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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

CO_2 emissions are still rising

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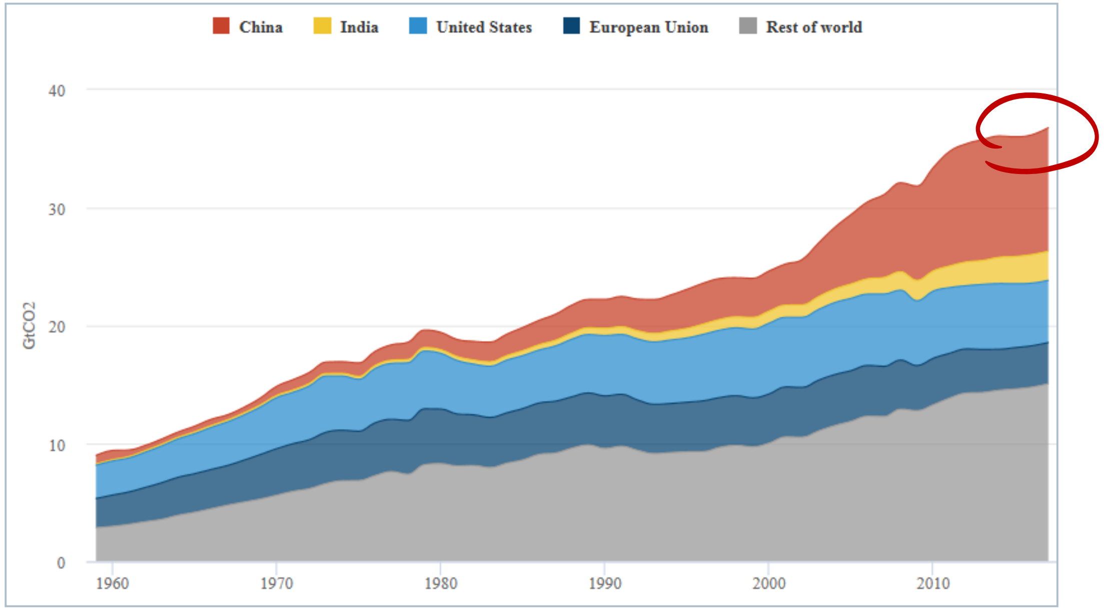
Regional and sectoral split of global CO_2 emissions

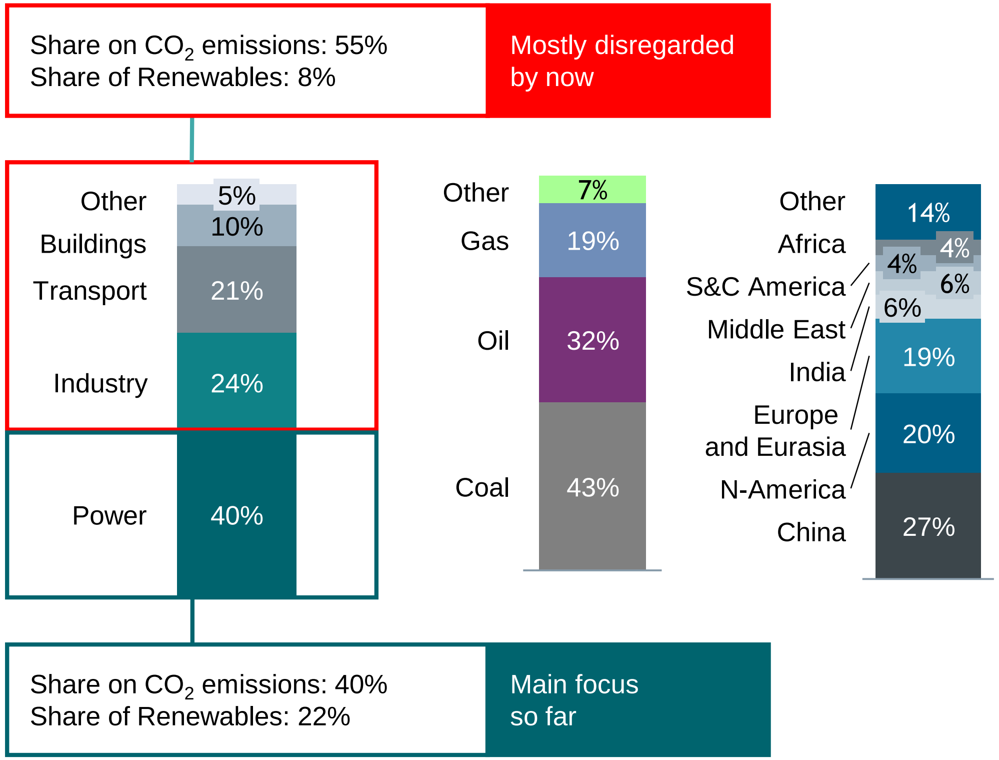
Global CO_2 emissions from fossil fuels 1980 – 2017

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



Source: Carbon Brief

Shares in global CO_2 emissions by sectors, fuel type and regions



CO_2 emissions reduction has been focused on power, but a more holistic approach is needed

Residual load key factor of generation and transmission

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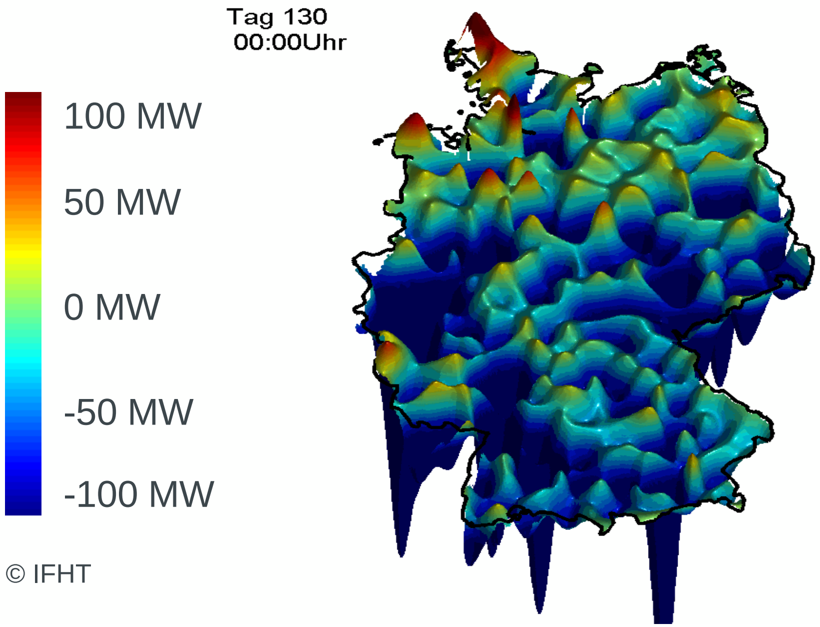
(PV) + (Wind) - (Verbrauch) = **(Residuallast)** = **f(t)**



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Network development plan

(>40% renewable energy)

Past
Supply follows consumption

Past
Supply follows consumption

Quelle: Netzentwicklungsplan Deutschland

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

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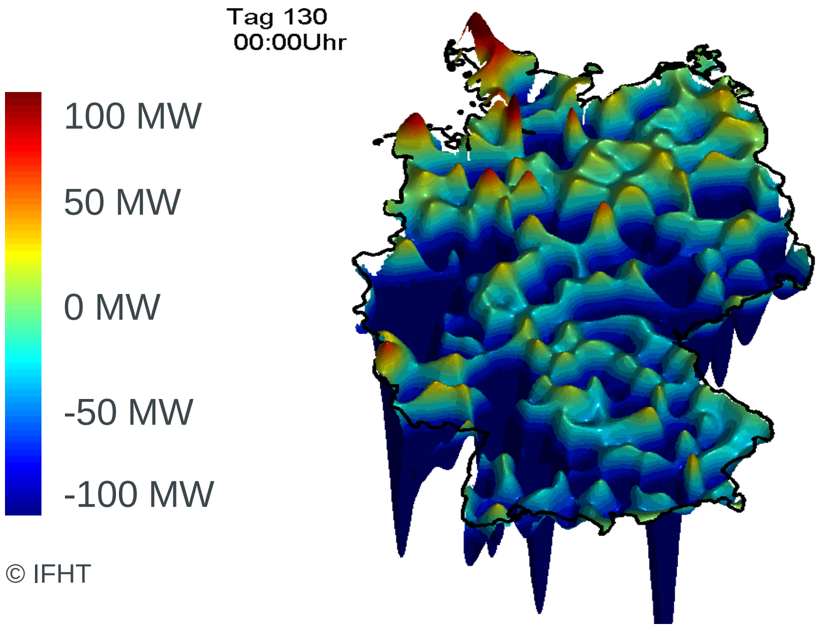
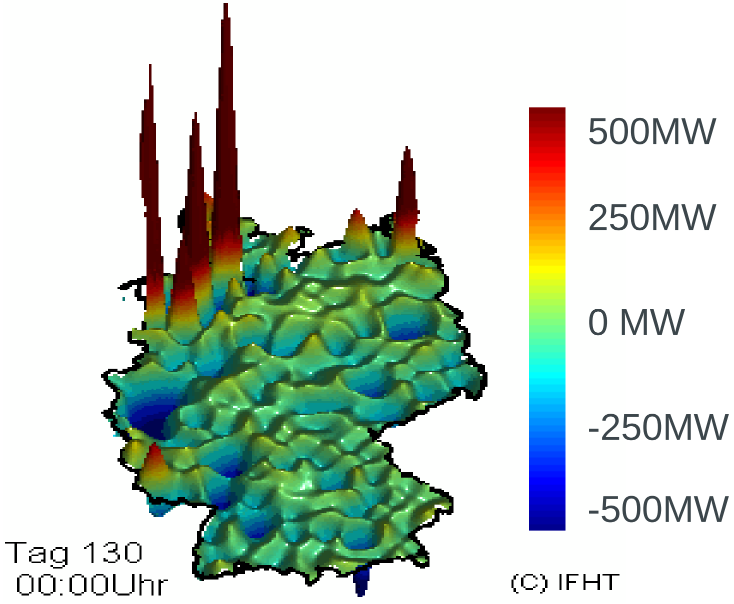
(PV) + (Wind) - (Verbrauch) = **(Residuallast)** = **f(t)**

80% erneuerbare Energie 2035+





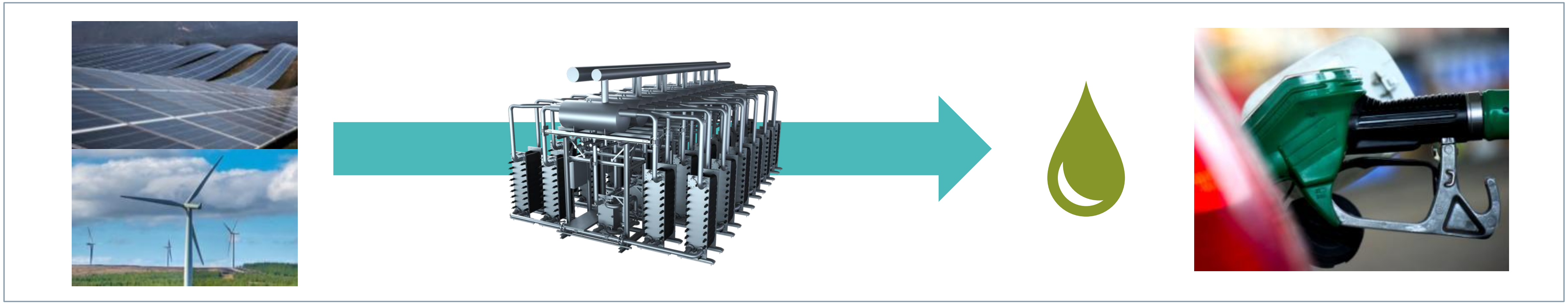
Past
Supply follows consumption

Today
Supply unequal consumption

Future
Supply decoupled from consumption

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

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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 Nm³ of H_2

2015

Silyzer 200
~43.000 op.h
~6.0 mio Nm³ of H_2

World's largest Power-to-Gas plants with PEM electrolyzers in 2015 and 2017 built by Siemens!

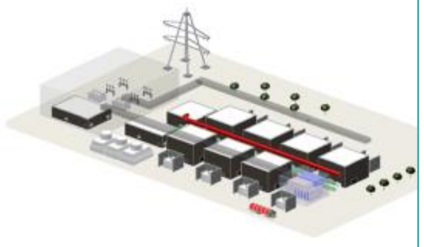
2018

Silyzer 300

Biggest PEM cell in the world built by Siemens!

2023+

Next generation
Under development



2030+

First discussions in cooperation with chemical industry

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

Silyzer 200
High-pressure efficiency in the megawatt range

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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

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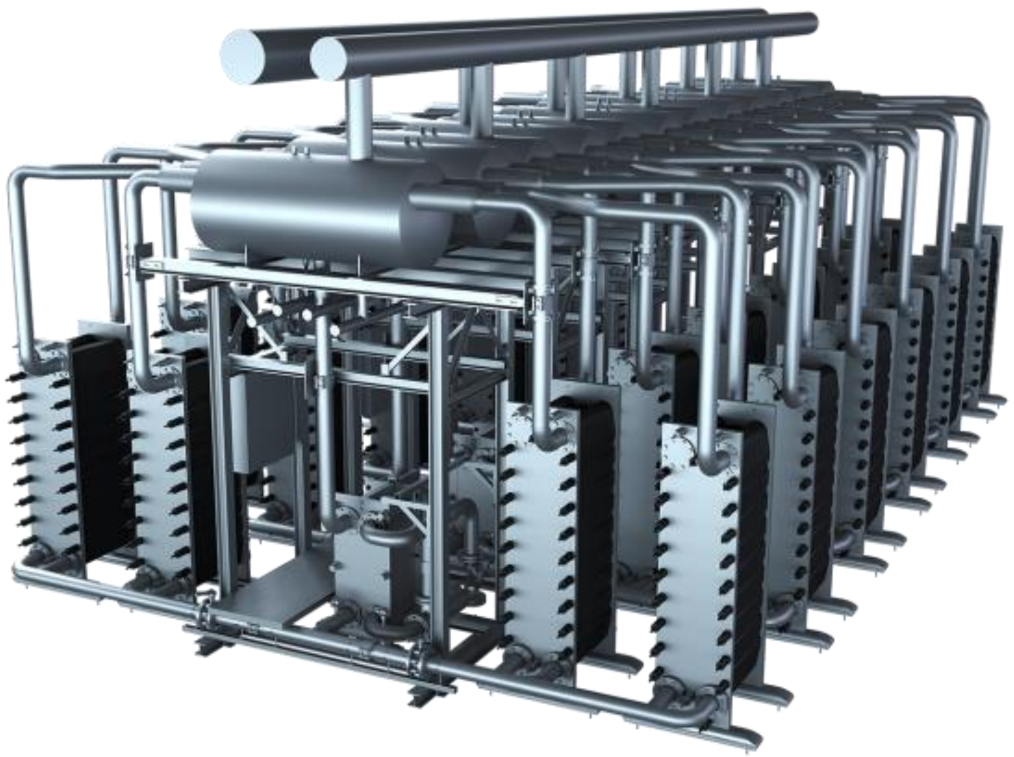
17.5 MW per full Module Array (24 modules)

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)



Silyzer 300 – Module Array (24 modules)

Reference project SILYZER 200 – from KW to MW PEM Technology at the Energiepark Mainz

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Demonstration

- Containerized version for demonstration projects (30-foot container size)
- Nominal load 100 kW_{el}
- Over-load capacity 300 kW_{el}
- Example: RWE Niederaußem
- **Commissioning in 2012**

Standort „Innovationszentrum Kohle" am RWE Kraftwerksstandort Niederaußem"

Commercial reference

- Location: Mainz-Hechtsheim
- Partner: Stadtwerke Mainz, Linde, Siemens, Hochschule RheinMain
- 6 MW_{peak} elektrolysis (3x SILYZER 200, each 1.25 MW and 2 MW_{peak})
- Direct connection to wind farm (8 MW)
- 1000 kg hydrogen storage (33 MWh)
- Total budget: 17 Mio. EUR
- Funding: ~50 % (BMWi)
- **Commissioning in 2015**

Ein Forschungsprojekt von

MAINZER STADTWERKE

SIEMENS

Gefördert durch

Bundesministerium für Wirtschaft und Energie

ENERGIESPEICHER
Forschungsinitiative der Bundesregierung

Windgas Haßfurt Power to Gas
Next step: Power to Methanol

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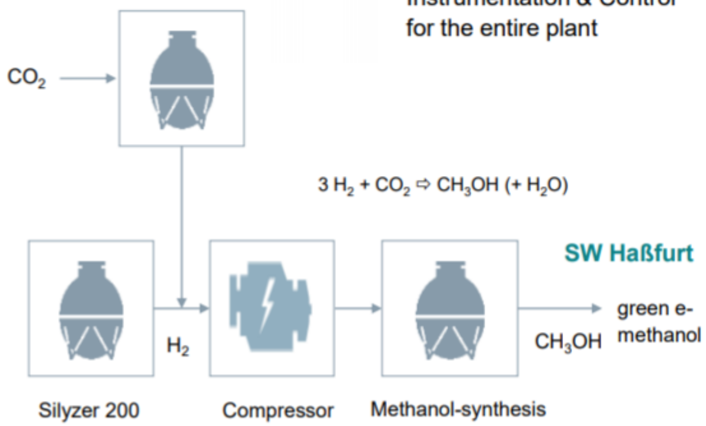
Project Structure and Partners

stadtwerk haßfurt	SW Haßfurt	Infrastructure site preparation
MAN	MAN Deggendorf	Reactor, design, erection, testing
FAU	FAU Erlangen	Scientific support for innovative CO_2 based methanol synthesis
TUM Technische Universität München	TU München	project coordination, system analyses,
PtJ		Funding, project coordination

Process Concept

Test plant in Haßfurt SIEMENS Balance of plant and Instrumentation & Control for the entire plant



E2Fuels: Erneuerbare Emissionsarme Kraftstoffe - Forschung zur Herstellung und Nutzung in einem sektorgekoppelten Ansatz
BWMi: Federal ministry for Economic Affairs and Energy (funding), PtJ: Projektträger Jülich (executing organization)

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

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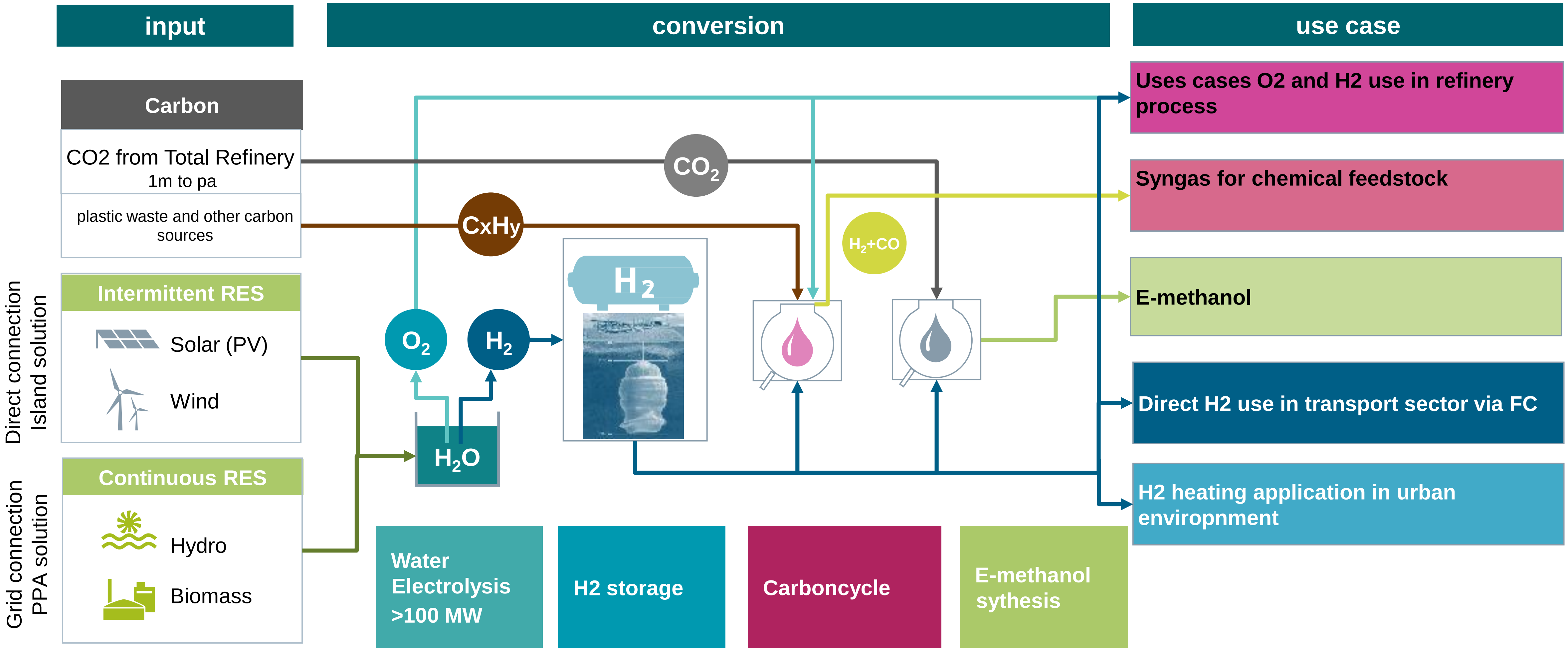

Large scale Power-to-Methanol project with competitive cost position (200 MW train) – from MW to GW

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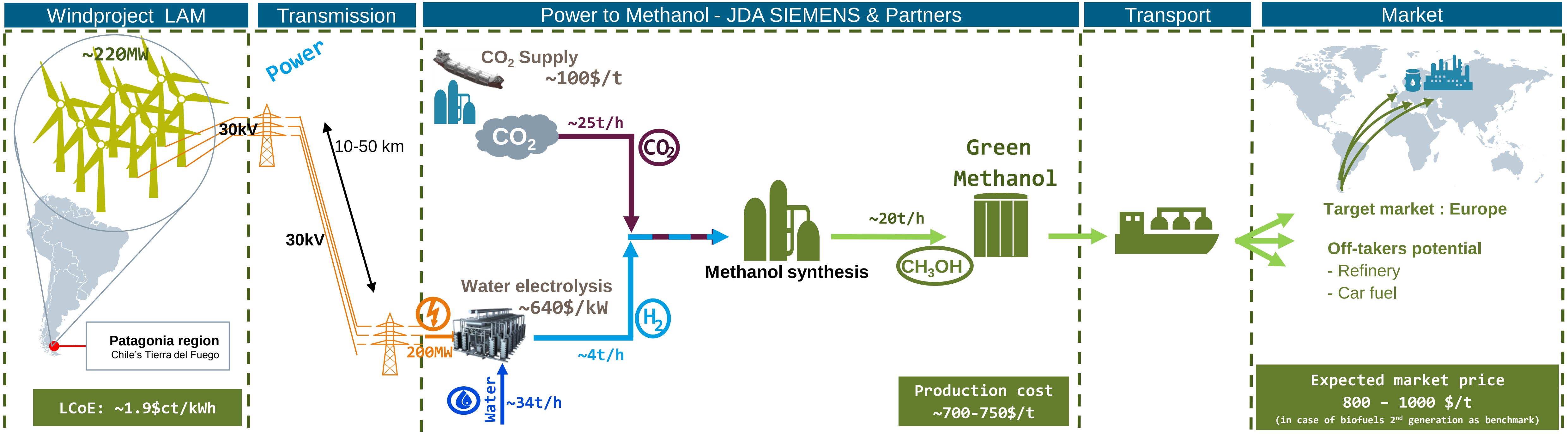

Description

- 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 CO_2 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 CO_2 emissions and increasing renewable energy usage

Various countries demonstrate strong potential for PtX production / exports …

Source: Frontier Economics

Electricity-based fuels might be cost competitive to biofuels in the future, and could result in lower CO_2 reductions cost

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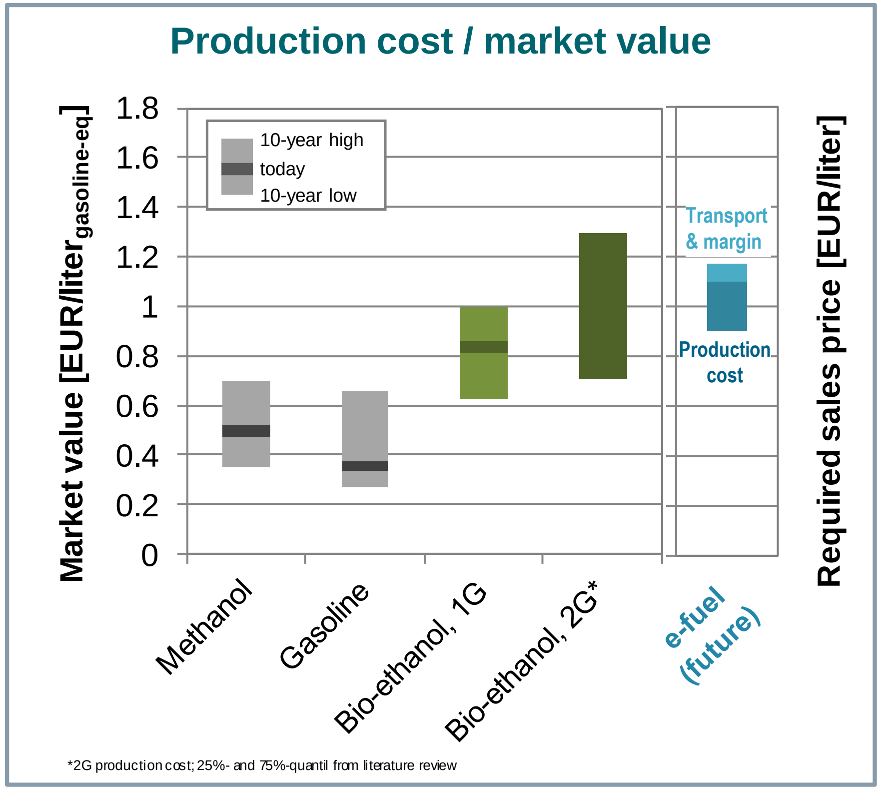
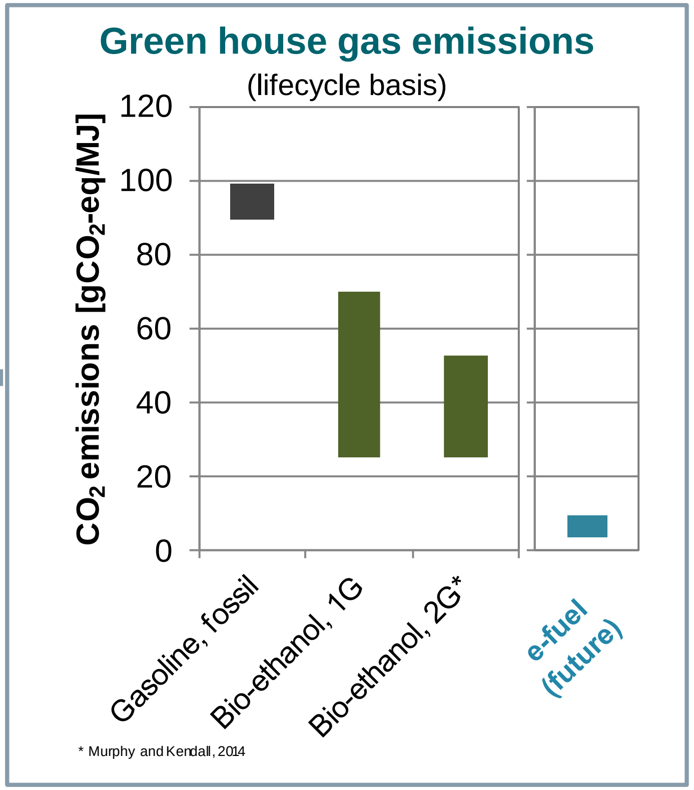
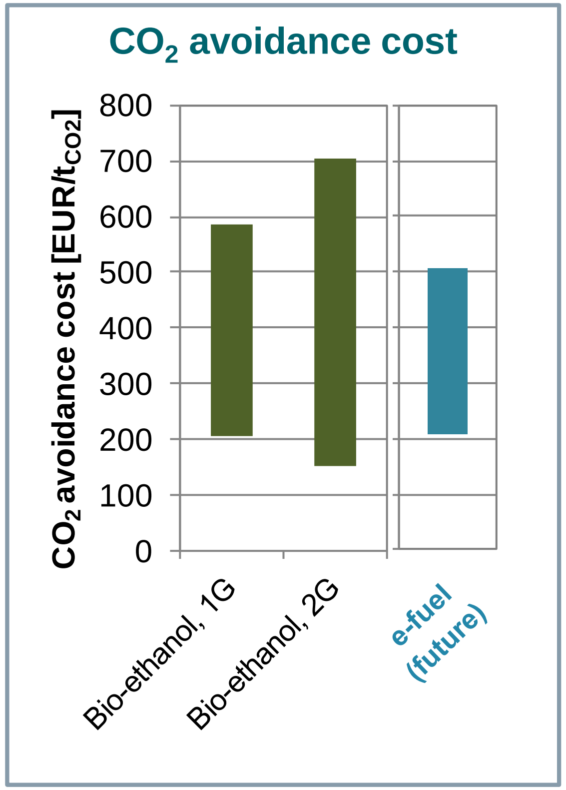
Production costs and CO_2 reduction potential of electricity-based fuel



Today's European price level in summer 2017





Thank you for your kind attention!

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

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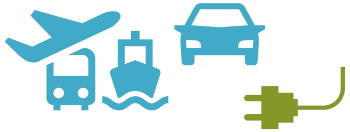
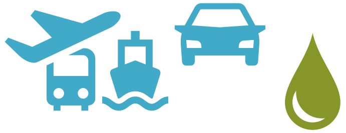
	 e-mobility	 e-fuel
CO_2 neutral (using renewable electricity)		
“Fuel vs. Food“		
No local emissions (NOx, particulate matter)		
Energy efficiency (efficiency along the process chain)		
Import of renewable energy		
Utilization of existing infrastructure		
Energy density & range		

Electricity-based fuels could be a future important link between the electricity and transport sectors, but require regulatory support in front running countries

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Summary and final remarks

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