel catamarans.

- 10 percentage points are because of lighter carbon fiber hulls.
- 30 percentage points are because of the ASV technology. The pressure from the air cushion lifts the ship halfway out of the water, which means that less water needs to be displaced when moving the vessel. In addition, the friction between the hull and the air cushion is less than the friction between the hull and the water.
- 40 percentage points are because of the efficiency. Diesel engines have an efficiency of some 33%, which means that 1/3 of the energy content of diesel is used for propulsion and 2/3 is used for unnecessary heating of the engine room. In electric operation, the efficiency is over 90%.

The good circle

By reducing the energy consumption it will be possible to use batteries and thereby reducing the energy consumption



The total energy savings are 80%. In hydrogen operation, the efficiency is less than for batteries - 50%, which means energy savings of 65%.
Energy savings are reflected in fuel costs. 1 kWh of electricity costs 7 cents. 1 kWh diesel also costs 7 cents (1 litre contains 10 kWh and costs 70 cents). Compared to operation with HVO, which costs 140 cents a litre, the electric drive costs only one tenth. (Swedish prices are used)
The old rule that it is expensive to drive fast no longer applies. Instead, the following examples indicates that it is economical to drive fast.

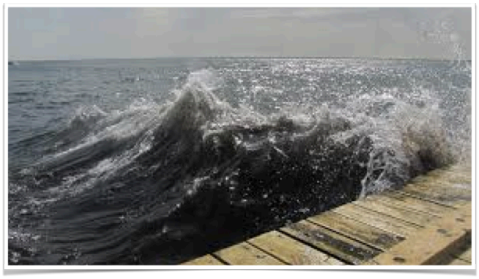
1.5 The new technology - comparison between fast ships

Valö is built at Brödrene Aa in Norway and is considered to be very energy efficient. If it was to run with HVO, fuel costs would be so high that it would be cheaper to buy a new electric-powered BB Green 24 vessel with approximately the same passenger capacity.

Valö consumes 12 l/nm = 120 kWh/nm in 25 knots Modern HVO diesel in 25 knots: 1500 hours/year x 12 x 25 x 140 cents EUR 630,000 per year	BB Green 24 consumes 26 kWh/nm in 25 knots Electric in 25 knots: 1500 hours/year x 26 x 25 x 7 cents EUR 70,000 per year

1.6 The new technology - comparison of wakes

Wake wash is the result of the fact that a lot of water is moved when vessels drive at high speed. Planing vessels do not create much wake wash at high speed. The same applies to BB Green, which in its own way is planing on the air cushion. Wake wash contains a lot of energy and is a sign of non-efficient hulls. A vessel that makes small wake wash does not cause damage and can therefore be given an exemption to drive fast where there is a speed limit because of damage risk. This means shorter travel times and better use of the vessel.



Most ferries make large wakes	BB Green 24 makes about 20 cm wakes

1.7 The new technology - comparison slow vs. fast

A BB Green 24 that keeps an average speed of 20 knots performs the same transport work with the same departure frequency as two ships at 10 knots but at a lower cost. Two diesel-powered vessels consume 10 times more energy, have twice as much crew and are faced with diesel engine maintenance costs. Besides, it's shorter travel time.

Solöga consumes 13 l/nm = 130 kWh/nm in 11 knots	BB Green 24 consumes 26 kWh/nm in 25 knots