

Connecting Energy Sectors with Hydrogen

Solid Oxide Electrolysis

2016-07-12 Dr.-Ing. Oliver Borm / (De-)zentrale Energiewende



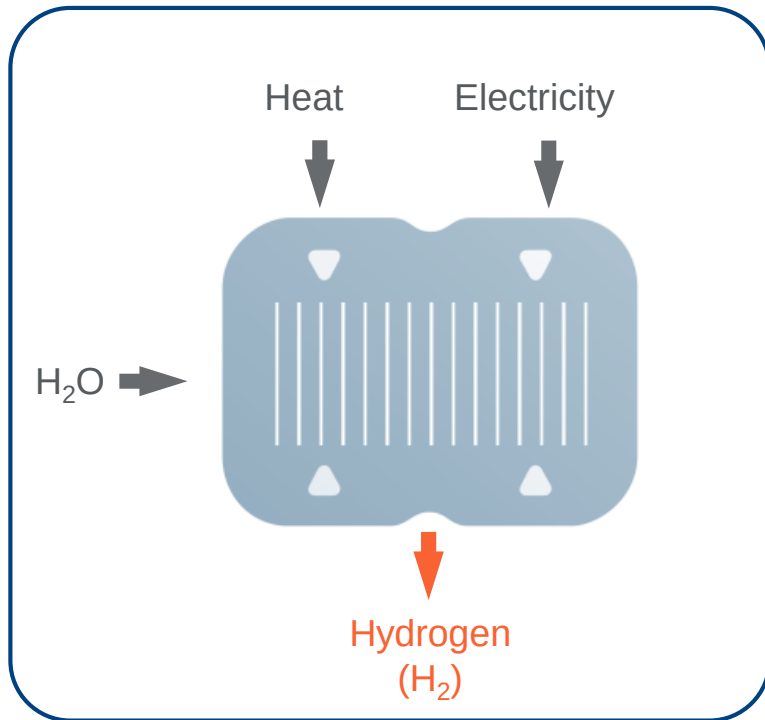
AGENDA

- + Technology
- + Sector Coupling
- + Technologies for Hydrogen Production
- + Hydrogen & Power-to-Liquids

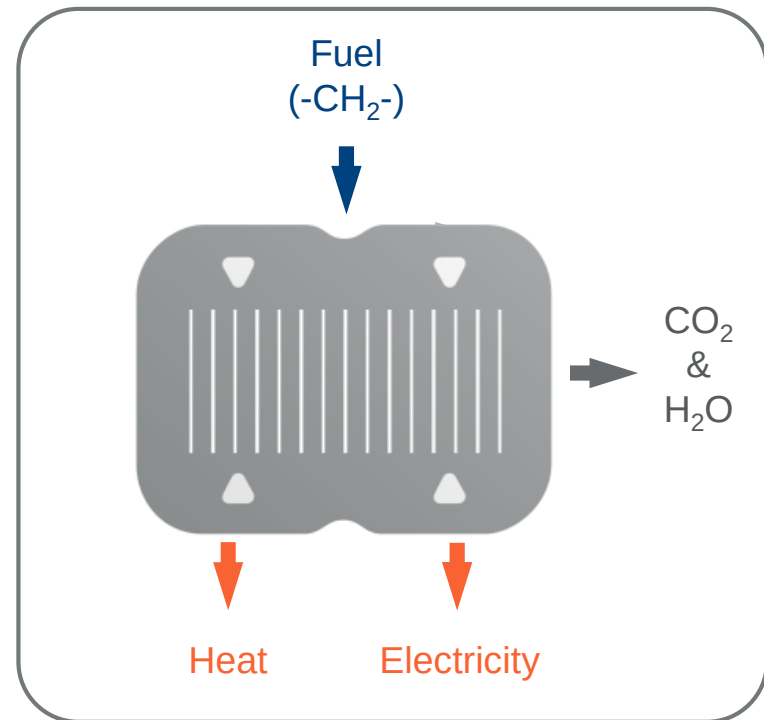


Solid Oxide Cells convert...

...electricity into **hydrogen**



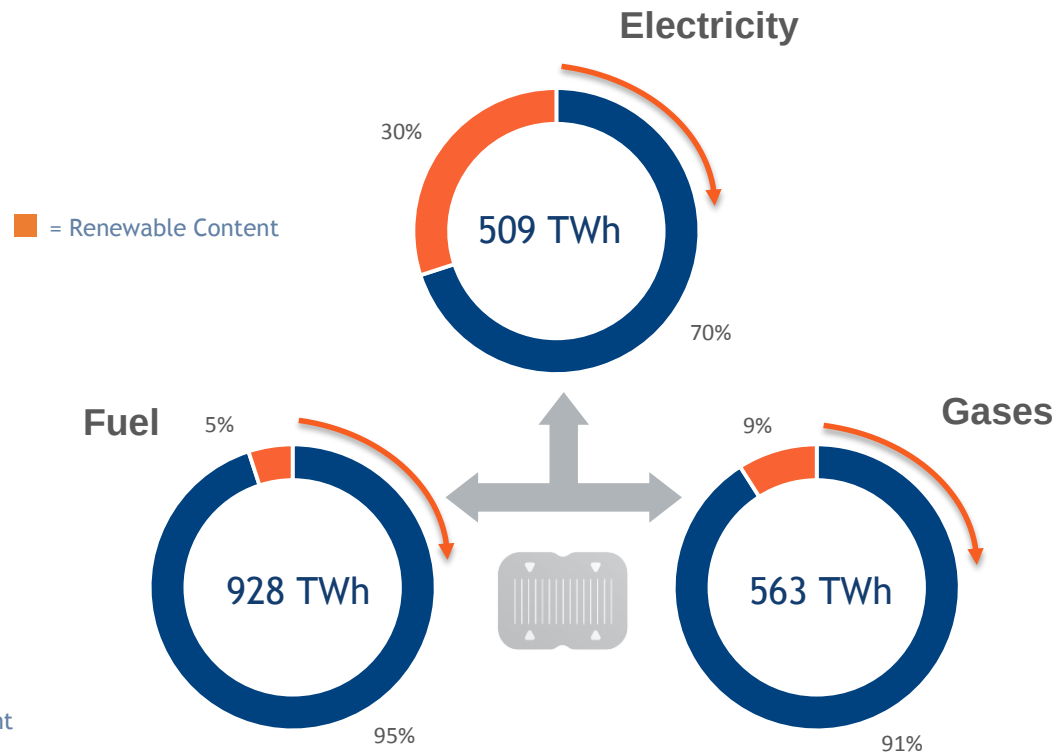
...chemical energy into **electricity** and **heat**





+ Sector Coupling

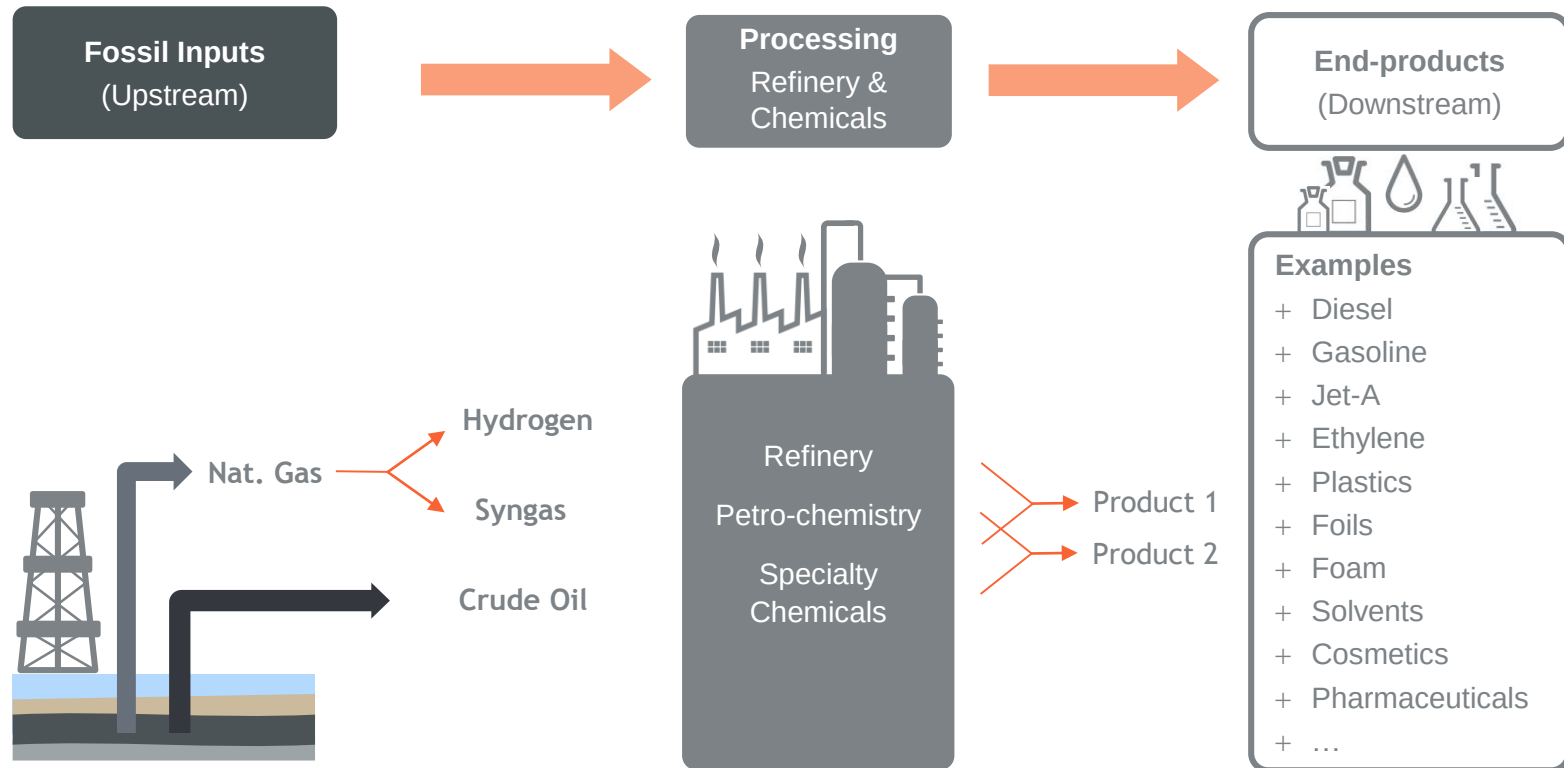
100% “Energiewende” via Sector Coupling



Source: Umwelt Bundesamt

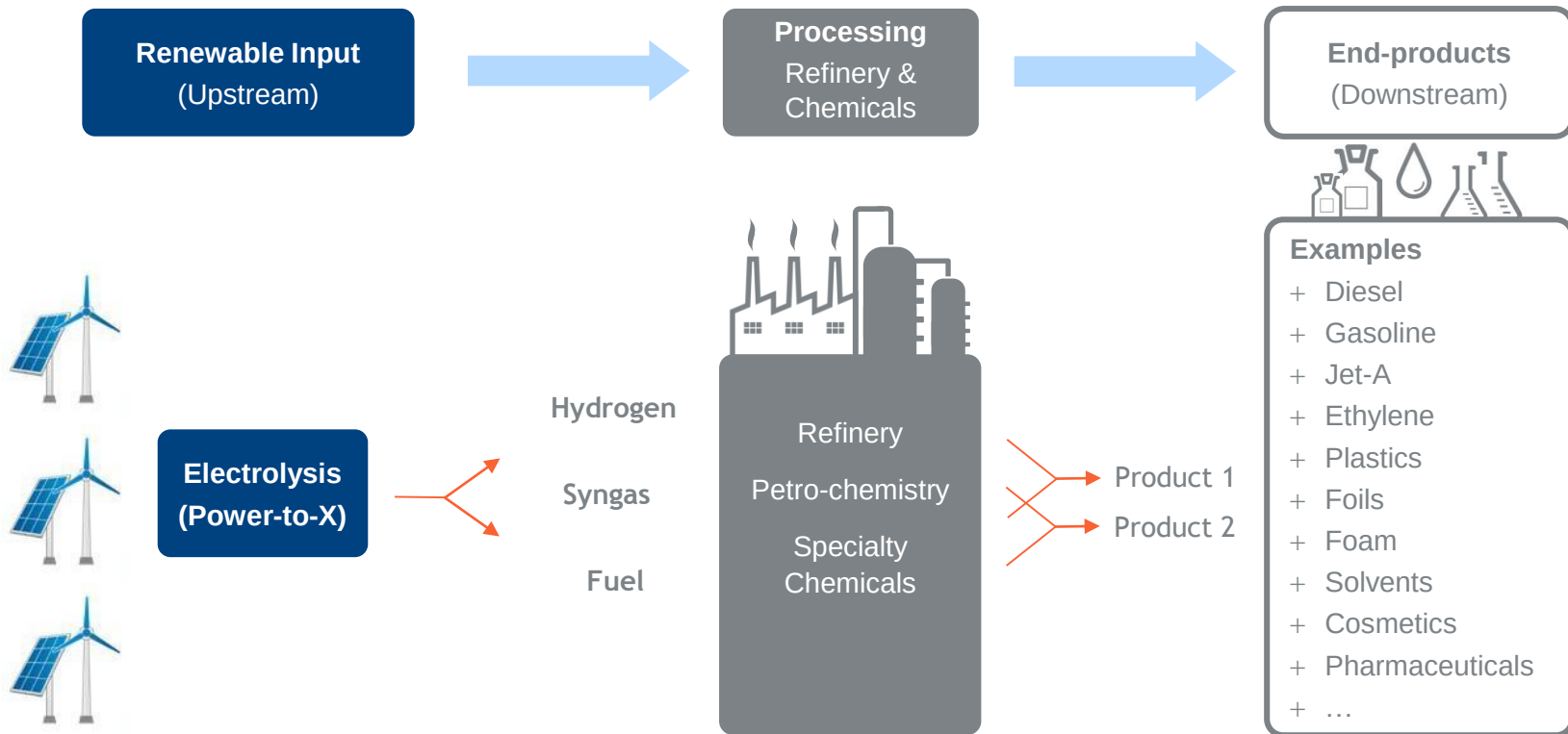
Sunfire builds the bridges between the electricity, fuel and gas sectors to provide renewable energy everywhere (sector coupling).

Existing Value Chain for Oil and Gas



Large assets already in place using fossil natural gas and oil as a feedstock.

Sector Coupling using Existing Value Chain



Sunfire makes use of existing assets instead of changing each processes individually (no disinvest)

Power-to-X Process Options

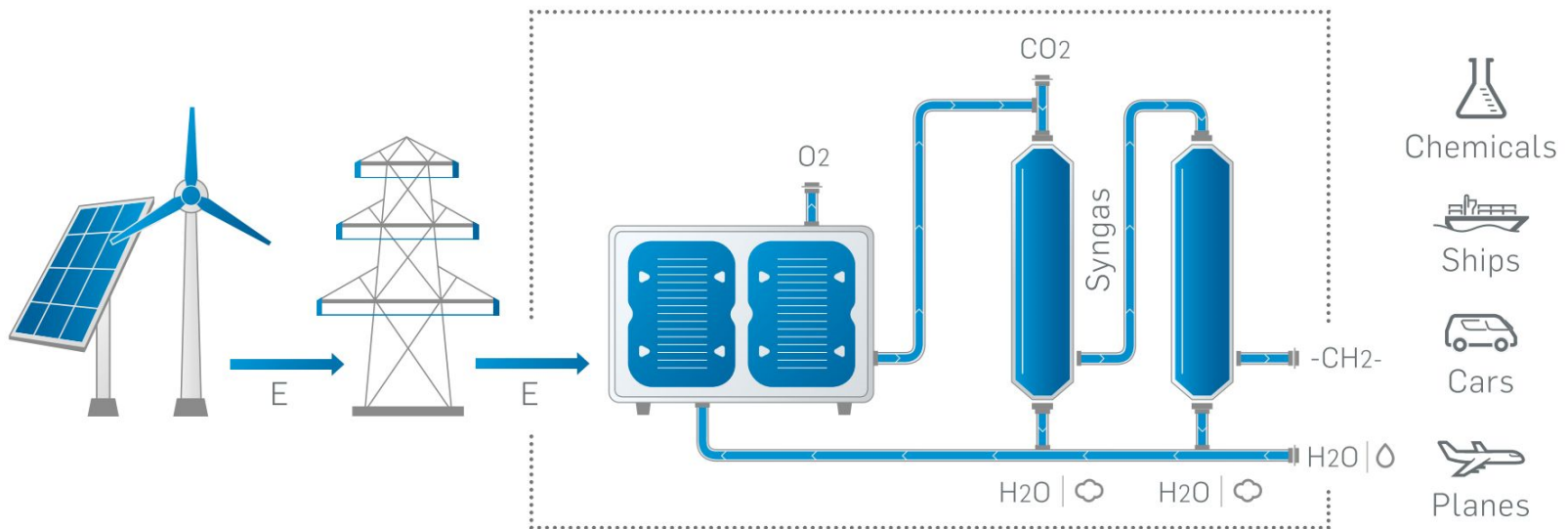
Renewable electricity

Electrolysis

Conversion

Fischer-Tropsch

Fuel infrastructure





+ Technologies for Hydrogen Production

Technologies for Renewable Hydrogen Production

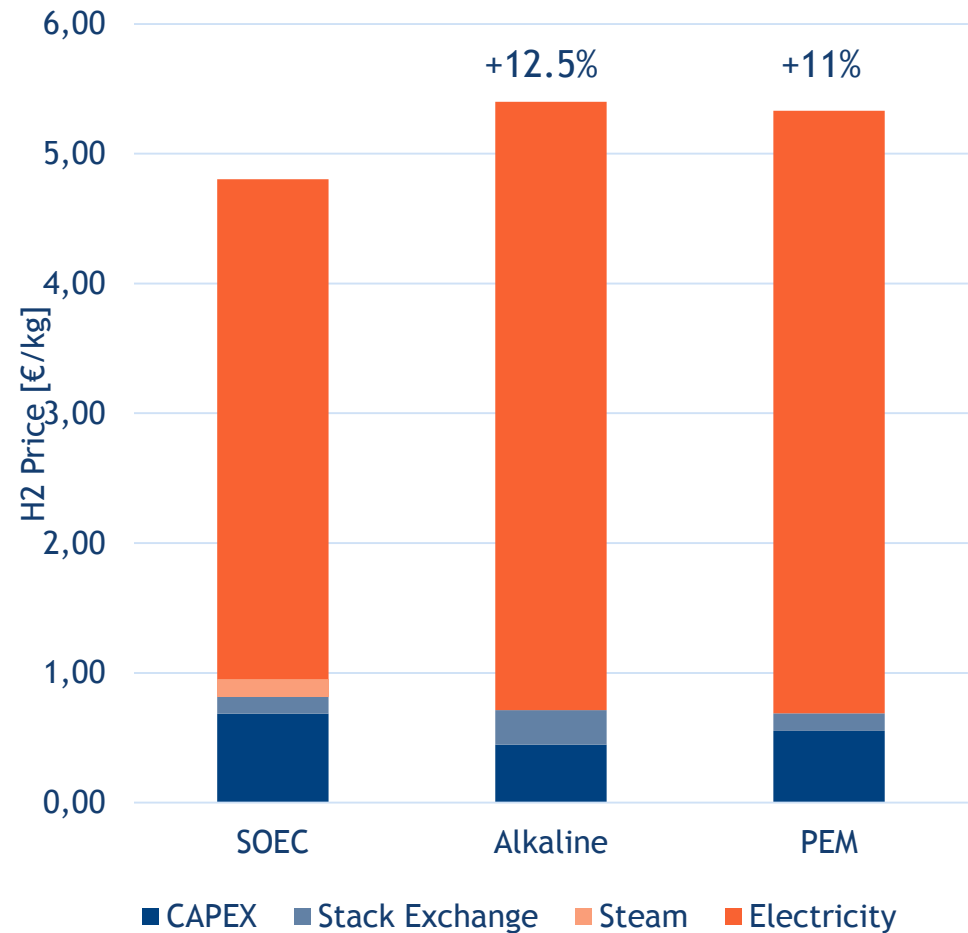
	Efficiency in % _{LHV} (kWh/Nm ³)	Costs in €/kW (€/kW divided by η)	Advantages
Alkaline	63 (4.8)	800 (1,270)	Reliable, Robust
PEM	65 (4.7)	1,000 (1,540)	Flexible
SOEC	82 (3.7)	1,500 (1,830)	Efficient, Reversible

- + Sunfire requires steam for efficiency, but has CO-electrolysis potential and power-to-hydrocarbon synergy
- + 2020 Scenario

H2 Cost Comparison SOEC, Alkaline, PEM

Assumptions (2020 scenario):

- + Electricity Costs: 80 €/MWh
- + Capacity Utilisation rate: 60 %
- + IRR 9 %





+ Hydrogen & Power-to-Liquid

H2 Potential in German Refineries (Fuel only)

Assumptions:

- + Current H2 requirement in German refineries: 136 kt/a (globally = 20,150 kt/a)
- + Ren. fuel quota to increase from 3.5 to 6% GHG emission reduction in 2020 (biofuels not sufficient to fill gap)
- + Use of hydrogen to reduce Upstream Emissions as requested by COUNCIL DIRECTIVE (EU) 2015/652 implemented in national regulation

H2 demand	t/a	136,000
Nominal installed power (SOEC)	MW	1,100
Electricity consumption	GWh/a	5,782
Percentage of fuel quota	% GHG	0.50

-> 1,100 MW at 60% utilization rate

-> 0.5% GHG reduction is the exact advanced fuel required

Reference Projects



- + 1x 150 kW SOEC power input and 30 kW SOFC power output
- + SOEC efficiency of $>80\%_{\text{LHV}}$
- + Reaching a lifetime of greater 10,000 h with a degradation rate below 1 %/1,000 h
- + Meeting the H2 quality standards of steel industry



- + 2x 100 kW SOEC power input and 40 kW SOFC power output
- + Roundtrip efficiency ca. 45%
- + Electricity storage for autonomous electricity supply during day and night (PV connected)



150 kW SOEC unit in Dresden, Germany



200 kW SOEC unit in Los Angeles, USA



Power-to-Liquids Potential in Germany

Assumptions:

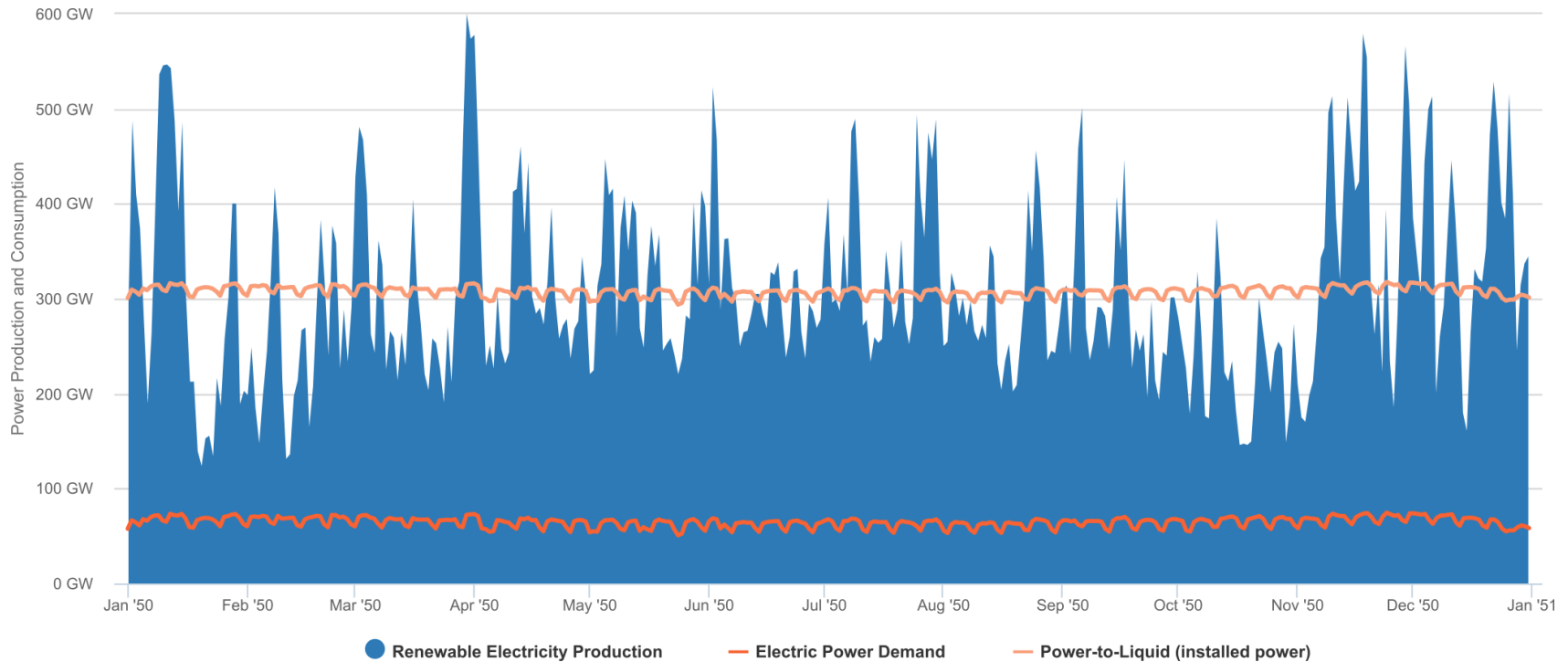
- + Current liquid Fuel demand in Germany: 928 TWh
- + Utilisation rate of renewable energy (Wind, PV): 30 %

Fuel equivalent energy	GWh/a	928,000
Electricity consumption	GWh/a	1,325,000
Installed renewable el. for PtL	GW	500
Installed SOEC power for PtL	GW	250

-> at 30% utilisation rate
of renewable electricity generation
-> at 60% utilisation rate PtL



Integrated Energy Vision 2050 for Germany



- + Installed renewable power: 600 GW
- + Installed Power-to-Liquid capacity: 250 GW
- + 1,325 TWh electricity shift into fuel sector

- + In 2015 only ca. 1.5 TWh excess electricity
→ caused 140 Mio. EUR surplus costs for EEG

Reference project PtL



- + Plant produces synthetic diesel, waxes, naphtha (drop-in fuel)
- + High efficiency of ca. $\eta_{el}=60\%$ (electricity to fuel)
- + Renewable electricity, CO₂ from various sources (i.e. ambient air), no biomass required
- + Audi confirms the fuel's eco-friendliness
- + Gamechanger technology for renewable liquids



Extreme Value Comparison





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VIELEN DANK

E N E R G Y
E V E R Y W H E R E