Electricity-based fuels as a link between the electricity and transport sectors

Business cases for ‘wind driven hydrogen’, Florian Bergen, Siemens AG
ETIP Wind workshop Feb. 21st 2019
CO₂ emissions are still rising

Regional and sectoral split of global CO₂ emissions

Global CO₂ emissions from fossil fuels 1980 – 2017

Global energy-related carbon emissions rose to a historic high of 32.5 gigatons in 2017, after three years of being flat, due to higher energy demand and the slowing of energy efficiency improvements.

Share on CO₂ emissions: 55%
Share of Renewables: 8%

Mostly disregarded by now

Share on CO₂ emissions: 40%
Share of Renewables: 22%

Main focus so far

CO₂ emissions reduction has been focused on power, but a more holistic approach is needed.

Source: Carbon Brief
Residual load key factor of generation and transmission

(PV) + (Wind) - (Verbrauch) = (Residuallast) = f(t)

Supply follows consumption

Past

Network development plan
(>40% renewable energy)

Quelle: Netzentwicklungsplan Deutschland

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Residual load key factor of generation and transmission
Sector coupling and conversion needed

\[(\text{PV}) + (\text{Wind}) - (\text{Verbrauch}) = (\text{Residuallast}) = f(t)\]

Past
Supply follows consumption

Today
Supply unequal consumption

Future
Supply decoupled from consumption

80% erneuerbare Energie 2035+
Electricity-based fuels

Direct and indirect pathways
Renewable hydrogen needs to become the energy carrier of the future for wind and solar power to decarbonize the economy.
Silyzer portfolio scales up by factor 10 every 4-5 years driven by market demand and co-developed with our customers

Silyzer portfolio roadmap

0.1 MW 1 MW 10 MW 100 MW 1000 MW

2011
Silyzer 100
Lab-scale demo
~4.500 op.h\(^1\)
~150k Nm\(^3\) of H\(_2\)

2015
Silyzer 200
~43.000 op.h
~6.0 mio Nm\(^3\) of H\(_2\)
World’s largest Power-to-Gas plants with PEM electrolyzers in 2015 and 2017 built by Siemens!

2018
Silyzer 300

2023+
Next generation
Under development

2030+
First discussions in cooperation with chemical industry

1) op.h.: operating hours as of Oct. 2018

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Silyzer 200
High-pressure efficiency in the megawatt range

5 MW
World’s largest operating PEM electrolyzer system in Hamburg, Germany

60 kWh
Specific energy consumption for 1 kg hydrogen

20 kg
Hydrogen production per hour

1.25 MW
Rated stack capacity
Silyzer 300 –
the next paradigm in PEM electrolysis

17.5 MW
per full Module Array
(24 modules)

75%
System efficiency
(higher heating value)

24 modules
to build a
full Module Array

340 kg
hydrogen per hour
per full Module Array
(24 modules)
Reference project SILYZER 200 – from KW to MW PEM Technology at the Energiepark Mainz

Demonstration
- Containerized version for demonstration projects (30-foot container size)
- Nominal load 100 kW<sub>el</sub>
- Over-load capacity 300 kW<sub>el</sub>
- Example: RWE Niederaußem
- Commissioning in 2012

Commercial reference
- Location: Mainz-Hechtsheim
- Partner: Stadtwerke Mainz, Linde, Siemens, Hochschule RheinMain
- 6 MW<sub>peak</sub> electrolysis (3x SILYZER 200, each 1.25 MW and 2 MW<sub>peak</sub>)
- Direct connection to wind farm (8 MW)
- 1000 kg hydrogen storage (33 MWh)
- Total budget: 17 Mio. EUR
- Funding: ~50 % (BMWi)
- Commissioning in 2015
Windgas Haßfurt Power to Gas
Next step: Power to Methanol

Capacity: 1,25 MW
H2 production: 225 Nm3/h
Real World Lab GreenHydroChem – first step into 100MW+
Sector coupling chemical feedstock, transport and domestic use

**Input**

- **Carbon**
  - CO2 from Total Refinery
  - 1m to pa
  - plastic waste and other carbon sources

- **Intermittent RES**
  - Solar (PV)
  - Wind

- **Continuous RES**
  - Hydro
  - Biomass

**Conversion**

- H2O
- CxHy

**Use case**

- Uses cases O2 and H2 use in refinery process
- Syngas for chemical feedstock
- E-methanol
- Direct H2 use in transport sector via FC
- H2 heating application in urban environment
Large scale Power-to-Methanol project with competitive cost position (200 MW train) – from MW to GW

Description
- World’s best wind load factors 65-75%
- Target of 1 GW electrolyser capacity (1.4 GW wind power)
- 2 Off-take pathways (diversification)
  - Electricity to Argentina (~100km HV over headline needed)
  - Export Green Methanol to Europe (premium price)
- Start with ‘pilot train’ 200 MW

Business drivers/objectives
- Argentina market is attractive with electricity price ~9 $ct/kWh
- Green Methanol market with huge potential and forecasted market size increase 6%/year.
- Green Methanol market price ~760 $/t (CRI Island project) with an expected increase to 800–1000 $/t near-term
- Contributes to the EU’s objectives of decreasing CO₂ emissions and increasing renewable energy usage

Value Proposition
- Low LCoE due to high wind load regime: competitive electricity price, methanol production cost close to competitiveness
- Develop international hub “Power to Methanol” with dedicated port (with access to both Atlantic and Pacific ocean)
- Develop an innovative green fuel production technology contributing to EU’s objectives of decreasing CO₂ emissions and increasing renewable energy usage

Windproject LAM
- ~220MW
- 30kV
- Patagonia region
- LCoE: ~1.9$ct/kWh
- Description

Transmission
- 10-50 km
- 30kV
- Power

Water electrolysis
- ~640$/kW
- ~34t/h
- ~220MW

Power to Methanol - JDA SIEMENS & Partners
- CO₂ Supply
  - ~100$/t
- CO₂
  - ~25t/h
- Methanol synthesis
  - ~20t/h
- CH₃OH
- Methanol production cost
  - ~700-750$/t
- Green Methanol: Target market – Europe
- Value Proposition
- Expected market price 800 – 1000 $/t (in case of biofuels 2nd generation as benchmark)
- Off-takers potential
  - Refinery
  - Car fuel

Market
- Target market: Europe

Transport
- 30kV
- 10-50 km
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Various countries demonstrate strong potential for PtX production / exports …

Source: Frontier Economics

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Electricity-based fuels might be cost competitive to biofuels in the future, and could result in lower CO$_2$ reductions cost.

Production costs and CO$_2$ reduction potential of electricity-based fuel

*2G production cost; 25% - and 75%-quantil from literature review

Today's European price level in summer 2017

* Murphy and Kendall, 2014
Thank you for your kind attention!

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Electricity-based fuels as valid option besides direct e-mobility

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<th>e-mobility</th>
<th>e-fuel</th>
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<tr>
<td>CO₂ neutral</td>
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<td>(using renewable electricity)</td>
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<td>“Fuel vs. Food“</td>
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<tr>
<td>No local emissions</td>
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<td>(NOx, particulate matter)</td>
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<td>Energy efficiency</td>
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<td>(efficiency along the process chain)</td>
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<td>Import of renewable energy</td>
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<td>Utilization of existing infrastructure</td>
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<td>Energy density &amp; range</td>
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Electricity-based fuels could be a future important link between the electricity and transport sectors, but require regulatory support in front running countries.

The decarbonization of long distance, heavy weight & marine transport and aviation requires CO$_2$ neutral fuels with high energy density.

The Power-to-Fuel technology can utilize low cost electricity (< 3 ct/kWh) at locations with good solar and wind conditions and can provide CO$_2$ neutral fuel that is compatible with today’s liquid fuel infrastructure.

Process and plant design is a challenge due to the fluctuating energy input. A high operational flexibility and low specific cost of electrolysis and chemical synthesis are the key to improve the overall plant economics.

Electricity based fuels are cost competitive to 2. Gen. biofuels (50 MW+ scale), have a very low carbon footprint, and have the potential to result in lower CO$_2$ avoidance cost.

E-fuel can help to balance between load (Regions with high RE Potential) and demand centers on a globally