Integrated design for demonstration of efficient liquefaction of hydrogen (IDEALHY)

Fuel Cells and Hydrogen Joint Undertaking (FCH JU)

Grant Agreement Number 278177

Title:	Report on Efficiency and Cost Calculations
Authors / Project Partner:	David Berstad, Petter Nekså, Harald T. Walnum / SINTEF Energi AS
	Lutz Decker / Linde Kryotechnik AG
	Alice Elliott / Shell Global Solutions International B.V.
	Hans Quack / Technische Universität Dresden
Work Package:	Component Assessment and Optimisation of Feasible Large-Scale Liquefaction Process
Deliverable Number:	D2.7
Date:	11 November 2013
Report Classification:	Restricted (here: *Publishable Summary*)

New Energy World JU
fuel cells & hydrogen for sustainability

Approvals	
WP Leader	✓
Coordinator	✓
FCH JU	**pending**

Contacts
david.berstad@sintef.no **info@idealhy.eu**

Acknowledgements

The research leading to these results has received funding from the European Union's Seventh Framework Program (FP7/2007–2013) for the Fuel Cells and Hydrogen Joint Technology Initiative, under grant agreement number 278177.

Disclaimer

Publishable summary

In the now concluded process selection phase (Work Package 1, WP1) of IDEALHY the most promising hydrogen liquefaction concept was selected for further development in the succeeding Work Package 2 (WP2). The selected liquefier concept was described by a set of process characteristics with respect to: hydrogen pressure level and process pathway; refrigeration cycle types and refrigerants for precooling and cryogenic cooling; and expansion devices for final expansion and liquefaction.

This report describes the final energy optimization of the selected IDEALHY liquefaction process, and the energy, footprint and cost estimates made thereof. The main focus of the optimization was to locate the optimum temperature split between the mixed refrigerant (MR) precooling cycle and the cryogenic Nelium (helium/neon mixture) Brayton cooling cycle. Several cases for the MR cycle, for instance with/without pre-chilling or with/without two-phase flow at the MR heat exchanger inlet, have been optimized, and a final optimum split temperature has been identified.

The MR cycle was optimized for several cases and boundary conditions. For each case, the optimum MR composition, pressure levels and flow rate were found. The performance of the MR cycle was compared to that of the Brayton cycle, and an optimum split temperature was found by first plotting the aggregate power consumption of the two cycles. In addition, it was found advantageous to use a pre-chilling utility also for the MR cycle, as this stabilizes the operating conditions.

With this result it was possible to predict the overall power consumption of a 50 tpd plant. At full capacity the required power is 13.33 MW. This corresponds to a specific power requirement of 6.4 kWh/kg and a thermodynamic (exergetic) efficiency of 42 %. This is based on realistic assumptions of the efficiencies of the main components, which were obtained through inquiries to potential component suppliers.

With this result the main goal of the IDEALHY project has been reached.

The size and cost of a 50 tpd plant has also been briefly discussed, showing a draft layout of the plant and estimated pipe diameters for the main pipelines. Cost estimates suggest that the novelty of the processes results in a high initial CAPEX for the very first plant, which means that a demo plant able to demonstrate the technology is unlikely to be economically sustainable in the absence of additional funding (e.g. subsidies).

It should however be noted that the very high efficiency of the IDEALHY process will in principle lead to a relatively low ultimate cost of the compressors and other ambient temperature installations like motors, transformers, cooling water system. It is therefore expected that for later series IDEALHY plants the CAPEX will be lower than for plants built with any alternative process.

Key words

Hydrogen
Liquefaction
Optimisation of free parameters
Optimum precooling temperature
Overall power needs of total plant
Plant footprint
Pipe dimensions

Table of Contents