ch2p

Fostering the clean transport transition for a h2althy place to live!

Co-generation of hydrogen and electricity with high-temperature fuel cells

D1.9: Usage scenario report

WP 1 , T 1.1

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[1] PU = Public

PP = Restricted to other programme participants (including the Commission Services).

RE = Restricted to a group specified by the consortium (including the Commission Services).

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Versions

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1 Abstract

The CH2P project aims to develop a combined hydrogen and power production system, using gas from the natural gas grid, for use at hydrogen stations. This report defines the use cases for such a system by looking at the demand profiles for hydrogen and power. Demand profiles include hydrogen refuelling as well as power consumption of the system itself and surrounding power consumers, for power export and grid balancing and charging of battery electric vehicles. It also gives the implications of this demand in the form of a set of operating points, which can be used for modelling and design of the system. The work further showed that the power integration of the CH2P system needs to consider the significant power peaks that occur in hydrogen and conventional stations.

2 Introduction

Hydrogen is an energy carrier that has potential to help decarbonize worldwide energy systems. In the mobility sector hydrogen can be used in fuel cell electric vehicles (FCEVs), which qualify as zero-emission vehicles. Depending on the method of hydrogen generation and distribution, the well-to-wheel greenhouse gas emissions may approach zero as well.

To enable the introduction of FCEVs a hydrogen retail infrastructure must be build up. The roll-out of a hydrogen retail station network has started in Japan, California and Germany and other countries are following. Several options for the supply of hydrogen to these stations have been demonstrated by Shell:

- Truck delivered compressed hydrogen (Hamburg)
- Pipeline delivery hydrogen (Torrance)
- Truck delivered Liquid hydrogen (Berlin)
- On-site hydrogen production via electrolysis (Hamburg)
- On-site hydrogen production via reforming of natural gas (Newport Beach)

Shell cooperates with SolidPower, a company working on solid oxide fuel cell technology, to develop an efficient on-site natural gas based hydrogen generation system that can also produce electricity. In future bio-methane and/or renewable hydrogen enriched natural gas is envisioned as a feed. Part of this work is conducted with European subsidy and several other partners in the Combined Hydrogen and Power project (www.ch2p.eu).

This report specified the use cases and associated operating points of the system developed in CH2P.

3 Emerging market application

CH2P project aims to contribute to lower carbon emissions for hydrogen as well as power generation and to lower the cost of hydrogen for mobility. A successful completion of the project – planned for mid 2020 – will give the opportunity to create synergies between the Energy and Transport sectors and penetrate the emerging market of Hydrogen Refueling Station (HRS) with a high performances technology, supporting step by step the transition to a clean energy society from the mobility sector to future possible deployment of the CH2P technology in stationary applications.

As reported by the [H2ME project] "FCEVs and the associated refueling infrastructures are currently in the very early stages of the market introduction. The current priority is to introduce vehicles in markets where a strategy is in place to support their use with an appropriate infrastructure for hydrogen fuel supply, distribution and sale. Inevitably, in the early years this infrastructure will grow slowly as the demand for vehicles raises. During the introduction phase (i.e until 2020), the number of stations will remain low but will increase faster than the demand for hydrogen to ensure an adequate hydrogen refueling network coverage allowing FCEV sales to a broader market. A mature market (i.e self-sustaining) is expected to be reached by 2025."

Looking at the ongoing process for the HRS infrastructure deployment, as shown in the following figure, the expected operating HRS planned to be installed by 2020 is around 210 stations in the EU4 (UK, Germany, France and Italy), but increases to more than 350 new HRS if we consider the geographical area of the central EU member state. Most of these HRS will be at support of captive fleets at initial small scale distribution (ranges 20Kg/day – 200Kg/day) during the introduction phase of an hydrogen based mobility.

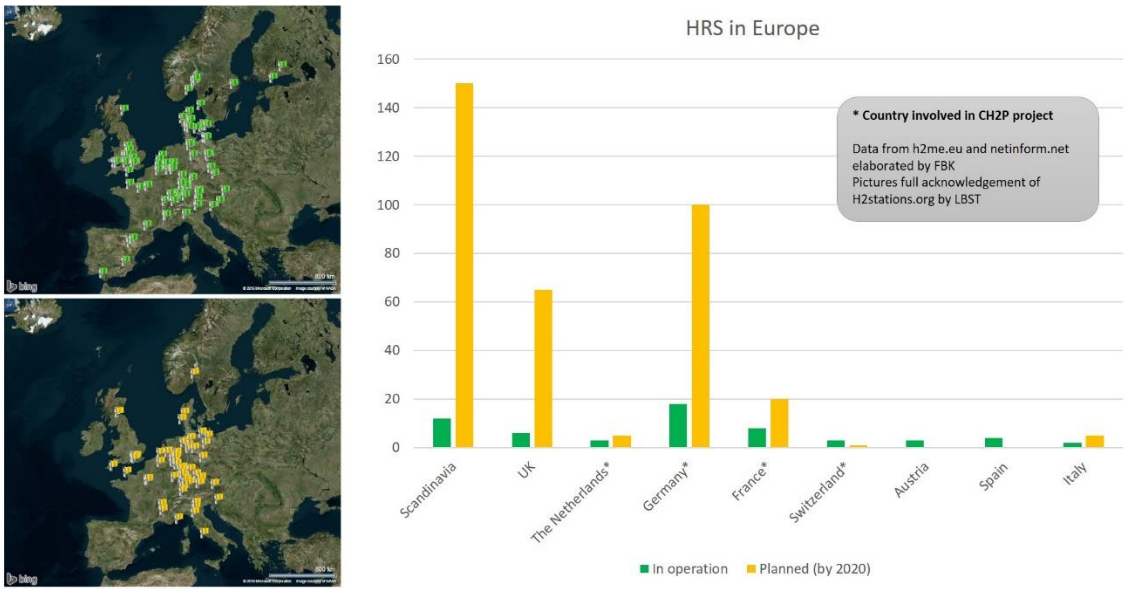

Figure 3.1: Plan of HRS new installation by 2020 (2016 data analysis).

CH2P will contribute to this innovation process by developing a new prototype system for hydrogen generation capacity of 20 kg/day at the end of 2018 and will realize an up-scaled system at the size of 100 kg/day of hydrogen production capacity – for infield testing in HRS – for the end of 2019. The reason is the development of a final prototype of significant scale for further market deployment of the technology in the short time, possibly before 2025.

By this way, a successful preliminary result of the CH2P research activity, especially as regards the two system prototypes, could be an interesting solution for the realization of the new planned HRS. In fact, the CH2P tested technology will be available before the end of 2020, where it is expected a consistent increase in the HRS deployment.

CH2P technology will be the solution for on-site hydrogen generation and distribution, moving fast into a more efficient HRS solution and accelerating the market deployment of this technology in order to reach – as cited before – a mature market hopefully before 2025 when the hydrogen technology could contribute in making “clean mobility a reality for better places to live!“.

4 CH2P operating environment

To satisfy customer needs, Shell decided to integrate most of its hydrogen filling stations in existing fuel retail stations. This means CH2P systems will be installed at sites that have a convenience shop, a car wash and sell conventional fuels and potentially electricity for battery electric vehicles as well as hydrogen. The CH2P system needs to be integrated in the hydrogen station. Furthermore, the various elements of the retail station consume electricity that can potentially be generated by the CH2P system.

4.1 Hydrogen station layout and electricity use

The boundary condition of the system in the CH2P project is delivery of fuel cell quality hydrogen at 30 bar pressure[2]. This may have to be compressed further to the lowest storage pressure, which also acts as a buffer between the CH2P system and the fuelling station to decouple hydrogen demand from hydrogen production (see Figure 4.1). The capacity of this storage is expected to be between 50% and 100% of the daily hydrogen station capacity. From this low pressure storage the hydrogen is compressed further into the high pressure storage, before being cooled to -40°C and dispensed at 700bar.

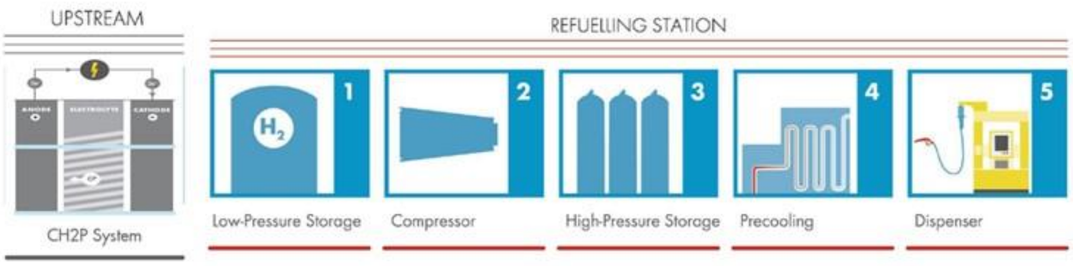

Figure 4.1: Possible layout of a hydrogen fuelling station with CH2P system

The electricity consumption of hydrogen stations was measured as part of the CH2P project.

For an 80 kg/day station 6 months measurement concluded:

[2] *In reality the output pressure needs to be optimized together with the compression capacity of the hydrogen station*

Power use = 2.3 kWh/kg H2 for compression
+ 8.5 kW cooling
+ 0.3 kW other

Detailed analysis of power quality at a different hydrogen station showed large peaks in power consumption, especially when the compressor starts. A peak current of 325 A was measured, whereby the average current drawn by the compressor was only 37 A. The maximum power drawn at the station was measured as 274 kVA, whereby the average consumption is 45 kVA when both the compressor and the cooling system are running.

These power levels and the fluctuations must be considered in the design of the CH2P system electronics.

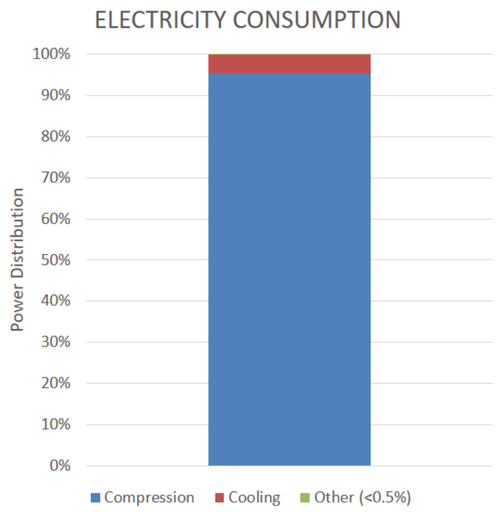

Figure 4.2: Typical electricity consumption of hydrogen station (for an 80kg/day)

4.2 Electricity use of a conventional fuel station

A typical power consumption of a conventional retail station in Europe is around 40-80 kW, although this varies depending upon type of site and the customer needs which it is servicing. Only a small amount (4 to 5%) is used for the fuelling processes. More is used for lighting (≈30%), but only at night. Other consumption includes air conditioning, heating (electrical heating in markets like NL and UK), car wash and the shop for hot food and refrigeration.

Power measurements with a 10 second sampling rate at a single station show that average power varies between 20 and 70 kW. Within the 10 seconds intervals, differences of 40 kW are observed between the average and the maximum power, indicating very short burst of power consumption, possibly when equipment is started up.

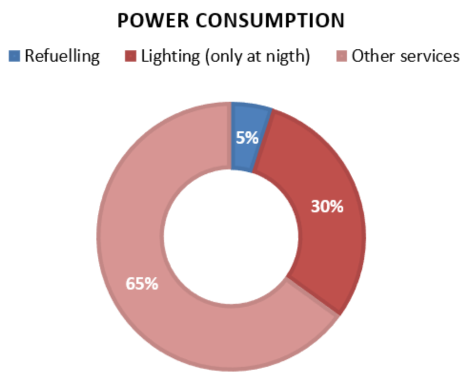

Figure 4.3: Typical power consumption of a conventional retail station

Again, these power levels and fluctuations must be considered in the CH2P design.

4.3 Electricity use for charging battery electric vehicles

Infrastructure for charging battery electric vehicles is currently being rolled out, though a single standard has not yet emerged. Tesla is building a 120kW fast chargers network, whereas other OEMs (BMW, Daimler, Ford and the Volkswagen Group) announced in November 2016 to build up an ultrafast 350kW charging infrastructure across Europe. These sites see a need for 6 charge posts per site and they calculate a need of power in the order of 1.2 MW per sites.

Figure 4.2 gives the smart charging curve of a battery electric vehicle. It shows the stepwise reduction of charging voltage and constant current during charging, minimizing battery degradation effects.

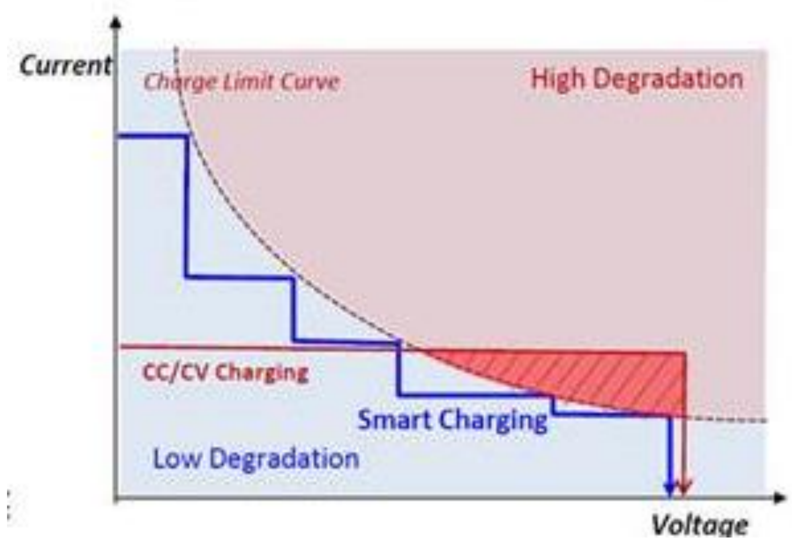

Figure 4.4: Example of a BEV smart charging curve

The CH2P system can be used to charge the car directly or via an intermediate storage battery located at the site. The car battery is a "slave" and will charge automatically at a slower rate if the CH2P system cannot supply the full demand of the vehicle. The charging system is always under CH2P control.

The vehicle battery requires DC power and the CH2P system produces DC power. However, since DC-DC converters with the required power electronics are not currently available, a conversion to AC power will be required. This may add a 2-3% efficiency loss to the system for battery charging.

5 Usage scenarios considered

The objective of the CH2P project is to realize an efficient system for cogeneration of hydrogen, heat and power, fuelled by methane-rich gases and using solid oxide fuel cell technology. This system will be placed at a refuelling station, supplying the hydrogen required and potentially power and heat for adjacent applications.

The use cases under consideration are

a) Hydrogen production for the station + power production to run the CH2P system itself
b) Hydrogen production for the station + power to cover on-site electricity consumption like the CH2P system, the hydrogen station and the conventional refuelling station (including lighting, car wash and shop)
c) Hydrogen production for the station + power production for export (to the grid, including for power balancing, or to neighbouring electricity consumers)
d) Hydrogen production for the station + power production for charging battery electric vehicles

In all cases the hydrogen production can vary depending on utilisation of the station (see Figure 5.1) and the use of remaining heat, for example for the car wash, can be considered.

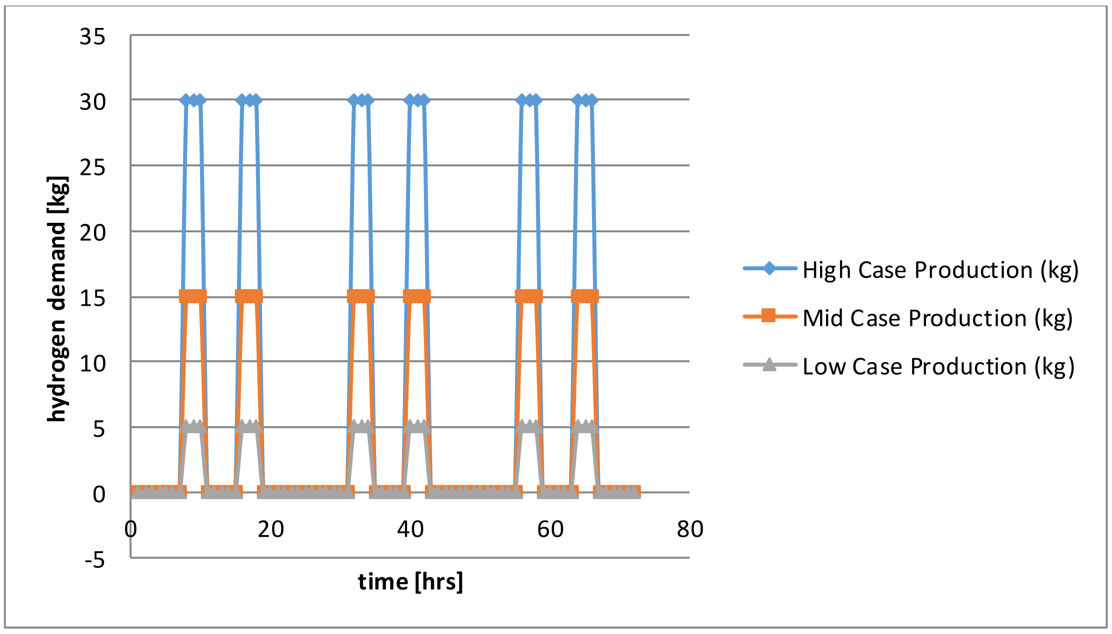

Figure 5.1: Hydrogen demand profiles for high, medium and low utilisation

6 Implications for CH2P system

The CH2P operating envelope required to meet all considered use cases in give in Figure 6.1 for the 100kg/day unit that will be built for the CH2P Project, whereby point

1. Use Case b) with low utilisation of the hydrogen station
2. Use Case b) with high utilisation of the hydrogen station
3. Use Case c) or d) with high utilisation of the hydrogen station
4. Use Case c) or d) with medium utilisation of the hydrogen station
5. Use Case c) or d) whereby the hydrogen storage at the station is full
6. Use Case a) with high utilisation of the hydrogen station

These operating points will be modelled to assess the suitability of the CH2P system for the use cases defined.

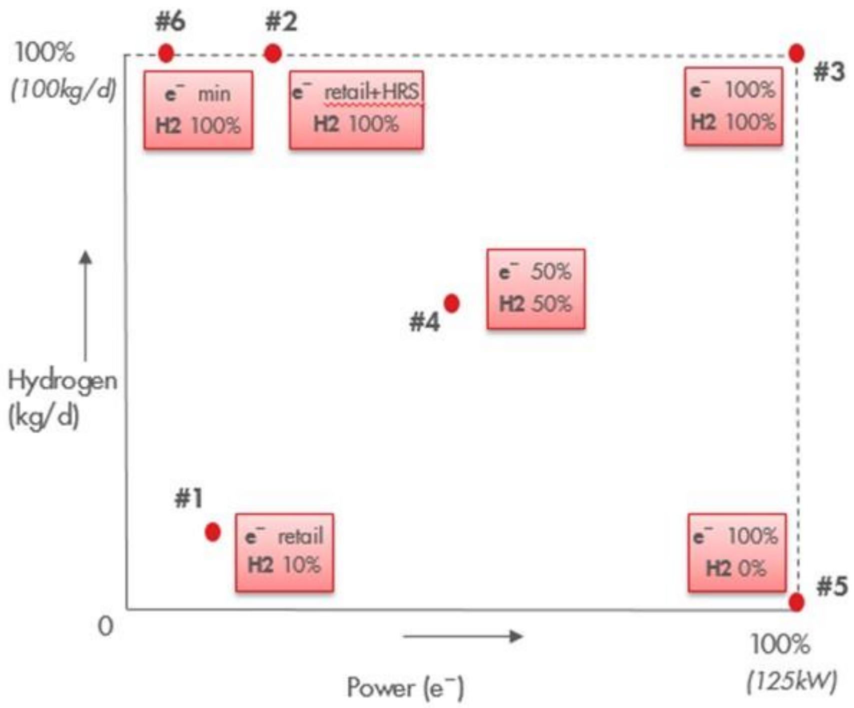

Figure 6.1: Operating envelope CH2P system

7 Conclusion

The usage scenarios for the CH2P system have been defined based on demand for hydrogen and power at an operating hydrogen stations. These scenarios include hydrogen supply for stations with varying utilisation as well as varying power demand.

Based on these demand scenarios 6 operating points of the CH2P system have been selected as basis for detailed modelling of the system and subsequent system design.

The work specifically highlighted the existence of significant short-duration power fluctuations on top of the average power consumption of hydrogen and conventional fuel stations. This may have implications for the electronics to be used on the CH2P system.