Final report for VINNOVA

Pre-study report

# Environmentally Adapted Power Production Onboard Ships

A niche market for early introduction of Fuel Cells?

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## *Summary*

This document and its attachments constitute the final report from the pre-study Environmentally Adapted Power Production Onboard Ships.

The purpose of the project is to increase the knowledge about fuel cells and their potential application for power generation onboard merchant ships as preparation for a potential demonstration project at a later stage. This report and its appendices are intended to facilitate decision-making in the ongoing process towards more efficient and environmentally benign technology for powering ships.

The overall objective is to evaluate state of the art fuel cells from the technical, environmental, potential user market and commercial aspects. This has been done through four separate studies attached to this overarching report.

It has been found that fuel cells have a strong potential to enter the market for power production onboard ships, however they are not competitive purely on a commercial basis today. The timing is mainly affected by developments in fuel cell costs, but also to external factors such as oil price and environmental legislation. In fact, apart from safety and reliability, cost and environmental impact appear to be the most critical parameters also from a customer perspective.

The pre-study concludes that hydrogen as a fuel for this specific fuel cell based application will not be likely to provide an acceptable cost level for quite some time. Tougher international limitations on $CO_2$-emmissions also for shipping, may contribute to hydrogen becoming cost-effective sooner, however no such limitations are expected to be introduced on a larger scale in the near future. It is expected that fuels such as natural gas are likely to provide a viable alternative long before that. However, comparing today's available alternatives to diesel generators, electrical shore connection and dual fuel gas engines are the most competitive.

Considering the various fuel cell technologies suited for this particular application, it is expected that high temperature fuel cells have very promising prospects in a longer perspective, based on projected improvements with regard to efficiency, cost and durability in combination with their ability to burn various types of fuel. Demonstration projects involving SOFC fuel cells are already underway. The PEM fuel cells provide advantages likely to make it the preferred choice for smaller applications.

Due to the findings of this study, it is unlikely that this work will continue on into demonstration of a PEM-system as originally intended. This is also due to the fact that a sufficient level of interest and dedication among the Swedish industry partners could not be found at this point in time.

It is recommended that further studies are made to evaluate the opportunities for fuel cell technology onboard smaller vessels, such as smaller river ferries or sailing yachts. The size, the mode of operation as well as the customer requirements indicate that this is likely to provide an easier market entry for fuel cells. An important aspect to consider is that on smaller boats this may also include propulsion.

# *Sammanfattning*

(In Swedish)

Detta dokument med bilagor utgör slutrapporten för förstudieprojektet Miljöaanpassad elproduktion på fartyg i hamn.

Syftet med projektet har varit att öka kunskapen om möjligheten att använda bränsleceller för att generera elektricitet ombord på fartyg. Detta har genomförts som förberedelse inför ett eventuellt demonstrationsprojekt i ett senare skede. Denna slutrapport är ämnad att underlätta beslut i utvecklingsprocessen för mer effektiva och miljöanpassade sätt att generera elektricitet ombord på fartyg.

Det övergripande syftet är att utvärdera bränslecellstekniken från ett tekniskt, miljömässigt, marknadsmässigt samt kommersiellt perspektiv. Detta har skett genom utförande av fyra separata delprojekt vars delrapporter finns bifogade denna övergripnade slutrapport.

Studien har funnit att bränsleceller har en stark potential att på sikt erbjuda ett kommersiellt alternativ för elproduktion ombord fartyg, men i dagsläget är de ännu inte konkurrenskraftiga från ett rent kostnadsperspektiv. Tidpunkten för en kommersiell introduktion beror huvudsakligen på en minskad kostnad för bränslecellerna, men även på externa faktorer så som oljepriset och miljölagstiftningen. Bortsett från säkerhet och pålitlighet är det från ett användarperspektiv även kostnad och miljöpåverkan som är de mest kritiska faktorerna.

För den specifika tillämpningen att producera elektricitet ombord på fartyg visar studien att vätgas sannolikt inte kan erbjuda en accepterbar bränslekostnad ännu på flera år. Strängare internationella utsläppskrav för koldioxid för sjöfarten kan bidraga till att vätgasen blir mer konkurrenskraftig, men inga sådana begränsningar i större skala är att vänta den närmaste tiden. Det är troligare att alternativa bränslen så som naturgas blir gångbara långt innan dess. Om vi jämför alternativen till dagens dieseldrivna elgeneratorer så visar sig landansluten elförsörjning samt gasdrivna fler-bränslemotorer vara de mest konkurenskraftiga.

Baserat på uppskattade förbättringar av effektivitet, kostnad och livslängd i kombination med förmåga att använda olika typer av bränslen, framstår det relativt tydligt att högtemperaturbränsleceller är den bränslecellstyp som på sikt lämpar sig bäst för den studerade tillämpningen. Demonstrationer med SOFC-bränsleceller planeras redan inom projektet Fellowship. PEM-bränslecellens fördelar kommer sannolikt göra den framgångsrikare i tillämpningar med inte fullt så stort effektbehov.

Med anledning av denna studies resultat är det osannolikt att detta projekt fortsätter in i en demonstration av ett PEM-system så som ursprungligen planerat. Detta beror också på att intresset från de svenska industriparterna i dagläget inte varit tillräckligt starkt.

Projektet rekomenderar att vidare studier genomförs för att utvärdera möjligheterna för att använda bränsleceller i mindre båtar, till exempel lätta personfärjor eller segelbåtar. Storleken, belastningsmönstret samt användarkraven för det segmentet borgar för en tidigare kommersialisering av bränslecellstekniken. En viktig aspekt är att i detta sammanhang även framdrift av båten kan vara möjlig.

# *Contents*

Summary ..... 2
Sammanfattning ..... 3
Contents ..... 4
Introduction ..... 5
  Purpose ..... 5
  Main objectives ..... 5
  Background ..... 5
  Scope ..... 6
Project description ..... 6
  Timeframe ..... 6
  Participants ..... 6
  Organisation ..... 7
Project execution ..... 7
  Technical Pilot Study ..... 7
  Environmental Impact Analysis ..... 7
  Market Analysis ..... 7
  Commercial Study ..... 7
Conclusions and Recommendations ..... 8
References ..... 9

# *Introduction*

## Purpose

The purpose of the project is to increase the knowledge about fuel cells and their potential application for power generation onboard merchant ships as preparation for a potential demonstration project at a later stage. This report and its appendices are intended to facilitate decision-making in the ongoing process towards more efficient and environmentally benign technology for powering ships.

## Main objectives

The overall objective is to evaluate state of the art fuel cells from the technical, environmental, potential user market and commercial aspects.

Thus the main objectives of the project are:

1. Clarify the technical and cost implications of installing a pilot hydrogen fuel cell power generation system onboard a ship
2. Assess the reduced emissions through an environmental impact analysis of such a system
3. Analyse the potential market for shipboard fuel cell power generation systems and identify possible early market niches
4. From a shipowner´s perspective, establish under what conditions a fuel cell power supply system could be an attractive investment

These objectives have been addressed by four separate studies, as described later in this report.

## Background

In light of the improvements in fuel cell technology and its progress towards commercialisation, the region of West Sweden (Västra Götalandsregionen) in the year 2003 took the initiative to the collaboration project HyFuture. The aim was to stimulate the growth in this emerging market through bringing together a network of interested parties. Today, this collaboration project includes more than 100 organisations whereof 40 are actively involved in one or more pre-studies, information- or demonstration projects.

There are five main reasons why it was the region of West Sweden that launched into this project. Firstly, the region's development strategy aims to make the region one of the European leaders in sustainable technologies, so there is a strong political driver. Secondly, strong synergies exist with the investments made in natural gas and biogas in West Sweden. Thirdly, 1000 kg pure hydrogen per hour (33 MWh) is available from the petrochemical industries in Stenungsund just north of Gothenburg, potentially serving as many as 50 000 fuel cell vehicles. Fourthly, the majority of the Swedish automotive industry (Volvo and Saab) is located in the region. Last but not least, Gothenburg has the biggest harbour in Scandinavia and is the home port of Stena Line.

Already at the very start of the initial discussions of HyFuture, the application of fuel cells and hydrogen technology for power production on board ships was highlighted as interesting further investigation. The topic was then discussed in a separate working group and it was this group that in October 2004 managed to secure project funding from VINNOVA of SEK 500 000, matched by the efforts put in by the project participants.

### Scope

The initial scope of this project was to perform a technical planning and cost analysis for building a 50 kW demonstration system. The results from the pre-study would then serve as input to a decision on whether or not this system should be built and installed at one of Stena Line's ships. A key characteristic of the project was to build the system together with mainly Swedish suppliers of technology and services.

During the spring of 2005 it was realised that the cost for building the demonstration system would exceed SEK 10 000 000. The project participants concluded that this amount was more than they were prepared to invest themselves, and thus external funding was required. To achieve this, in turn, the project was required to also include a more thorough consideration of the commercial aspects. It was agreed that only equipped with such information, the project would stand a chance of attracting the funding required to actually build a demonstration system.

Due to this, the main objectives of the project were extended to what is described above under the heading Main objectives.

## *Project description*

The pre-study project has been a combination of an investigation, an engineering challenge and technical planning. This chapter summarises the project set-up.

### Timeframe

The pre-study was carried out between 2004-11-01 and 2005-12-31.

### Participants

The following table identifies the project stakeholders and their corresponding roles.

| Organisation | Role in the Project | Contribution |
|---|---|---|
| AGA Gas | Technical expertise | Time |
| ETC Battery and FuelCells – Vätgasgruppen/SamVäte | Project management, information dissemination, knowledge management and coordination with other relevant hydrogen projects | Offices |
| Stena Line | End user | Time |
| PowerCell (Volvo Tec) | Component supplier | Time |
| Miljöförvaltningen, Göteborgs Stad | Environmental impact analysis | Time |
| Kommunstyrelsen, Göteborgs Stad | Member of steering group | Time |
| Sveriges Redareförening | Member of steering group | Time |
| VINNOVA | Funding | SEK 500 000 |
| Processkontroll | System design | Time |

### Organisation

The project team consisted of representatives from each of the above mentioned organisations, except for Kommunstyrelsen Göteborg, VINNOVA and Processkontroll.

The project steering group has consisted of representatives from Stena Line, Sveriges Redarförening, Kommunstyrelsen Göteborg, PowerCell and ETC.

## *Project execution*

The project was divided into four main parts: Technical Pilot Study, Environmental Impact Analysis, Market Analysis, and Commercial Study.

### Technical Pilot Study

This study is produced with input from a group of potential stakeholders to provide a basis for a possible 50 kW PEMFC pilot project. The work involved:

- Specification and preliminary system design
- Shipboard integration and maintenance aspects
- Hydrogen supply and storage
- Estimated construction timetable
- Estimated investment and operation cost

The report of the study is attached as appendix 1.

### Environmental Impact Analysis

This analysis has studied the environmental impact of installing a PEMFC system on board the ship Stena Jutlandica, under three scenarios:

- The system installed is the 50 kW pilot system
- The system installed is a full scale system replacing the currently installed and used power of 3340 kW. A catalytic converter is installed.
- The system installed is a full scale system replacing the currently installed and used power of 3340 kW. A catalytic converter is not installed.

The report of the analysis is attached as appendix 2.

### Market Analysis

This is a thesis report covering the following main aspects of the marine fuel cell market:

- What is the market for shipboard power supply on a worldwide basis?
- Which are the relevant market segments and what are their perceived needs, i.e. "customer utilities"?
- For which segments could fuel cells be a suitable solution?

The report of the thesis is attached as appendix 3.

### Commercial Study

This part of the project has focused on the following issues:

- What is the actual status regarding cost and other critical "customer utilities", i e important performance aspects, for available alternative power generation systems today?
- How do the different alternatives compare with regard to these customer utilities?
- How could possible future developments change the scenario?

The report of the study is attached as appendix 4.

## *Conclusions and Recommendations*

Taking into account the results of each of the four sub-projects, these are the combined findings of this pre-study:

1. It is feasible to build a 50 kW PEMFC plant within 13 months, at a cost of about 12,4 MSEK. Hydrogen fuelled electricity could then be produced at a cost of about 17 SEK/kWh (1,8 Euro/kWh) or – with hydrogen from Stenungsund - about 13 SEK/kWh (1,35 Euro/kWh). Remaining issues to be resolved are, e g:
    a. Hydrogen infrastructure from AGA or Stenungsund
    b. Authority approval and certification of system onboard
2. The introduction of a hydrogen fuel cell system for power production onboard a modern ship equipped with state-of-the-art emission control systems, does not add much value. However, if such emission control equipment is not installed, a significant reduction in $NO_x$-emissions can be achieved.
3. There is an annual market of about 5 000 000 kW (average unit size 400kW) for shipboard power generation. Fuel cells have the potential to enter that market provided that critical issues are resolved, such as safety, cost and durability. The most suitable market segments for entry appear to be Ferry/roro and container vessels.
4. The following commercial aspects have been identified:
    a. Apart from safety and reliability, cost and environmental impact appear to be the most critical parameters from a customer perspective.
    b. Comparing today's available alternatives to diesel generators, electrical shore connection and dual fuel gas engines are competitive, whereas fuel cell price and durability result in considerably higher cost per kWh.
    c. High temperature fuel cells have very promising prospects in a longer perspective, based on projected improvements with regard to efficiency, cost and durability in combination with their ability to burn various types of fuel.
    d. The high price of hydrogen, in combination with safety and infrastructure challenges, implies that such a shift could only be motivated by legislation and/or strong incentives for CO2 reduction, such as emission reduction trading or similar.
    e. The PEM fuel cells provide advantages likely to make it the preferred choice for smaller applications, such as power production or even propulsion for smaller vessels, such as light river ferries or sailing yachts.

5. For the studied application of fuel cells for power production on board ships, a sufficient level of interest and dedication among the Swedish industry partners could not be found at this point in time.
6. Taking into account the large power consumption on board the merchant ships and the early stage technology of hydrogen fuel cells, it is concluded that an easier market entry could be achieved by the same application but on board smaller vessels, such as smaller river ferries or sailing yachts. On smaller boats this may also include propulsion.
7. Forecasting when an emerging technology will be commercially competitive is very hard. Forecasting when the time is just right to launch demonstration projects for the same technology is even harder. Further studies into this topic are recommended for this industry.

## *References*

SJÖHOLM, M. (2005) A Technical Report from the Pilot Study Environmentally Adapted Power Production Onboard Ships - A pilot fuel cell system with a 50 kW capacity. *Included as Appendix 1.*

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SUAREZ, E. & SUTHEEWASINNON, J. (2005) Master Thesis: Market Analysis and Competing Technologies of Fuel Cells in the Maritime Sector. *Included as Appendix 3.*

SÖDAHL, B. (2005) Fuel Cells for Power Generation on Ships in Port - a commercial study. *Included as Appendix 4.*