HYDROGEN - SELECT THE PROPER SOLUTION

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Hydrogen, hydrogen generation, on-site generation, steam reforming, methanol reforming, methanol cracking

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Introduction

From which point is it economically feasible to generate hydrogen on-site 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 individual strategies of each company. This article shall give an overview about available possibilities to supply hydrogen and provides 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 Nm^3/h. Diagram 1 below represents an overview of the main technologies nowadays on hand.

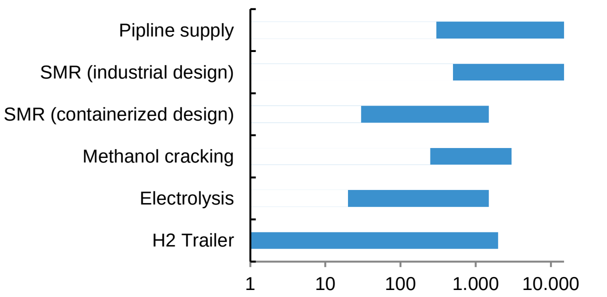

Diagram 1, H_2 range in Nm^3/h of different systems

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 i.e. hydrogen generation by electrolysis of water, and containerized steam methane reformers i.e. hydrogen generation by reforming of natural gas and steam, are available for capacities around 100 Nm^3/h up to more than 500 Nm^3/h hydrogen. Cracking of methanol, i.e. hydrogen generation by methanol and water mixture and steam methane reforming (SMR) in industrial design are both considered from about 500 Nm^3/h hydrogen and above demand. The limitation in size of the methanol cracking technology is mainly related to the economic feasibility which will be illustrated in diagrams 3 and 5. Hydrogen is also available via pipeline in some regions with well-developed infrastructure and large scale hydrogen generating plants nearby.

Definition Steam Methane Reformer (SMR):
Containerized SMRs are modularized small size SMRs put into one or more container– one module can produce up to around 500 Nm^3/h H_2.
Industrial SMRs are individually designed solutions with focus at operation in industrial areas.

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.
After highlighting major possibilities of hydrogen supply, the requirements for different systems are crosschecked with available resources on hand. Therefore Table 1 helps to indicate which technology fits best to certain regions or industries. No utilities are required on-site 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 Nm^3/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 containerized SMR is a competitive solution if a standardized 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.

	H_2 Trailer	Electrolysis	Methanol cracker	SMR (container)	SMR (industrial)	Pipeline
Resources						
Workforce	-	+/-	+/-	+/-	+/-	-
Power	-	+	+/-	+/-	+/-	-
Natural gas	-	-	-	+	+	-
Methanol	-	-	+	-	-	-
Demin. Water	-	+	+	+	+	-
Cooling Water	-	+	+	+	+	-

Table 1, + = required, - = not required, +/- = minor

Regardless of resources required for each technology, the supply of hydrogen via different systems is also a structural as well as a strategic question. Table 2 refers to the distinction of hydrogen supply via delivery to site (e.g. trailers, pipeline) and the on-site hydrogen generation. The infrastructure as per this table may be understood as the well-developed traffic network and hydrogen filling stations within acceptable reach. Most of the structural points listed below are rated in favor 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 on-site 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 time 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 of strategic decisions to increase the company's autonomy.

Economic feasibility

In the following, 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.

	On-site H_2 generation	H_2 delivery to site
Structure		
Infrastructure	+	-
Maintenance	-	+
Civil work	-	+
Plot space	-	+
Strategy		
Delivery time	-	+
Initial effort	-	+
Autonomy	+	-
H_2 Availability	+	-

Table 2, + = rated positively, - = rated negatively

Scenario 1 (Central Europe): 2500 Nm³/h H_2

Economic assumptions*:	
H_2 via Trailer:	**0,30 € / Nm³**
Natural Gas price:	**0,28 € / Nm³**
Methanol price:	**0,25 € / kg**

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 containerized SMR solutions as the typical capacity of these systems is designed for the hydrogen demand below 500 Nm³/h.

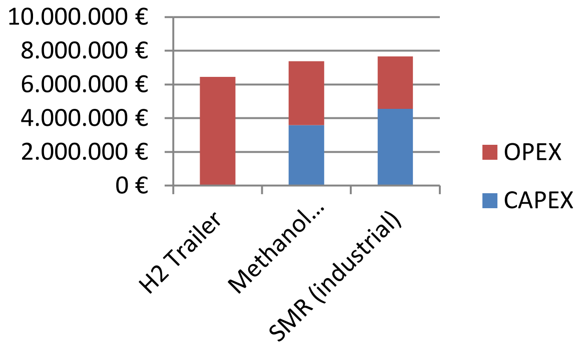

Diagram 2, CAPEX and OPEX for first year (2500 Nm³/h H_2)

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 equalized after less than 2 years mainly due to the lower price of natural gas compared with methanol. The cumulated cost curve of the hydrogen supply of 2500 Nm3/h via trailer shows that this solution is favorable for short time supply (below 2 years) however is not economically feasible for longer time periods.

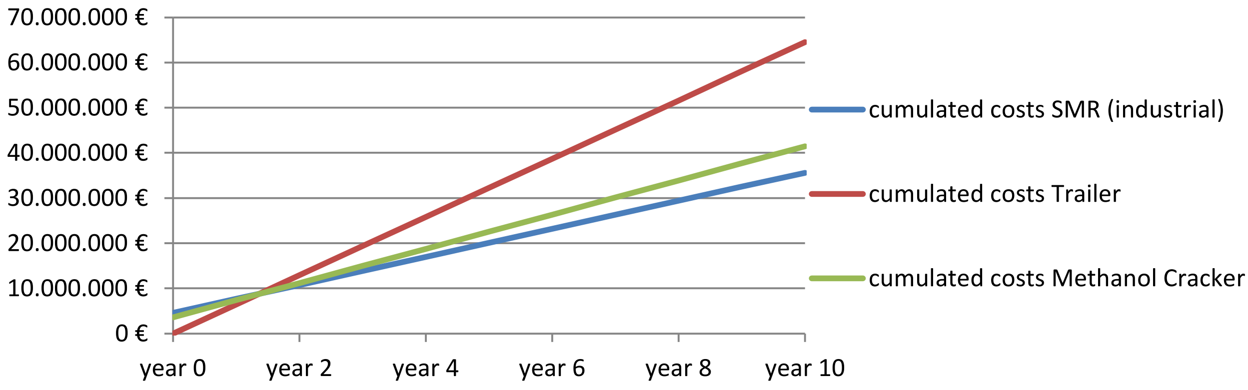

Diagram 3, Chronological observation of CAPEX and OPEX for 2500 Nm³/h hydrogen supply)

Scenario 2 (South East Asia): 1.000 Nm^3/h H_2

Economic assumptions*:	
Natural Gas price:	**0,36 € / Nm^3**
Methanol price:	**0,32 € / kg**
Electric power:	**0,15 € / kWh**

Scenario 2 aims to display a realistic picture of the hydrogen supply of 1.000 Nm^3/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. On this background this scenario will take a look at the hydrogen supply from electrolysis, methanol cracker, containerized SMR and industrial designed SMR.
Diagram 4 displays the similar cost level of the SMR's as well as the methanol cracker technology whereas even the OPEX of the electrolysis is exceeding each other column by far. The natural gas price is based on liquefied natural gas (LNG) price. The containerized 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.

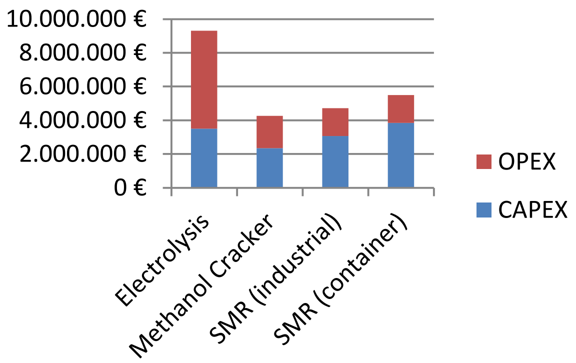

Diagram 4, CAPEX and OPEX for first year (1000 Nm^3/h H_2)

Diagram 5 below represents the related approach as diagram 3 for scenario 1. The electrolysis is not considered due to the indicated and recognizable high costs.

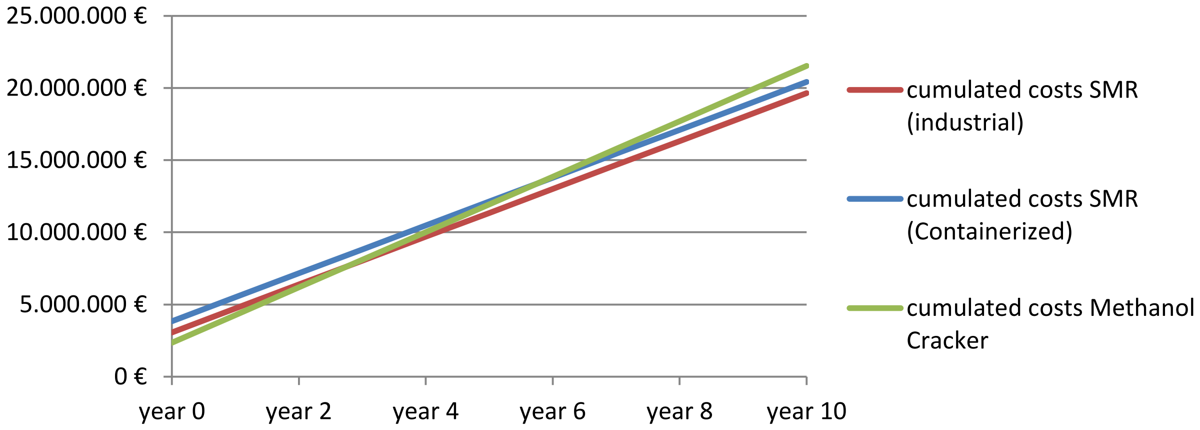

Diagram 5, Chronological observation of CAPEX and OPEX for 1000 Nm^3/h hydrogen supply)

Contrary to the scenario of 2500 Nm3/h hydrogen demand in Central Europe it is not as easy to identify the most economic system at 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 case by case. However usually natural gas based SMR technology is the more economic one after about 3 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 containerized hydrogen containers, the industrial solutions for on-site hydrogen generation are losing some of their market for capacities lower than 1000 Nm3/h. However, as this paper shows and some readers might have experienced during own projects, there are always several ways alongside the standard solution. Many individual possibilities are available depending on the region, the industry sector, individual strategies of each company and of course of the quantity of required hydrogen to select the proper solution for hydrogen supply.

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