TASK 23 Small-scale reformers for on-site hydrogen supply
Status report, April 2007

1. Task description

The main objective of Task 23 Small-scale reformers for on-site hydrogen supply (SSR for hydrogen) is to provide a basis for harmonization of technology for on-site hydrogen production from hydrocarbons – fossil and renewable. The overall objectives of the task are:

- Develop a basis for harmonized capacities for the on-site hydrogen reformer unit
- Identify and examine issues related to the promotion of widespread use of on-site hydrogen reformer units
- Develop a global market guide for the use of on-site hydrogen reformers
- Describe the technology link to renewable sources

The approach can be illustrated as follows

Background

The results developed in Annex 16, Subtask C Small stationary reformers for distributed hydrogen production, have been the starting point of Task 23. The objective of Subtask C was to define system solutions for early markets by evaluating the reformer technology from two angles, the market requirements and the technology performance. Subtask C identified a strong need to continue the harmonized effort to develop on-site reforming for efficient and clean hydrogen. A number of challenges were identified within system integration and optimization of various components, gas storage, control units and hydrogen dispensers. At the closing of Subtask C the number of installed prototypes and their operating hours were limited. As consequence of this and based on the identified challenges, Subtask C members recommended a continuation of the IEA-HIA work on harmonized small-scale reformers for on-site hydrogen production, this is currently Task 23.

Subtasks

The subtasks are designed to meet the objectives and to provide results in form of deliverables. Task 23 has been divided into three main parts:

- Subtask 1 Harmonised industrialisation (*Leader:* Børre T. Børresen (Norway))
- Subtask 2 Sustainability and renewable sources (*Leader:* Corfitz Nelsson (Sweden))
- Subtask 3 Market studies (*Leader:* Isamu Yasuda (Japan))

2. Activities

Expert meeting

An expert meeting has been held in Berlin in April 2007. The meeting included a visit to the CEP Messedamm hydrogen station and the CEP Total hydrogen station. Two different technologies are demonstrated at these stations, namely on-site electrolysis and reforming.

Representatives from seven countries (Denmark, Germany, Netherlands, Japan, France, US and Norway) attended the meeting in Berlin.

The next expert meeting will be held in October 2007. The location was originally Houston, Texas in coordination with The Fuel Seminar. Since none of the task members are attending this seminar, the meeting will most probably be relocated to Amsterdam (Netherlands).

3. Major Accomplishments

Subtask 1 Harmonised industrialisation

There exist today 272 hydrogen refuelling stations worldwide (Source www.lbst.de). In addition numerous stations are planned.

The Japanese government has developed scenarios describing the Hydrogen Society in Japan. The scenarios are as follows:

- 2030: 15 million fuel cell cars and 8500 refuelling stations
- 2010: 50000 vehicles, 500 refuelling stations

To fulfil this vision a mandatory introduction on governmental hydrogen/fuel cell vehicles will be made. Three capacities have been considered in the Japanese scenario, namely 100, 300 and 500 Nm3/h. A daily supply for these capacities are 105, 315 and 525 Nm3/day respectively. Decentralised production is considered more expensive than centralised and CO2 cost has not been considered in the Japanese scenario.

In the US 14 states have road maps for hydrogen and 3 states are developing maps.
The estimated cost is 2-3$ per kg hydrogen and a development of 500 stations per year.

Parameters defining a harmonized system are crucial. In Annex 16 the following requirements were identified.

- Reliability and durability
- Production capacity
- Footprint and height
- Monitoring
- Variable load
- Minimum start-up/shut-down times
- Service, training and maintance
- Regulations, codes and standards
- Efficiency > 80%
- Hydrogen purity 99.95% and CO < 1ppm
- Costs
- CO2 capture

Reformer capacities depend on the natural gas quality. For instance, in Europe the nitrogen content varies among the countries, and in Japan the city natural gas has a higher heating value than in the rest of the world. Moreover, the capacities should be defined on the production side and not on the feed side of the production unit.

Japan defines three capacities 100, 300 and 500 Nm3/hour for small-scale reformers. ISO TC WG9 defines less than 400Nm3/h as the standard capacity. Reformers can be developed in any required size. However, it is important for the vendors that norms and standards for size, footprint and capacity exist. This to be able to concentrate on engineering issues and not to worry about changes in the boundary conditions.

Task 23 suggests utilizing the Japanese capacities as a starting point and this will be the basis for the future work in Subtask 1.

<u>Subtask 2 Sustainability and renewable sources</u>
Hydrogen cannot be provided at a reasonable cost, when including CO2 capture and storage (CCS). However, CO2 emissions and NOx cannot be excluded and this is a challenge. Japan, for instance, has few natural resources and has been provided with few CO2 emissions. However, CCS is becoming an issue in Japan.

The world has approximately 100 years more in fossil fuel reserves, Technology development on the use of bio-fuels is essential. Reforming bio-gas removes the CO2 issue, green reforming could be a solution. A well-to-wheel analysis of future automotive fuels has been delivered by JRC in March 2007 (EUCAR) and claims that advanced biofuels and hydrogen has a higher potential for substituting fossil fuels than conventional bodies.

The following feedstocks have been discussed: biogas, ethanol, bio-diesel, DME, glyserin, ammonia and sugars. As food is still a problem in the 3rd world, food (sugar, vegetable oil etc) should not be used as feedstock for hydrogen production.

There is a large growth of dimethyl ether (DME) plants in China, and a possible scenario is using DME for heavy trucks etc. and transforming DME to hydrogen for use in fuel cell cars.

N-GHY has developed a multi-fuel reformer. The advantage with this is to be able to switch between feedstock depending on the cost of CO_2 emissions.

A study will be made by the task members on various options on when to convert a feedstock to hydrogen and when to use it directly.

Subtask 3 Market studies

In the US a large quantum of hydrogen is produced in large scale plants, 66 plants, 26<1000Nm3/h. It is difficult for small scale hydrogen producers to compete in price.

What could improve the situation:

- Cheaper and more efficient small scale reformers
- Fewer and more compact components
- Hydrogen refuelling market growth
- DOEs aim of 500 stations per year is reached

Threats:

- Natural gas prize
- Green hydrogen politics
- CO_2 emissions

The subtask has identified three markets to be used in the future task work:

- Asia (Japan)
- US (California)
- Europe (Germany)

These markets have different characteristics and market data is available.
Input parameters have been agreed on and these are:

- Capital cost of the facility
- Cost reduction by volume production
- Feedstock cost
- Feedstock consumption
- Cost of consumables
- Utility cost
- Energy efficiency
- CO_2 emission
- GH_2 and LH_2 transportation cost
- Capital charge
- Currency exchange rate
- Political cost on CO_2 emission

These parameters are the basis for the future task work.

4. Status of Milestones

The main milestones are the expert meetings. Two meetings (October 2006 and April 2007) have been held and are in accordance with the work plan.

The next task meeting is scheduled for October 2007.

5. Semi-annual work plan

The work plan for the next 6 months is as follows.

Subtask 1

To be able to reach the goals set for Subtask 1, the work for the next period of time will focus on the following:

- Compare technologies within the capacities defined in the Japanese scenarios as regards components, footprint, size, noise and operation hours
- Choose two vendors and compare size of electrolysis and reformer for 500Nm3/h

Table 1.Work plan Subtask 1 for the next period

Work task	**Work description**	**Deadline**	**Responsible person**
Issues from an end-user point of view	Parameters required for defining a harmonized system.	Next meeting	Børre T. Børrensen (Statoil)
Technology status of small scale reformers, Annex 16	Summary of the state-of-the art study performed in Annex 16. Whats new since then?	Next meeting	Anne Marit Hansen (Hydro)
Comparison size, footprint and operating hours	Compare parameters of electrolysis and reformers for 500Nm3/h	Next meeting	Anne Marit Hansen (Hydro)
UC Davis H2 pathways program: Infrastructure modelling	Present results from the projects: • Hydrogen station siting analysis • Refueling station size analysis	Next meeting	Jaques Saint-Just (H2 Plus)

Subtask 2

To be able to reach the goals set for Subtask 2, the work for the next period of time will focus on the following:

- Technology for small-scale CO2 capture
- On the use of various feedstocks, conversion to hydrogen or direct use

Table 2. Work plan Subtask 2 for the next period

Work task	**Work description**	**Deadline**	**Responsible person**
Technology for small scale CO2 capture	An overview / state of the art on technology for small scale CO2 capture	Next meeting	Kim Johnsen (IFE)
On-site CO2 capture	Presentation on cost estimates for small scale CO2 capture	Next meeting	Didier Grouset (N-GHY)
Ammonia as feedstock	On the use as ammonia in the production of H2	Next meeting	John B. Hansen (Haldor Topsøe)
Diesel reforming	Present research activities at ECN within diesel reforming.	Next meeting	Erwin Stobbe (ECN)
EUCAR/Concawe	WTW: Summary of the	Next meeting	Corfizt Nelsson

study	main results		(SGC)
Bio technology	Information on the work on bio-technology in the US	Next meeting	David King (PNNL)

Subtask 3
To be able to reach the goals set for Subtask 2, the work for the next period of time will focus on the following:

- Market data collection

Table 3. Work plan Subtask 3 for the next period

Work task	**Work description**	**Deadline**	**Responsible person**
Germany	Parameters describing the German market	Next meeting	?? (HyGear)
California	Parameters describing California	Next meeting	Isamu Yasuda (Tokyo Gas)
Japan	Parameters describing the Japanese market	Next meeting	Isamu Yasuda (Tokyo Gas)

6. Task participation

The current member list is as shown in Table 4.

Table 4. Member list

Country	Organization	Expert	Contact address
Denmark	Haldor Topsoe	J.B.Hansen	Jbh@topsoe.dk
Germany	IGS Mahler	U.Hofmann	Ulrich.Hofmann@mahler-igs.com
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Netherlands	Shell Global Solutions	Chardutta Patil	Chardutta.Patil@shell.com
Japan	Tokyo Gas	I.Yasuda	iyasuda@tokyo-gas.co-jp
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Norway	IFE	K.Johnsen	Kim.Johnsen@ife.no
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Sweden	SGC	C.Nelsson	Corfitz.nelsson@sgc.se
France	N-GHY	D.Grouset	Didier.grouset@n-ghy.com
France	H2Plus Ltd	J.Saint-Just	Jacques.Saint-Just@h2plus.net

Mr. David King from Pacific Northwest National Laboratory (US) participated in the meeting in Berlin. Further participation has not been confirmed.

VTT (Finland) has agreed to join task 23. An effort is being made to invite American stakeholders to the task.