SCCER Biosweet

WHITE PAPER POWER-TO-X
Chances and Risks for the Swiss Energy System

Sandra Moebus
3rd September 2019
16.00 – 1630 including questions
1972 founded

Education
- 1'600 students
- 8 degree courses BSc
- 1 degree course MSc

Further Education
- 20 MAS / CAS programs

Applied Sciences
- 85 Professors
- 230 scientific staff members
Section Power-to-X

Eleven research members under direction of Prof. Dr. Markus Friedl

- EU projects STORE&GO and Pentagon / HEPP
- Feasibility studies and scientific project support
- Expert talks Power-to-Gas
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Content

- SCCER Joint Activity White Paper Power-to-X
  - Project & Product
  - Technology Overview & Perspectives

- Selected Results
  - Synthesis
  - Gas market
  - Life Cycle Assessment in mobility
SCCER JA White Paper Power-to-X

PROJECT & PRODUCT
20 Researchers from seven Swiss Institutions

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1 PSI Paul Scherrer Institute (PSI), Villigen
2 EMPA Swiss Federal Laboratories for Materials Science and Technology (EMPA)
3 ETH ETH Zurich, Department of Humanities, Social and Political Sciences, Energy Politics Group
4 ETH ETH Zurich, Department of Mechanical and Process Engineering, Institute for Energy Technology, Aerothermochemistry and Combustion Systems Laboratory
5 ZHAW Zurich University of Applied Sciences (ZHAW), School of Engineering
6 HSR HSR Hochschule für Technik Rapperswil, Institute for Energy Technology
7 University of Geneva, Institute for Environmental Sciences
8 University of Lucerne, Faculty of Law
Challenge

- Paris Climate Agreement: drastic reduction of GHG emissions
- Energy Strategy 2050: Increasing the share of solar PV and wind energy in the electricity system with simultaneous withdrawal from nuclear energy
- P2X technologies as a potential future flexibility and emission reduction option
- PtX technology is relatively new and not yet fully commercialized
- Knowledge about PtX is limited and not synthesized

Project Aims / Procedure

- Summary of the most important PtX findings
- Creating a synthesis for the Swiss energy market
- Interdisciplinary team of experts
- Preparation of the individual topics
- Synthesize and publish the results
Product: White Paper Power-to-X

White Paper

- Around 30 pages (DINA4)
- Different perspectives and synthesis
- Languages
  - German
  - English
  - French

White Paper Report

- Around 100 pages (DINA4)
- Different chapters and synthesis
- Author per chapter
- Language
  - English

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Download: [www.sccer-hae.ch/wpp2x.php](http://www.sccer-hae.ch/wpp2x.php)
SCCER JA White Paper Power-to-X

TECHNOLOGY OVERVIEW & PERSPECTIVES
Power-to-X Technology Overview

- **Electricity (low-carbon / low cost)**
- **Electrolysis**
  - Heat (if SOEC)
  - H₂O
  - O₂

- **Upgrading/conditioning of Hydrogen (H₂)**
  - Distribution to consumers

- **CO₂ from carbon source**
  - Methanation (CH₄)/Methanol (CH₃OH) synthesis / Fischer-Tropsch fuel (CₓHᵧOH) synthesis
  - H₂O
  - Heat

- **Upgrading/conditioning of hydrocarbon fuels (CH₄, CH₃OH, CₓHᵧOH)**
  - Distribution to consumers

- **Buildings**
- **Mobility**
- **Utilities**
- **Industry**

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Perspectives on Power-to-X

Power System Perspective
- Present and future situation
- Grid stability
- Ancillary services
- Requirements for sizing and siting of P2X in electrical grids
- Techno-economic analysis with focus on market integration

Techno-economic Perspective
- Key components and processes

Technology Overview
- P2X pathways

CO₂ Sources and Markets
- Biogenic
- Industrial
- Direct Air capture

Power Market Analysis
- Gaseous fuels CH₄, H₂
- Transport sector
- Industry sector H₂, CH₄ as feedstock
- Combined revenues

Regulatory Perspective
- Law affecting all P2X systems
- Law affecting P2X in the markets
  - Electricity
  - Transport
  - Heating
- Innovation policy

Environmental Perspective
- LCA (incl. use of product as relevant and possible)
- Compare P2X with conventional technology
Advantages of PtX unfold across combined markets
- Flexibility for electricity market
- Reuse of CO$_2$ (carbon cycle)
- Sustainable fuels (E-FUELS) for end users
- Added value from by-products (e.g. waste heat, O$_2$)

Costs and sustainability of PtX strongly depend on electricity
- Renewable electricity is mandatory

Legal framework influence the profitability of PtX
- PtX plant are considered as end users → electricity grid fees

Electricity costs for PtX depend on location (electricity grid fees) and thus limit the potential of PtX applications.
- E.g. electricity price without grid fees: 8 Rp./kWh ≈ 16 Rp./kWh SNG production
- E.g. electricity price with grid fees: 12 Rp./kWh around 24 Rp./kWh SNG production
Location for PtX plants: cement and waste incineration plants

Swiss CO$_2$ sources

- All wastewater treatment plants (ARA)
  - ca. 7 Mt CO$_2$ p.a.

Cement plants

- ARA areas >10'000 residents
  - ca. 2.7 Mt CO$_2$ p.a.

Waste incineration plants

- ARA areas >30'000 residents
  - ca. 4.2 Mt CO$_2$ p.a.

- ARA areas >30'000 residents
  - ca. 0.17 Mt CO$_2$ p.a.

- ARA areas >30'000 residents
  - ca. 0.16 Mt CO$_2$ p.a.

- ARA areas >30'000 residents
  - ca. 0.13 Mt CO$_2$ p.a.

Teske et al. 2019
Cost optimization for Power-to-X

- Reliable and cost effective electricity supply from renewable energies (for at least 3'000 to 4'000 hours per year)
- Location without electricity grid fees for electricity supply
- Short routes to the customers
- PtM: Certificate for SNG as a renewable gas (sell it to a higher price)
- Low price for carbon dioxide CO₂
- Revenues from service control (negative and / or positive)
- Revenues from sale of waste heat and oxygen O₂
- Partnership with car importer for fleet emission reduction
Future Research

- Innovative technologies for electrolysis
  - Efficiencies above 80%
  - Half of investment costs

- Research on technology-upscaling in orders of magnitude of commercial product streams

- Potential location analysis for PtX in terms of
  - renewable electricity
  - carbon sources
  - end users
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GAS MARKET
Core Component Electrolysis

- Alkaline electrolysers in large scale application
- Polymer-electrolyte-membrane-technology (PEM) as smaller plants; higher power density and higher efficiency at higher costs (compared to alkaline)
- Adjustment of costs in future expected (PEM and alkaline)
- Solid oxide electrolysis under development (high temperature technology with high efficiency)

- Criteria for low $\text{H}_2$ production costs:
  - Supply with low-cost electricity
  - Several thousands of operating hours
Gas Market Power-to-Hydrogen

- **2018**: Price level for Power-to-Hydrogen:
  100 - 180 CHF / MWh (144 CHF / MWh on average)

- **NG steam reforming** costs around 60 CHF / MWh

- **2030**: P2H becomes competitive
  - costs for NG increase and/or
  - environmental laws for CO2 emissions
  - low electricity costs for electrolysis

- **2030**: Price level for PtH 40 - 150 CHF / MWh
Gas Market Power-to-Methane

- **2018**: Price level for SNG from Power-to-Methane 170 - 250 CHF / MWh (194 CHF / MWh on average)
  - CH Business Case: 120-190 CHF / MWh SNG

- **2018**: Price for NG around a factor of 3 lower than PtM production costs.

- Especially private customers are willing to pay the ecological added value for biogas and SNG, the price level is around 150 CHF / MWh.
  - Private end users are the preferred customers for the distribution of SNG.

- **2030**: Price level for PtM is 65 - 175 CHF / MWh
  - First assumption: learning effects
  - Second assumption: High costs for CO$_2$ with DAC
Life Cycle Assessment

- **GHG emissions (CO$_{2eq}$) in mobility**
  - Battery electric vehicle
  - Fuel cell electric vehicle
  - Internal Combustion Engine Vehicle (ICEV) gasoline, diesel, gas
  - (ICEV) supplied with SNG (PtM)

- **Depending on the GHG emissions (CO$_{2eq}$) of electricity**

- **Advantage of SNG driven car**
  - ICEV diesel- and gas around 100g CO$_{2eq}$/kWh for electricity
  - BEV around 15g CO$_{2eq}$/kWh
  - Fuel cell electric vehicle around 30g CO$_{2eq}$/kWh
Life Cycle Assessment

2018

Greenhouse gas emissions of vehicles [g CO$_2$eq/km]

- Battery electric vehicle
- Fuel cell electric vehicle
- ICEV SNG
- ICEV diesel
- ICEV gas
- ICEV petrol

CO$_2$ intensity of electricity [g CO$_2$eq/kWh]

Bauer & Cox 2019 (tbp)
Life Cycle Assessment

Bauer & Cox 2019 (tbp)
Electrification in mobility

Held et al. 2018

Anteile (nicht) direkt elektrifizierbarer Fahrzeuge

Direkt elektrifizierbar: 98.2%
Direkt elektrifizierbar nicht möglich: 4.4%
Nicht direkt elektrifizierbar: 1.8%
QUESTIONS & ANSWERS
Thank you for your attention!