Hydrogen

Select the proper solution

A white paper from **Caloric**, by **Dr. Florian von Linde** and **Josef Rupprecht**

From which point is it economically feasible to generate hydrogen onsite rather than being dependent on the supply of hydrogen from hydrogen contractors? And which solution might be the most attractive one for your individual application? These questions are strongly related to the region, the industry sector, and the individual strategies of each company. Here, we give an overview of the available possibilities to supply hydrogen and provide an economic estimation for different hydrogen supply systems.

Available systems

This paper focuses on the most common ways of supplying hydrogen with capacities up to 15,000 Nm³/h. Diagram 1 (*below*) represents an overview of the main technologies nowadays on-hand.

Typically hydrogen is transported via trailers for supplying small and medium amounts of hydrogen. The delivery via trailers is especially recommended for discontinuous consumption of hydrogen. It is noticed that electrolysis, the generation of hydrogen by electrolysis of water, and containerised steam methane reformers (hydrogen generation by reforming of natural gas and steam) are available for capacities around 100 Nm³/h up to more than 500 Nm³/h of hydrogen.

The cracking of methanol (hydrogen generation by methanol and water mixtures) and steam methane reforming (SMR) in industrial design are both considered from demand of about 500 Nm³/h of hydrogen and above.

"Typically hydrogen is transported via trailers for supplying small and medium amounts of hydrogen…"

The limitation in size of the methanol cracking technology is mainly related to the economic feasibility. Hydrogen is also available via pipeline in some regions with well-developed infrastructure and large scale hydrogen generating plants nearby.

Selection criteria

The selection of the adequate technology is usually not only related to the required amount of hydrogen, but also to different parameters as discussed in the following circumstances.

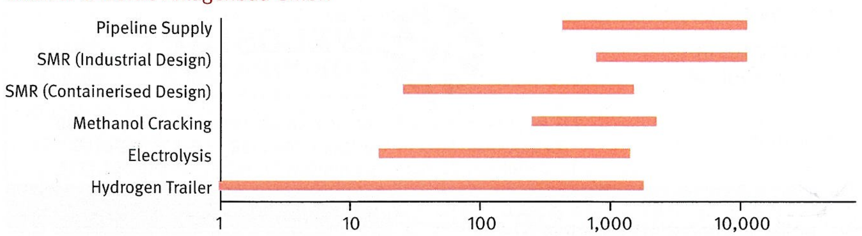
After highlighting major possibilities of hydrogen supply, the requirements for different systems are cross-checked with the available resources on-hand. No utilities are required onsite for the supply of hydrogen from contractors via trailer; however a developed transport network is mandatory. The water electrolysis is commonly used for small hydrogen capacities below 100 Nm³/h but is still considered in cases when electrical power is extremely cheap or gas and methanol are simply not available. The choice to select either methanol cracker or SMR technology is strongly related to the availability and costs of the consumables.

The containerised SMR is a competitive solution if a standardised system is sufficient for the customer. In contrast, industrial designed hydrogen generating plants are individually designed with possibilities to use LPG or naphtha instead of natural gas.

Regardless of the resources required for each technology, the supply of hydrogen via different systems is also a structural as well as a strategic question. The infrastructure may be understood as the well-developed traffic network and hydrogen filling stations within acceptable reach. Most of the structural points are rated in favour of the delivery of hydrogen to the site, except the infrastructure. Efforts in Maintenance, civil work and required plot space are by far less compared with setting up an onsite generation plant. The initial investment and the delivery time of the system cause more planning and initial budgetary efforts.

However, for many companies it is a strategic question whether to be dependent on hydrogen contractors or follow a certain level of autonomy. Companies are strongly focused at this point from the very beginning of project planning, when short-term lack of hydrogen leads to production losses of several days such as in the polysilicon industry. The hydrogen availability of each supply system is often background to the strategic decisions to increase the company's autonomy.

Diagram 1. Hydrogen Range to Nm³/h of Different Systems
Source: CALORIC Anlagenbau GmbH



Economic feasibility

In the following examples, two scenarios are chosen to give a reference. The initial investment (CAPEX) and the costs during operation of the plant (OPEX) will be considered for both scenarios.

Scenario 1 assumes that a hydrogen pipeline is not available. The electrolysis is not considered in this scenario due to its high operating costs (approx. 4.5 kW/Nm³ with 0.2 €/kW) as well as containerised SMR solutions as the typical capacity of these systems is designed for hydrogen demand below 500 Nm³/h.

Diagram 2. CAPEX and OPEX for First Year (2,500 Nm³/h Hydrogen Supply)
Source: CALORIC Anlagenbau GmbH

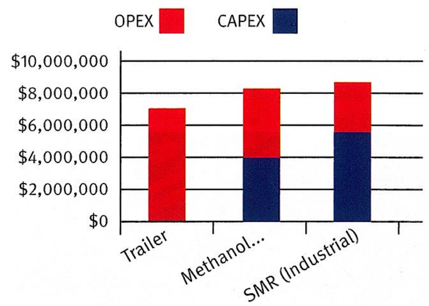


Diagram 3. Chronological Observation of CAPEX and OPEX for 2,500 Nm³/h Hydrogen Supply
Source: CALORIC Anlagenbau GmbH

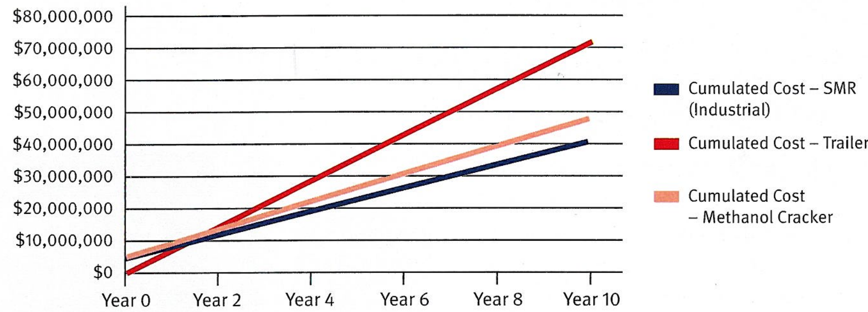


Diagram 2 illustrates the CAPEX as well as the OPEX for the supply of 2,500 Nm³/h hydrogen from sources not being eliminated before. While the cost columns seem to be at similar stage for the methanol cracker and the SMR, the level is noticeably lower for the hydrogen trailer. The diagram shows only the CAPEX and the OPEX for one year. Diagram 3 below helps to get an idea to display the trend for the cost level over a period of time.

Diagram 3 indicates clearly the SMR as the most feasible solution for the supply of 2,500 Nm³/h of hydrogen, considering at least two years of hydrogen demand. Even though the initial CAPEX of the SMR is about 25% higher than the CAPEX of the methanol cracker, the costs are equalised after less than two years, mainly due to the lower price of natural gas compared with methanol. The cumulated cost curve of the hydrogen supply of 2,500 Nm³/h via trailer shows that this solution is favourable for short-term supply (under two years) however, is not economically feasible for longer time periods.

Scenario 2 (South East Asia) – 1,000 Nm³/h of hydrogen

Scenario 2 aims to display a realistic picture of the hydrogen supply of 1,000 Nm³/h in South East Asia. Many times companies in remote parts of South East Asia are challenged by not being able to access hydrogen from large filling stations via trailers. A hydrogen pipeline is also not available in considered areas. The infrastructure forces companies to arrange their own hydrogen facilities. Against this background, this scenario will take a look at the hydrogen supply from electrolysis, methanol cracker, containerised SMR and industrial designed SMR.

There is a similar CAPEX level between the SMR's as well as the methanol cracker technology, whereas even the OPEX of the electrolysis option exceeds each other option by far. The natural gas price is based on liquefied natural gas (LNG) price. The containerised SMR solution for this size of plant is not yet as interesting as for small sized hydrogen generating plants below 500 Nm³/h, since a number of containers are required to cover 1,000 Nm³/h hydrogen supply. However, the operating costs of both SMR solutions are on a similar level.

Contrary to the scenario of 2,500 Nm³/h hydrogen demand in Central Europe, it is not as easy to identify the most economic system at the combined CAPEX and OPEX of selected technologies. The costs for methanol and natural gas are close together for the South East Asia scenario, and quite some projects have to be decided on a case by case basis. However, usually natural gas-based SMR technology is the more economic route after around three years.

Conclusion

The presented basic conditions and scenarios may serve as a basis for evaluating the economic efficiency of different hydrogen supplies. Even though the scenarios display an indication of possible directions, these scenarios are not sufficient to indicate the perfect solution for each project.

With the trend going to high pressure hydrogen trailers, as well as containerised hydrogen containers, the industrial solutions for onsite hydrogen generation are losing some of their market for capacities lower than 1,000 Nm³/h. However, as this paper shows and some readers might have experienced during own projects, there are always several means to consider alongside the standard solution. Many individual possibilities are available depending on the region, the industry sector, the individual strategies of each company and of course, the quantity required to select the proper solution for hydrogen supply. gw

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