# Der Beitrag von e-Fuels zur Erreichung der Klimaziele

WKO OÖ, eFuels - Teil der Energiewende Österreichs, 1.9.2021

M. Rothbart

# Facts and Figures

## Global Footprint

Represented in 26 countries

45 Affiliates divided over 93 locations

45 Global Tech and Engineering Centers (including Resident Offices)

1948

Founded

11,000

Employees Worldwide

12%

Of Turnover Invested in Inhouse R&D

70+

Years of Experience

65%

Engineers and Scientists

1,500

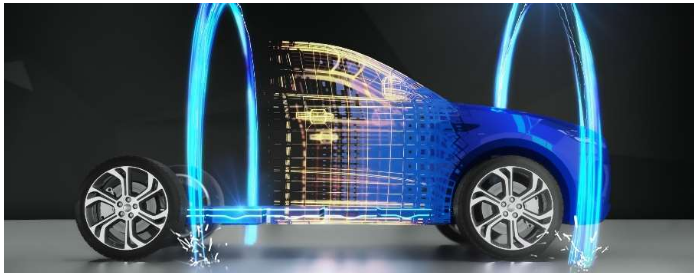
Granted Patents in Force

97%

Export Quota

# Looking Beyond the Limits of Technology

ELECTRIFICATION



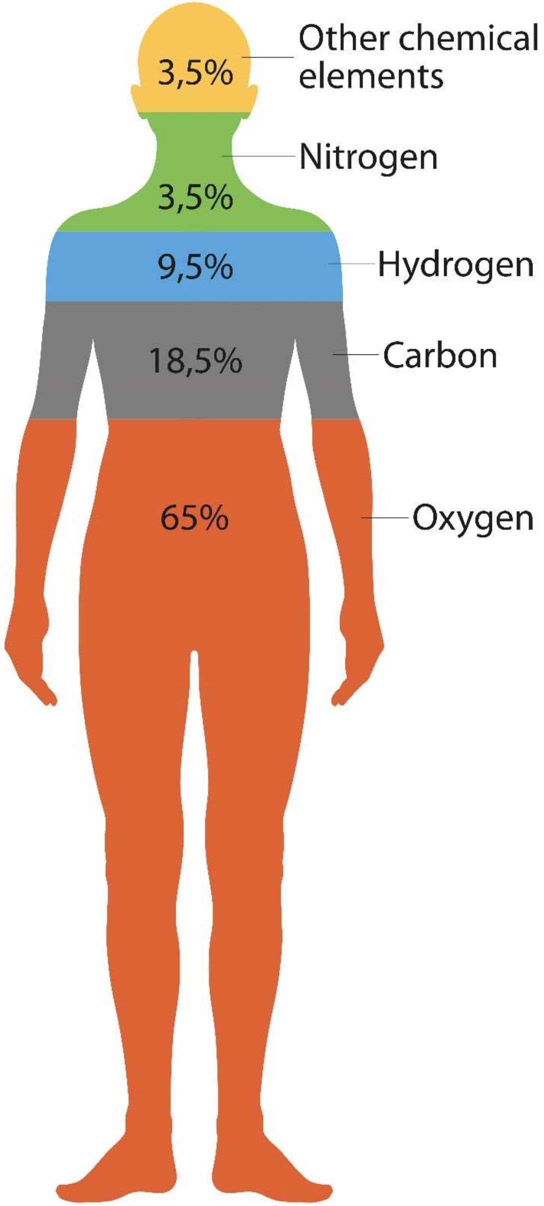
ADAS AND AUTONOMOUS DRIVING

ZERO-IMPACT EMISSION

VEHICLE ENGINEERING

DATA INTELLIGENCE

SUSTAINABILITY



renewable

13kg[1)] carbon

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1) For a 70kg total body weight
Source: https://en.wikipedia.org/wiki/Composition_of_the_human_body

# The Climate Goal driving the World !

Ursula von der Leyen, President of the European Commission

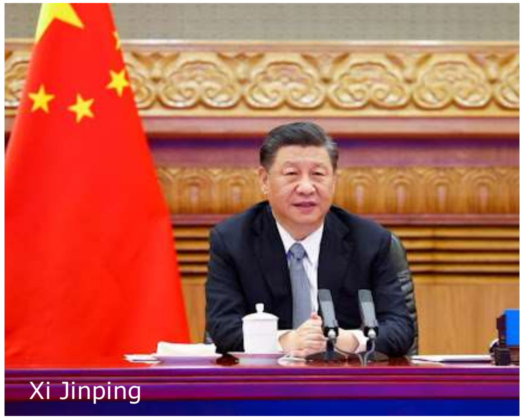
“We want to become the 1st carbon neutral continent by 2050.”

President Biden Sets 2030 Greenhouse Gas Pollution Reduction Target.

United States to achieve a 50-52 percent reduction from 2005 levels in economy-wide net greenhouse gas pollution in 2030.

“Save our climate”

Greta Thunberg, Swedish climate activist

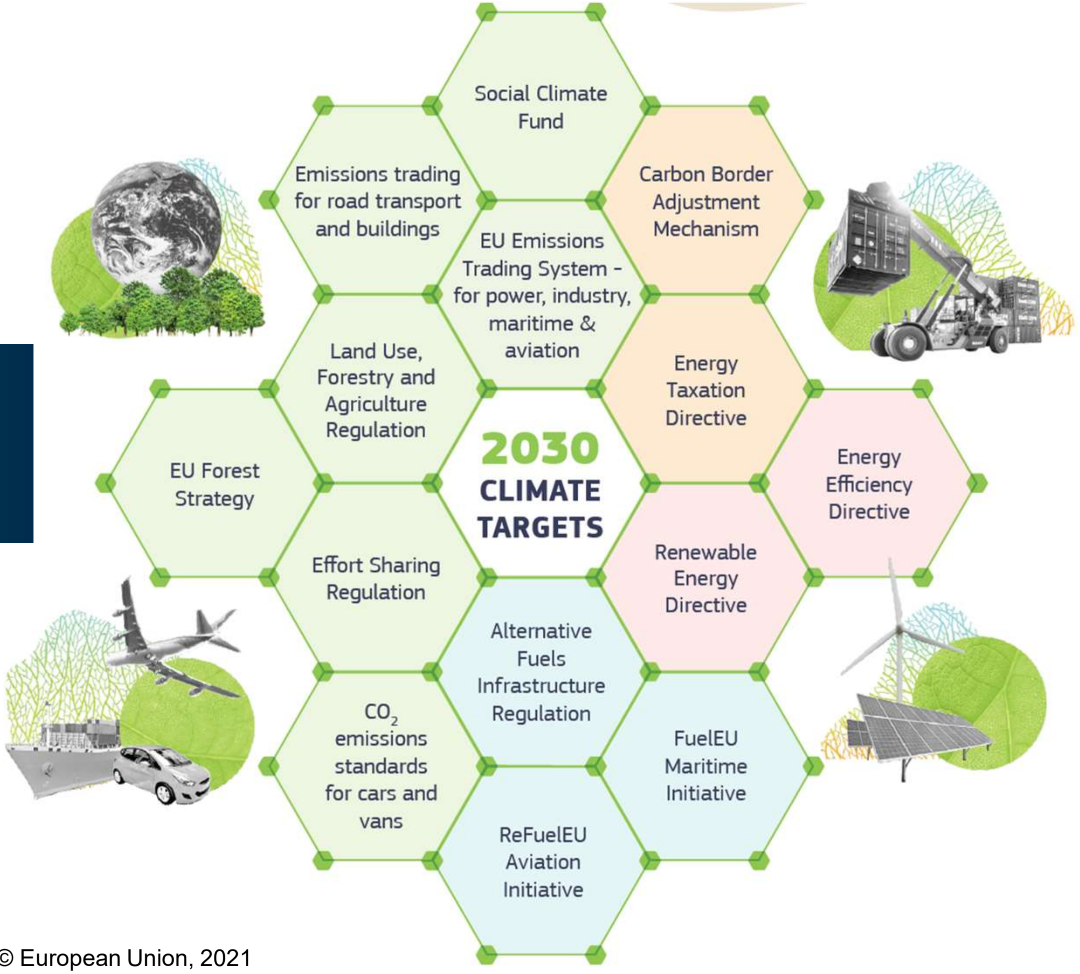


Xi Jinping

China: Xi Jinping confirms that China will peak emissions before 2030 and aims to achieve carbon neutrality before 2060

# Delivering the European Green Deal - The Decisive Decade

**“Fit for 55”**
The EU will **reduce its net greenhouse gas emissions by at least 55% by 2030**, compared to 1990 levels.*



2030 CLIMATE TARGETS

Social Climate Fund

Emissions trading for road transport and buildings

Carbon Border Adjustment Mechanism

EU Emissions Trading System - for power, industry, maritime & aviation

Land Use, Forestry and Agriculture Regulation

Energy Taxation Directive

EU Forest Strategy

Energy Efficiency Directive

Effort Sharing Regulation

Renewable Energy Directive

Alternative Fuels Infrastructure Regulation

$CO_2$ emissions standards for cars and vans

FuelEU Maritime Initiative

ReFuelEU Aviation Initiative

© European Union, 2021

*As agreed in the EU Climate Law. On 14 July 2021, the Commission presented proposals to deliver these targets and make the European Green Deal a reality.

# Delivering the European Green Deal - The Decisive Decade

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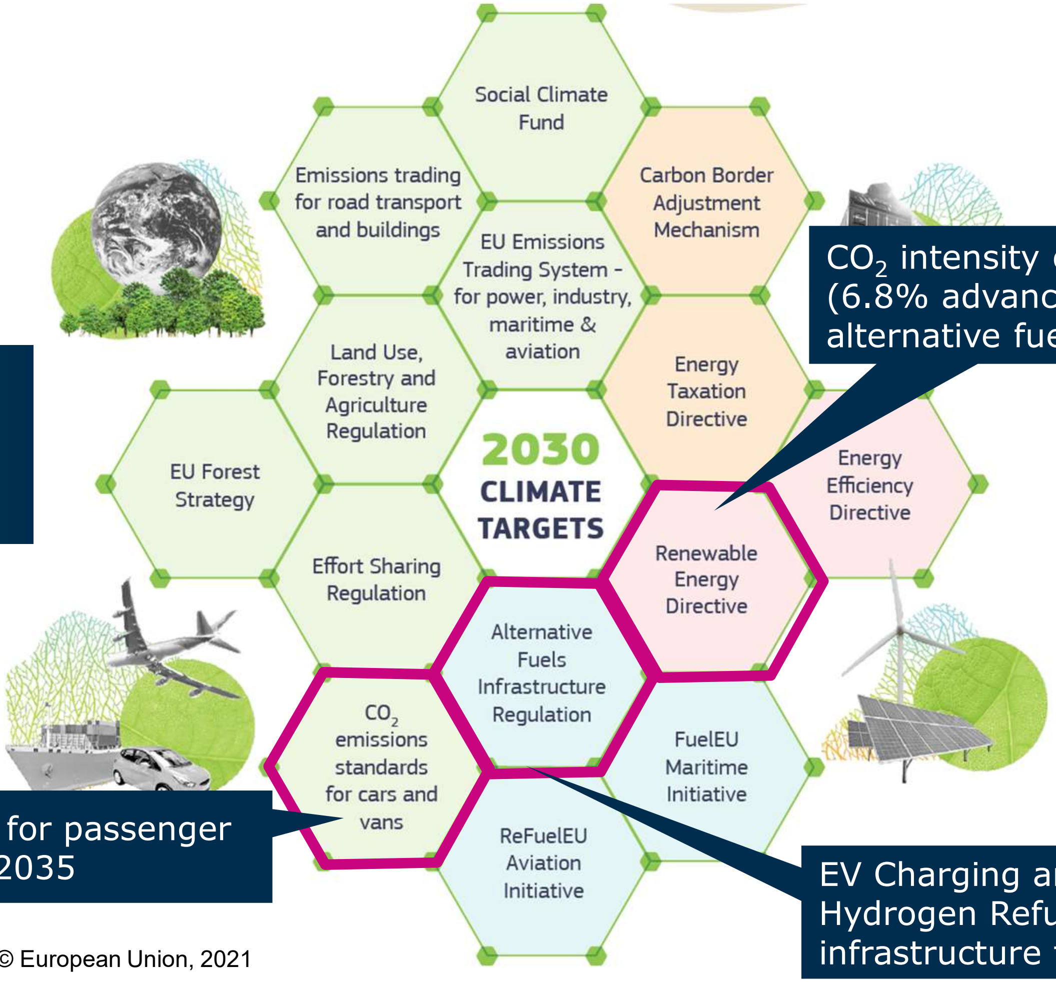

Social Climate Fund

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**2030 CLIMATE TARGETS**

Energy Efficiency Directive

Effort Sharing Regulation

Renewable Energy Directive

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$CO_2$ emissions standards for cars and vans

FuelEU Maritime Initiative

ReFuelEU Aviation Initiative

$CO_2$ intensity of fuels (6.8% advanced alternative fuels)

Zero Tailpipe $CO_2$ Emission for passenger & light duty vehicles after 2035

EV Charging and Hydrogen Refueling infrastructure targets

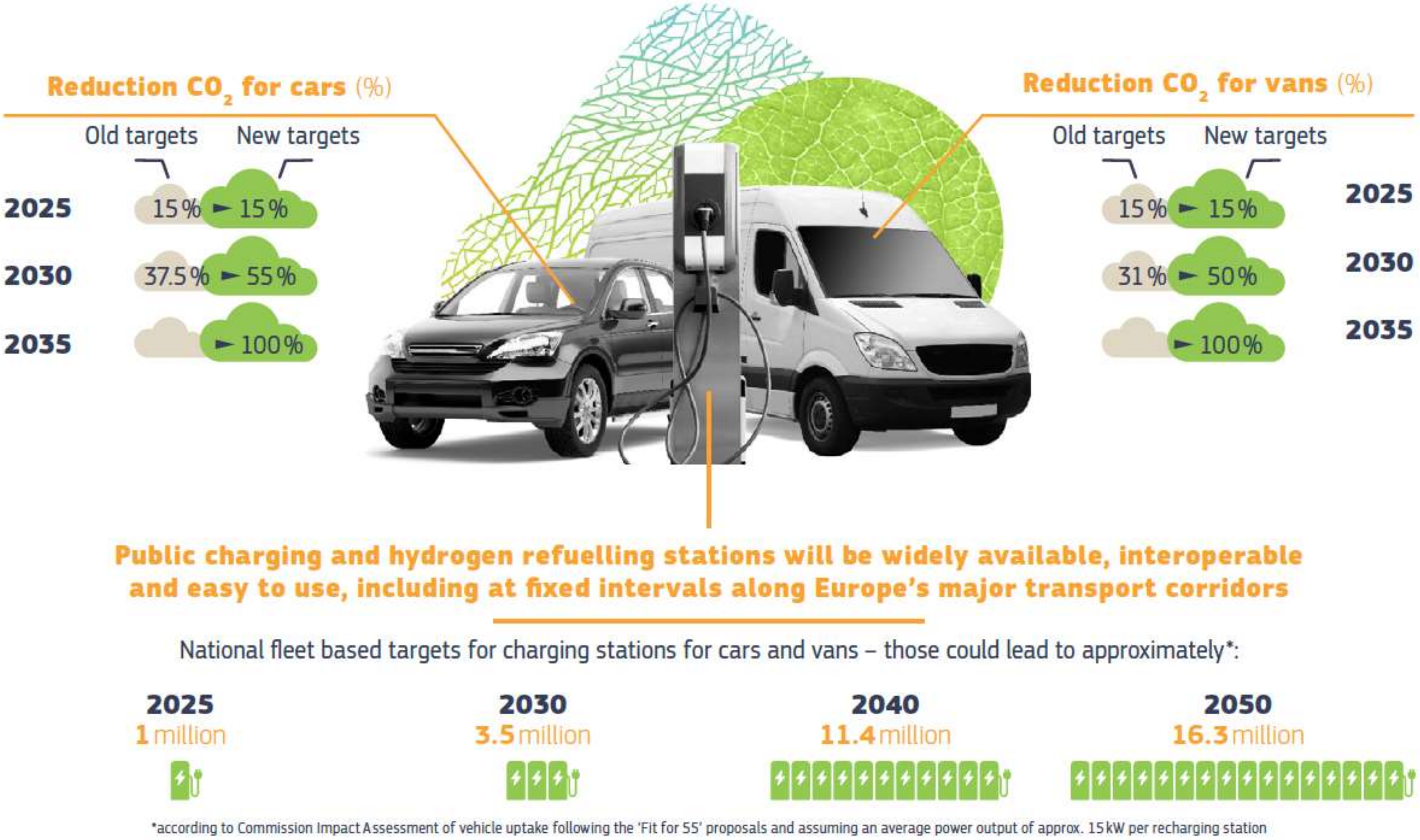
*As agreed in the EU Climate Law. On 14 July 2021, the Commission presented proposals to deliver these targets and make the European Green Deal a reality.

# Make Transport Greener

## CLEANER ROAD TRANSPORT

More ambitious $CO_2$ emissions standards for new cars and vans to help grow the number of zero- and low-emission vehicles on European roads.

Binding requirements for the rollout of public charging and hydrogen refuelling stations for cars, vans and trucks.



**Reduction $CO_2$ for cars** (%)

| | Old targets | New targets |
|---|---|---|
| **2025** | 15 % | 15 % |
| **2030** | 37.5 % | 55 % |
| **2035** | | 100 % |

**Reduction $CO_2$ for vans** (%)

| | Old targets | New targets |
|---|---|---|
| **2025** | 15 % | 15 % |
| **2030** | 31 % | 50 % |
| **2035** | | 100 % |

**Public charging and hydrogen refuelling stations will be widely available, interoperable and easy to use, including at fixed intervals along Europe's major transport corridors**

National fleet based targets for charging stations for cars and vans – those could lead to approximately*:

| **2025** | **2030** | **2040** | **2050** |
|---|---|---|---|
| 1 million | 3.5 million | 11.4 million | 16.3 million |

*according to Commission Impact Assessment of vehicle uptake following the 'Fit for 55' proposals and assuming an average power output of approx. 15 kW per recharging station

*Source: Make Transport Greener Factsheet, European Commission, 14.07.2021*

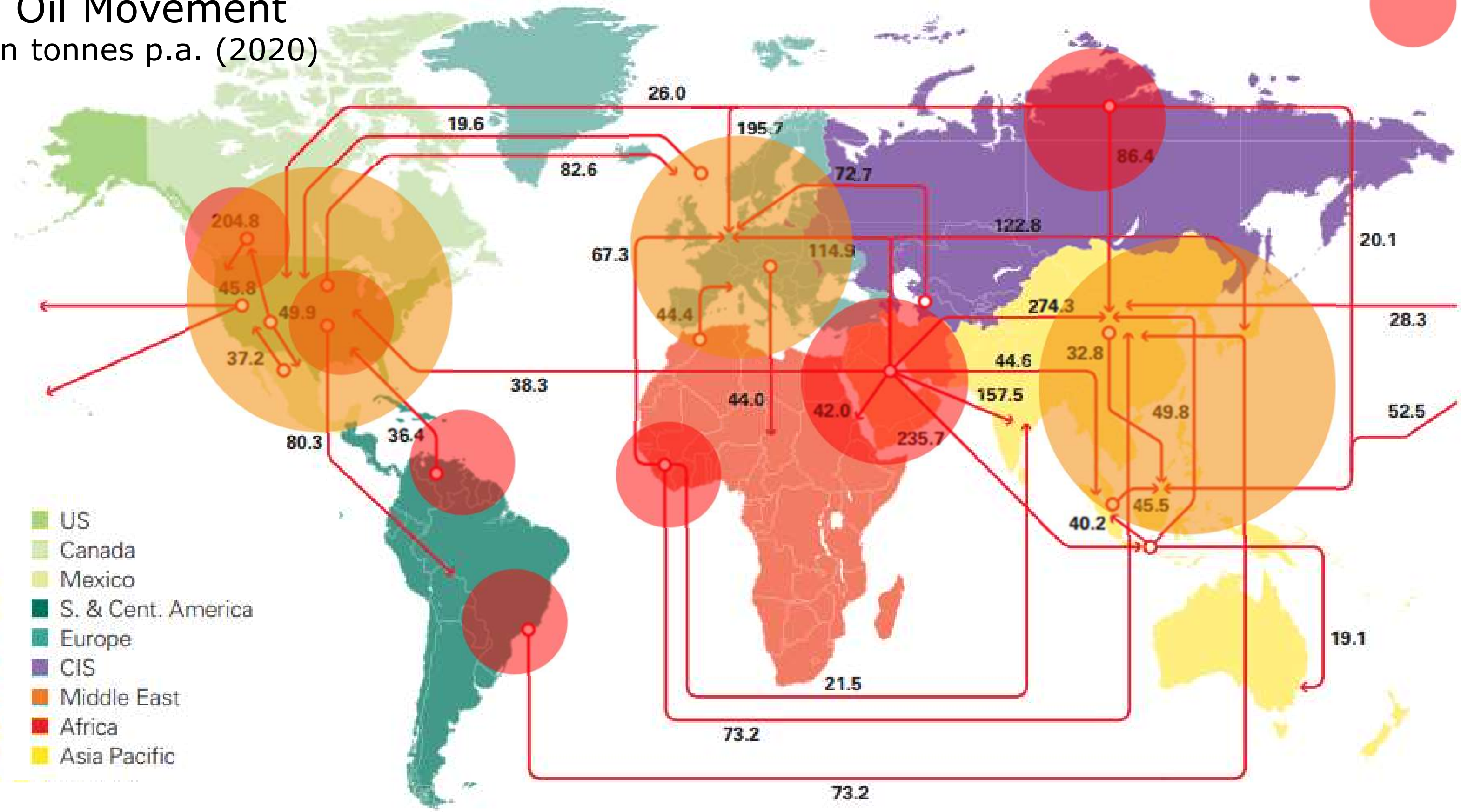
The world's first liquefied hydrogen carrier—Suiso Frontier, or 'hydrogen frontier'—at port in Kobe, southwestern Japan. © WSJ

# Energy Trade Today:
# No Match of Supply & Demand Regions

## Crude Oil Movement
in Million tonnes p.a. (2020)

● Demand Centers

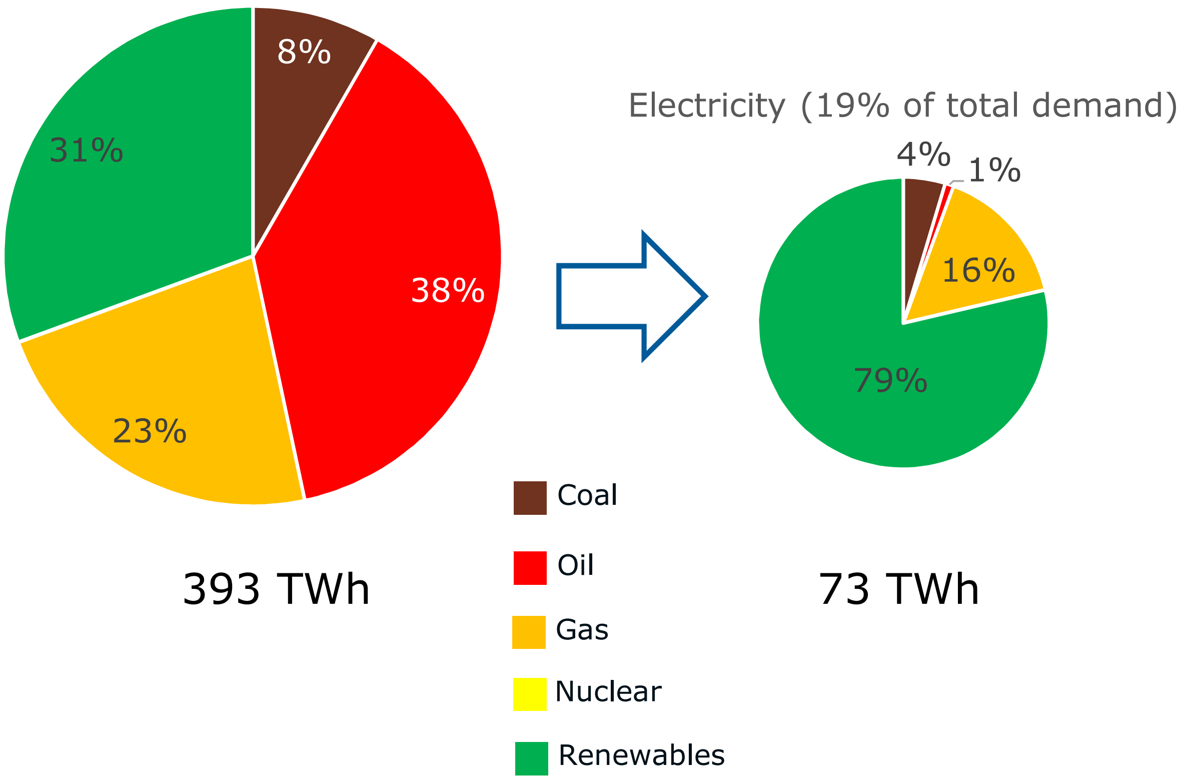
● Supply Regions



Source: Source: BP Statistical Review of World Energy 2021, Page 35

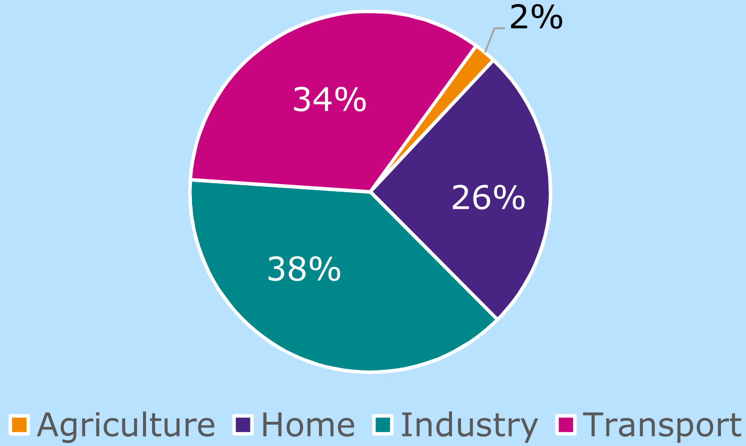
# Austria Energy Demand 2019

Energy Demand - Austria



Source: Eurostat Link

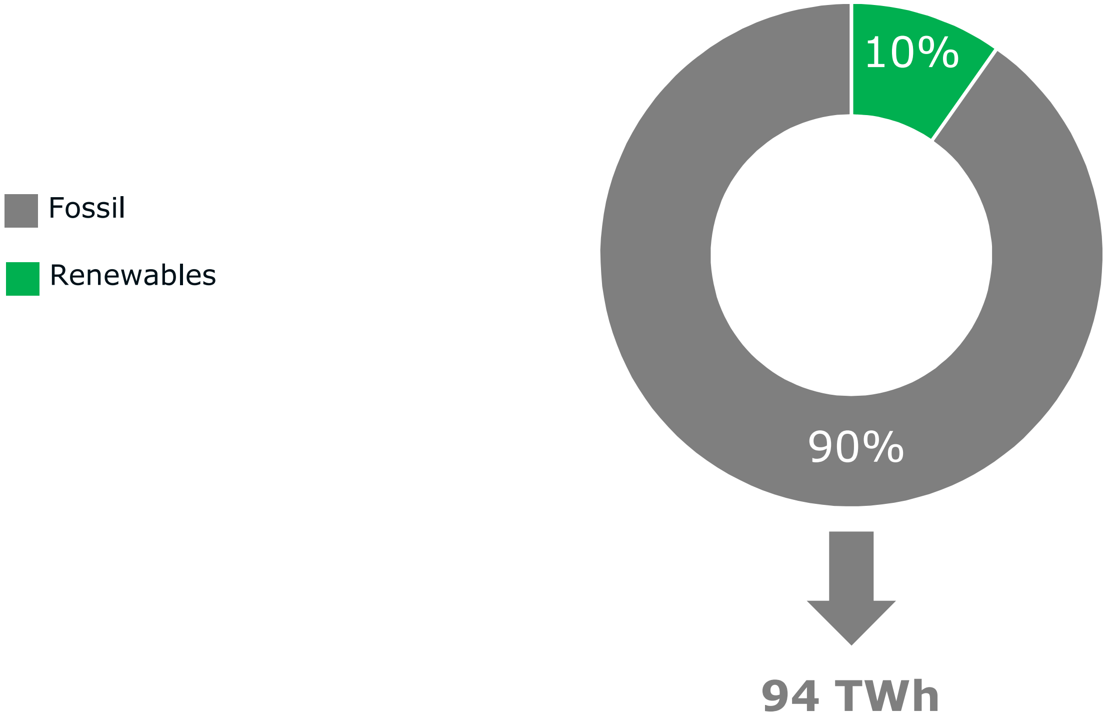
Energy end user by sector



*Shares based on final consumption of 305 TWh (after losses etc.)*

Source: eControl Link

# Energy Balance Austria - Transport



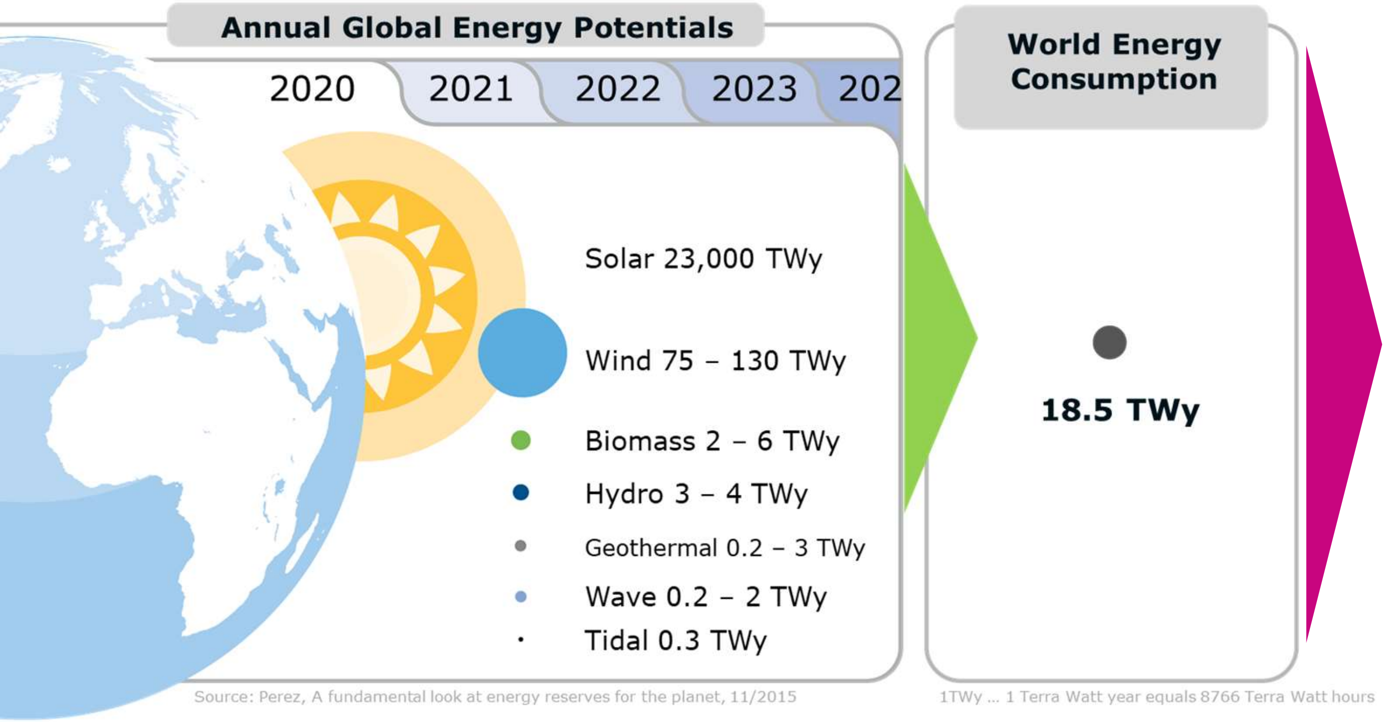
- Total fossil energy consumption transport of 2019 was
  **94 TWh**
- Total electricity production in 2018 was
  **65 TWh**

FOSSIL ENERGY TO BE CONVERTED IS MORE THAN **THE CURRENT ELECTRICITY PRODUCTION**

Source: STATISTIK AUSTRIA, Energiebilanz Österreich 2019, 14.12.2020

Electricity production Austria 2018: 234 PJ = 65 TWh

# Renewable Energy:
# Sufficient, but usually wrong place & time…



**Annual Global Energy Potentials**

2020 2021 2022 2023 202

- Solar 23,000 TWy
- Wind 75 – 130 TWy
- Biomass 2 – 6 TWy
- Hydro 3 – 4 TWy
- Geothermal 0.2 – 3 TWy
- Wave 0.2 – 2 TWy
- Tidal 0.3 TWy

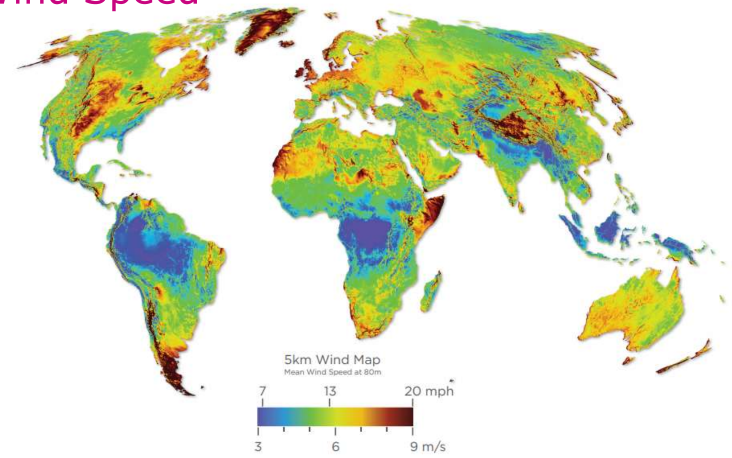
**World Energy Consumption**

**18.5 TWy**

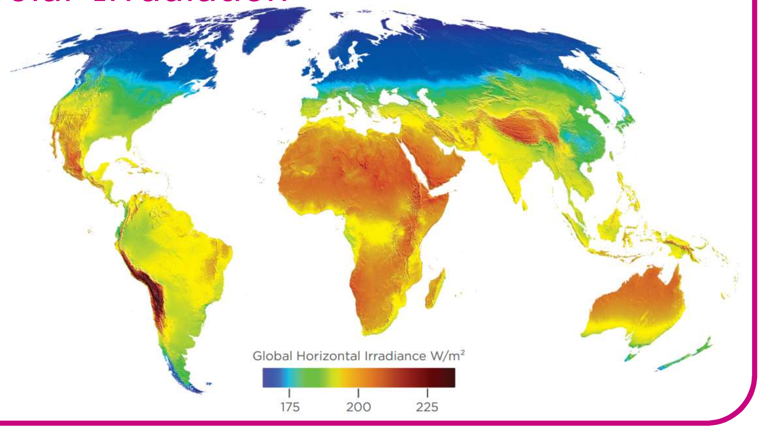
Source: Perez, A fundamental look at energy reserves for the planet, 11/2015

1TWy … 1 Terra Watt year equals 8766 Terra Watt hours

Wind Speed



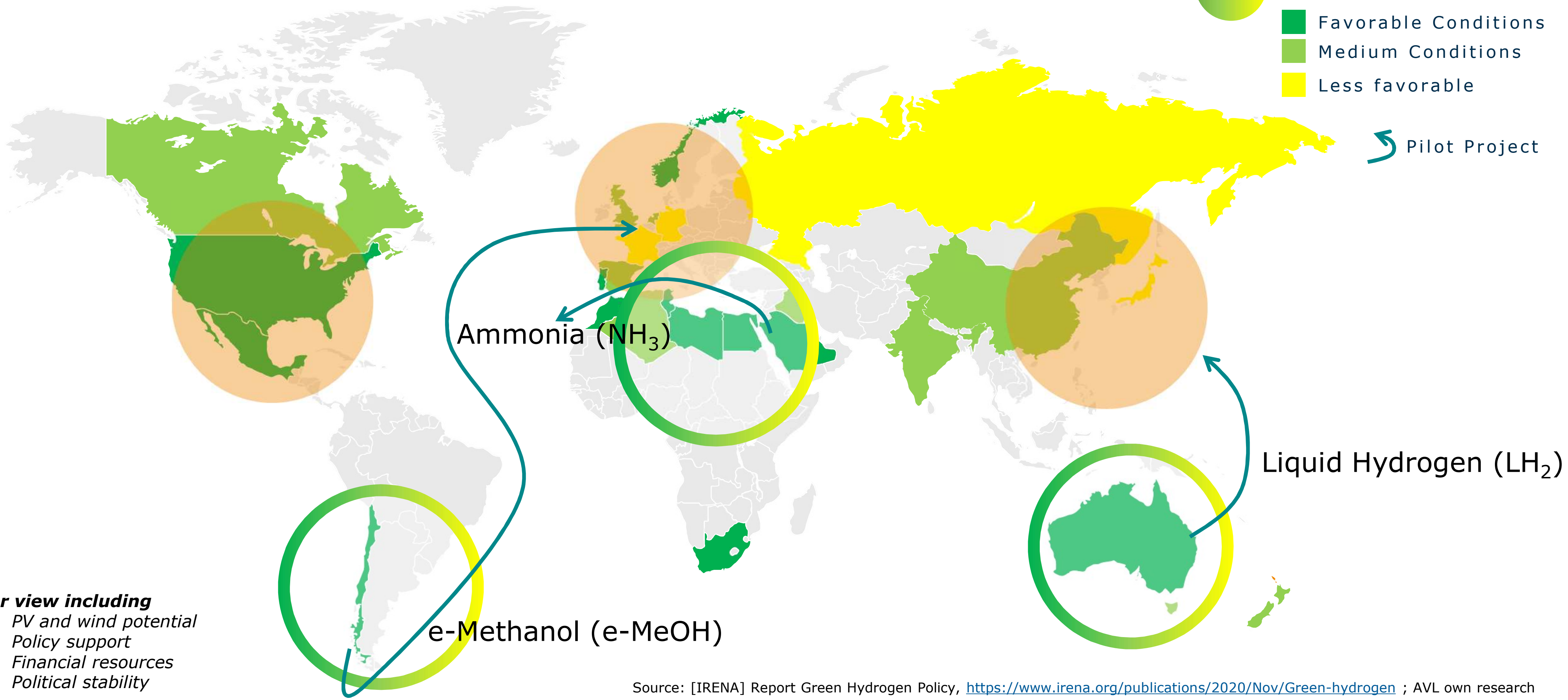
Solar Irradiation



➡ Production Potential is far away from Demand Centers

Source:
https://www.vaisala.com/sites/default/files/documents/Vaisala_global_wind_map.pdf?utm_content=Wind-Map
https://www.vaisala.com/sites/default/files/documents/Vaisala_global_solar_map.pdf?utm_content=Solar-Map

# Energy Trade Future:
# Green Hydrogen Production and Demand



● Demand Centers
USA, SE Asia, Europe

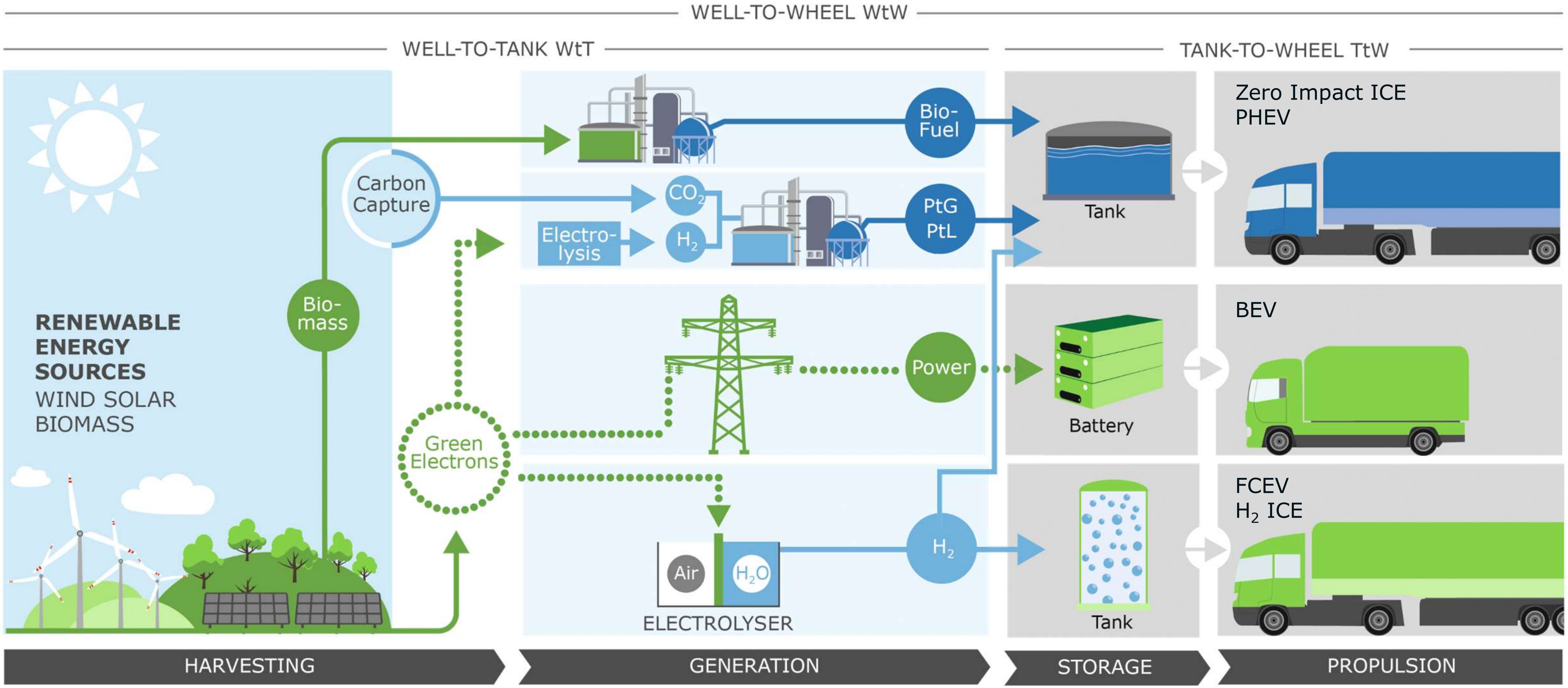
● Supply Regions
- 🟩 Favorable Conditions
- 🟩 Medium Conditions
- 🟨 Less favorable

↺ Pilot Project

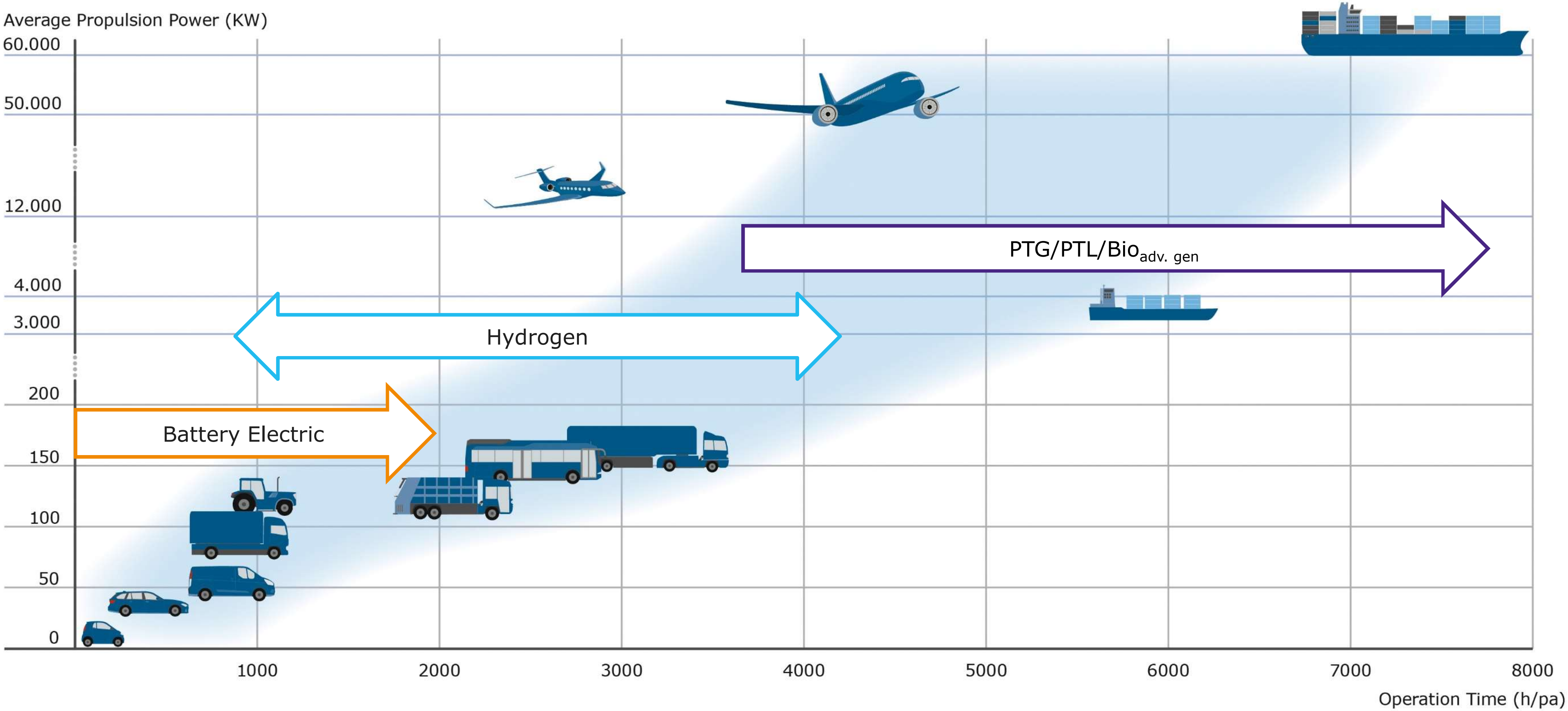
***Our view including***
- *PV and wind potential*
- *Policy support*
- *Financial resources*
- *Political stability*

Source: [IRENA] Report Green Hydrogen Policy, https://www.irena.org/publications/2020/Nov/Green-hydrogen ; AVL own research

# Pathways to clean and sustainable Propulsion Systems



# “Sustainable Fuel Map” for Transport Applications



GTL Fuel from SHELL vs. fossil Diesel, Source: TOOL-FUEL Services GmbH

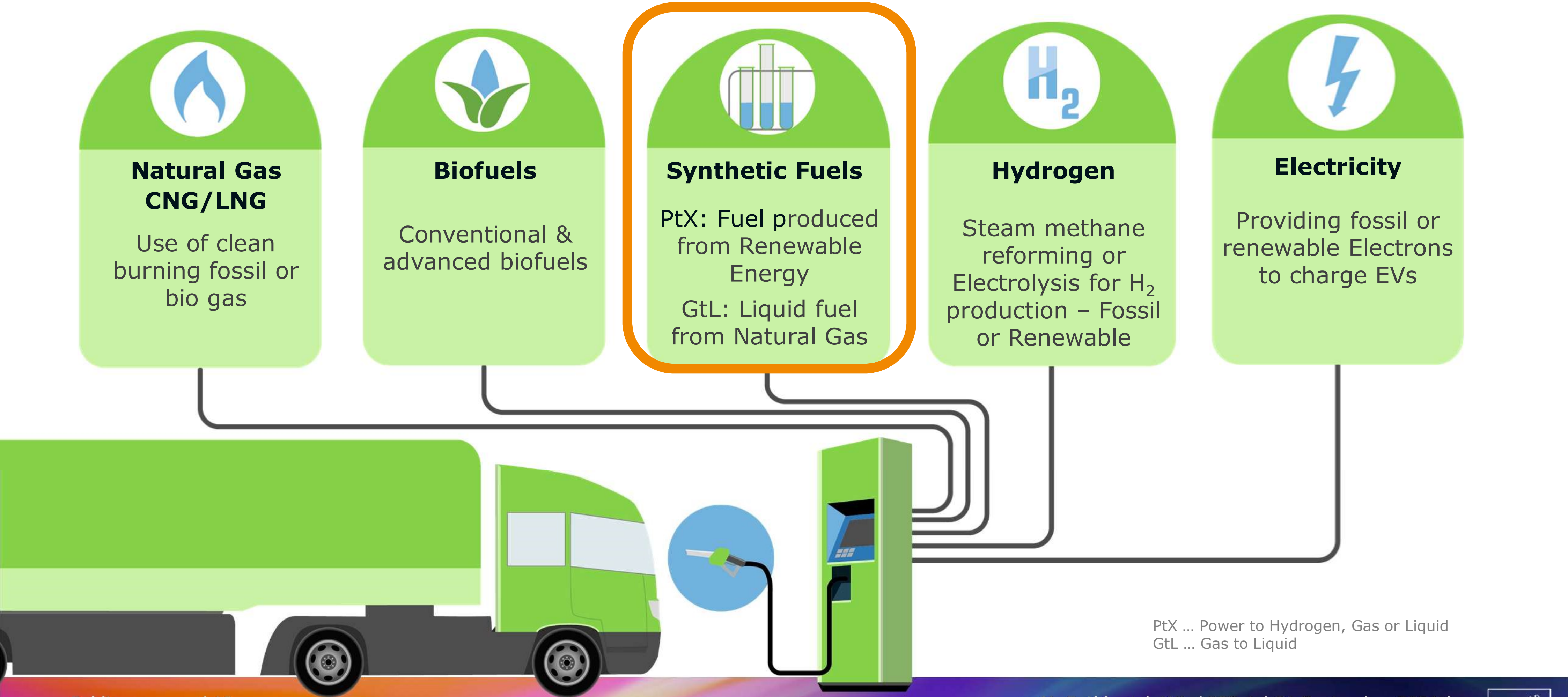
The Stone Age didn't end for lack of stone,

and the oil age will end long before

the world runs out of oil.

*- Sheik Ahmed Zaki Yamani*

# Options for Alternative Fuels



**Natural Gas CNG/LNG**

Use of clean burning fossil or bio gas

**Biofuels**

Conventional & advanced biofuels

**Synthetic Fuels**

PtX: Fuel produced from Renewable Energy

GtL: Liquid fuel from Natural Gas

**Hydrogen**

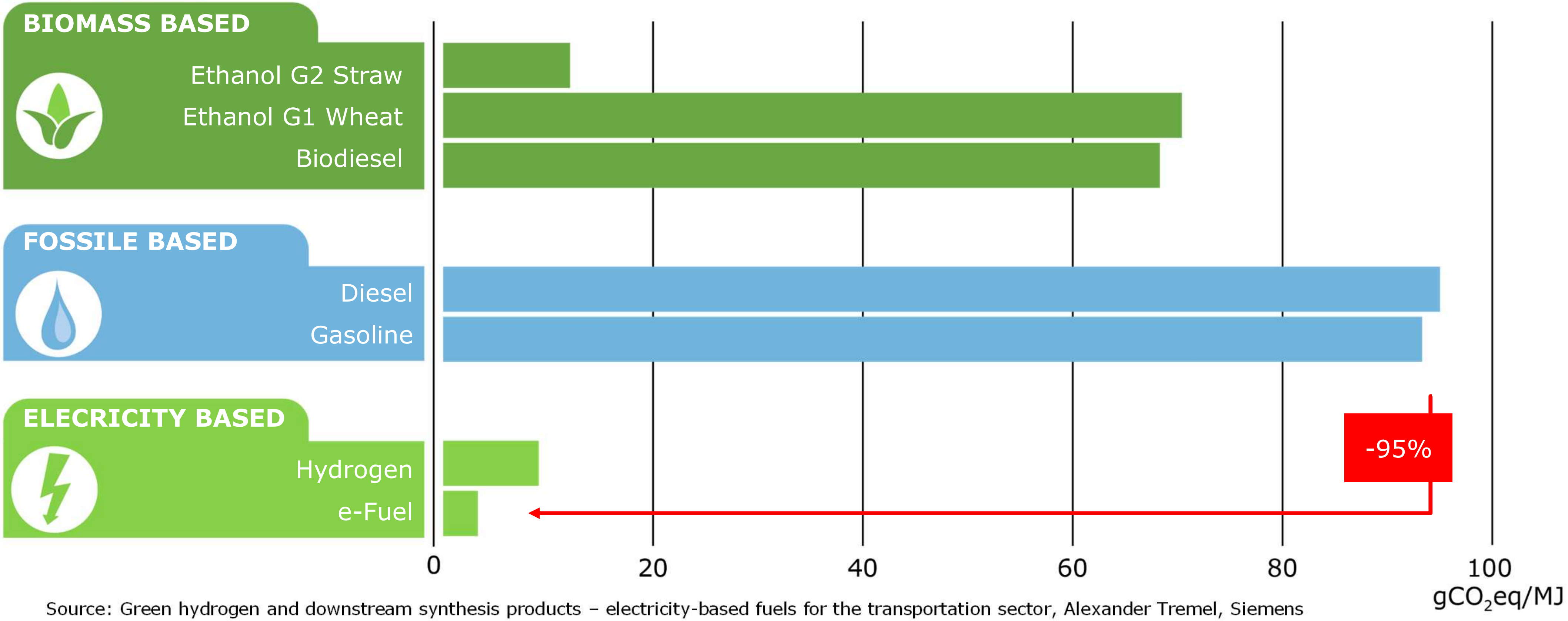
Steam methane reforming or Electrolysis for $H_2$ production – Fossil or Renewable

**Electricity**

Providing fossil or renewable Electrons to charge EVs

PtX … Power to Hydrogen, Gas or Liquid
GtL … Gas to Liquid

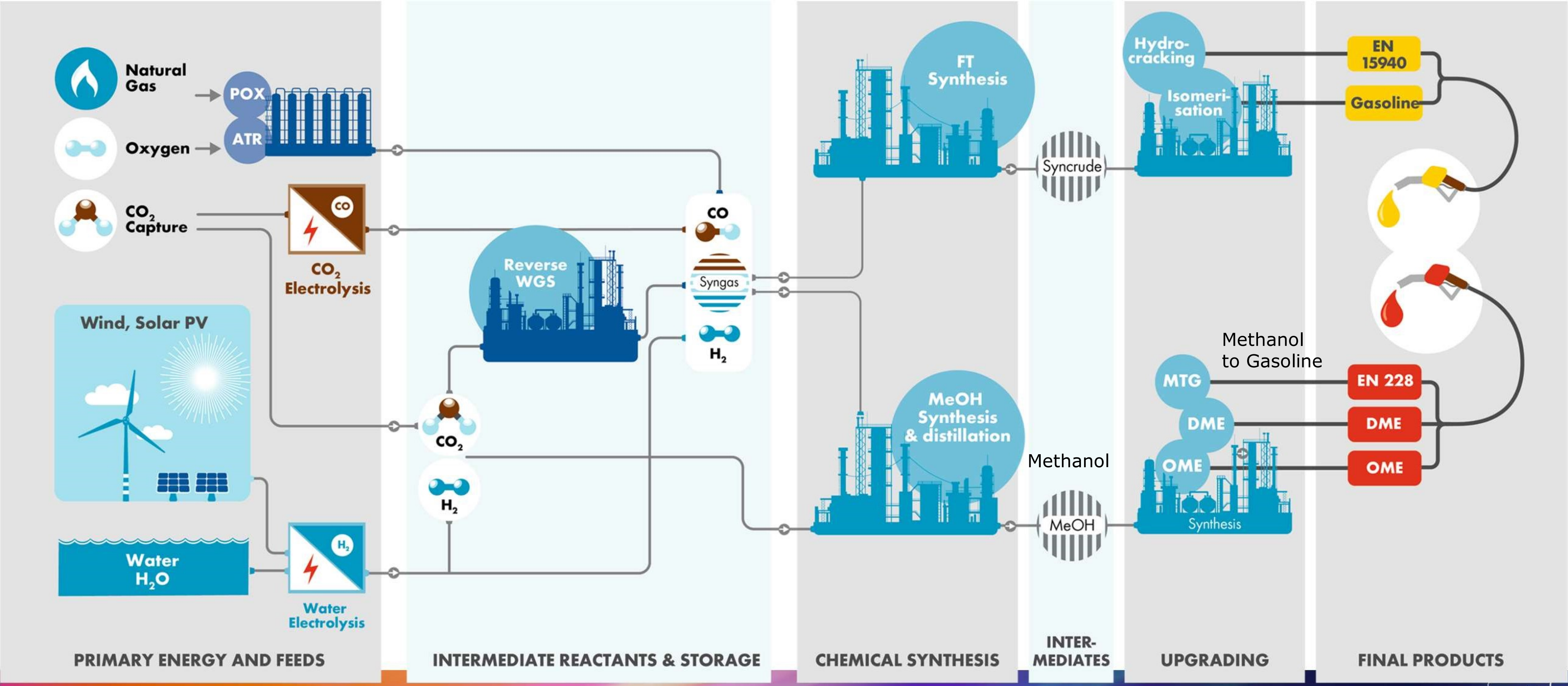
# Lifecycle Greenhouse Gas Emissions ($CO_2$ equivalents) for Fuels



Source: Green hydrogen and downstream synthesis products – electricity-based fuels for the transportation sector, Alexander Tremel, Siemens

Electricity-based fuels are expected to outperform second generation biofuels in green house gas emissions.

# Power-to-Liquid Production Pathways

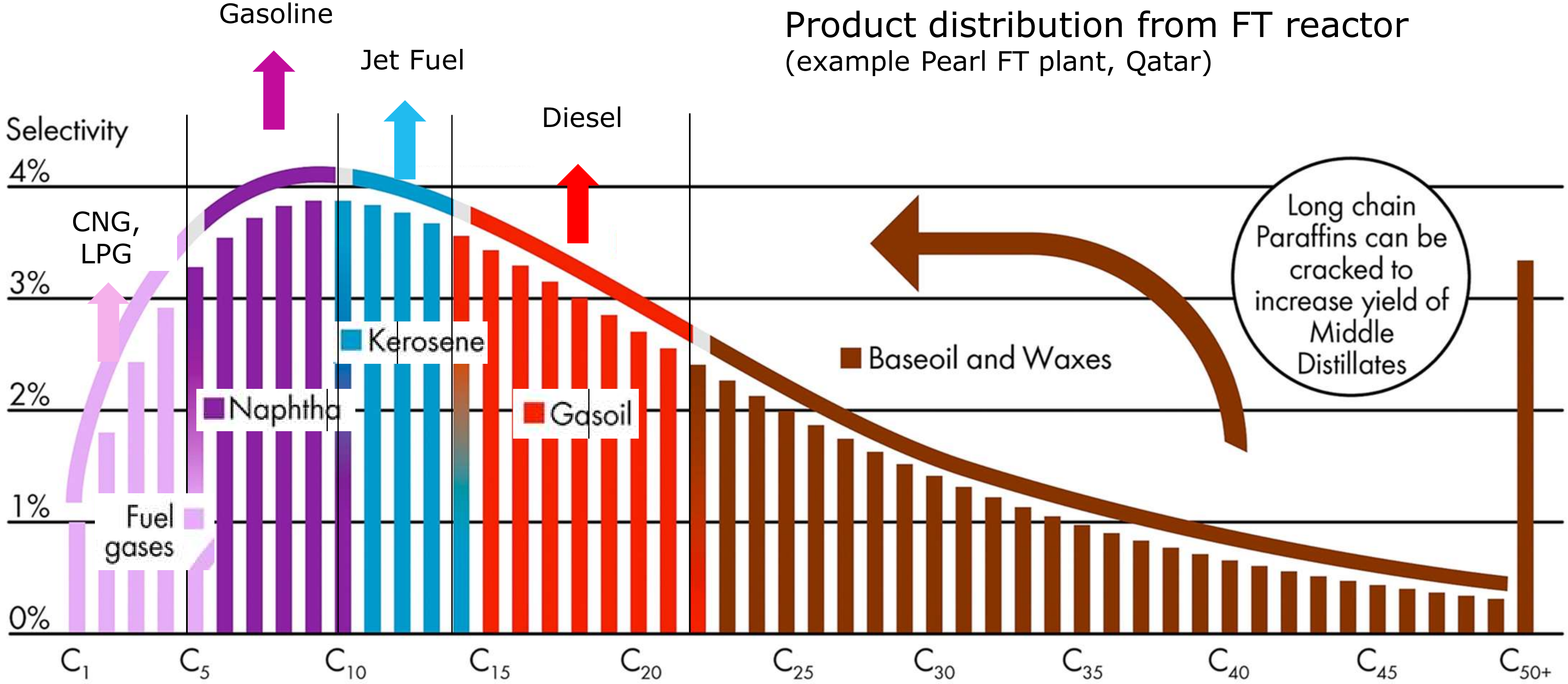


Methanol to Gasoline

Methanol

# FUEL COMPONENTS FROM E-FUEL PROCESSING: HYDROCARBON PRODUCT SLATE (EXAMPLE: FISCHER-TROPSCH)

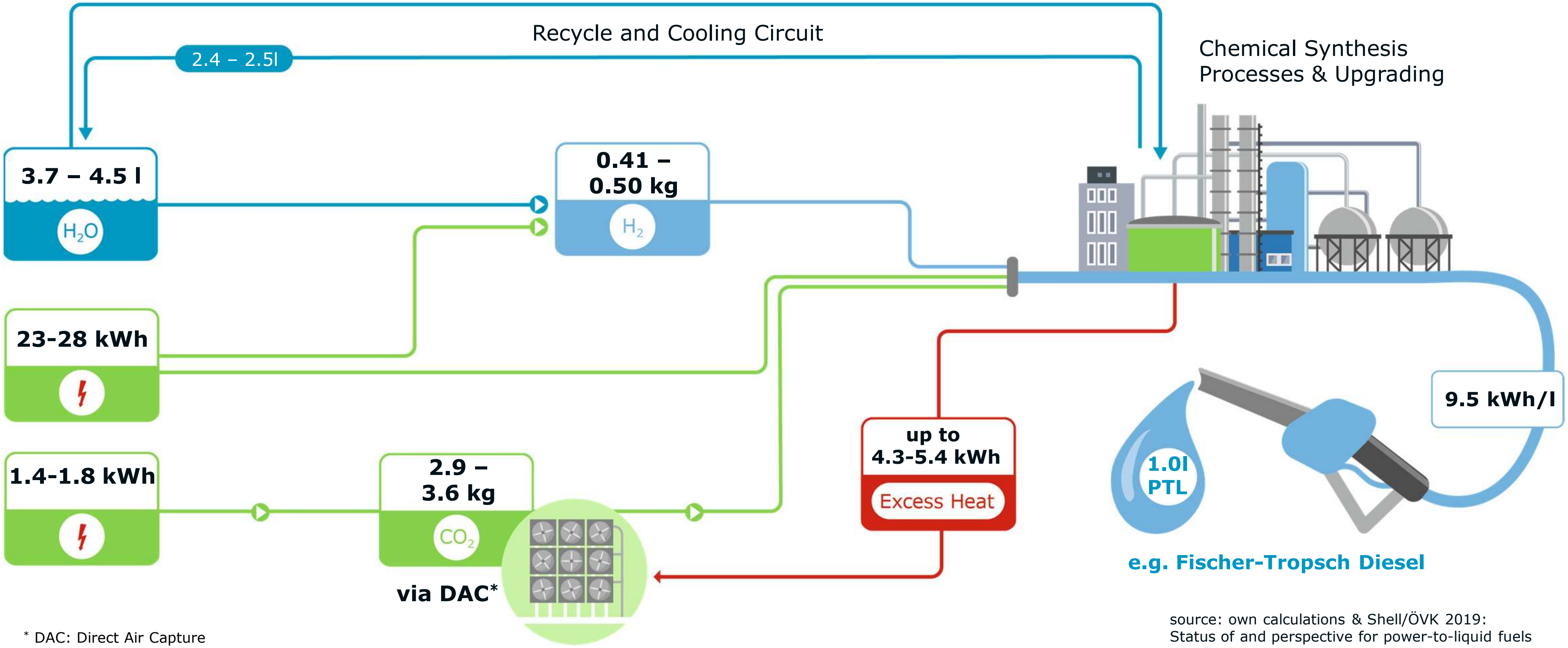
Product distribution from FT reactor
(example Pearl FT plant, Qatar)



PtX processes will always deliver a wide Diversity of HydroCarbons – depending on plant layout

Source: SHELL, https://www.shell.com/about-us/major-projects/pearl-gtl/the-world-s-largest-gas-to-liquids-plant.html

# Resources required for 1 liter of e-Fuel (here: FT process basis)



* DAC: Direct Air Capture

source: own calculations & Shell/ÖVK 2019: Status of and perspective for power-to-liquid fuels

e-Fuel production needs major supply of electricity, water and $CO_2$.
Continuous conversion process requires continuous feed.

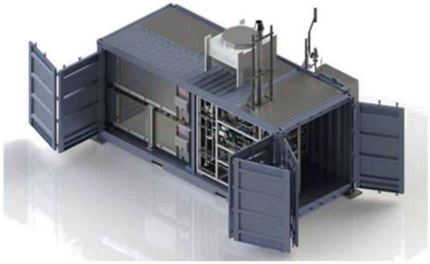
# Overview of Electrolysis Technologies

| | **Alkaline** | **PEM** | **SOEC** |
|---|---|---|---|
| Status | Mature | | R&D |
| Market Share | >90% | <10% | 0% |
| Temperature | Amb-120 °C | Amb-90°C | 600-800 °C |
| Pressure | 1-200 bar | 1-350 bar | 1-25 bar |
| Dynamics | weak | good | medium |
| **Cost and efficiency outlook 2030** | | | |
| CAPEX | 370-800 EUR/kW [1] | 250-1270 EUR/kW [2] | 300 - 800 EUR/kW [3] |
| OPEX | 2-5 % [2] | 2-5 % [2] | 2 % [2] |
| Efficiency | 48-63 kWh/kg$H_2$ [1] | 44-53 kWh/kg$H_2$ [1] | 36-43 kWh/kg$H_2$ [1] |
| Efficiency | 53-69 % [1] | 63-76 % [1] | 77-92 % [1] |

[1] Source: FCH-JU
[2] Of CAPEX p.a.
[3] AVL

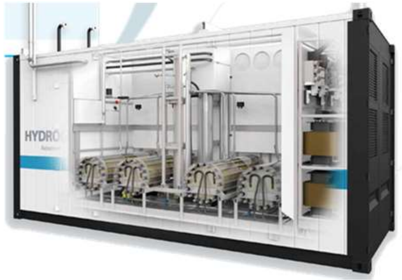
PEM…Polymer Electrolyte Membrane
SOEC…Solid Oxide Electrolysis Cell

**SOEC**



Source: Sunfire

**PEM-EL**



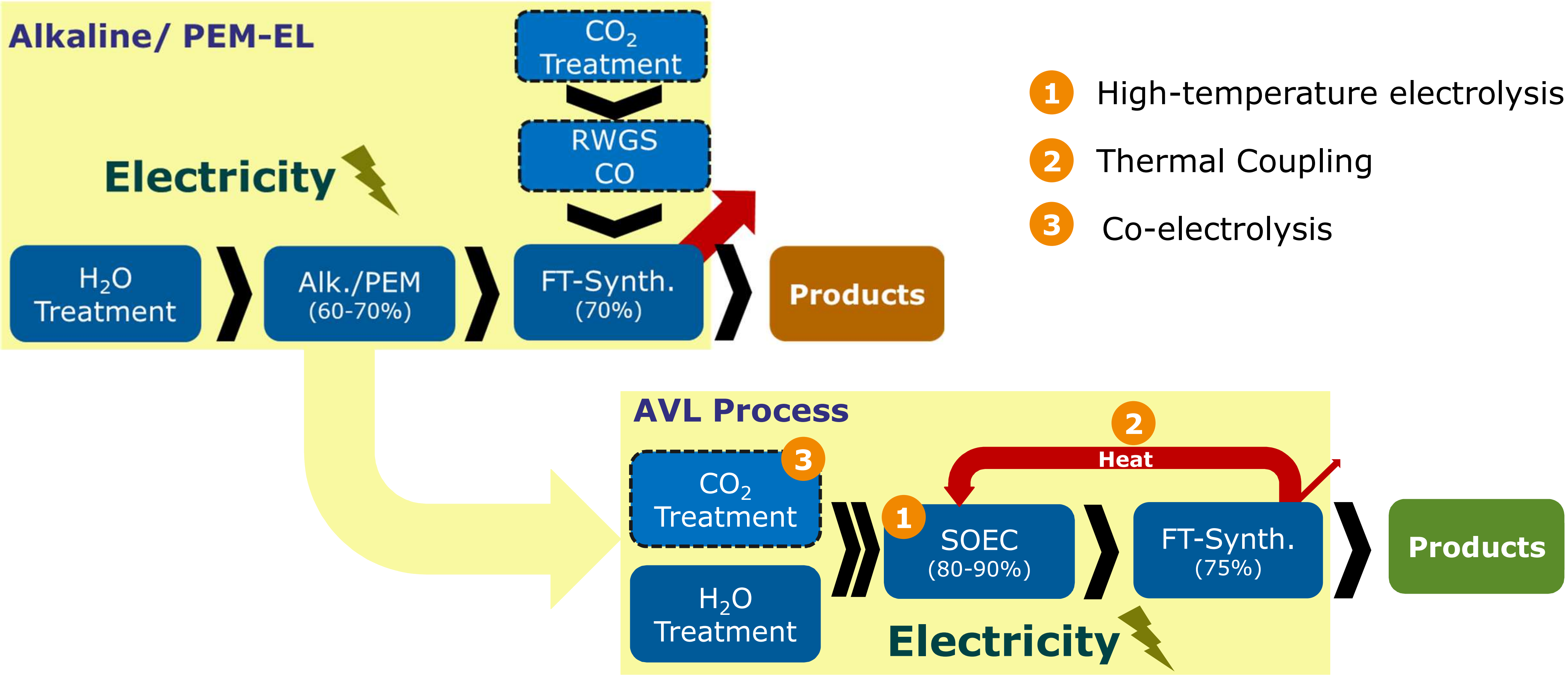
Source: Hydrogenics

**Alkaline**

Source: McPhy

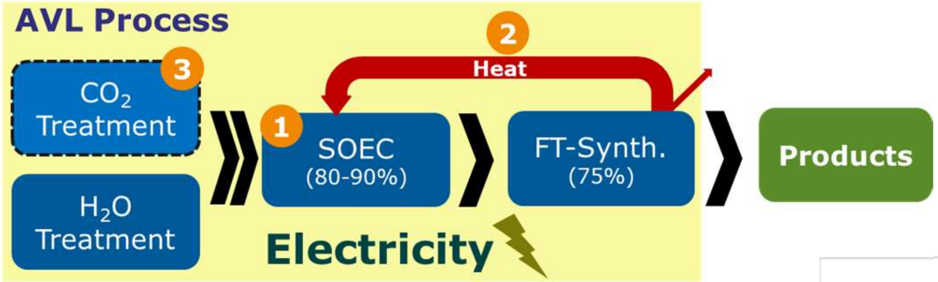
SOEC combines low cost potential with highest efficiencies as a basis for economic e-fuel production

# Innovative Process for eFuel Production



1. High-temperature electrolysis
2. Thermal Coupling
3. Co-electrolysis

# Efficiency Improvement of eFuel Production



**AVL Process**

③ $CO_2$ Treatment

$H_2O$ Treatment

① SOEC (80-90%)

② Heat

FT-Synth. (75%)

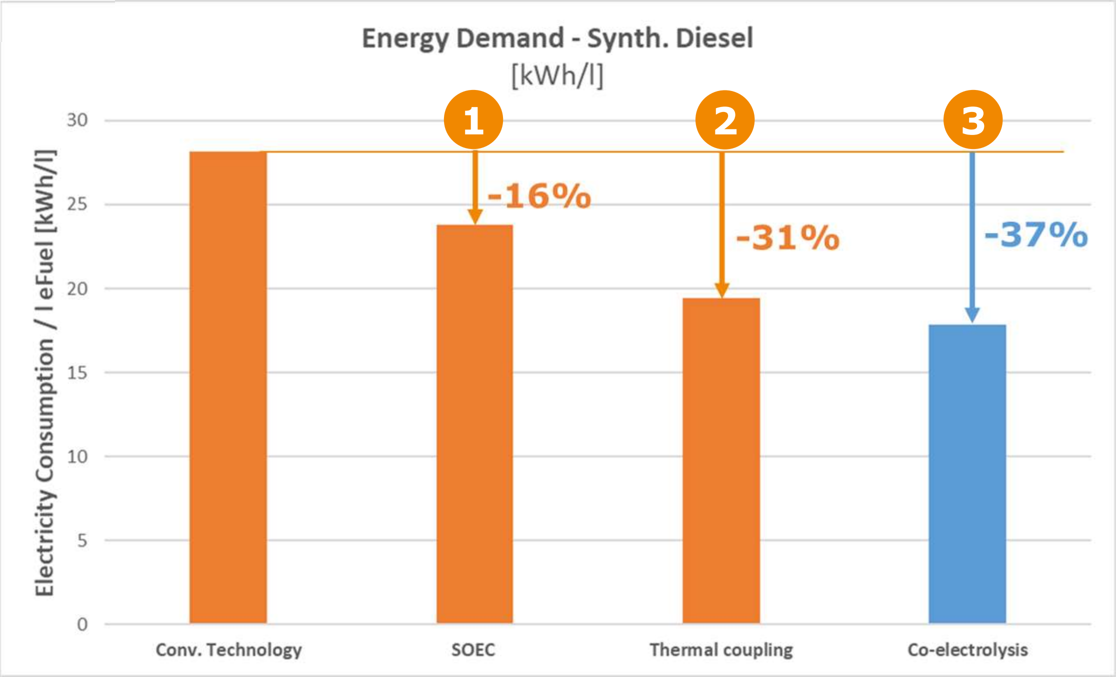
Products

**Electricity**

① High-temperature electrolysis

② Thermal Coupling

③ Co-electrolysis



# Cost Advantages SOEC vs. PEM and Alkaline

**Cost reduction potentials for CAPEX:**

- Cheap catalysts (Nickel), no rare materials & earths used<br>→ **huge cost potentials via scaling effects**
- Co-Electrolysis → direct production of CO to be used in FT
- → **elimination expensive shift reactors of FT**

**Cost reduction potentials for OPEX:**

- Higher operating temperatures
- → **higher efficiency = less electricity required**
- Thermal coupling with industrial & synthesis processes
- → **higher efficiency** due to utilization of waste heat (steam)
- Elimination of FT shift reactors
- → **less electricity** required for reactor heating

Lower system complexity reduces **CAPEX**

+

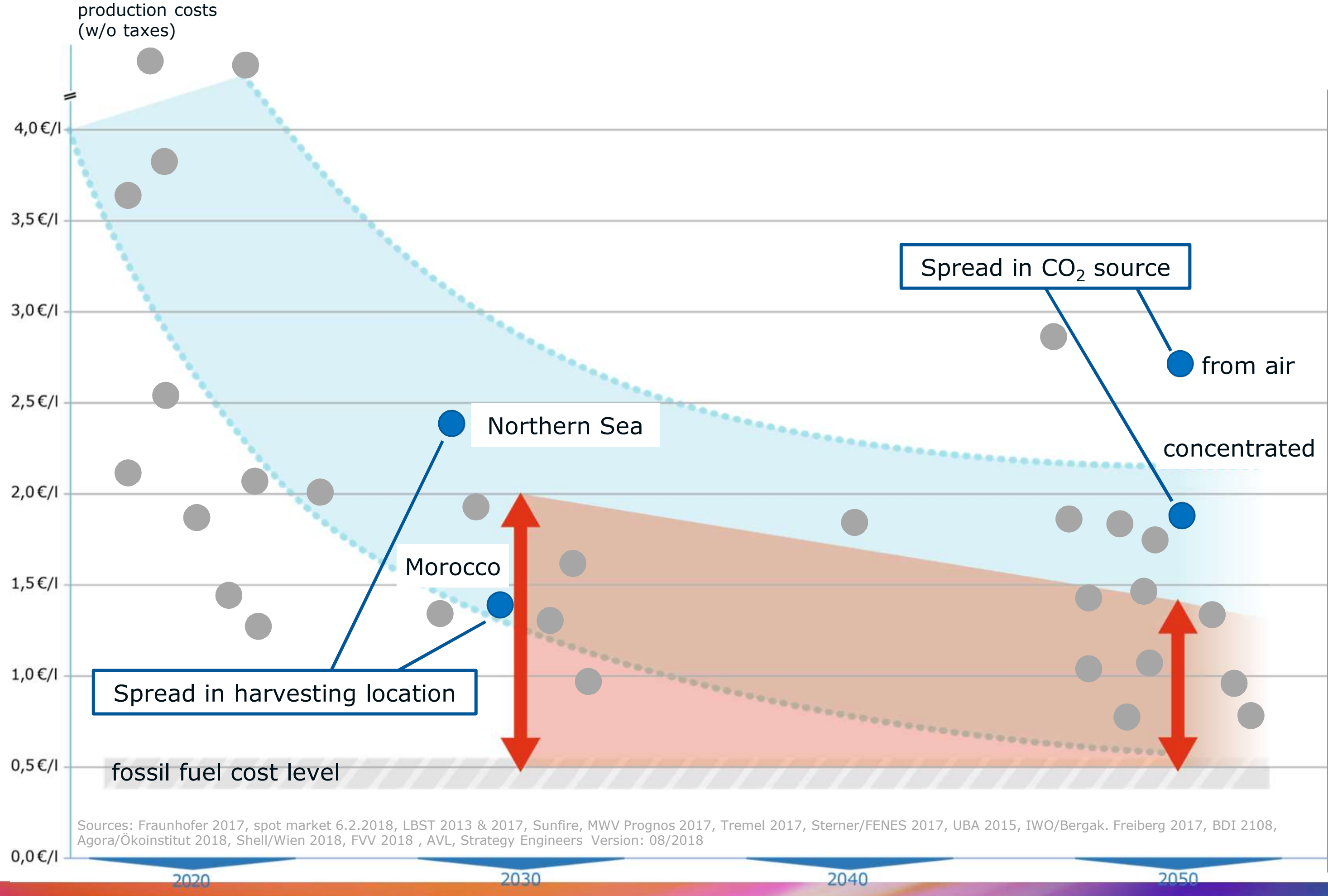
Lower electricity cost reduces **OPEX**

=

**TCO advantage**

Hardware cost and amount of electricity used in the overall process are the main TCO drivers

# Synthetic Fuel Cost Predictions



Sources: Fraunhofer 2017, spot market 6.2.2018, LBST 2013 & 2017, Sunfire, MWV Prognos 2017, Tremel 2017, Sterner/FENES 2017, UBA 2015, IWO/Bergak. Freiberg 2017, BDI 2108, Agora/Ökoinstitut 2018, Shell/Wien 2018, FVV 2018 , AVL, Strategy Engineers Version: 08/2018

Synthetic Fuel (PtL) expected costs compared to today's fossil fuel

2030
x Factor
3-5

2050
x Factor
2-3

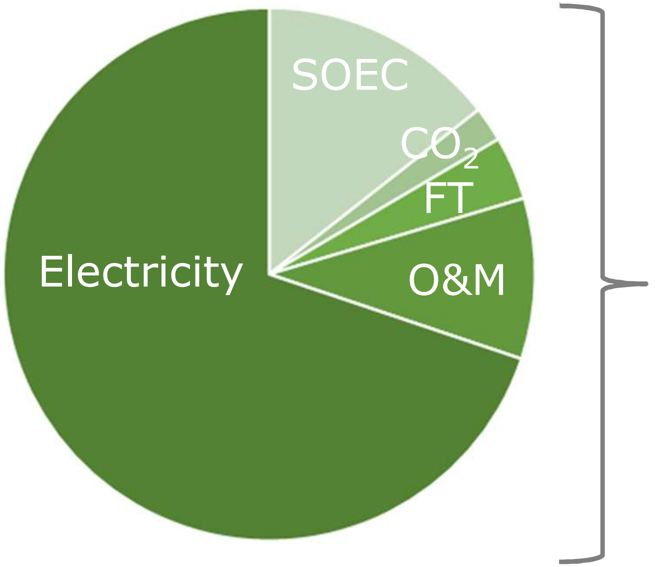
(production costs, w/o taxes)

Proper tax benefits could compensate the cost gap.

# Key Economic Boundary Conditions

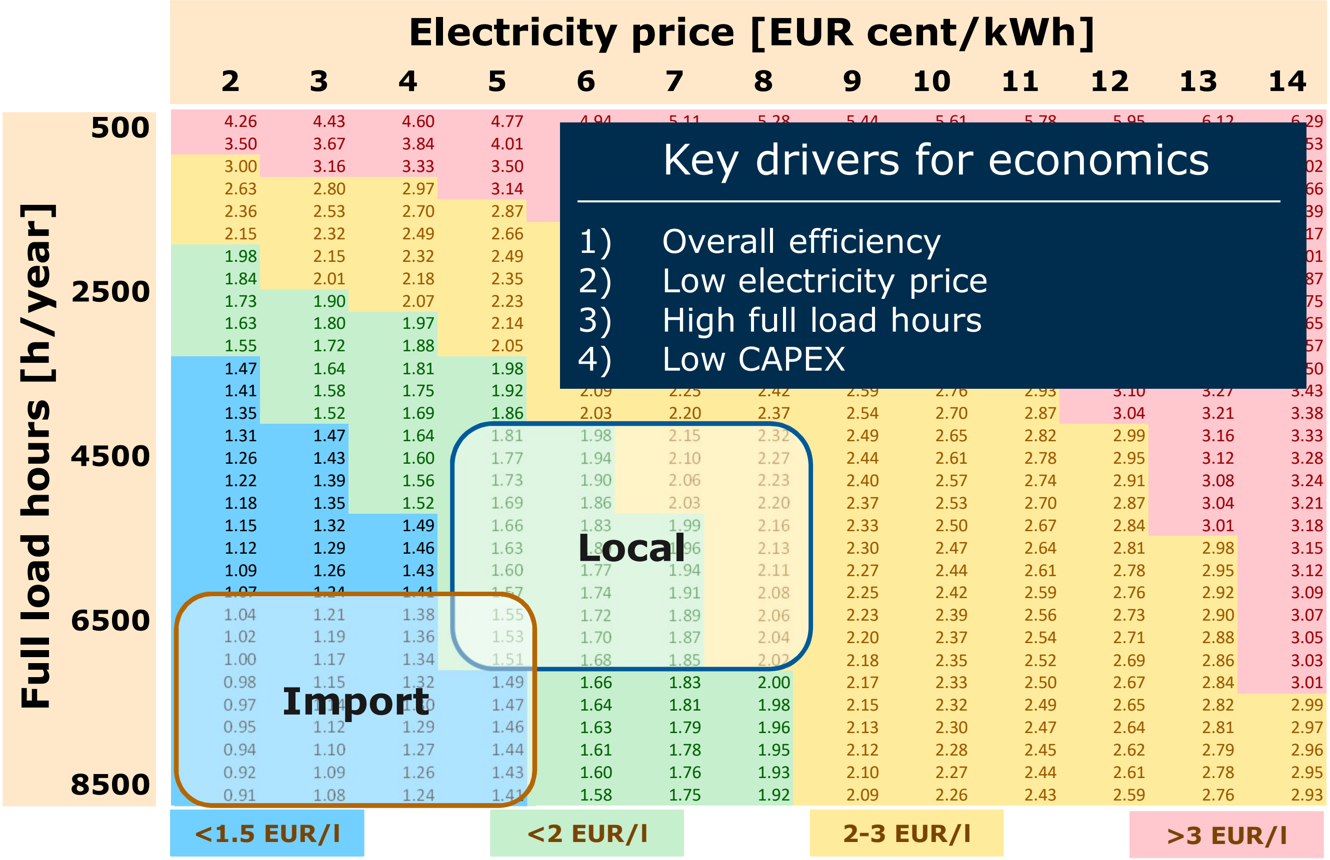
## Solid Oxide Electrolysis with Fischer-Tropsch Synthesis

**Total cost of ownership**



**2 EUR/l**

**@ 8 ct/kWh and 8000 h/year**



**Electricity price [EUR cent/kWh]**

**Full load hours [h/year]**: 500, 2500, 4500, 6500, 8500

| 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 4.26 | 4.43 | 4.60 | 4.77 | 4.94 | 5.11 | 5.28 | 5.44 | 5.61 | 5.78 | 5.95 | 6.12 | 6.29 |
| 3.50 | 3.67 | 3.84 | 4.01 | | | | | | | | | 53 |
| 3.00 | 3.16 | 3.33 | 3.50 | | | | | | | | | 02 |
| 2.63 | 2.80 | 2.97 | 3.14 | | | | | | | | | 66 |
| 2.36 | 2.53 | 2.70 | 2.87 | | | | | | | | | 39 |
| 2.15 | 2.32 | 2.49 | 2.66 | | | | | | | | | 17 |
| 1.98 | 2.15 | 2.32 | 2.49 | | | | | | | | | 01 |
| 1.84 | 2.01 | 2.18 | 2.35 | | | | | | | | | 87 |
| 1.73 | 1.90 | 2.07 | 2.23 | | | | | | | | | 75 |
| 1.63 | 1.80 | 1.97 | 2.14 | | | | | | | | | 65 |
| 1.55 | 1.72 | 1.88 | 2.05 | | | | | | | | | 57 |
| 1.47 | 1.64 | 1.81 | 1.98 | | | | | | | | | 50 |
| 1.41 | 1.58 | 1.75 | 1.92 | 2.09 | 2.25 | 2.42 | 2.59 | 2.76 | 2.93 | 3.10 | 3.27 | 3.43 |
| 1.35 | 1.52 | 1.69 | 1.86 | 2.03 | 2.20 | 2.37 | 2.54 | 2.70 | 2.87 | 3.04 | 3.21 | 3.38 |
| 1.31 | 1.47 | 1.64 | 1.81 | 1.98 | 2.15 | 2.32 | 2.49 | 2.65 | 2.82 | 2.99 | 3.16 | 3.33 |
| 1.26 | 1.43 | 1.60 | 1.77 | 1.94 | 2.10 | 2.27 | 2.44 | 2.61 | 2.78 | 2.95 | 3.12 | 3.28 |
| 1.22 | 1.39 | 1.56 | 1.73 | 1.90 | 2.06 | 2.23 | 2.40 | 2.57 | 2.74 | 2.91 | 3.08 | 3.24 |
| 1.18 | 1.35 | 1.52 | 1.69 | 1.86 | 2.03 | 2.20 | 2.37 | 2.53 | 2.70 | 2.87 | 3.04 | 3.21 |
| 1.15 | 1.32 | 1.49 | 1.66 | 1.83 | 1.99 | 2.16 | 2.33 | 2.50 | 2.67 | 2.84 | 3.01 | 3.18 |
| 1.12 | 1.29 | 1.46 | 1.63 | [illegible] | 1.96 | 2.13 | 2.30 | 2.47 | 2.64 | 2.81 | 2.98 | 3.15 |
| 1.09 | 1.26 | 1.43 | 1.60 | 1.77 | 1.94 | 2.11 | 2.27 | 2.44 | 2.61 | 2.78 | 2.95 | 3.12 |
| 1.07 | 1.24 | 1.41 | 1.57 | 1.74 | 1.91 | 2.08 | 2.25 | 2.42 | 2.59 | 2.76 | 2.92 | 3.09 |
| 1.04 | 1.21 | 1.38 | 1.55 | 1.72 | 1.89 | 2.06 | 2.23 | 2.39 | 2.56 | 2.73 | 2.90 | 3.07 |
| 1.02 | 1.19 | 1.36 | 1.53 | 1.70 | 1.87 | 2.04 | 2.20 | 2.37 | 2.54 | 2.71 | 2.88 | 3.05 |
| 1.00 | 1.17 | 1.34 | 1.51 | 1.68 | 1.85 | 2.02 | 2.18 | 2.35 | 2.52 | 2.69 | 2.86 | 3.03 |
| 0.98 | 1.15 | 1.32 | 1.49 | 1.66 | 1.83 | 2.00 | 2.17 | 2.33 | 2.50 | 2.67 | 2.84 | 3.01 |
| 0.97 | 1.14 | 1.30 | 1.47 | 1.64 | 1.81 | 1.98 | 2.15 | 2.32 | 2.49 | 2.65 | 2.82 | 2.99 |
| 0.95 | 1.12 | 1.29 | 1.46 | 1.63 | 1.79 | 1.96 | 2.13 | 2.30 | 2.47 | 2.64 | 2.81 | 2.97 |
| 0.94 | 1.10 | 1.27 | 1.44 | 1.61 | 1.78 | 1.95 | 2.12 | 2.28 | 2.45 | 2.62 | 2.79 | 2.96 |
| 0.92 | 1.09 | 1.26 | 1.43 | 1.60 | 1.76 | 1.93 | 2.10 | 2.27 | 2.44 | 2.61 | 2.78 | 2.95 |
| 0.91 | 1.08 | 1.24 | 1.41 | 1.58 | 1.75 | 1.92 | 2.09 | 2.26 | 2.43 | 2.59 | 2.76 | 2.93 |

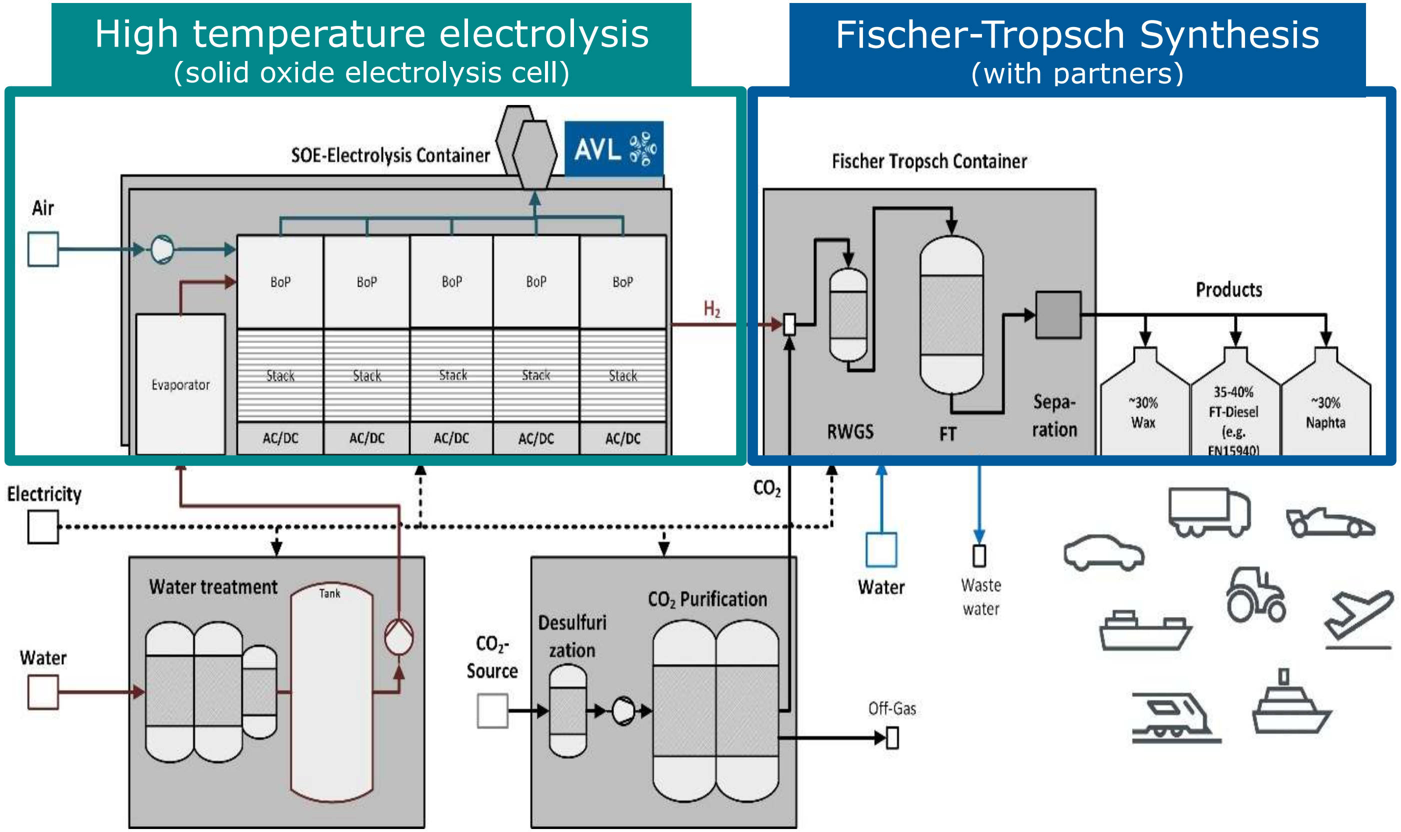
**<1.5 EUR/l** **<2 EUR/l** **2-3 EUR/l** **>3 EUR/l**

Key drivers for economics

1) Overall efficiency
2) Low electricity price
3) High full load hours
4) Low CAPEX

Source: own calculations

# Power-to-Liquid Demonstration Plant

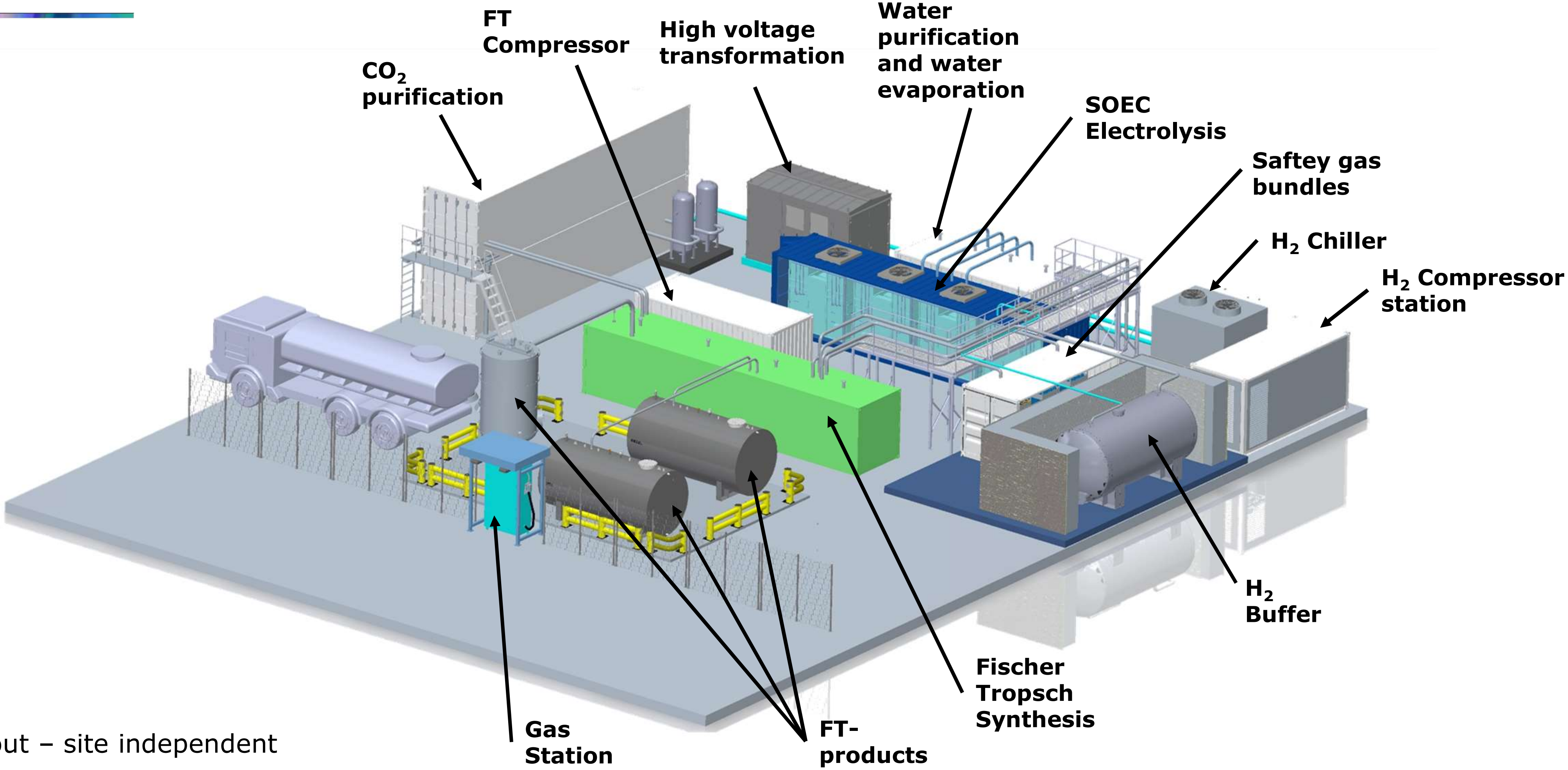


High temperature electrolysis
(solid oxide electrolysis cell)

Fischer-Tropsch Synthesis
(with partners)

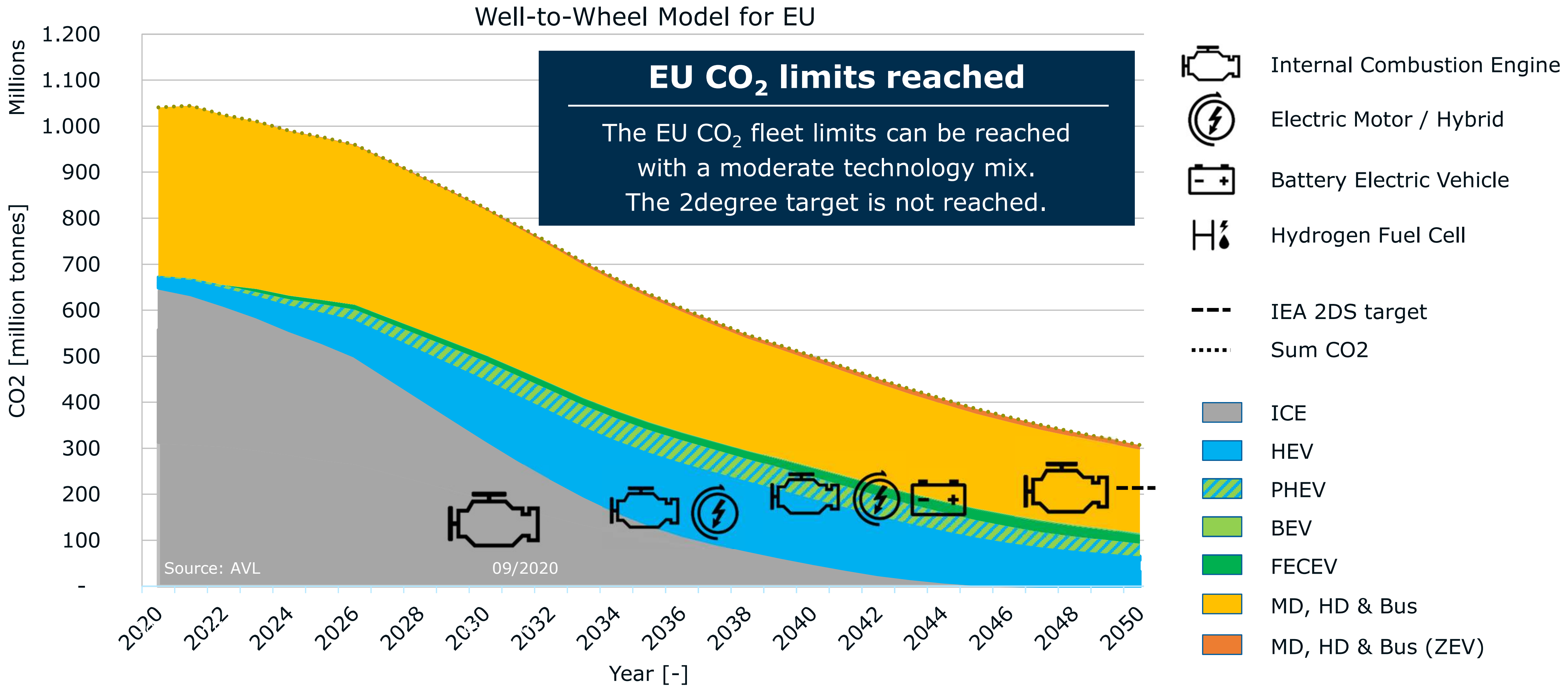
- $1MW_{el}$ renewable electricity
- Production per year:
  - Diesel: 160.000 L
  - Wax: 150.000 L
  - Naphta: 150.000 L
- Status:
  - Technology development of SOEC/synthesis process
  - Site selection
- Start of operation in early 2023

# 1MW Power-to-Liquid Demonstration Plant



Plant layout – site independent

# Scenario 1 – Average EU
# Well-to-Wheel Model – EU28



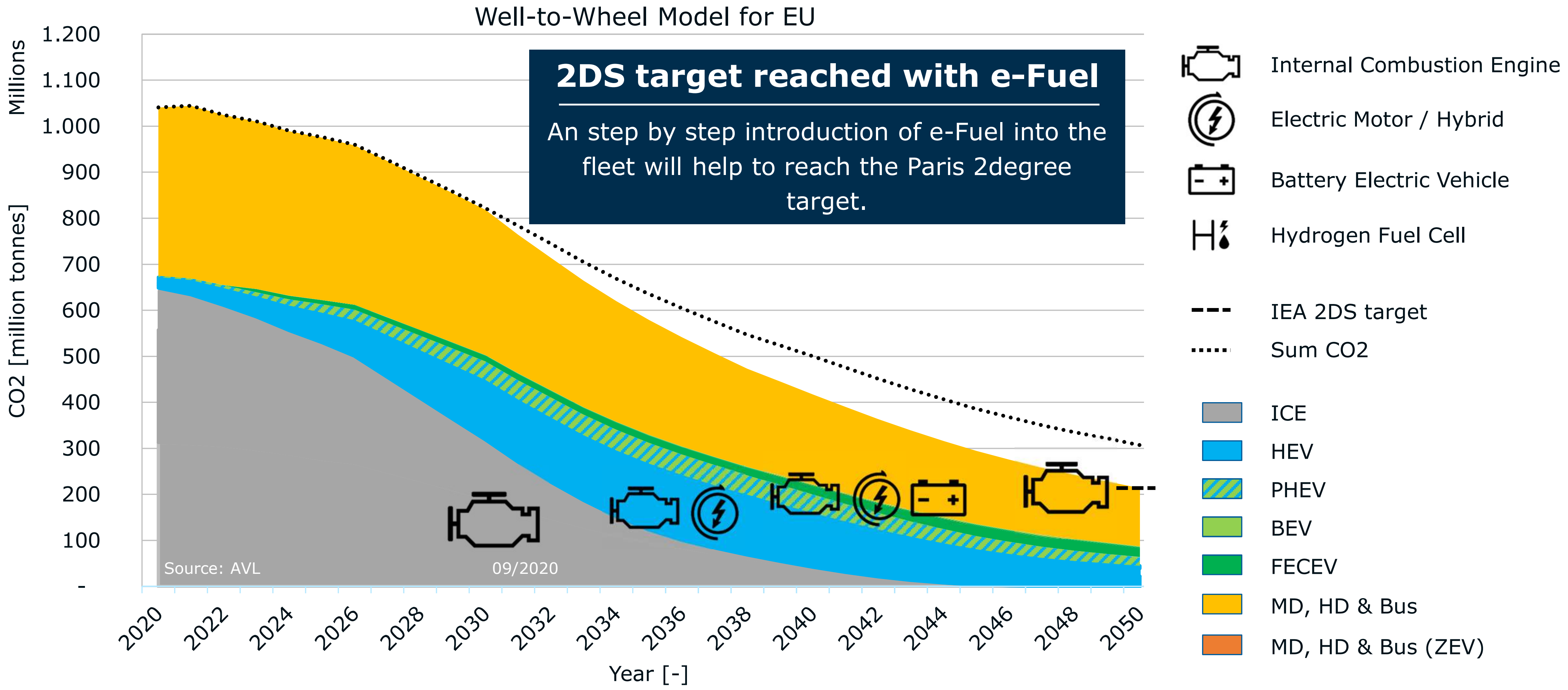
**EU $CO_2$ limits reached**

The EU $CO_2$ fleet limits can be reached with a moderate technology mix. The 2degree target is not reached.

Source: AVL

09/2020

# Scenario 2 – 2DS with e-Fuels
# WTW Model – EU28



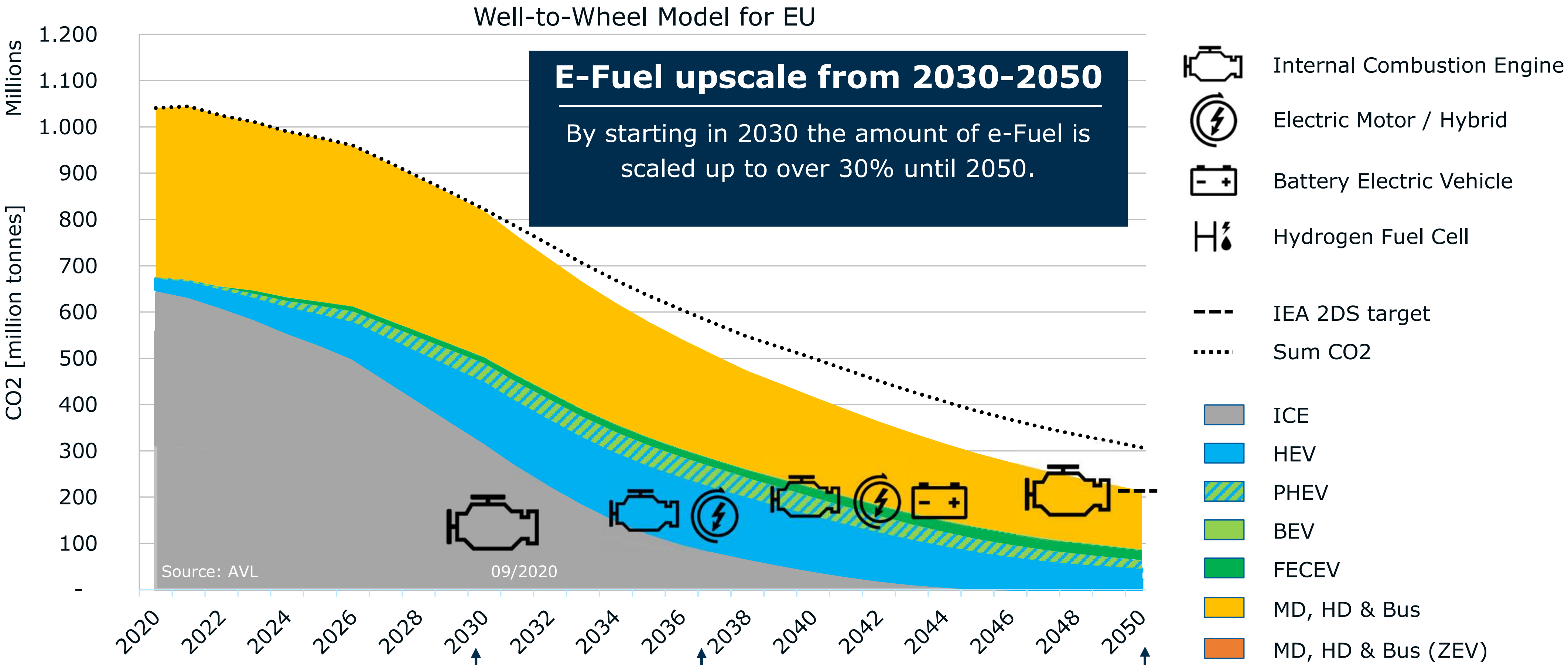
**2DS target reached with e-Fuel**

An step by step introduction of e-Fuel into the fleet will help to reach the Paris 2degree target.

Source: AVL

09/2020

# Scenario 2 – 2DS with e-Fuels
# WTW Model – EU28



**E-Fuel upscale from 2030-2050**

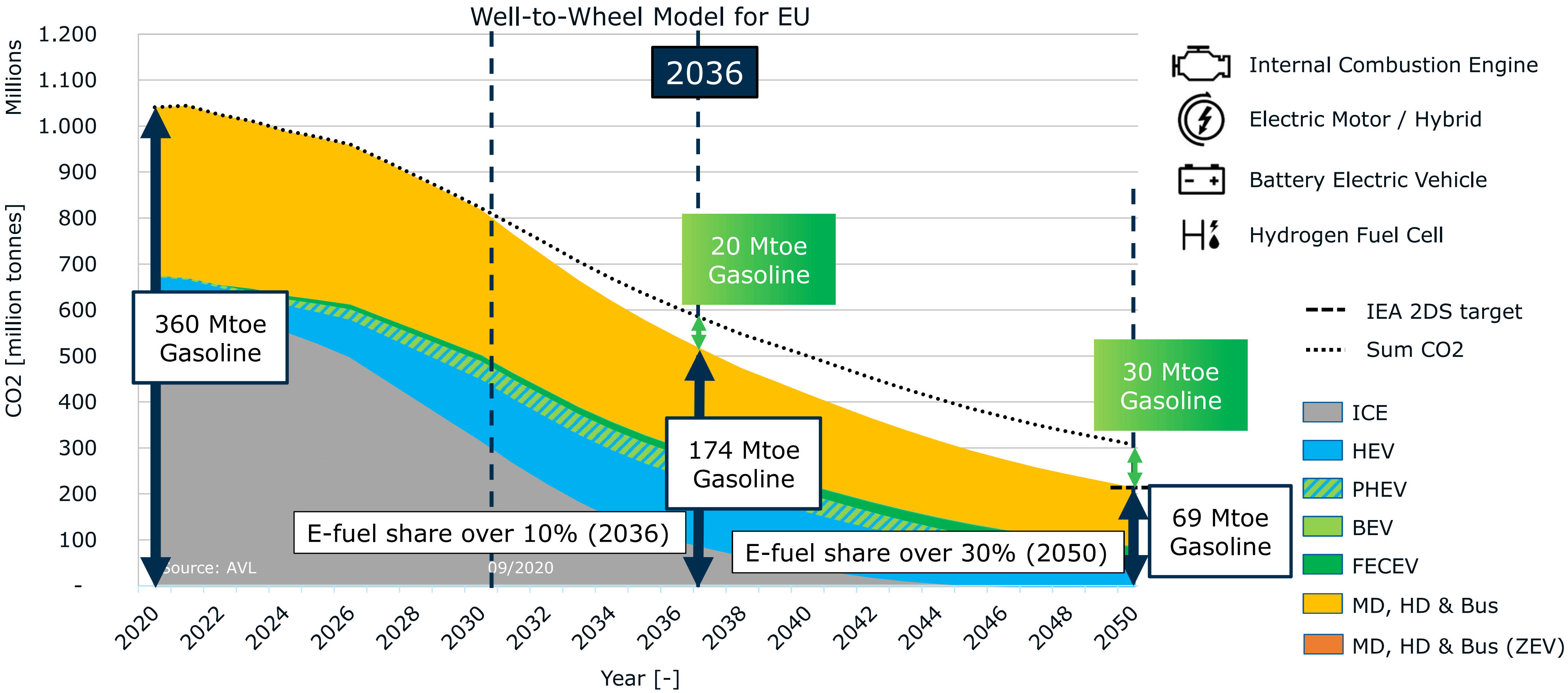
By starting in 2030 the amount of e-Fuel is scaled up to over 30% until 2050.

Start phase in of e-Fuel

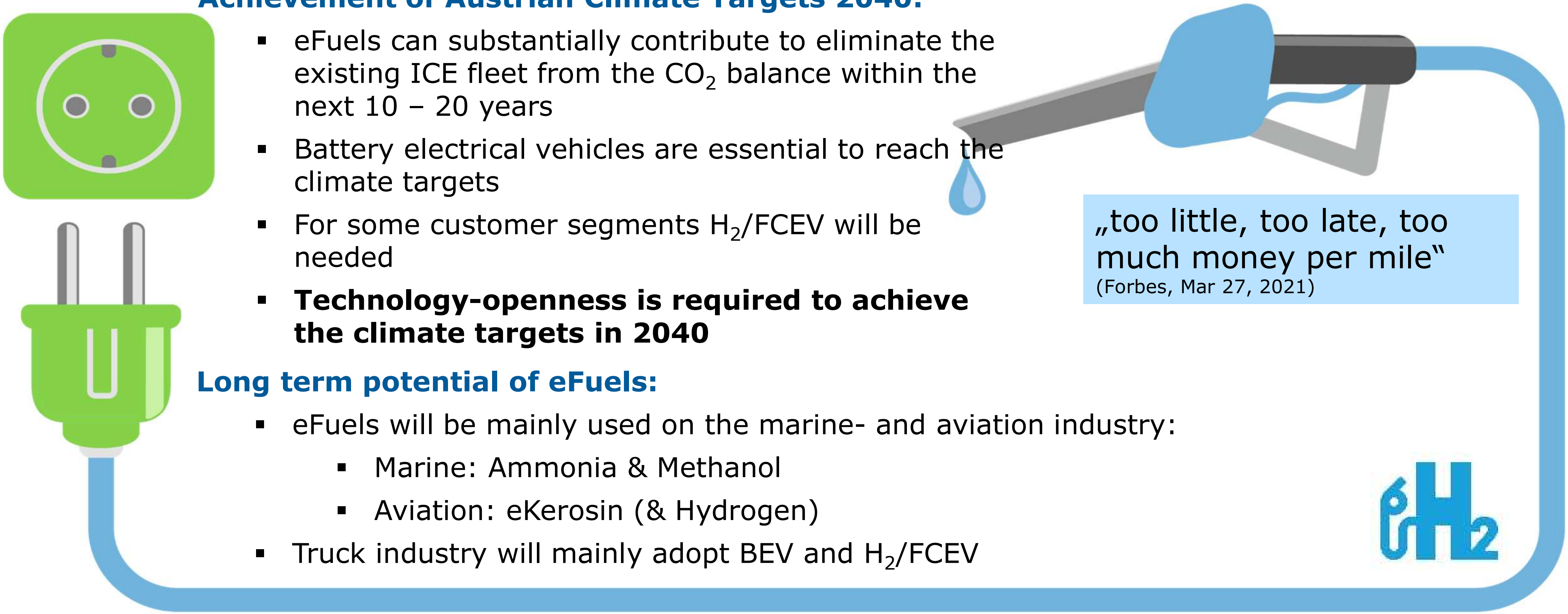
e-Fuel share over 10%

e-Fuel share 31%

# Scenario 2 – 2DS with e-Fuels
# WTW Model – EU28



# Future Potential of eFuels



## Achievement of Austrian Climate Targets 2040:

- eFuels can substantially contribute to eliminate the existing ICE fleet from the $CO_2$ balance within the next 10 – 20 years
- Battery electrical vehicles are essential to reach the climate targets
- For some customer segments $H_2$/FCEV will be needed
- **Technology-openness is required to achieve the climate targets in 2040**

## Long term potential of eFuels:

- eFuels will be mainly used on the marine- and aviation industry:
  - Marine: Ammonia & Methanol
  - Aviation: eKerosin (& Hydrogen)
- Truck industry will mainly adopt BEV and $H_2$/FCEV

„too little, too late, too much money per mile“
(Forbes, Mar 27, 2021)

# Thank you

AVL

www.avl.com