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Hydrogen from natural gas reforming with CCS: A clean fuel?

«ELEGANCY» is a European research project investigating the potential role of so-called «blue hydrogen», generated via methane reforming coupled with carbon capture and storage (CCS). Such low-carbon hydrogen, to be used as transport or heating fuel as well as in industry, could contribute to Swiss and European pathways towards carbon-neutrality. The Swiss project partners – PSI and ETHZ – are quantifying environmental benefits and potential drawbacks of such H2-CCS chains.

Life Cycle Assessment results show that blue hydrogen has the potential for substantial reduction of greenhouse gas emissions in the transport sector. From the environmental perspective, such hydrogen should primarily be used for heavy-duty, long-distance transport – the market in which fuel cell vehicles might also be the preferred zero-emission technology from the technical perspective, since battery vehicles face severe constraints in terms of range and charging time.

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https://www.sintef.no/elegancy/

Introduction

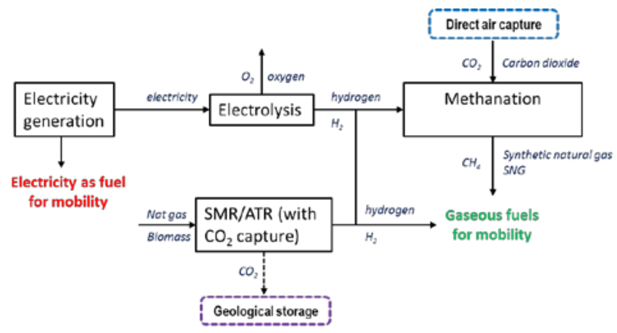
Clean fuels and vehicles are required for two reasons:

1. Climate change mitigation
2. Reduction of air pollutants

Low-carbon hydrogen and Fuel Cell Electric Vehicles (FCEV) offer benefits in this context. Low-carbon hydrogen can be produced either via electrolysis, or via natural gas (or bio-methane) reforming coupled with CCS. Reforming-based H2 production with CCS has the advantage of not relying on renewable electricity, which is limited in terms of generation potential. Using bio-methane as feedstock even allows for negative CO2 emissions.

Life Cycle Assessment (LCA) of such H2-CCS chains with different reforming and CO2 capture technologies is performed in order to answer the question whether such hydrogen is actually a clean fuel to be used for decarbonisation of the Swiss transport sector.

Goal & scope



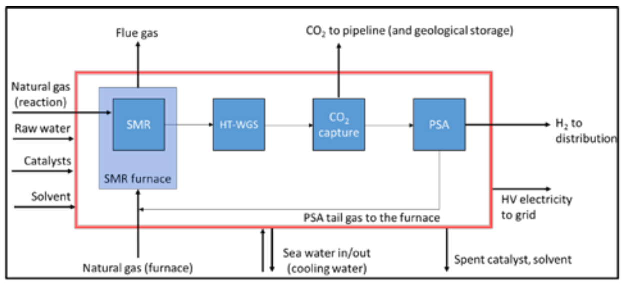
The following options are compared applying LCA:

1. Battery electric vehicles (BEV)
2. Fuel cell electric vehicles (FCEV) with H2 from:
   a. Electrolysis
   b. Natural gas reforming with CCS
3. Internal combustion engine vehicles (ICEV) with synthetic natural gas (SNG)

(Blue) hydrogen production

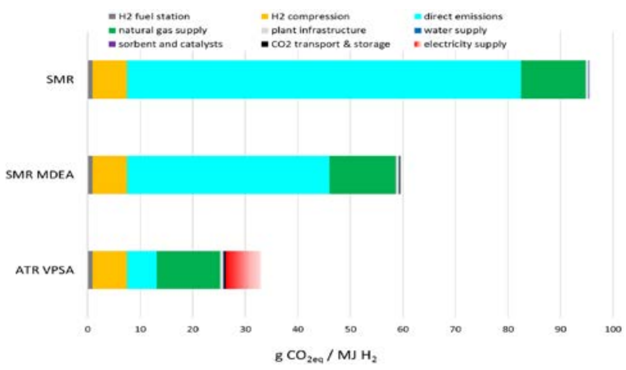
Three natural gas reforming production pathways are analysed using detailed process models:

1. Steam methane reforming (SMR) without CCS
2. SMR with solvent (MDEA) based CO2 capture from the syngas and pressure swing adsorption (PSA) for hydrogen purification (51% CO2 capture)
3. Auto-thermal reforming (ATR) with vacuum PSA based CO_2 capture and hydrogen purification (92% CO2 capture)

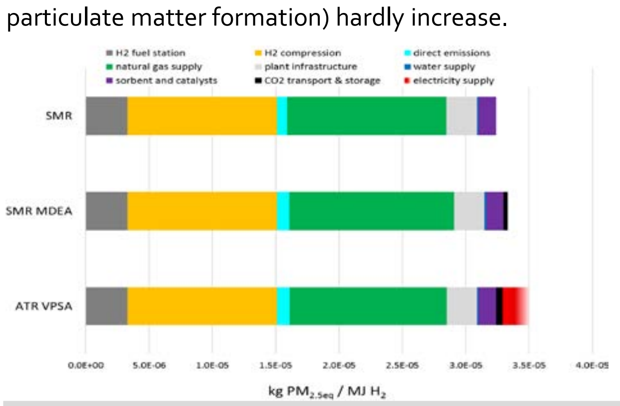


GHG emissions from H2 production

LCA results show that depending on the H2 production process, their energy supply and CO2 capture rate, life-cycle GHG emissions of natural gas reforming can be reduced by 35-70% with CCS.

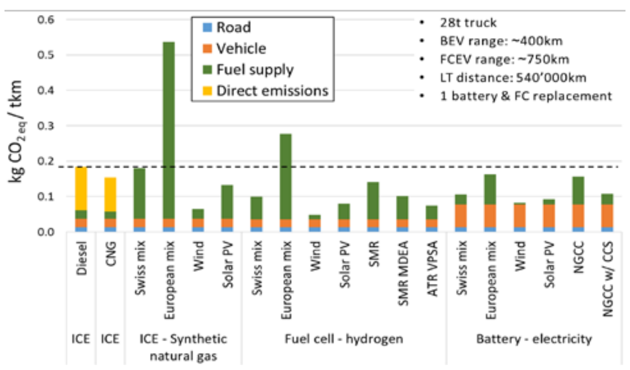


Despite of inceasing natural gas demand and further additional process inputs for CO2 capture and the subsequent transport and geological storage of CO2, other environmental burdens than GHG emissions (e.g., particulate matter formation) hardly increase.

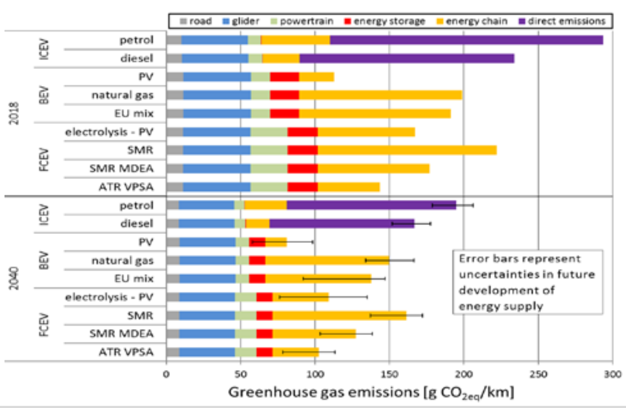


GHG emissions of vehicles

Comparing trucks with different fuels and powertrains regarding their life-cycle GHG emissions shows that FCEV with blue hydrogen are among the preferred options.



For passenger vehicles, direct use of low-carbon electricity with battery electric vehicles allows for a more substantial reduction of GHG emissions than blue H2 with FCEV.



Discussion & Conclusions

- Natural gas based hydrogen production with CCS can be considered as clean fuel.
- H2 production must aim at high CO2 capture rates.
- FCEV using such blue hydrogen can substantially reduce GHG emissions as well as air pollutants.
- Freight transport is the preferred end-use market, both from an environmental and technical perspective.

Further work will address costs and an optimal design of a European hydrogen and CO2 production and transport infrastructure.

Abbreviations

ATR	Auto-thermal Reforming
BEV	Battery Electric Vehicle
CCS	Carbon Capture and Storage
CNG	Compressed Natural Gas
CO2eq	Carbon dioxide equivalents
FCEV	Fuel Cell Electric Vehicle
GHG	Greenhouse Gas
H2	Hydrogen
ICEV	Internal Combustion Engine Vehicle
LCA	Life Cycle Assessment
LT	Lifetime
MDEA	Mono-diethanol-amin
NGCC	Natural Gas Combined Cycle
PM	Particulate Matter
PV	Photovoltaics
SMR	Steam Methane Reforming
SNG	Synthetic Natural Gas
VPSA	Vacuum Pressure Swing Adsorption
WGS	Water-Gas-Shift