



# Electric synthetic fuels on their way to industrialisation

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Investors

**ELECTRANOVA**  
CAPITAL

**idinvest**  
PARTNERS

**INVIE/N CAPITAL**  
CEZ GROUP

**KFW**



## Company Facts

### Knowhow

- 90 Employees
- Skills in Ceramics, Stack + System Production, Engineering, Synthesis Processes, etc.

### Investors

 ELECTRANOVA  
CAPITAL idinvest  
PARTNERS INVIE/N CAPITAL  
CEZ GROUP KFW TOTAL

### Patents

- 43 patent families (i.e. »process patent sunfire« WO/2008/014854)

### Recognition

- Cleantech 100 Company 2014/2015/2017/2018 (only fuel cell + electrolysis company)
- Fast Company Most Innovative Company of 2016 (with Tesla and Toyota)
- German Gas Industry's 2016 Innovation & Climate Protection Award
- Kanthal Award 2017 for solutions in Sustainability, Quality of Life and Energy Efficiency

### Revenues

- Multi-million Euro Revenues in Global Markets since 2011

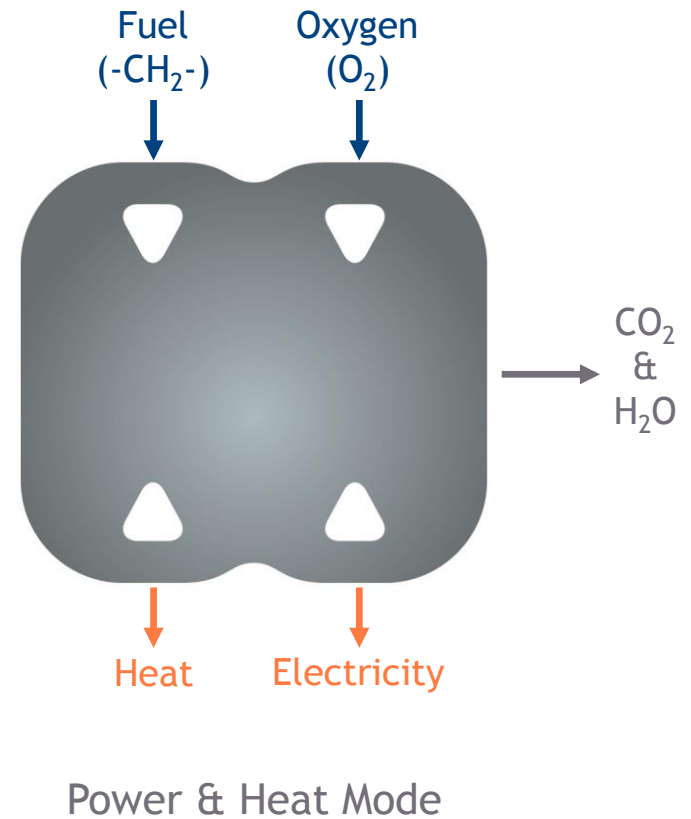
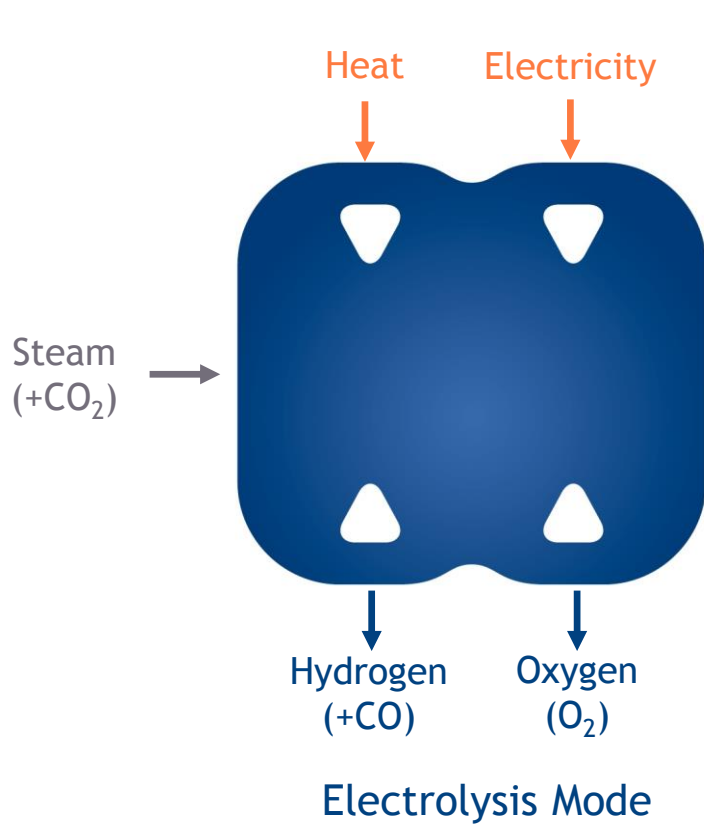


# + Sunfire Technology

# Solid Oxide Cells Convert...

... electricity into hydrogen / syngas

... fuels and gases into electricity and heat



## Three Core USPs

- + **Highest efficiency** in hydrogen production ( $82\%_{\text{LHV}}$  or  $3.7 \text{ kWh/Nm}^3$ ) and power & heat production ( $35 - 60\%_{\text{AC}}$  and  $90\%_{\text{total}}$ ) compared to legacy technologies such as PEM and Alkaline
- + **Tolerance to carbon** in electrolysis mode via co-electrolysis of  $\text{CO}_2$  and  $\text{H}_2\text{O}$  and in fuel cell mode via internal reforming of hydrocarbons (natural gas, LPG, diesel, etc.)
- + **Flexible** adjustment of output from part load to full load ( $30\% - 120\%$ ) in a short timeframe

Sunfire promises **low costs**, **high reliability** and **readiness to scale**.



Stack production in Dresden



System testing in Dresden

# One Core - Multiple Products

PowerCore



Sunfire-Remote

- Reliable power generation in remote sites
- 5 kW · X



Sunfire-HyLink

- Efficient hydrogen production
- 185 kW · X



Sunfire-SynLink

- Efficient syngas production
- 185 kW · X

Established SOC concept

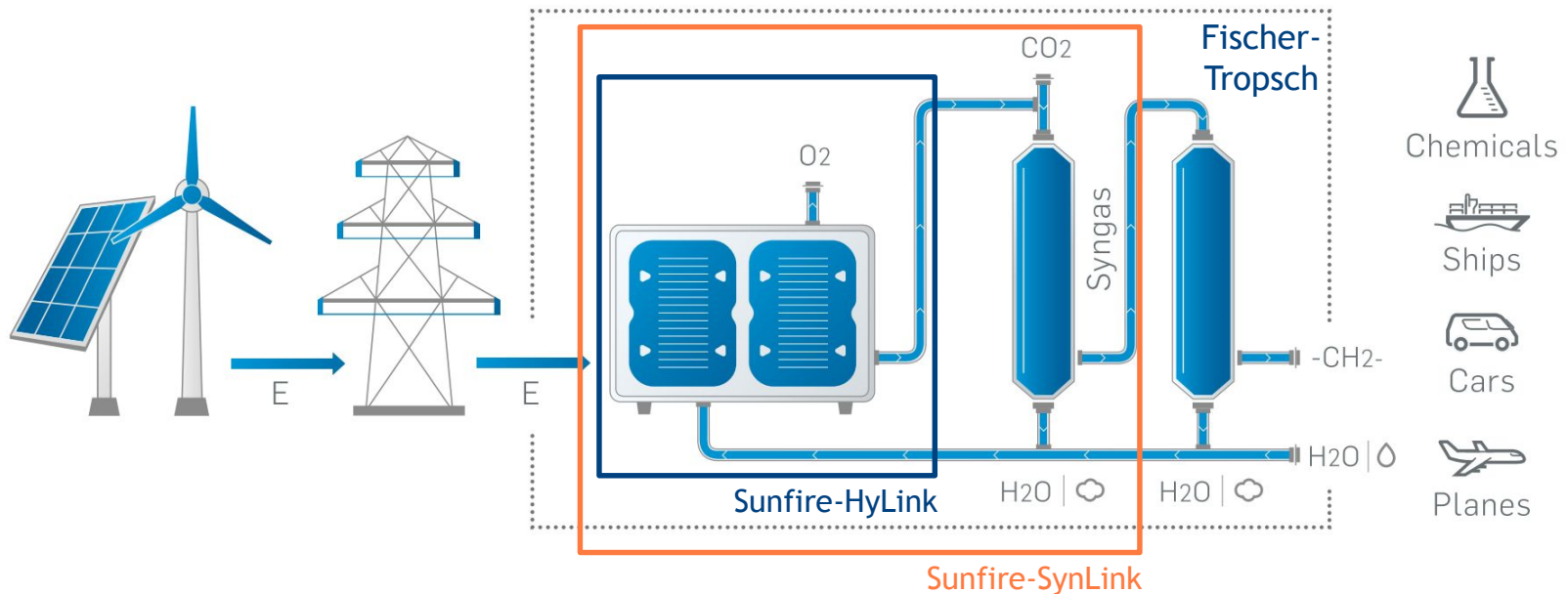


Multiple Applications



## e-Crude Production Pathways

Stage 1: electrochemical  $H_2$  production through Sunfire-HyLink system, followed by reverse water gas shift conversion (RWGS)



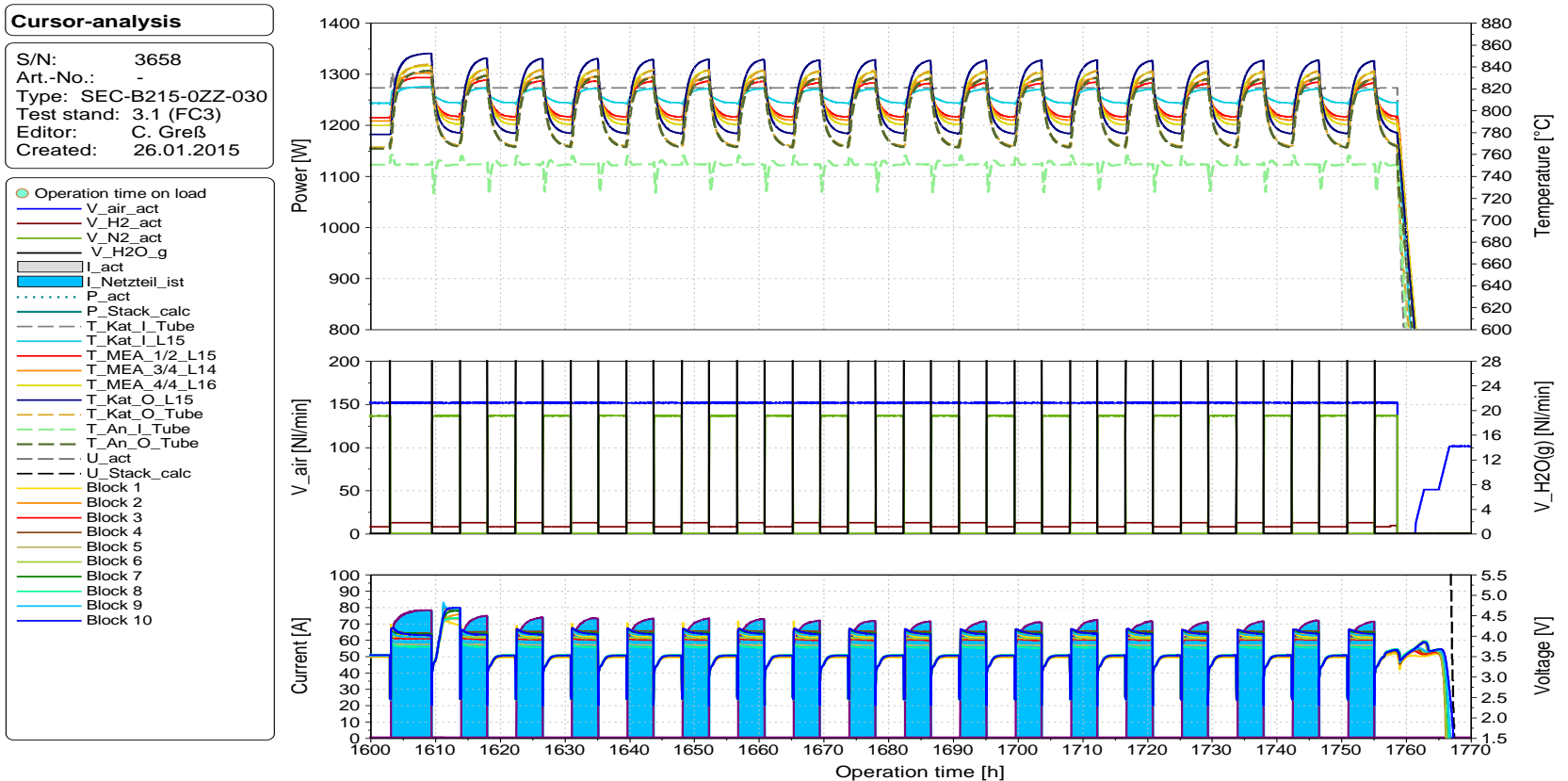
Stage 2: electrochemical syngas production through Sunfire-SynLink system

- 2 step process through direct syngas production (no RWGS reactor needed)
- High electricity-to-fuel efficiency ( $\sim 60\%_{LHV}$ )
- Reduced OPEX and CAPEX

# Sunfire SOC Operation

## + Test Stack (30 Cells 3YSZ / 5YbSZ + LSCF)

➤ 20 x On/Off in 1ms from 0 to 80% Power Input: **No Degradation**





# Sunfire SOC Operation

## + Test Stack (20 Cells 3YSZ + LSCF)

- 26 rSOC-Cycles: Linear Voltage Degradation **0,06 %/Cycle**
- 23 Thermocycles: **no cell defects**

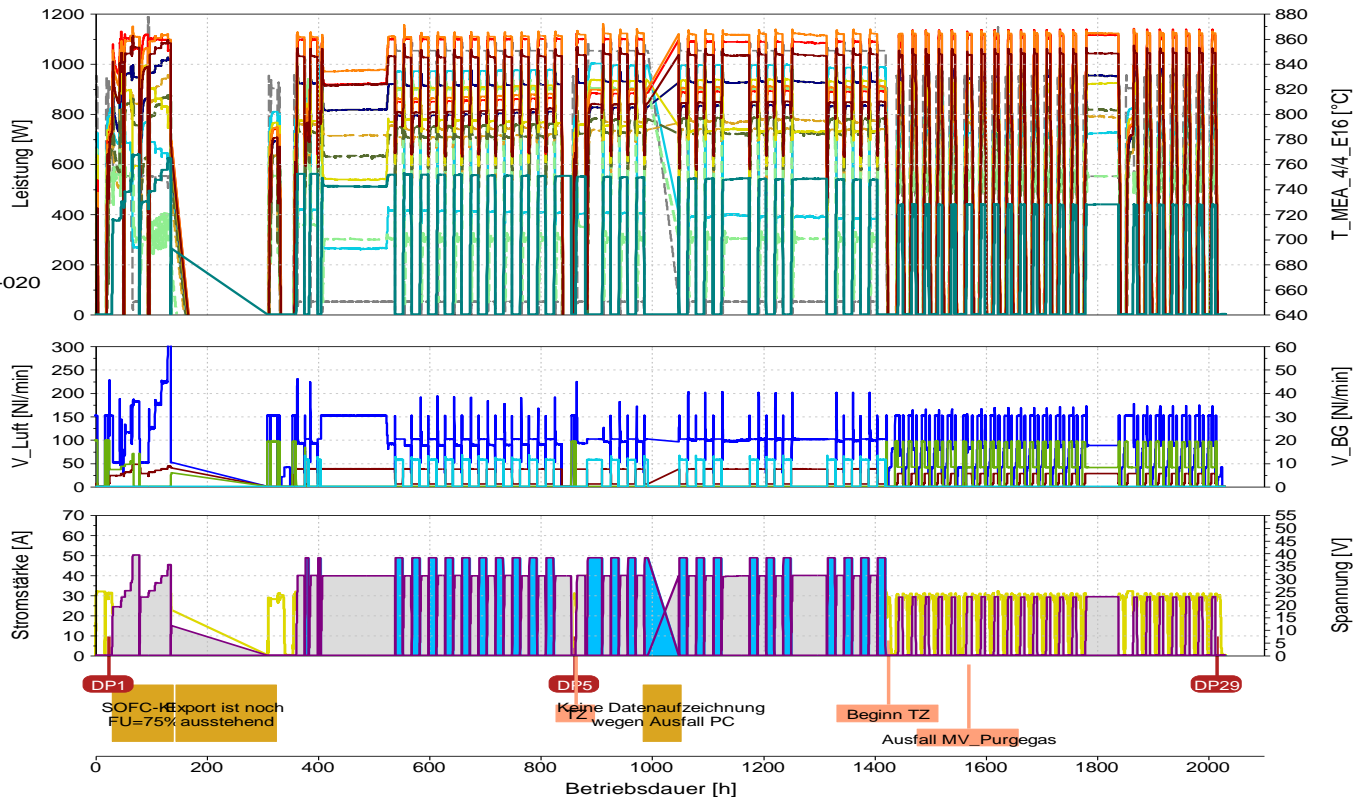
### Übersicht

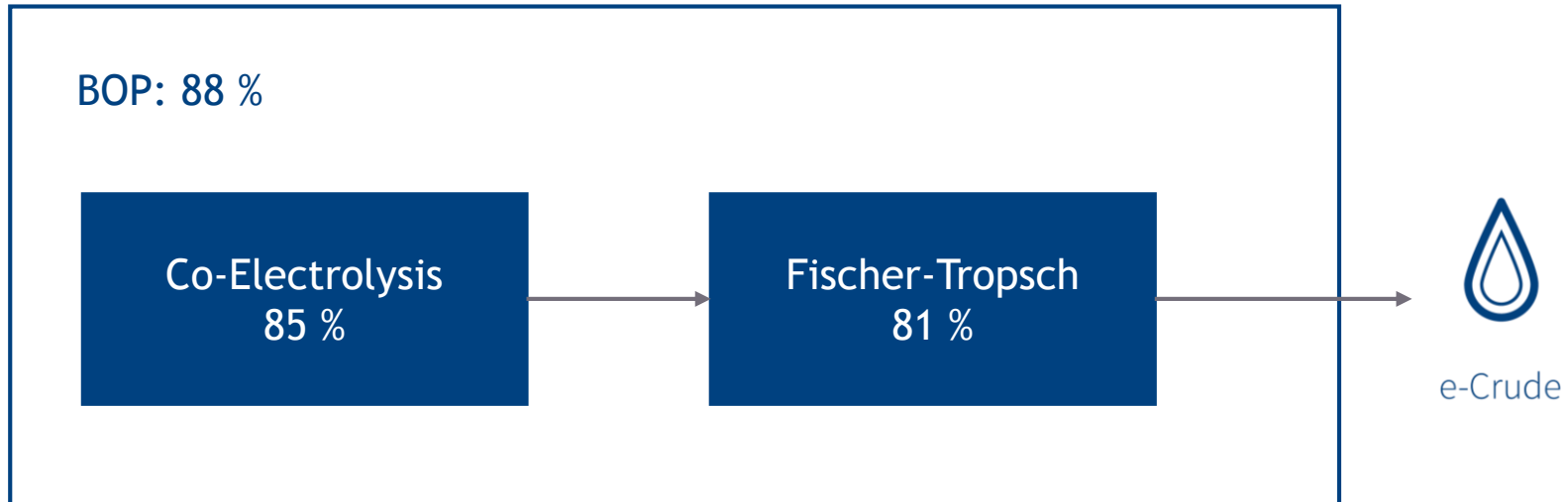
t > 600°C: 1761 h  
 t(SOFC) > 5A: 940 h  
 t(SOEC) > 5A: 346 h

Versuchsinfo:  
 rSOC  
 Zyklen

Sr.-Nr.: 3426  
 Art.-Nr.: -  
 Typ: SEC-B215-OZZ-020  
 Zellfläche: 127 cm<sup>2</sup>  
 Teststand: 3.1 (FC3)  
 Bearbeiter: R. Stäber  
 erstellt: 16.10.2014

— V\_Lu\_ist  
— V\_H2\_ist  
— V\_N2\_ist  
— V\_H2O(g)\_ist  
— U\_Stack\_calc  
 I\_Last\_ist  
 I\_Netzteil\_ist  
— P\_Stack\_calc  
--- T\_Kat\_E\_Rohr  
— T\_Kat\_E\_E10  
— T\_Kat\_A\_E10  
— T\_Kat\_A\_E10  
— T\_Kat\_A\_Rohr  
— T\_An\_E\_Rohr  
--- T\_An\_A\_Rohr  
— T\_MEA\_0/4\_E14  
— T\_MEA\_1/2\_E15  
— T\_MEA\_3/4\_E04  
— T\_MEA\_4/4\_E16





## Single Step Efficiencies

- + Overall efficiency:  
 $0,85 * 0,81 * 0,88 \Rightarrow 55 - 61 \% \text{ (LHV/kWh}_{el}\text{)}$
- + Sunfire produces Fischer Tropsch synthetic fuel, which needs to be processed in refineries

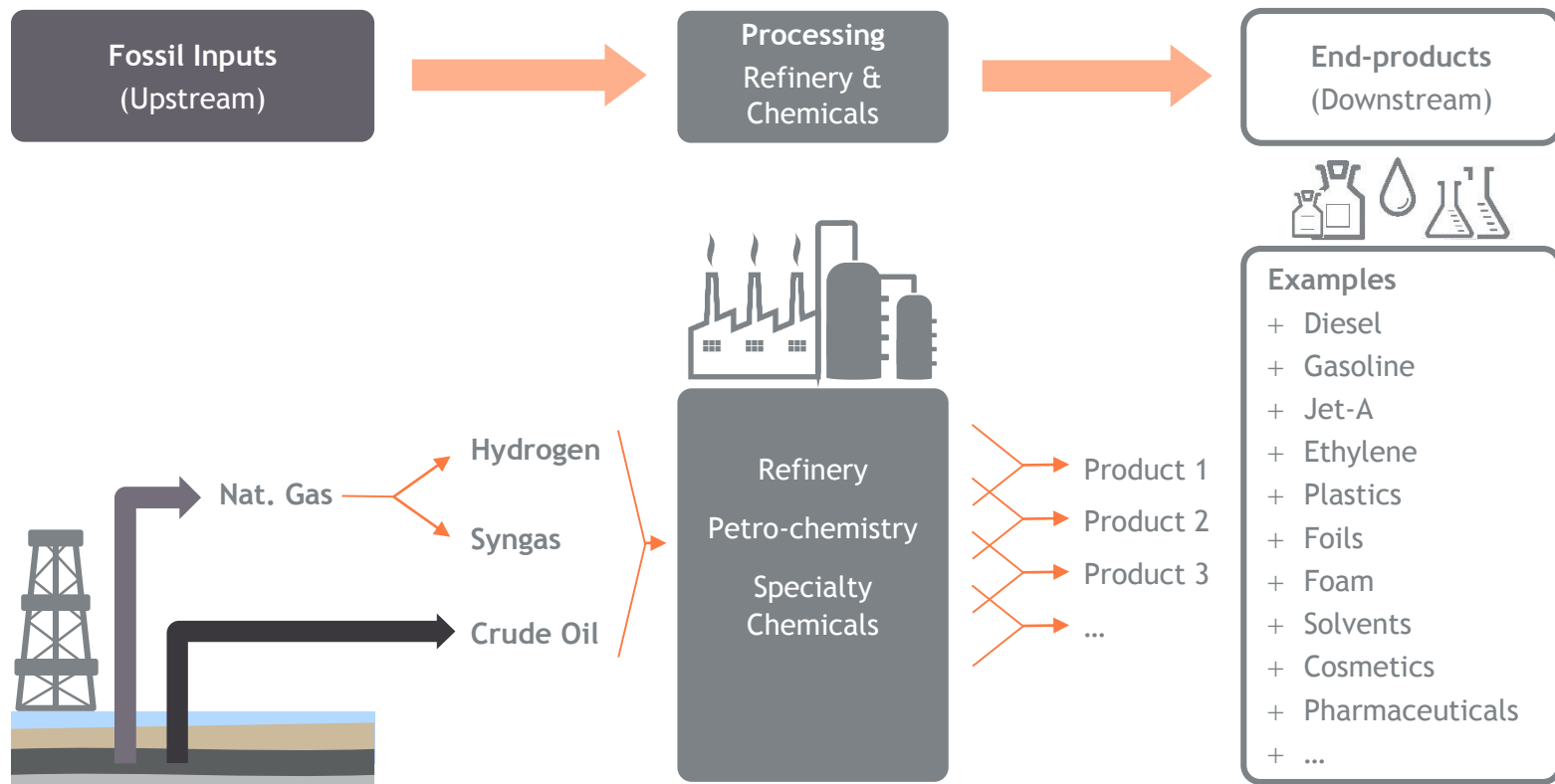


# + Sector Coupling

Focus: PtX

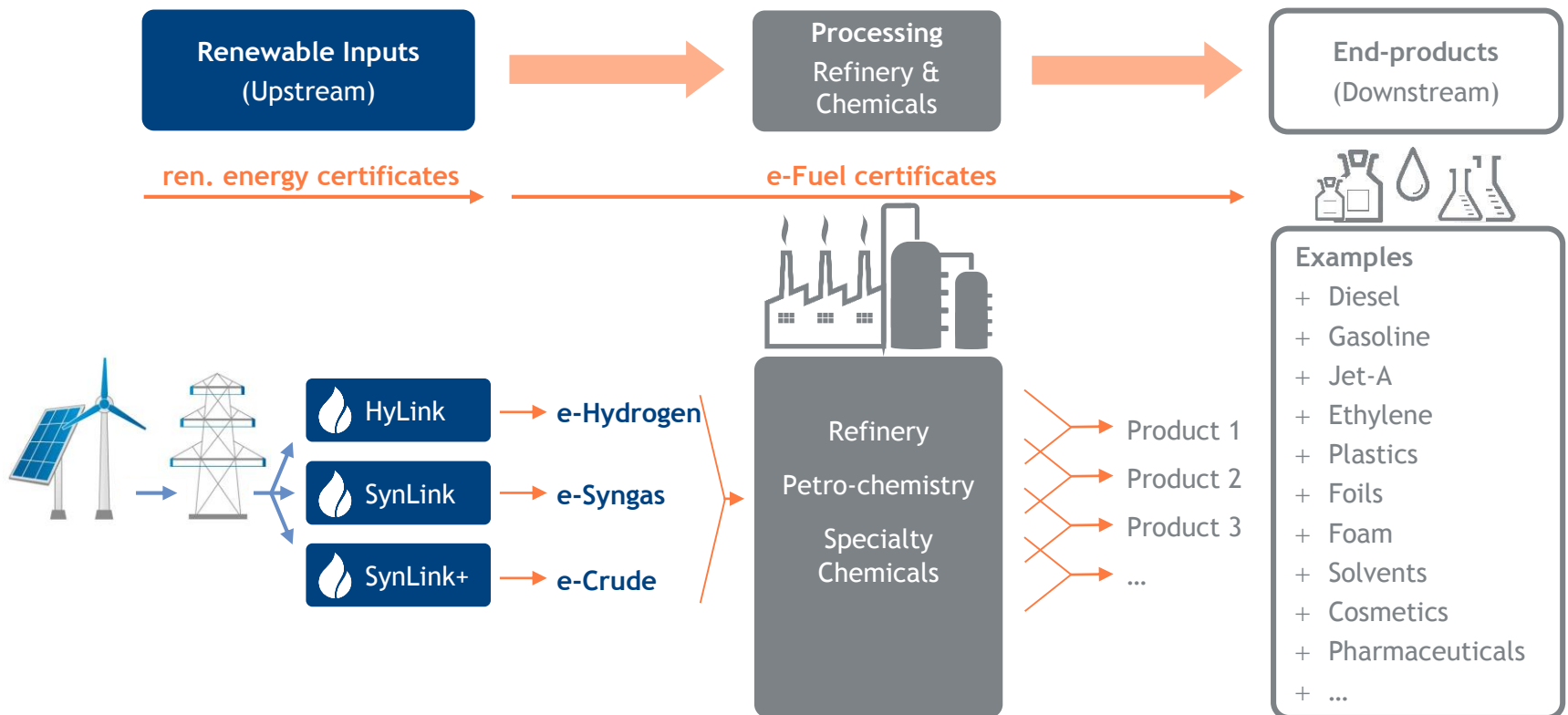
## Existing Value Chain for Oil and Gas

- + Large assets already in place using fossil natural gas and crude oil as feedstock
- + Economically feasible industrial decarbonisation in industrialized countries necessary
  - Otherwise industry will move to regions with less environmental protection



# Sector Coupling with Sunfire Using the Existing Value Chain

- + **Sunfire** makes use of existing assets instead of changing all processes and infrastructures individually (no disinvest - **no stranded assets**)
- + **Renewable/ CO<sub>2</sub>-neutral property** is sold with **e-Fuel certificates** to any possible customer, similar to renewable energy in the electricity grid → **Open-Grid-Concept**

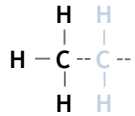
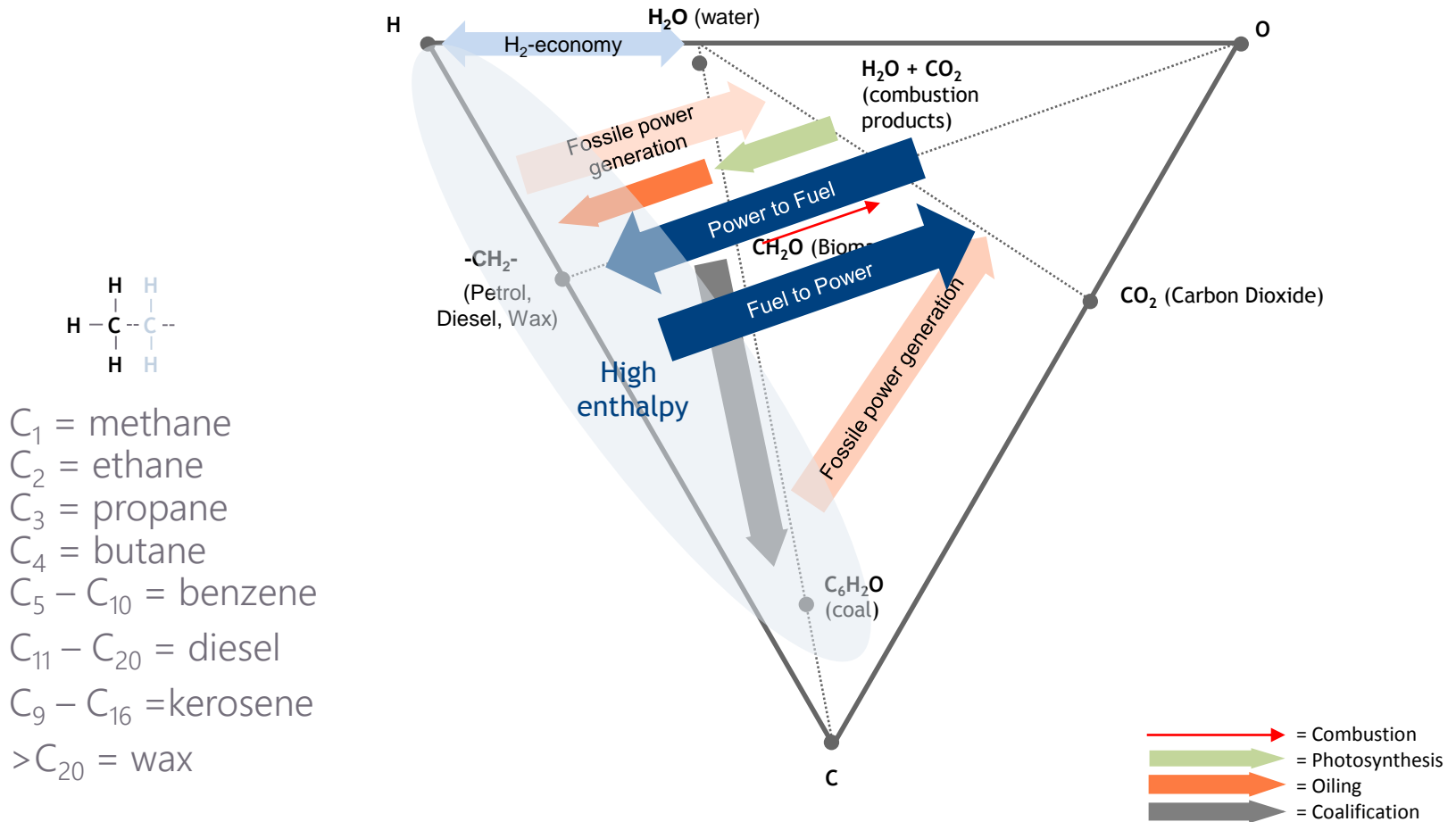




+  
**C - H - O**

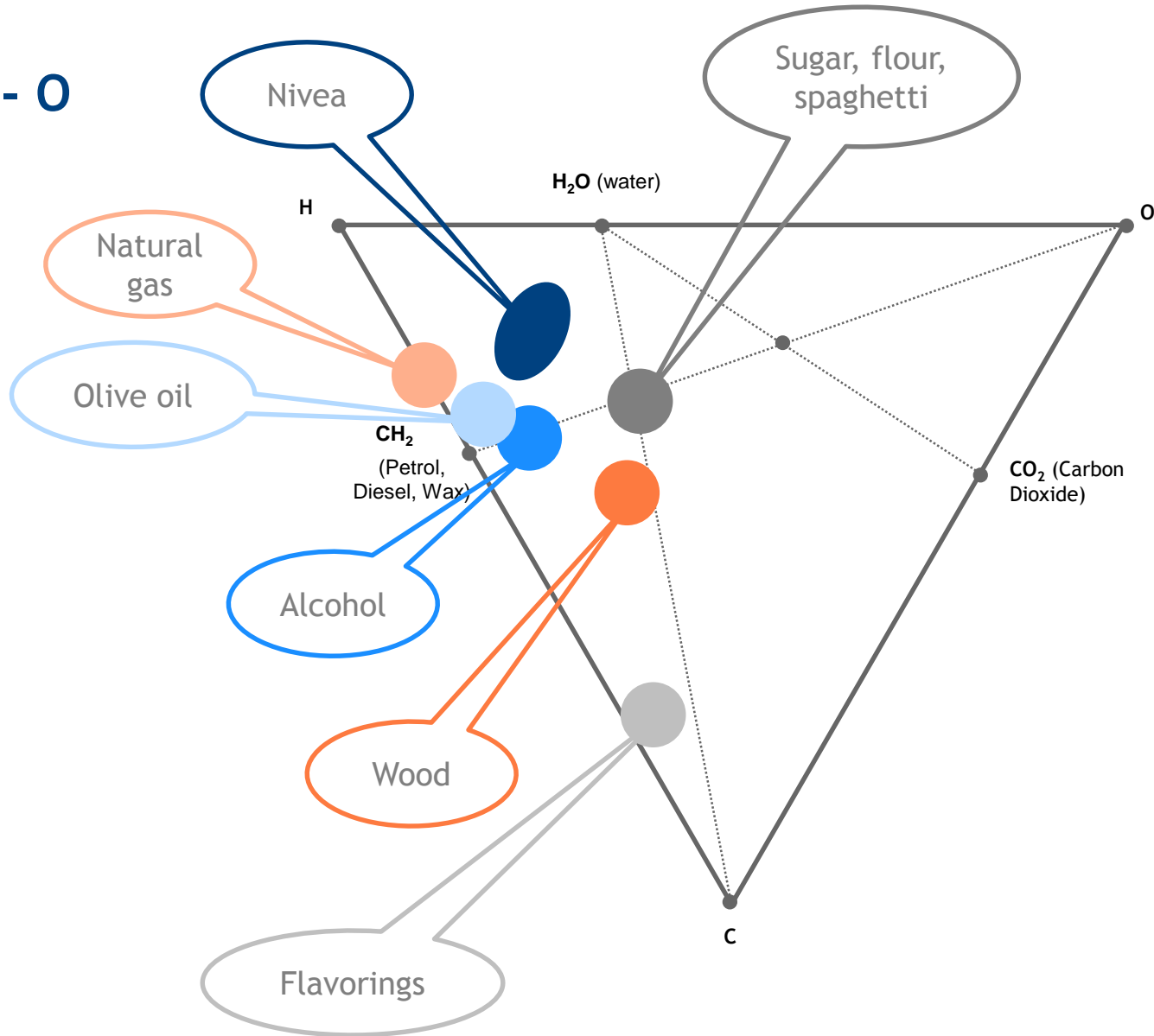
A general approach

# C - H - O



- $\text{C}_1$  = methane
- $\text{C}_2$  = ethane
- $\text{C}_3$  = propane
- $\text{C}_4$  = butane
- $\text{C}_5 - \text{C}_{10}$  = benzene
- $\text{C}_{11} - \text{C}_{20}$  = diesel
- $\text{C}_9 - \text{C}_{16}$  = kerosene
- $>\text{C}_{20}$  = wax

# C - H - O







# + Power-to-Liquids

Current Status and Next Steps

## Sunfire BMBF Project

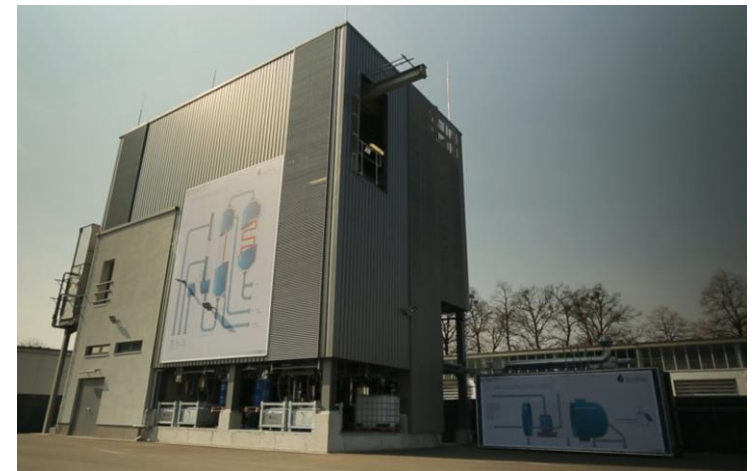
### Steam Electrolysis

- + Capacity: 5 - 10 kW
- + Start up: As of Q4/2014



### Fuel 1 test plant for RWGS & Fischer-Tropsch

- + Capacity 1 bbl/day (159 Liters)
- + Start up As of Q4/2014



# Sunfire BMBF Project Opening Ceremony on November 14<sup>th</sup>, 2014



# Sunfire BMBF Project

German Federal Minister of Education and Research receives the first liters / Car manufacturer Audi confirms the fuel's eco-friendliness!



## Sunfire e-crude properties

Aromate content < 1 wt.-%, no sulphur

cleaner combustion (no particles)

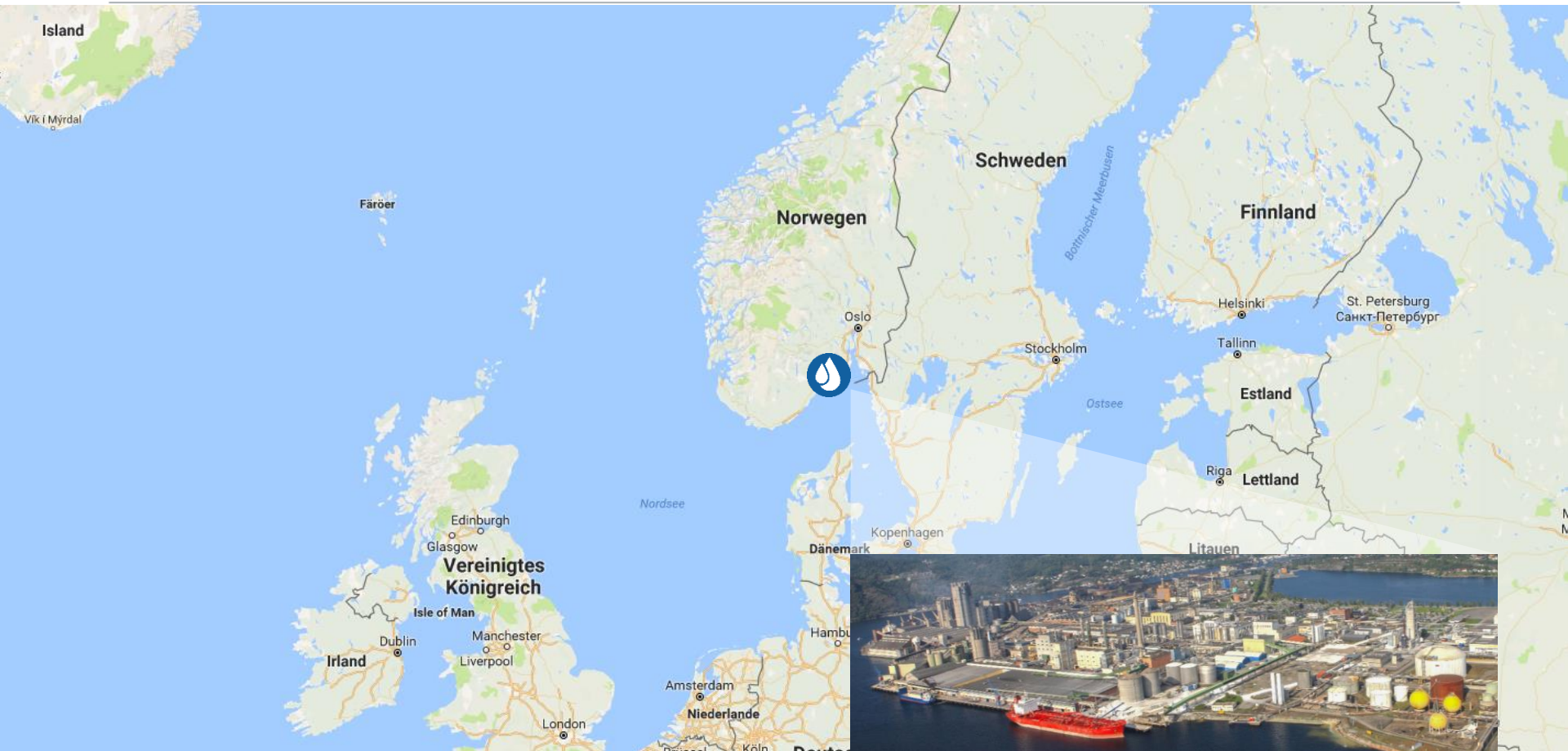
High proportion of n-alkanes

good ignition quality (cetane no.)

CHARACTERISTICS	DIESEL (EN590)	SUNFIRE FIRST DISTILLATE
GRAVIMETRIC DENSITY	820 ... 840 kg/m <sup>3</sup>	780 kg/m <sup>3</sup>
LHV	42,5 MJ/kg	44,71 MJ/kg
ENERGY DENSITY	34,9 ... 35,7 MJ/L	34,9 MJ/L
CETANE NUMBER	> 51	65 ... 76

\*Preliminary Analysis from Petrolab/Speyer

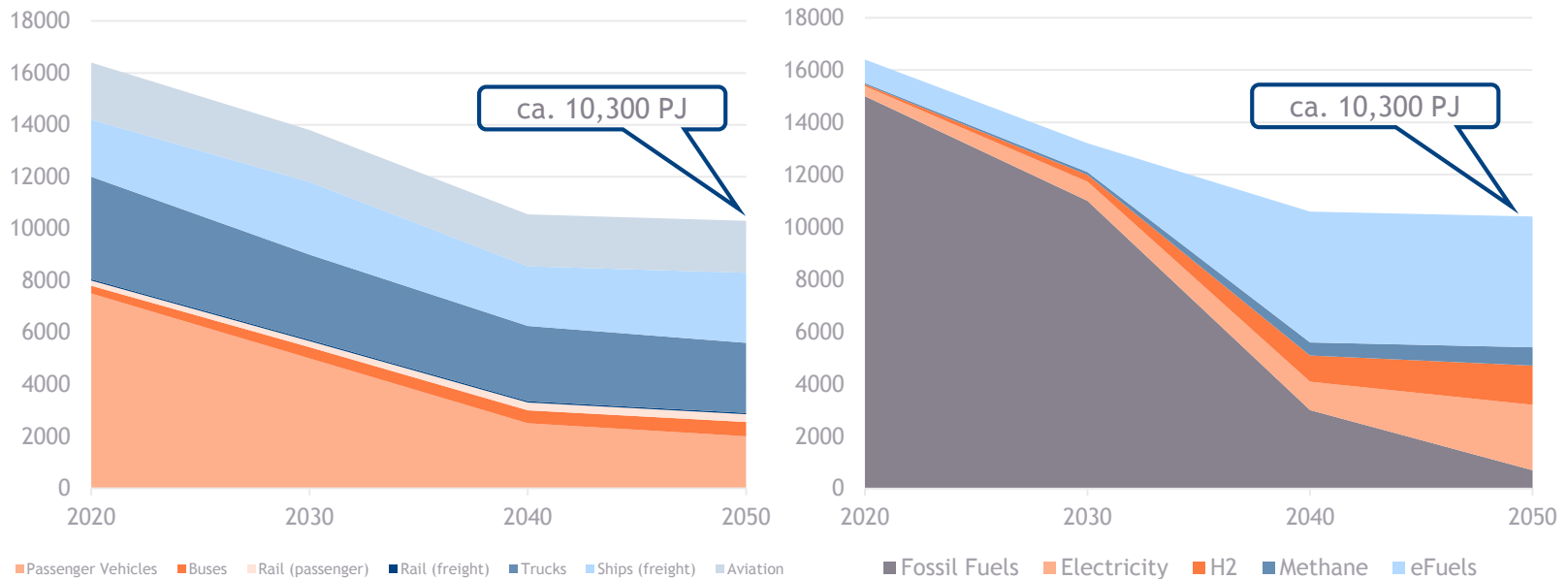
=> Drop in for refineries



## Stage 2 Sunfire-SynLink+

- + Sunfire e-Crude production with Nordic Blue Crude for e-Kerosine, e-Diesel and e-Wax
- + Start of operation: ca. 2021
- + Capacity: ca. 8,000 t/a e-Crude
- + 21,000 tonnes/a of CO<sub>2</sub> mitigation
- + Electricity-to-fuel efficiency of ca. 60 %<sub>LHV</sub>

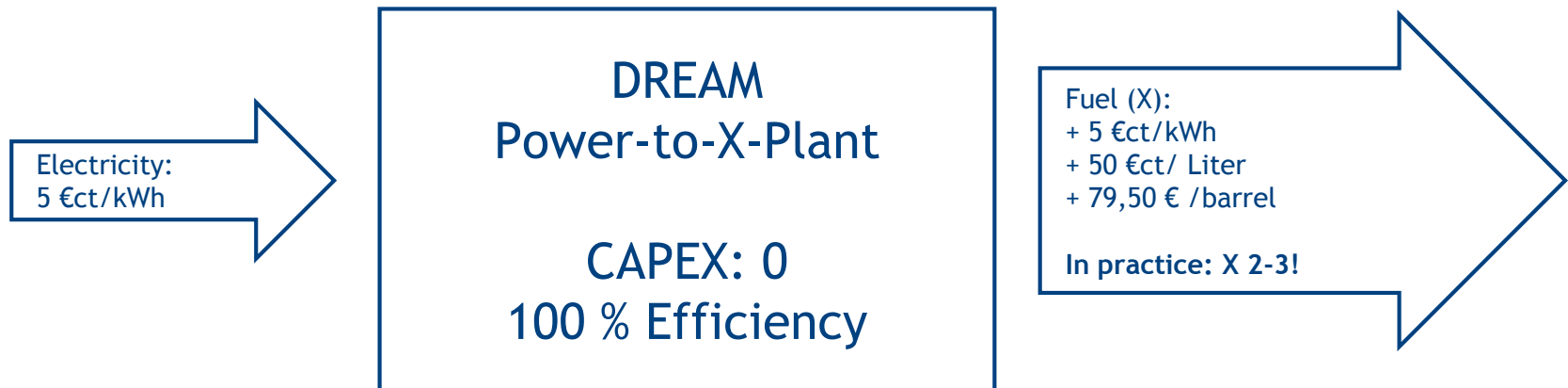
## e-Fuels Predicted to Play Large Role in the Future



Calculation based on dena/LBST „E-Fuels -The potential of electricity based fuels for low emission transport in the EU”, 2017

- + In 2050, hard-to-electrify sector will make up 50 % or 5,000 PJ
- + For e-Fuels to be available in those quantities after 2030, we must start now

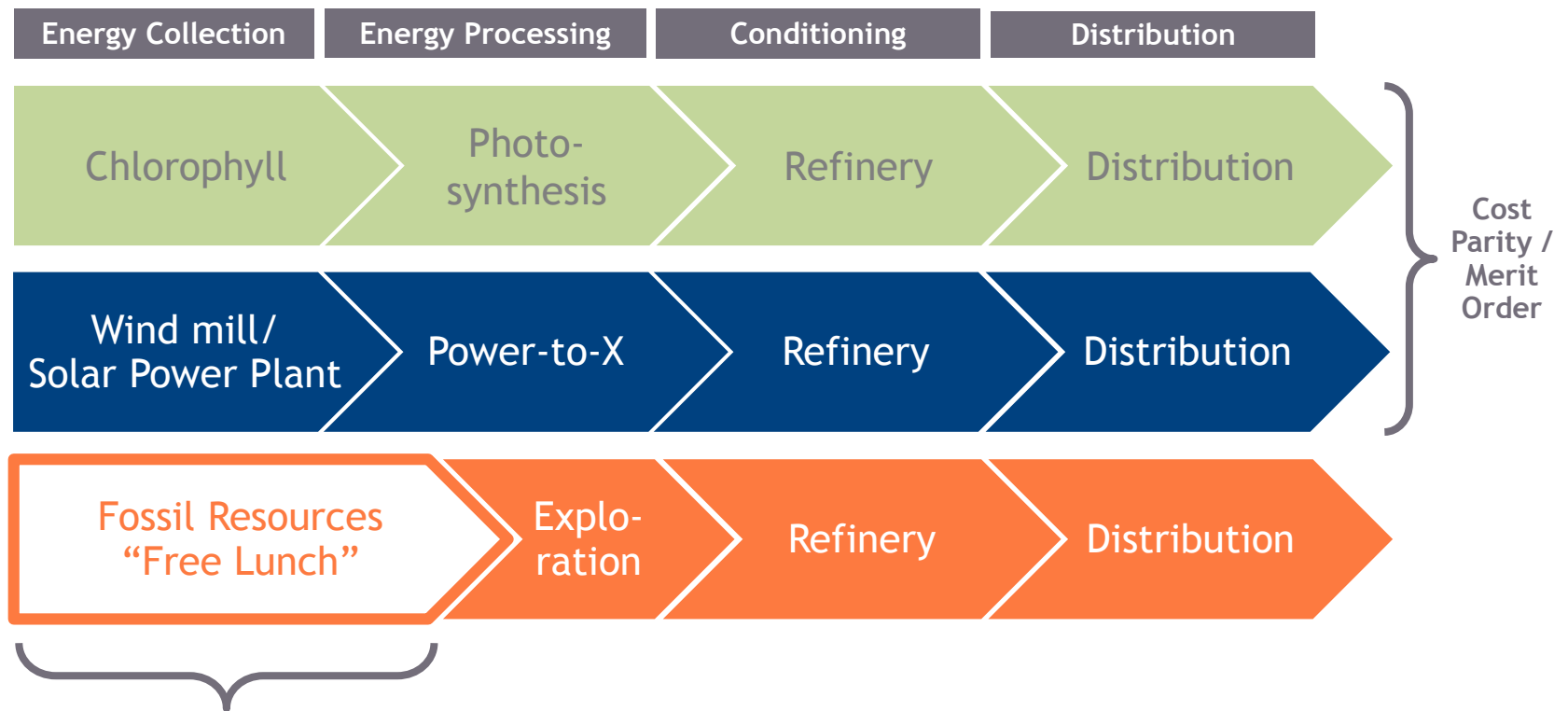
## Value Chain Chemical Industry





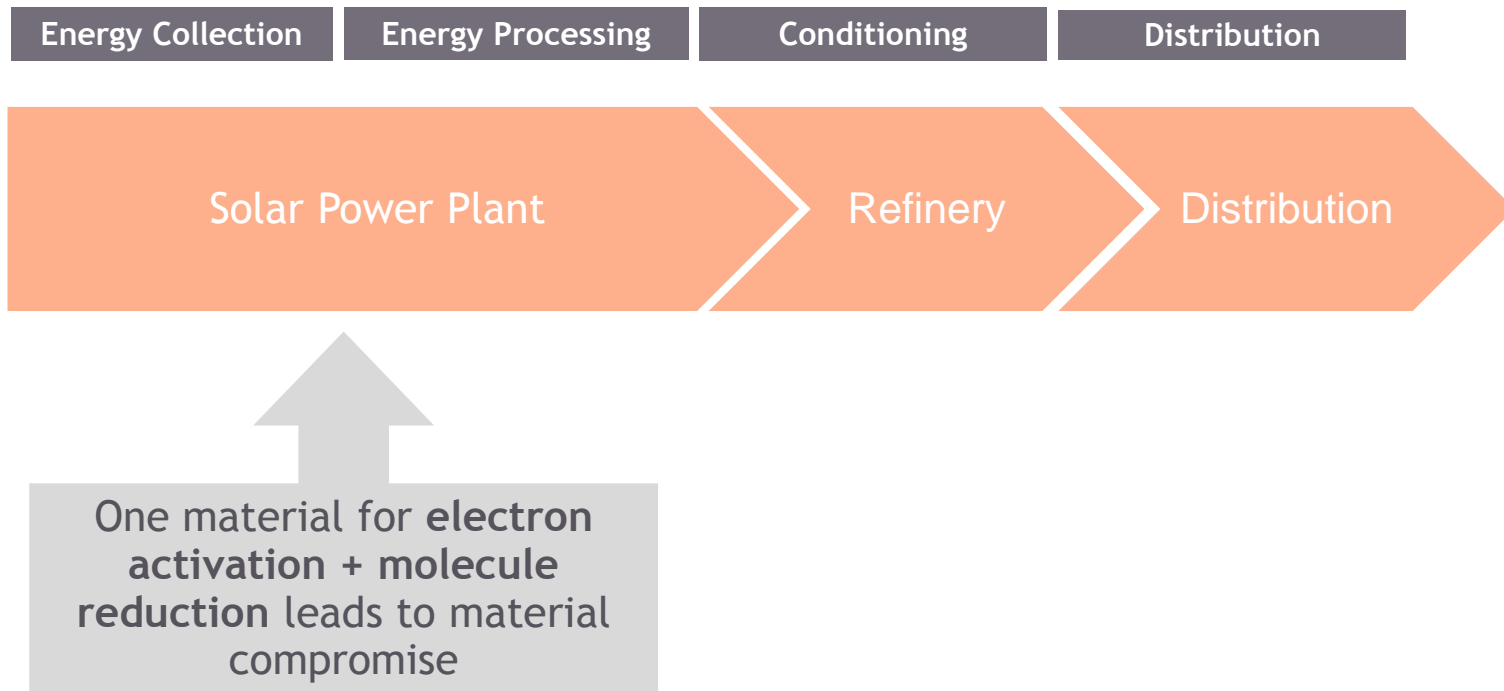
# Value Chain Chemical Industry

## Fossil & Renewable Value Chains in Comparison



- + Not closable via R&D (first law of thermodynamics)
- + Cost externalisation via CO<sub>2</sub> - emission

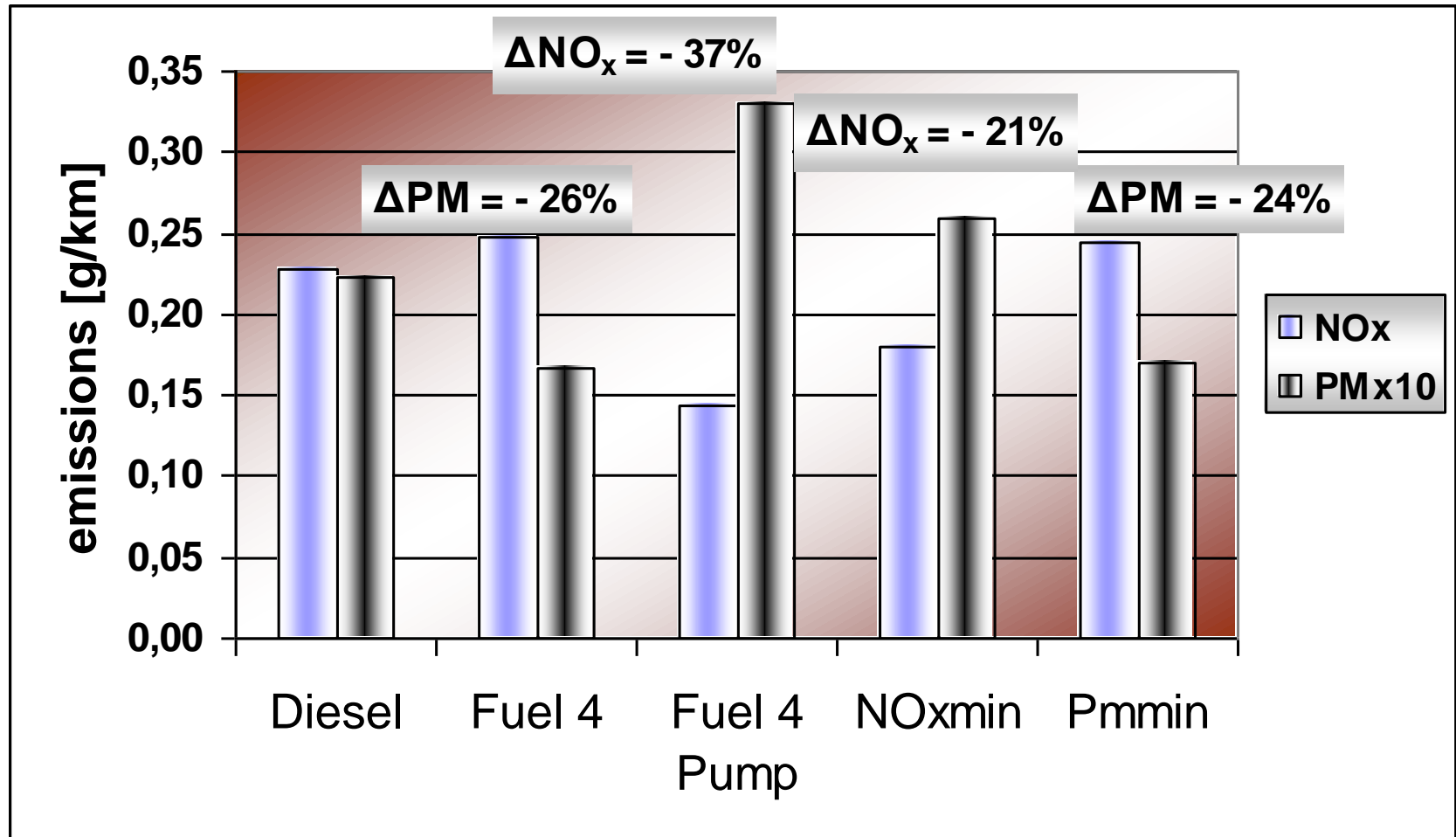
## Solar Fuel Production



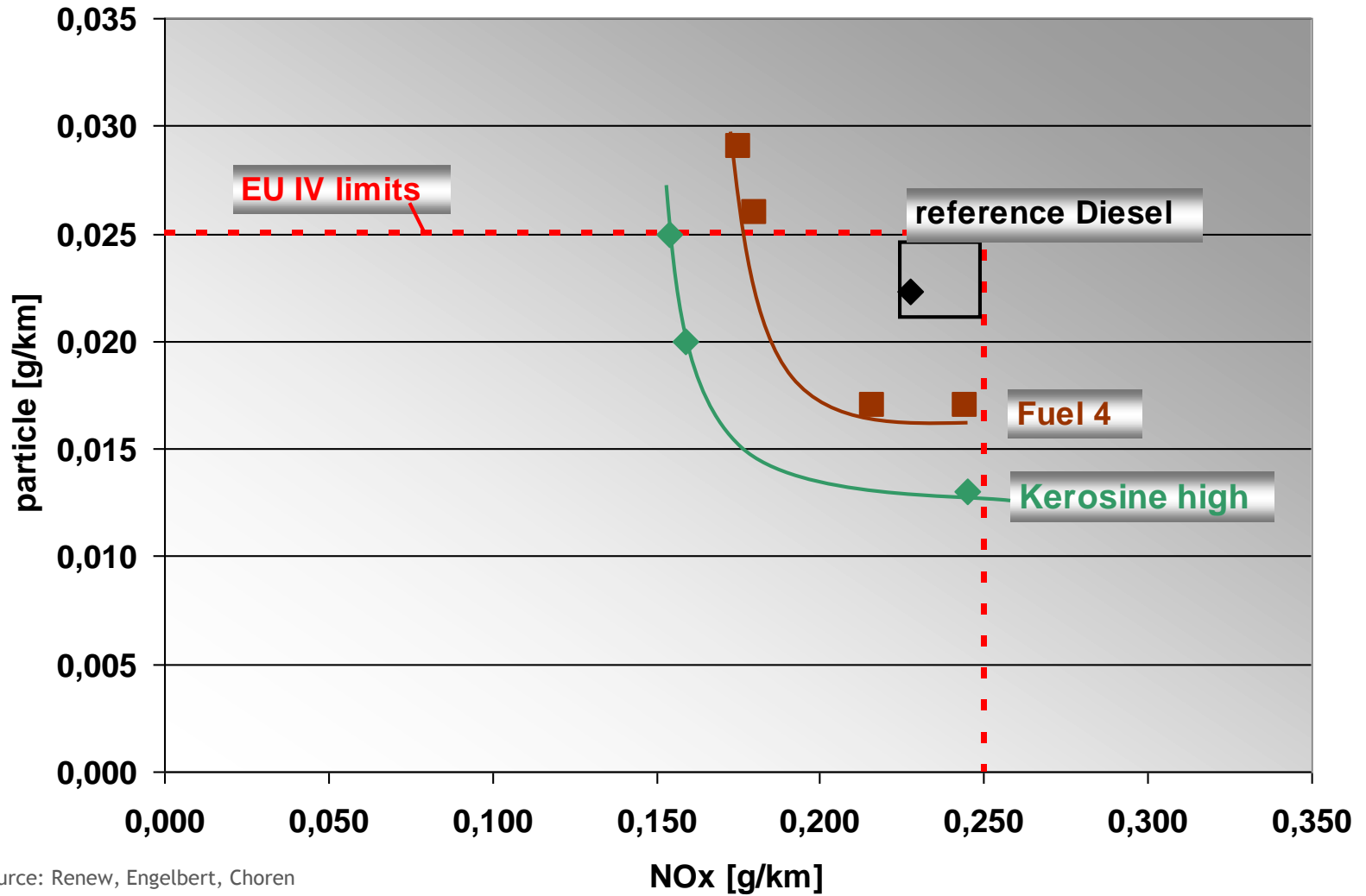


# + Emission & LCA

## Particles and NOx

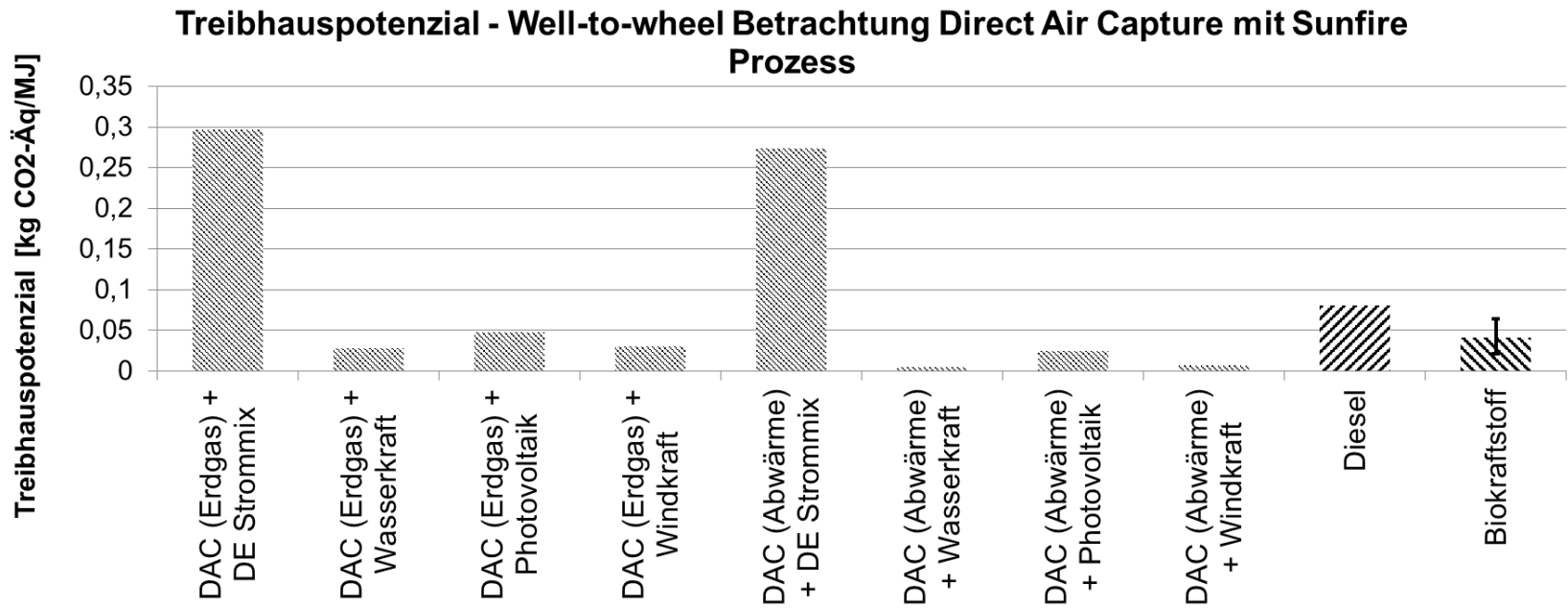


# Particles and NOx



Source: Renew, Engelbert, Choren

# LCA - GHG





# THANK YOU!

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

Upon request, further presentation material can be provided for each Sunfire product.

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