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Economic perspectives of Power-to-Gas technologies in bio-methane production

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ABSTRACT

A study on integration of Power-to-Gas technology with bio-methane production from bio-syngas produced by biomass gasification shows that a significant amount of excess electricity can be accommodated in bio-SNG production. By adding hydrogen produced from intermittent renewable sources to a CO_2 methanation section, production capacity of methane can be doubled. The business case for Power-to-Gas for bio-methane has been evaluated using three future cumulative electricity prices curves. Results show that a positive business case exists only for price curves based on large amounts of intermittent electricity installed. The room for investment for the electrolyser will mainly and highly depend on future commodity prices and price curves, and will benefit significantly from a decrease in the cost price of the electrolyser. The projected room for investment available for a PEM electrolyser is lower than for a Solid Oxide Electrolyzer (SOE), because of its lower efficiency and resulting higher operating costs. In the case of large capacity of intermittent electricity, the projected room for investment of an SOE electrolyser is 650 €/kW and for a PEM electrolyser 350 €/kW, which corresponds to the projections of future electrolyser costs.

1. Introduction

Power-to-Gas (P2G) is a concept that allows for connecting and balancing the gas-grid with the power-grid and can be used to balance supply and demand for both commodities. Electricity from renewable sources is expected to significantly increase in the future as a result of the current European policies, as well as in other parts of the world. Conventional measures such as grid expansion and increasing the capacity of flexible power plant can only balance supply and demand in the electricity grid up to a certain level and in the long term new technologies are needed that enable efficient transmission and storage of energy supplied by highly fluctuating and non-controllable, natural, power sources [1]. The Power-to-Gas conversion chain uses the excess renewable electricity from fluctuating renewable sources for the production of hydrogen via water electrolysis and converts hydrogen with CO_2 to methane via the Sabatier reaction, which is fed into the natural gas distribution system as SNG (Substitute Natural Gas):

$$CO_2 + 4H_2 \leftrightarrow CH_4 + 2H_2O \quad \Delta H = -164.9\ \text{kJ/mol}$$

Hence the advantage of Power-to-Gas concept is 2-fold: make use of peak electricity production typically induced by renewable sources in times of favourable weather conditions and mitigate the use of fossil fuel by using SNG. Furthermore the SNG can make use of the very large capacity of that is available in the Natural Gas transmission and storage infrastructure. Conversion to SNG rather than direct feed-in of electrolyser hydrogen in the natural gas grid avoids limitations to feed-in capacity set by the maximum amount of hydrogen allowed by the natural gas grid quality specifications. CO_2 is available in raw biogas from biomass fermentation processes for SNG production. Similarly, CO_2 is found in producer gas or bio-syngas from biomass gasification for SNG production that is currently in an advanced stage of development. Other sources for CO_2, but not further discussed here, are concentrated streams from industrial processes or from CO_2 from capture at fossil or biomass fuelled power plant.

Both the biogas from biomass fermentation and producer gas or bio-syngas from biomass gasification contain significant amounts of CO_2 (about 50%) that need to be removed to bring the SNG up to pipeline specification, which is normally done with mainly scrubbing technologies that involve a substantial efficiency penalty. Conversion of this CO_2 by the Sabatier reaction into methane avoids the energy required for the removal and increases the SNG production volume.

The economic feasibility of Power-to-Gas concepts has some very specific aspects that need special consideration. Electricity has in most occasions a higher market value than natural gas, but in times of favourable conditions for generation of renewable power, the large

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Nomenclature

α	Slope of the line profit line in the price duration curve [€/MW]
η_{system}	Overall efficiency of the system based on lower heating value [-]
ρ_{cat}	Bulk density of the methanation catalyst [kg/m^3]
APEA	Aspen process economic analyzer (software)
CRF	Capital return factor
EFF	Cold gas efficiency
Flow	Volumetric flow [m$_n^3$/h]
GHSV	Gas hourly space velocity [h^{-1}]
HEX	Heat exchangers
IG band	Industrial consumers of electricity > 150,000 MWh/year
In	Inlet
MEA	Mono-ethanol amine scrubbing
m_{cat}	Mass of catalyst in the methanation reactor [kg]
OP	Operating profit [M€/yr]
P	Electric power [MW]
PEM	Proton exchange membrane
P2G	Power-to-Gas
RFI	Room for investment
SNG	Substitute natural gas
SOE-EL	Solid oxide electrolyser, electrolysis mode
SOE-FA	Solid oxide electrolyser, fuel assisted mode
t	Cumulative operating hours [h/yr]
TCI	Total capital investment
LHV	Lower heating value [MJ/m$_n^3$]
Out	Outlet
$V_{g,in}$	Volumetric gas inlet flow to the reactor [m$_n^3$/h]

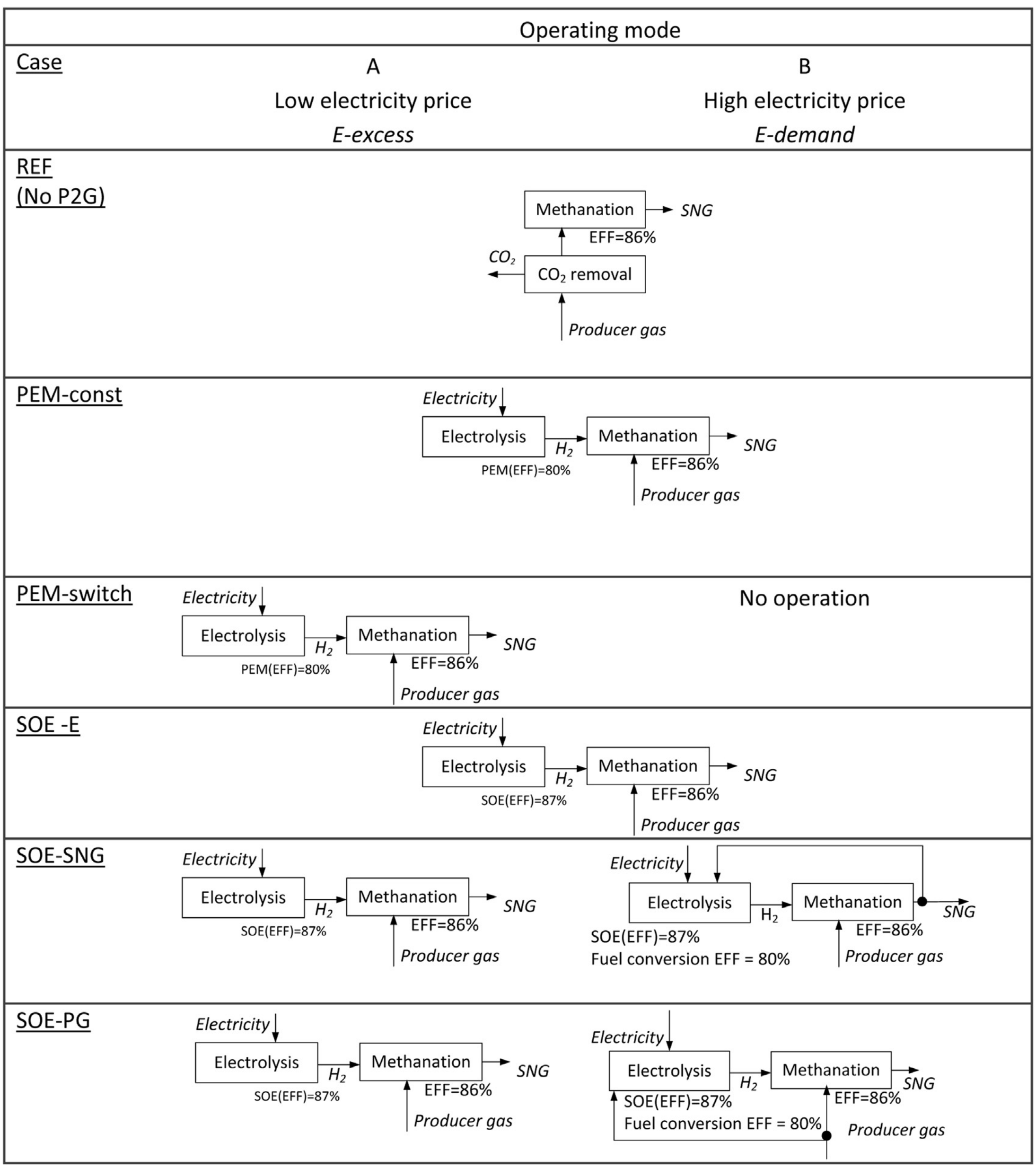

Fig. 1. Overview of concepts evaluated.