Assessing hydrogen production from wind and solar power with an LCA

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Agenda

Introduction

System definition

Environmental assessment

Conclusions
Introduction

Hydrogen in Germany for mobility mainly from wind energy

Problems: - Limited area
- Social acceptance

Alternative: Import of renewable produced hydrogen, e.g. from solar power

→ High temperature hydrogen production processes

→ Long distance hydrogen transport

Comparison of solar hydrogen production incl. long distance transport with onsite wind hydrogen production

Source: Kosa1983

Source: Fotolia© DeVice
High-temperature hydrogen production

High-temperature electrolysis

Thermochemical cycles

- Direct water splitting requires very high temperatures (2500 °C)
- Water splitting integrated into a chain of chemical reactions lowers the temperature to a manageable magnitude
- Sulfur–iodine cycle

Heat: 850 °C

\[
\begin{align*}
2\text{HI} & \longrightarrow \text{I}_2 + \text{H}_2 \\
\text{H}_2\text{SO}_4 & \rightarrow \text{H}_2\text{O} + \text{SO}_2 + \frac{1}{2}\text{O}_2 \\
2\text{H}_2\text{O} + \text{SO}_2 + \text{I}_2 & \longrightarrow \text{H}_2\text{SO}_4 + \text{HI}
\end{align*}
\]
Long distance distribution: Liquid Organic Hydrogen Carriers

- Chemical compounds that bind hydrogen
- Up to 6.2 wt% stored hydrogen in LOHC possible
- Liquid can be handled like mineral oil products
- Possible compounds: e.g. dibenzyltoluene or toluene/methylcyclohexane
LCA Methodology

Goal and scope definition

Inventory analysis

Impact analysis

Interpretation

Source: DIN 14040
Goal and Scope

Provision of 1 kg hydrogen at 700 bar for mobility applications at a hydrogen refueling station in Germany

Solar hydrogen production in North Africa compared with wind hydrogen production in Germany

State of the technology of 2030

Analysis of impact categories:

- Climate change
- Acidification
- Eutrophication
- Photochemical ozone creation
System Definition

CSP plant

Electricity -> S-I cycle -> H₂ → Hydrogenation of LOHC

LOHC → Transport → H₂ → Dehydrogenation of LOHC

H₂ → Purification → Compression

CSP plant

Electricity -> HT electrolysis → H₂ → Hydrogenation of LOHC

LOHC → Transport → H₂ → Dehydrogenation of LOHC

H₂ → Purification → Compression

WP plant

Electricity -> Electricity Grid

Electricity → Electrolysis → H₂ → Purification → Compression
Important Parameters

High-temperature electrolysis:
- Production capacity: 208 kg H₂/h
- Heat at 850 °C: 2.5 kWh/kg H₂
- Electricity: 36 kWh/kg H₂

Sulfur-Iodine cycle:
- Production capacity 417 kg H₂/h
- Heat at 850 °C: 78 kWh/kg H₂
- Electricity: 20 kWh/kg H₂

Alkaline water electrolysis:
- Production capacity: 4.4 kg H₂/h
- Electricity: 49 kWh/kg H₂
Efficiency

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Systems Analysis and Technology Evaluation (IEK-STE)
LCA results climate change

- LCA results for climate change
- Comparison of different electrolysis methods:
  - Alkaline Electrolysis
  - High Temperature Electrolysis
  - Sulfur-Iodine Cycle
- GWP in kg CO$_2$-eq/kgH$_2$
- Legend:
  - HRS
  - Ship
  - LOHC
  - Truck
  - Recycling
  - Direct Emissions
  - Production
  - Plant
LCA results comparison

Share of environmental impact

- HRS
- Ship
- Truck
- LOHC
- Recycling
- Direct Emissions
- Production
- Plant

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Conclusions

• Transportation of hydrogen with LOHC causes significant environmental impacts due to the heat demand for dehydration

• Heat for dehydrogenation from burning of hydrogen

• Usage for the excess heat should be considered

• The long transportation distance causes strong environmental impacts due to the direct emissions from the truck and the ship transport
Thank you for your attention!

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