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Synthetic natural gas via integrated high-temperature electrolysis and methanation: Part II—Economic analysis



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ABSTRACT

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Keywords: Solid oxide electrolysis Synthetic fuels Methanation Thermal integration Trechnoeconomic analysis This part II work is built on the energy performance results of part I and focuses on the cost of producing synthetic natural gas and sensitivity scenarios around main economic variables.

Capital costs for each plant section have been evaluated taking into account operational parameters such as pressure and temperature of the SOEC. The costing and financial methodology is based on a discounted cash flow analysis that was used to calculate the specific cost of synthetic natural gas (SNG) which ensures economic profitability of the investment.

The co-electrolysis case has higher capital, operating and maintenance costs; however it shows a weaker dependence on the electricity cost due to its higher plant efficiency. The impact of key parameters such as electrolysis stack cost, cell degradation rate and carbon dioxide feedstock cost were further investigated. Both "state-of-the-art" and "target" scenarios were defined to account for the expected enhanced technological maturity of the SOEC technology that is expected to occur in the following decade.

For the co-electrolysis case, break-even electricity prices (i.e., costs that yield an SNG cost comparable to that of fossil natural gas) of 8 \$/MWh and 67 \$/MWh were calculated for "state-of-the-art" and "target" scenarios, respectively.

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1. Introduction

In part I steam electrolysis and co-electrolysis based plants for SNG production via integrated SOEC-methanation systems were designed and analysed from a thermodynamic point of view. A LHV efficiency of 76.0% for steam electrolysis and 81.4% for coelectrolysis system were calculated, respectively. An input DC power of 10 MWe for electrolysis was chosen for both systems in order to fix the size of the plant. The overall plant efficiency can be considered almost scale-independent by using a modular solid oxide cell technology, even though the efficiency of some BoP components (e.g., compressors) is quite scale-dependent. On the other hand, plant power affects the economic assessment, because the escalation of some capital costs depending on size is generally nonlinear. However, the plant size assumed in part I has not been changed in this part II as the chosen 10 MWe could represent an ideal commercial module for power-to-gas in Europe [1].

Economic aspects of synthetic methane production based on renewable energy were studied in the works of Davis and Martin

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http://dx.doi.org/10.1016/j.est.2015.06.004 2352-152X/© 2015 Elsevier Ltd. All rights reserved. [2,3]. Authors studied SNG production through integrated low-temperature water electrolysis and methanation, providing a detailed economic analysis that is able to calculate the synthetic methane production cost.

In this work plant capital and annual costs have been considered in order to build a detailed cash flow analysis. Annual costs include operating and maintenance items, energy input (i.e., electricity) as well as material streams (e.g., CO₂ and H₂O) input cost. Each cost item will be described in the following sections.

Energy performance estimation (see part I) showed the importance of a good thermal integration within integrated SOEC-methanation plants. In this second part, pinch analysis methodology is further extended to design the heat exchanger network (HEN), which will represent the main investment cost of the whole plant.

Solid oxide cells degradation has been also taken into account because of its impact on economics. As will be discussed, degradation implies the installation of an additional active area (i.e., spare capacity) to compensate for decaying electrochemical cell/stack performance, translating in extra costs.

The main goal of this second part is the evaluation – through a detailed methodology explained in the following sections – of the as-produced SNG cost (in particular of its COP—"Cost of Product"),

Nomenclature				
AC	Alternating current			
BoP	Ralance of plant			
	Carbon capture and storage			
CF	Co-electrolysis			
CS	Carbon steel			
	Direct current			
DCF	Discounted cash flow			
DOF	US Department of Epergy			
	Technical University of Denmark			
FCO	Fconomizer			
FPRI	Electric Power Research Institute			
ΕI KI FVΔ	Electric rower Research Institute			
GCCSI	Global Carbon Canture and Storage Institute			
CHC	Greenhouse Gas			
HFN	Heat exchanger network			
IFA	International Energy Agency			
IRROE	Internal rate of return on equity			
LHV	Lower heating value			
NETI.	National Energy Technology Laboratory			
NG	Natural gas			
NGCC	Natural gas combined cycle			
R&D	Research and development			
SE	Steam electrolysis			
SH	Super-heater			
SNG	Synthetic natural gas			
SOC	Solid oxide cell			
SOEC	Solid oxide electrolysis cell			
SOFC	Solid oxide fuel cell			
SS	Stainless steel			
ZOGB	Zinc oxide guard bed			
	-			
Param	eters			
$\Delta T_{\rm ml}$	Logarithmic mean temperature difference (K)			
A	Area			
An	Annuity (\$)			
ASK	Area specific resistance (Ωcm^2)			
<i>B</i> ₁ , <i>B</i> ₂				
DEC	Constant values for BEC calculation			
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