Lösungsansatz auf dem Weg zu 100% grüner Energie

25. Februar 2025

Prof. Robert Fischer

Agenda

Overview AVL List GmbH

Solution approach on the way to 100 % green energy

AVL

>12,000
Employees Worldwide

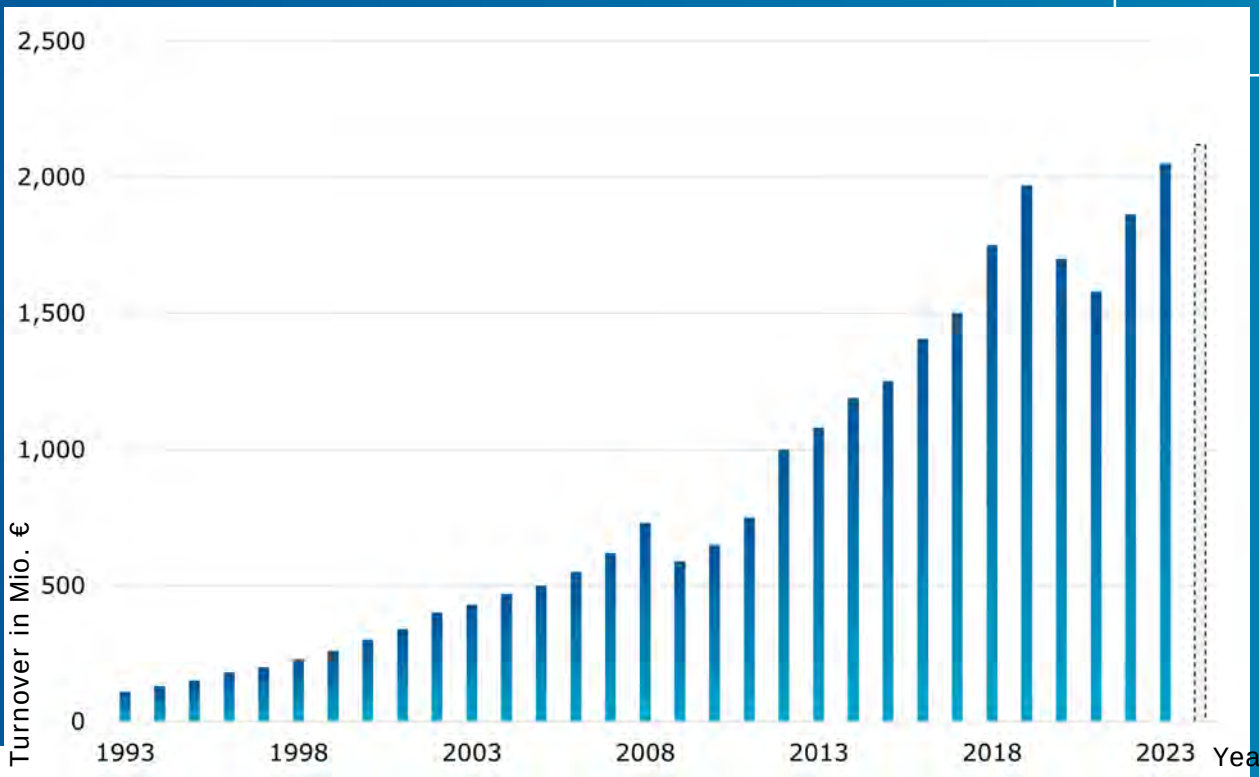
68%
Engineers and Scientists

26
Countries Represented

45
Global Tech and Engineering Centers

10%
Of Turnover Invested in In-house R&D

2,200
Granted Patents in Force



Customer Segments and Business Areas

Passenger Cars

2-Wheelers

Racing

Construction

Agriculture

Commercial Vehicle

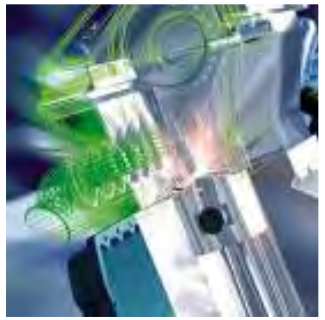
Locomotive

Marine

Power Plants

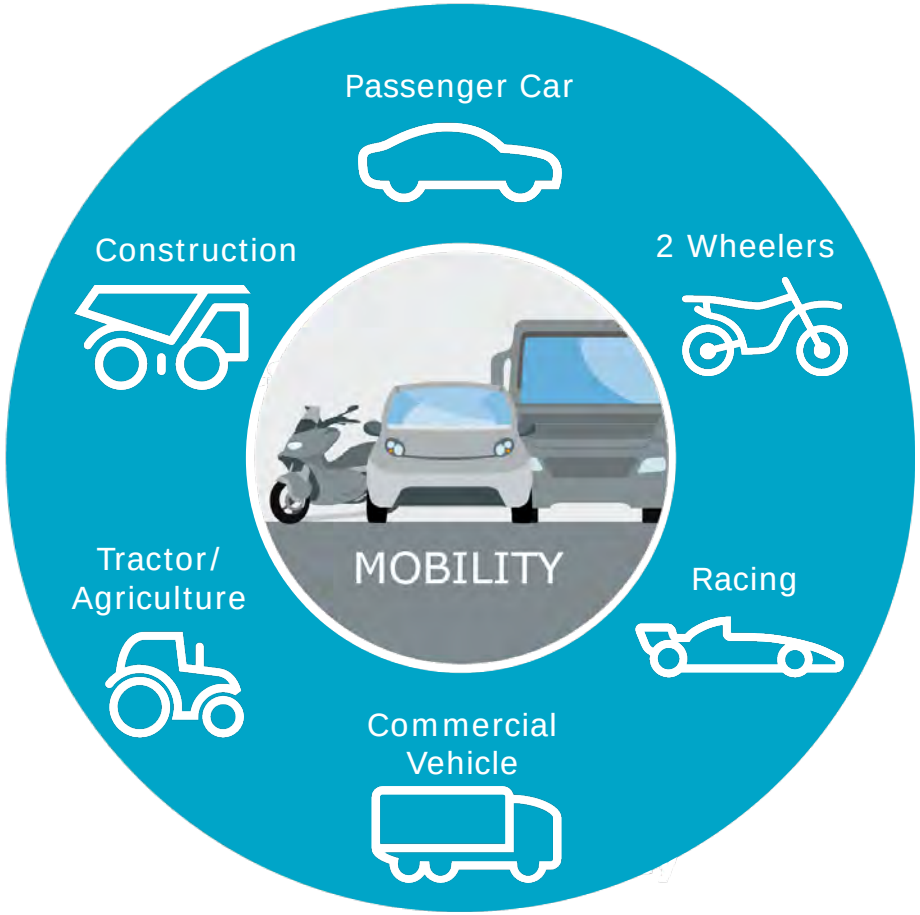
Engineering

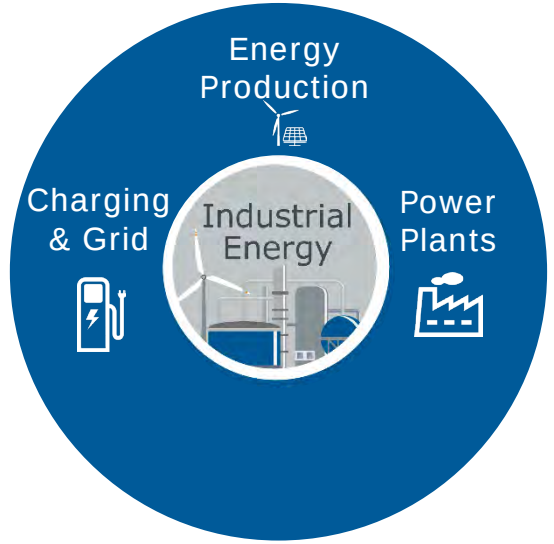
Development Platform



Simulation & Testing

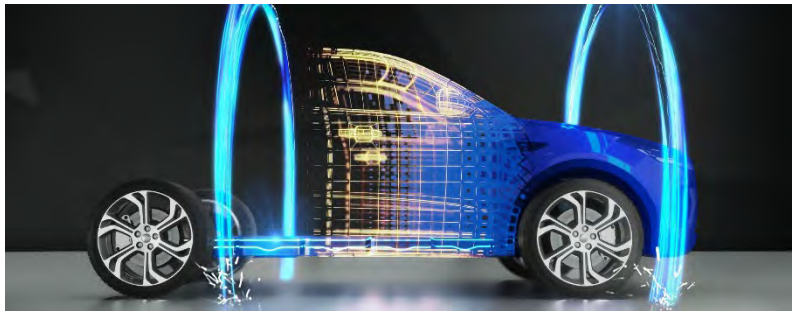
AVL Engineering & Technology Focus Areas





Looking Beyond the Limits of Technology

ELECTRIFICATION



ADAS AND AUTONOMOUS DRIVING

ZERO-IMPACT EMISSION

VEHICLE ENGINEERING

DATA INTELLIGENCE

Digital Intelligence @ AVL Operations

Data Provision Tools
(e.g Data Lake, UUT-ID,...)

Digitial Intelligence
e.g. DoE, AI, Machine Learning, Data Science, workflow optimization, LLMs, Toolboxes, Scripts, ...

Data Analytics & IT
- Analytics methods
- Analytics process
- Analytics tools

Data Organization
- Data structure / source
- Data management
- Data acquisition

→ Analytics ready

Domain Knowledge
- Product knowledge
- Product process knowledge (PEP)
- Execution knowledge

Engineering-IT:
DVP Tool, PDM, PLM, JIRA,...

Events & KPIs:
(e.g. testcases, toolbox)

Product necessary data
(e.g file contract)

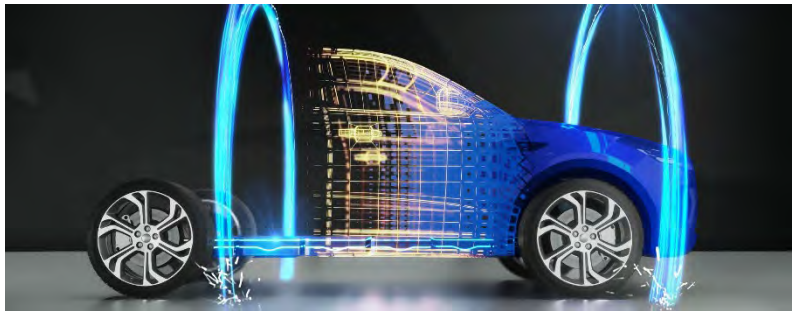
AVL

Microsoft

AVL combines its extensive expertise in the area of automotive development with Microsoft's innovative cloud and AI technology and AVL Data Analytics™

Looking Beyond the Limits of Technology

ELECTRIFICATION



ADAS AND AUTONOMOUS DRIVING

ZERO-IMPACT EMISSION

VEHICLE ENGINEERING

DATA INTELLIGENCE

E-Mobility - Highlights

Battery Innovation Center

Our center of excellence at our headquarters in Graz focuses on the development, implementation and validation of new, highly efficient battery production processes.

Hydrogen and Fuel Cell Test Center

The new center in Graz is one of the largest and most advanced test sites for fuel cells and electrolysis systems in the world.

AVL has more than 20 years of experience in Fuel Cell Engineering

SOFC APU
Development
(2002 - ongiong)

SOFC CHP
Development
(2010 - ongoing)

H2O ELECTROLYSIS
Development
(2013-2016)

Renewable electricity
integrated rSOC
(2016-2024)

Co-SOEC + Methanation
Development
(2018-2023)

Power to eFuel
eFuel and SAF
(2021-2026)

Hydrogen Production
SOEC Development
(2022-2026)

2002 2010 2013 2016 2018 2021 2022 2024

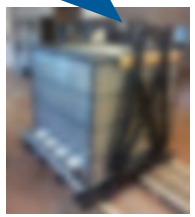
SOFC Engineering

SOEC Engineering

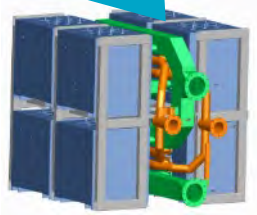
<5 kW

<20 kW

<200 kW



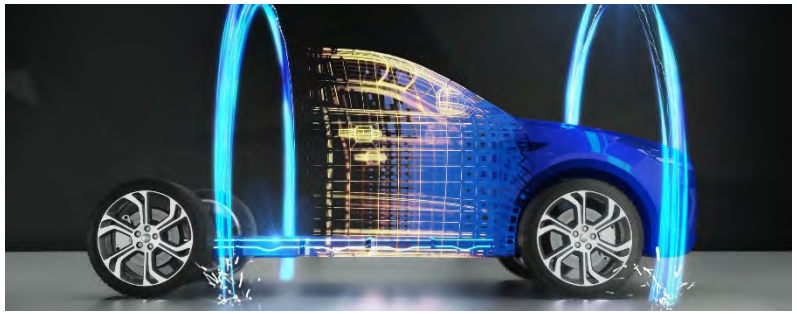
200 kW – 1 MW



1 MW – 100 MW

Looking Beyond the Limits of Technology

ELECTRIFICATION



ADAS AND AUTONOMOUS DRIVING

ZERO-IMPACT EMISSION

VEHICLE ENGINEERING

DATA INTELLIGENCE

AVL ZalaZONE

AVL (60%) : APZ (40%)

Joint venture

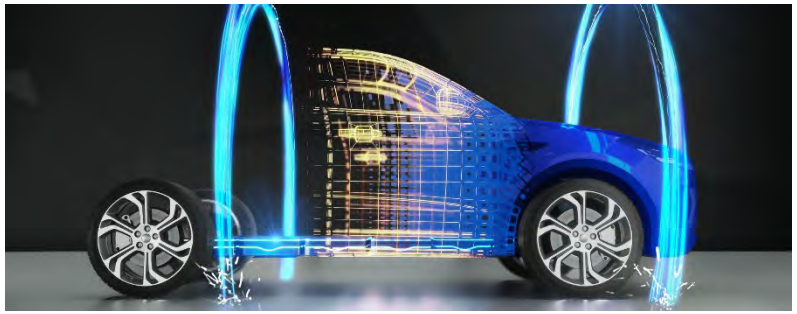
- 250-hectar specifically designed for development and validation tests of autonomous and electric vehicles:
- The smart city allows numerous traffic, technical (NCAP/GSR/V2X), and dynamic test scenarios.

PROVING GROUND

SMART CITY

Looking Beyond the Limits of Technology

ELECTRIFICATION



ADAS AND AUTONOMOUS DRIVING

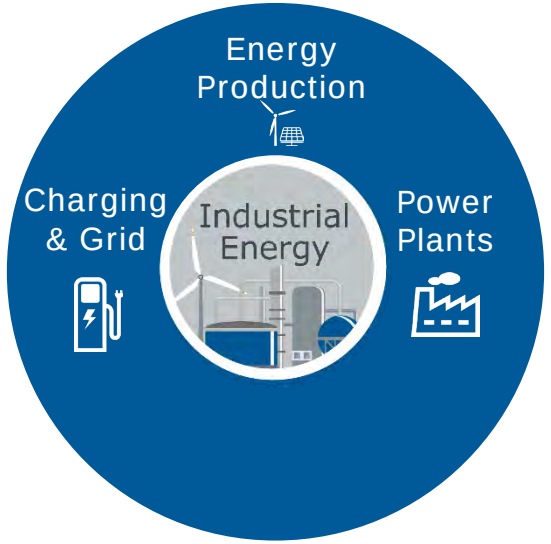
ZERO-IMPACT EMISSION

VEHICLE ENGINEERING

DATA INTELLIGENCE

AVL Engineering & Technology Focus Areas

Aviation




INTUITIVE MACHINES
... supporting beyond earth
MOON RACER
AVL
BOEING
MICHELIN
NORTHROP GRUMMAN

AVL Powertrain – a Network of Technical Centers





HQ Graz/**AUT** Steyr/**AUT** Graz/**AUT**





Paris/**FRA** Reggio Emilia/**ITA** Budapest/**HUN** Istanbul/**TUR**

EUROPE

Austria*
France
Italy
Hungary
Turkey
Germany
Spain
Sweden
Great Britain
Slovenia
Croatia





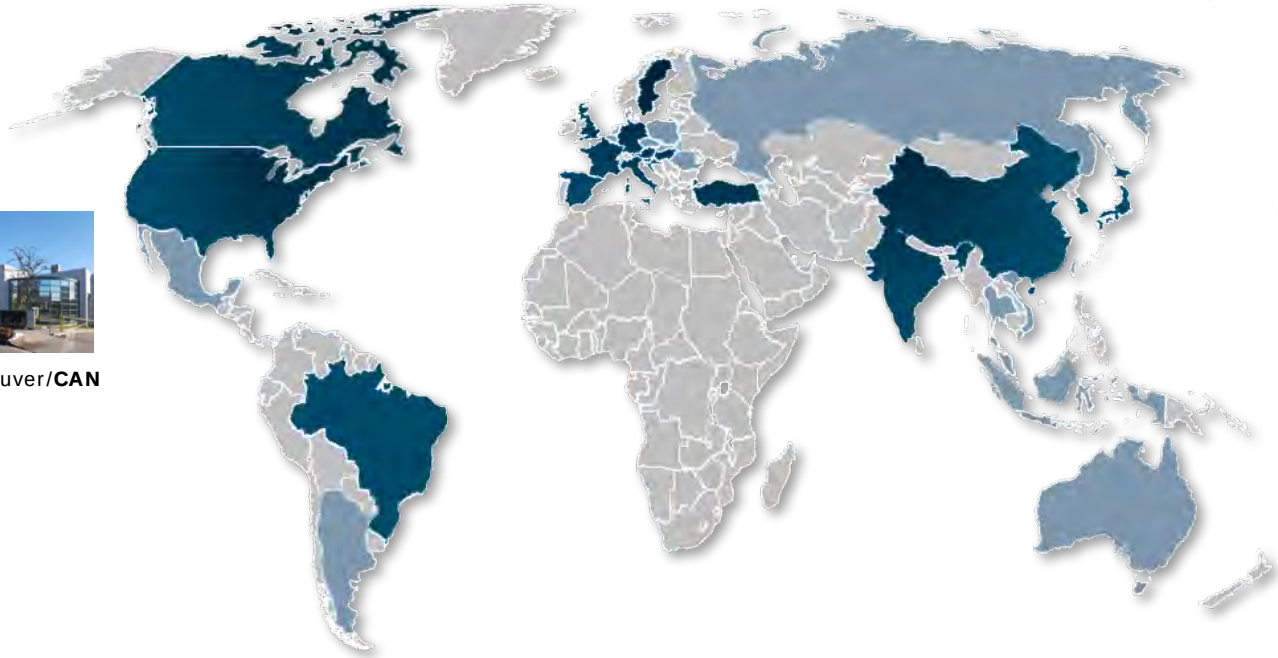


Stuttgart/**GER** Munich/**GER** Ingolstadt/**GER** Regensburg/**GER** Remscheid/**GER** Neuenstadt/**GER**






Basildon/**UK** Coventry/**UK** Södertälje/**SWE** Haninge/**SWE** Gotenborg/**SWE**



NORTH AMERICA / CANADA
USA
CANADA



Plymouth/**USA** Lake Forest/**USA** Ann Arbor/**USA** Vancouver/**CAN**


Sao Paulo/**BRA**

SOUTH AMERICA
Brazil




Delhi-Gurgaon/**IND** Shanghai/**CHN** Lingang/**CHN** Tianjin/**CHN** Chengdu/**CHN**

ASIA
China
India
Japan
Korea



Seoul/**KOR** Tokyo/**JPN**

+ 15 Engineering Offices
+ 6 Sales Offices
~ 5 Resident Offices

Agenda

Overview AVL List GmbH

Solution approach on the way to 100 % green energy

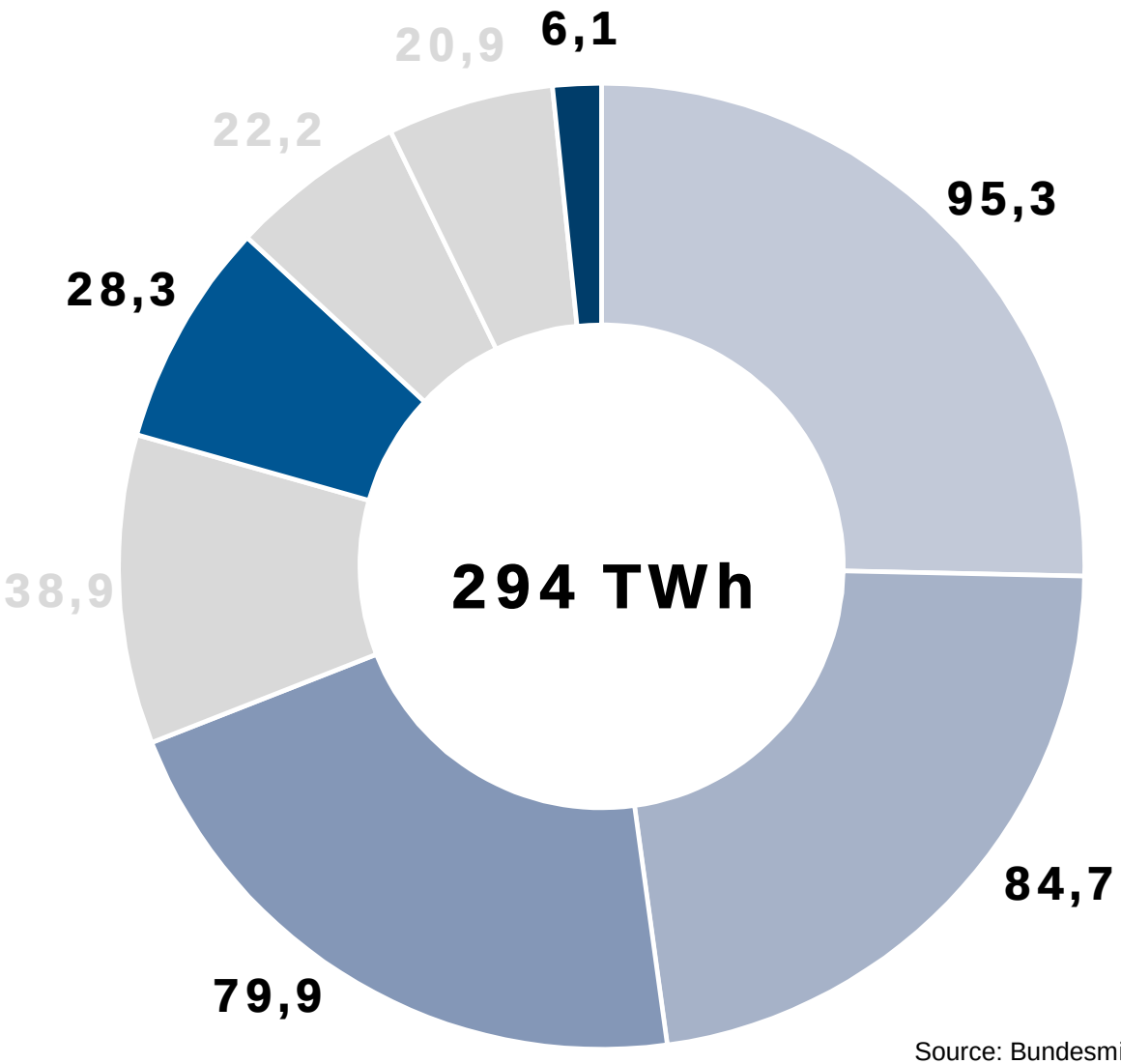
Solution approach on the way to 100% green energy

Austrian energy demand

Options for energy import

SOEC Power-to-Liquid

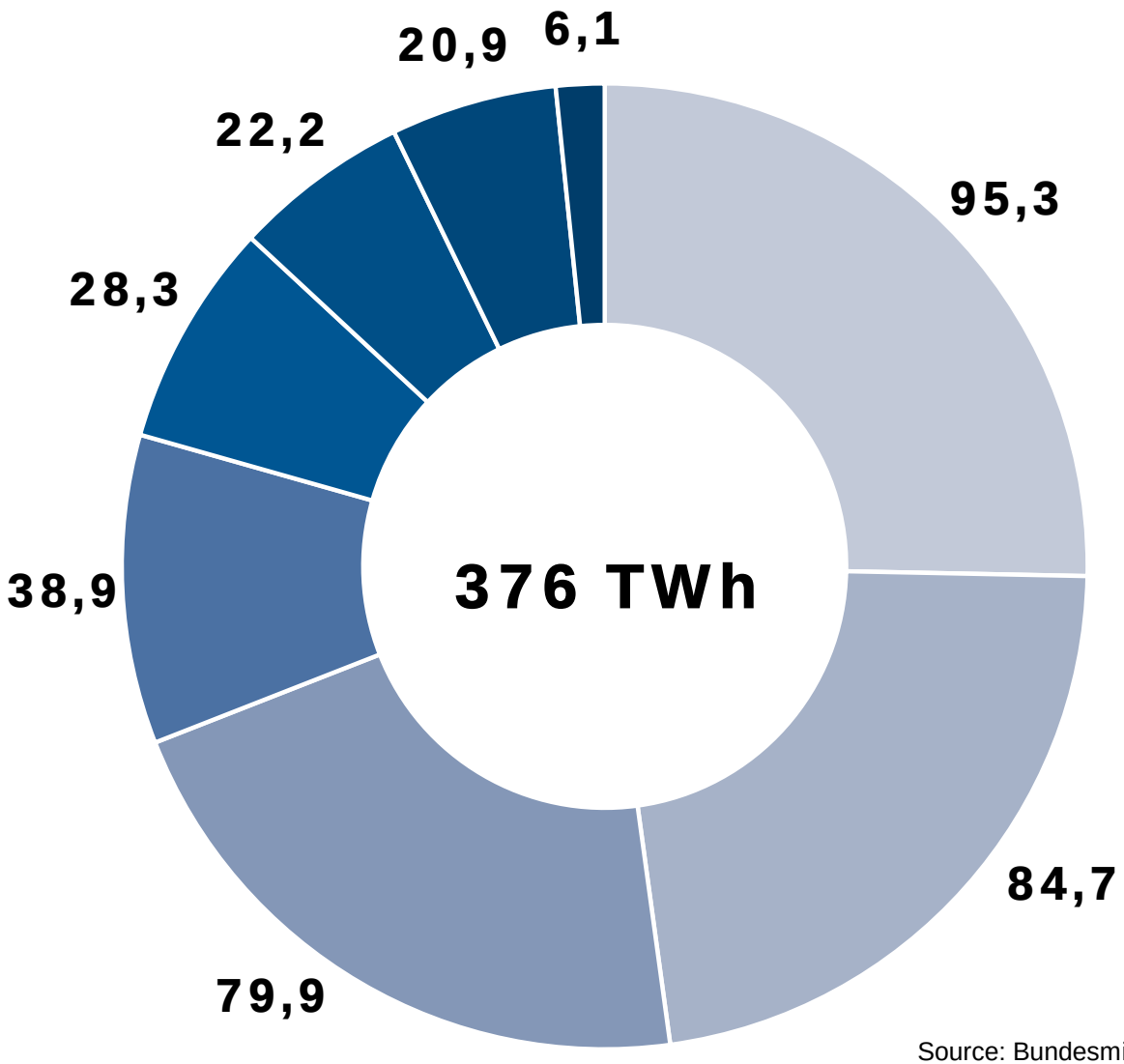
Energetic end consumer [TWh] Austria 2022



- traffic
- manufacturing sector
- private households
- consumption of the sectors
- services
- transformation losses
- non-energy consumption
- agriculture

Source: Bundesministerium für Klimaschutz, Umwelt, Energie, Mobilität, Innovation und Technologie (BMK), Energie in Österreich, 2023

Energetic GROSS end consumer [TWh] Austria 2022



- traffic
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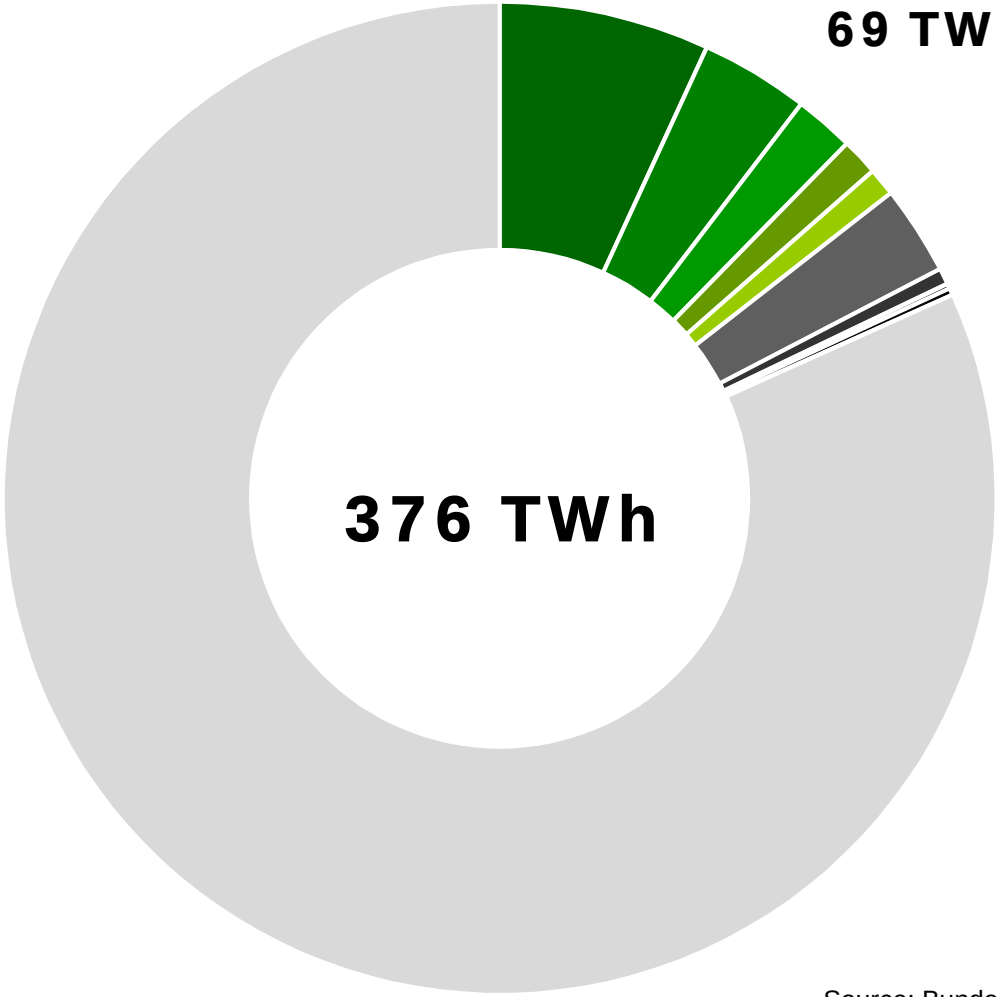
Source: Bundesministerium für Klimaschutz, Umwelt, Energie, Mobilität, Innovation und Technologie (BMK), Energie in Österreich, 2023

Share of electricity of energetic GROSS end consumer [TWh] Austria 2022



- power plant
- storage power station
- wind
- biogenic energy
- photovoltaics
- natural gas
- coal gas
- oil
- other/combustible waste

Source: Bundesministerium für Klimaschutz, Umwelt, Energie, Mobilität, Innovation und Technologie (BMK), Energie in Österreich, 2023

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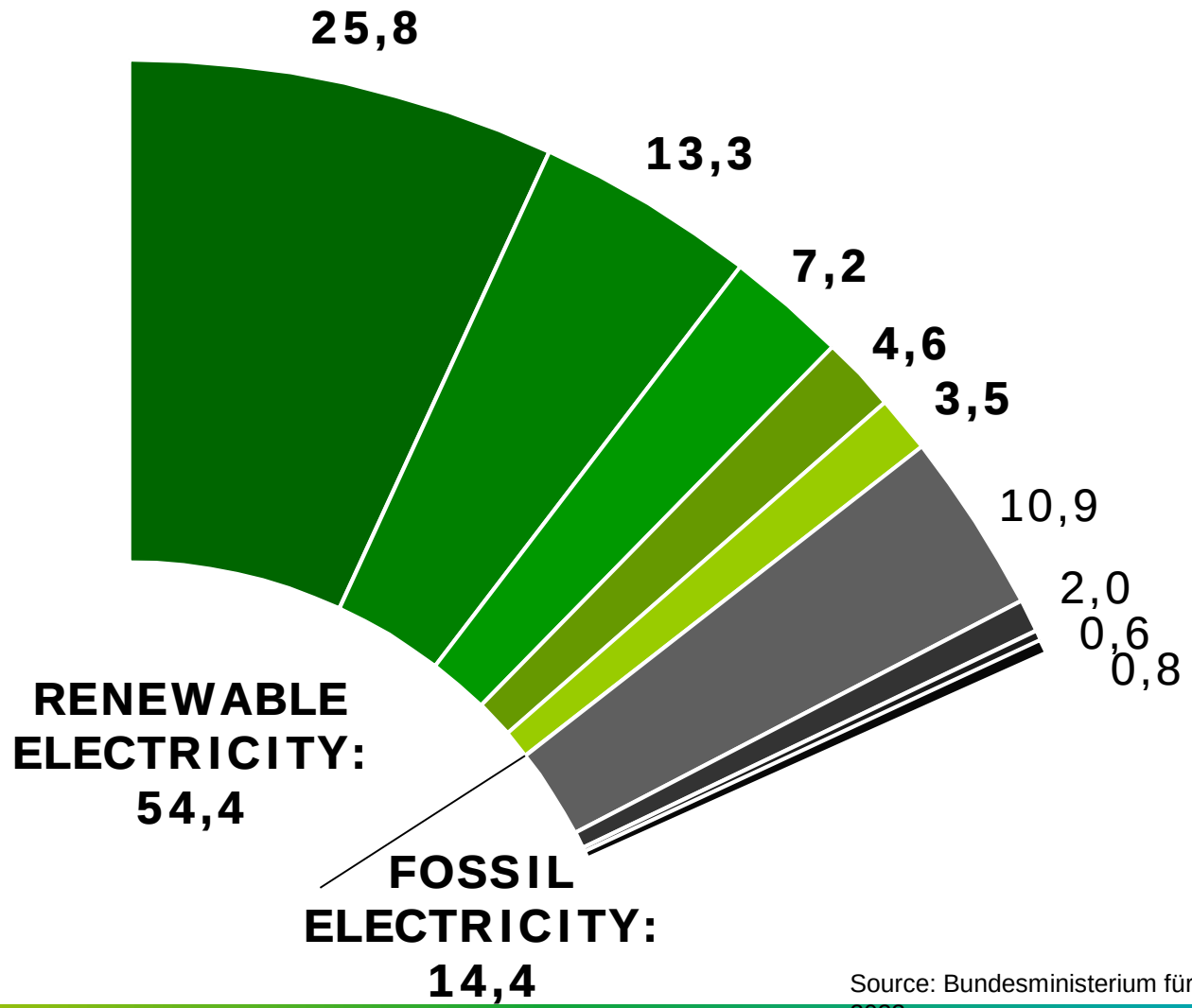

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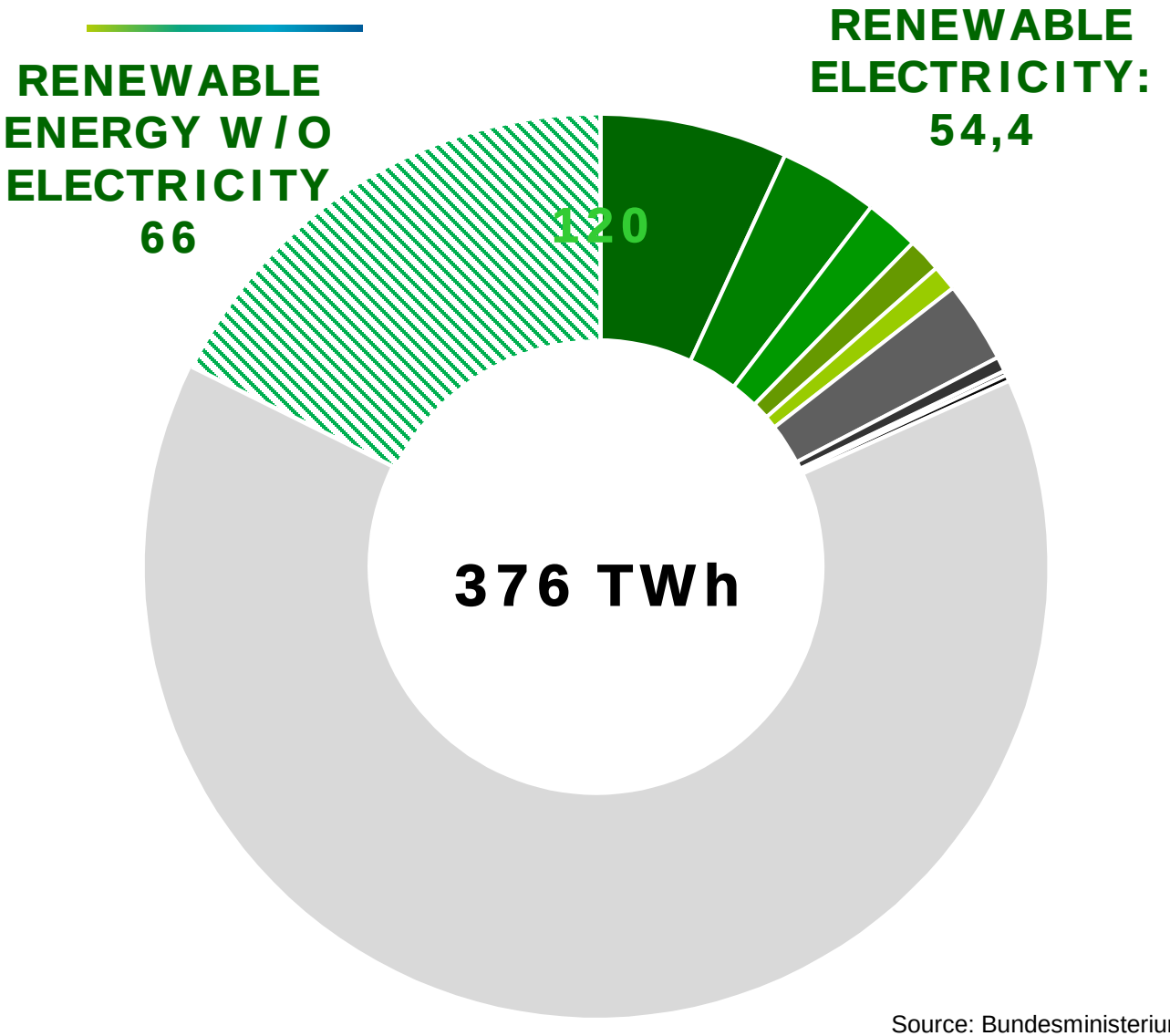

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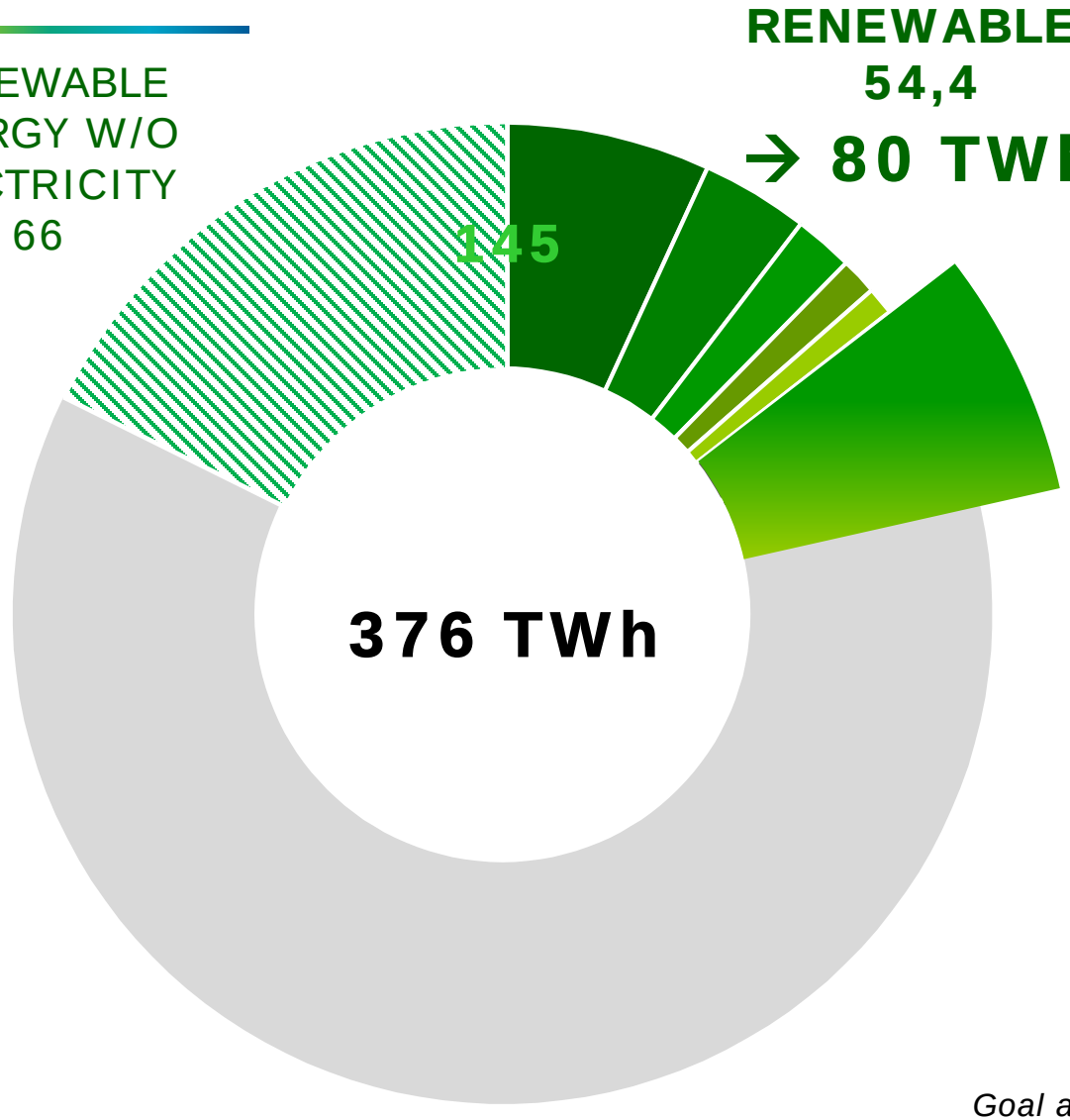
Source: Bundesministerium für Klimaschutz, Umwelt, Energie, Mobilität, Innovation und Technologie (BMK), Energie in Österreich, 2023

Share of electricity of energetic GROSS end consumer [TWh] Austria **2030**



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- coal gas
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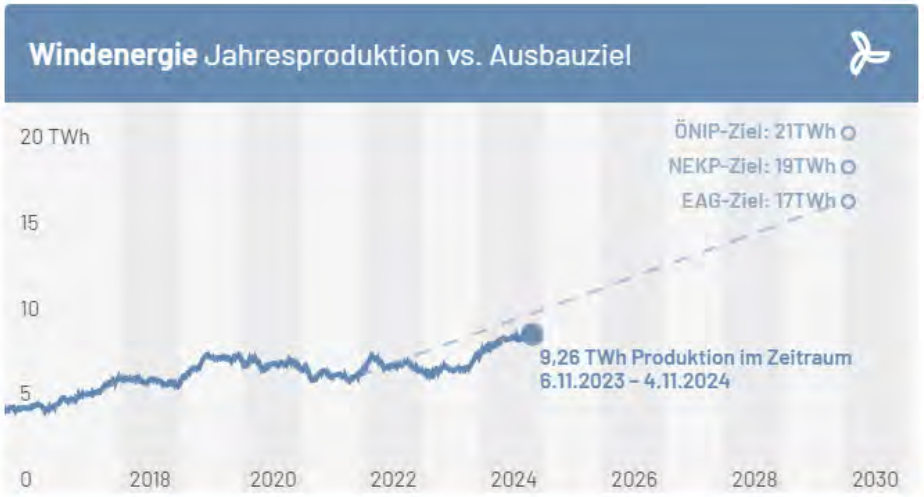
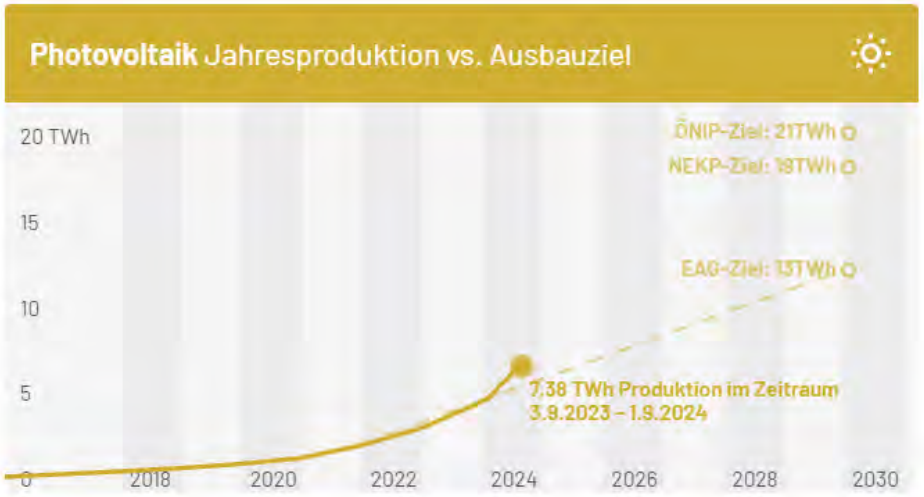
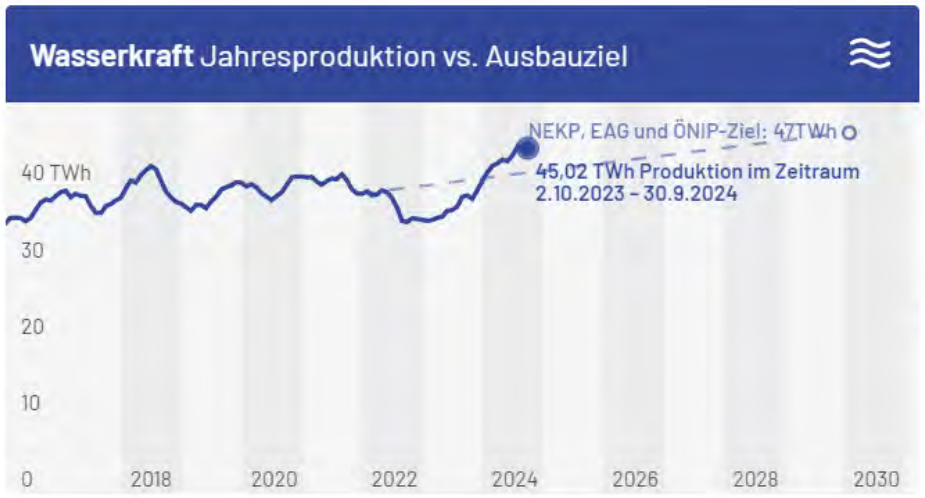
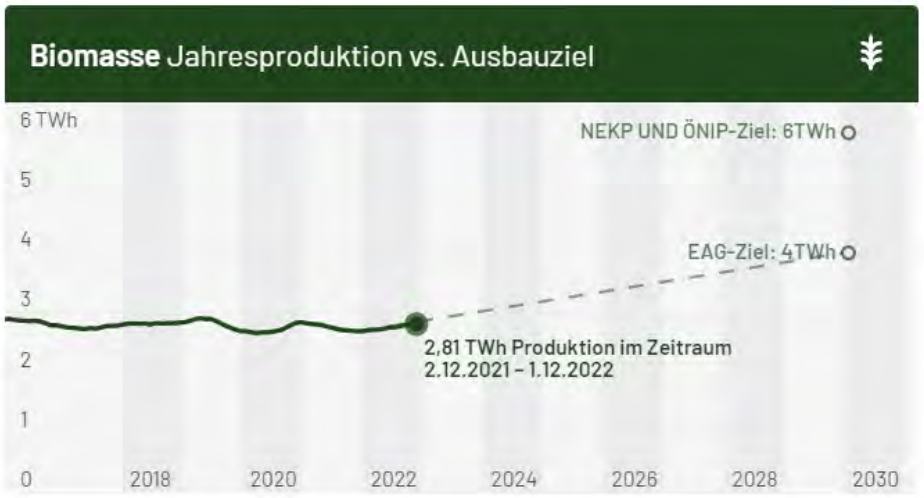
Goal according „erneuerbaren Ausbaugesetz“

Share of electricity of energetic GROSS end consumer [TWh] Austria **2030**









„every month 9 additional wind turbines“

„every month around 4.700 PV – plants“

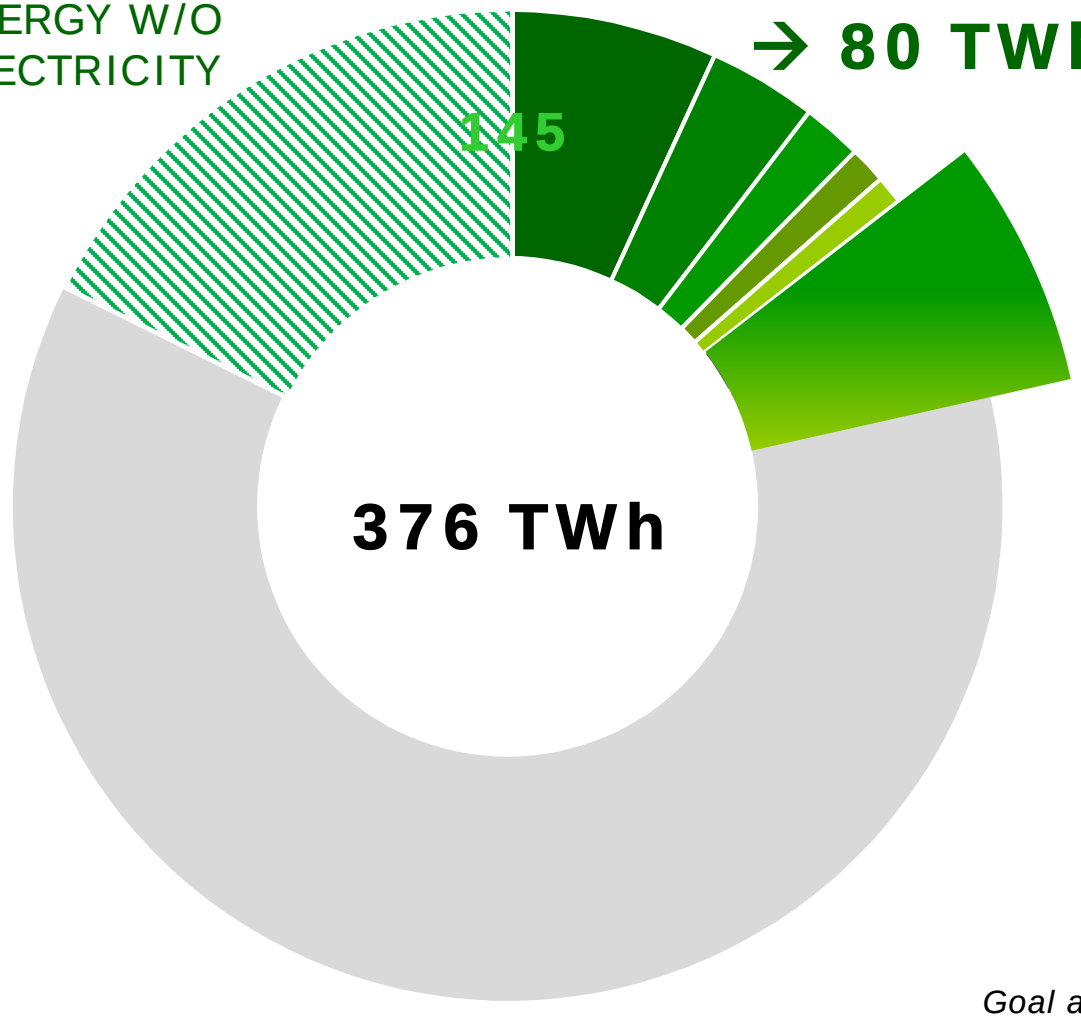
Source: Erneuerbare Energien – Klimadashboard Österreich; 04.11.2024; Grafik © Klimadashboard

Share of electricity of energetic GROSS end consumer [TWh] Austria **2030**

RENEWABLE ENERGY W/O ELECTRICITY

RENEWABLE: 54,4

→ 80 TWh



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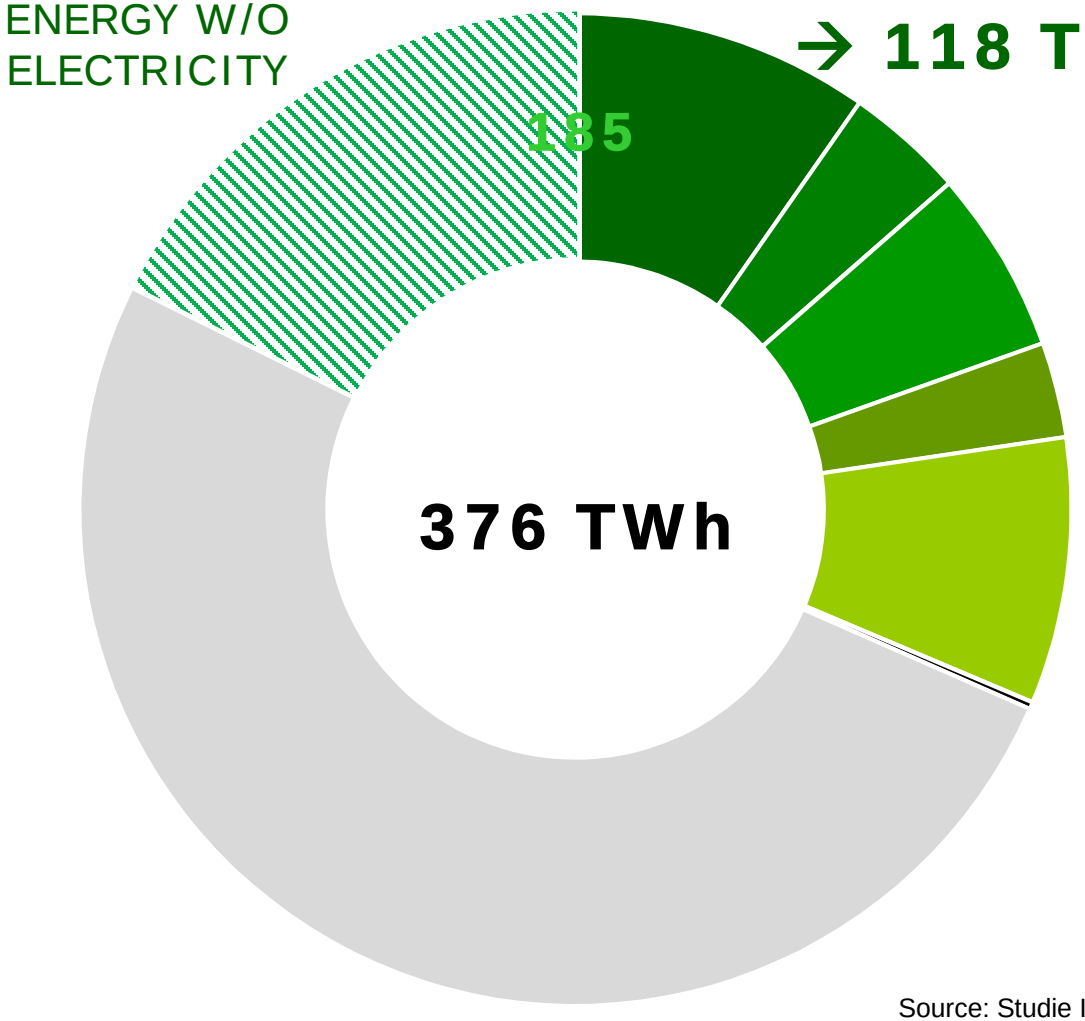
Goal according „erneuerbaren Ausbaugesetz“

Share of electricity of energetic GROSS end consumer [TWh]
POTENTIAL

RENEWABLE ENERGY W/O ELECTRICITY

RENEWABLE: 54,4

→ 118 TWh



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- combustible waste

Source: Studie IndustrIES Energieinfrastruktur fü 100% Erneuerbarer Engergie in der Industrie, Wien 2019

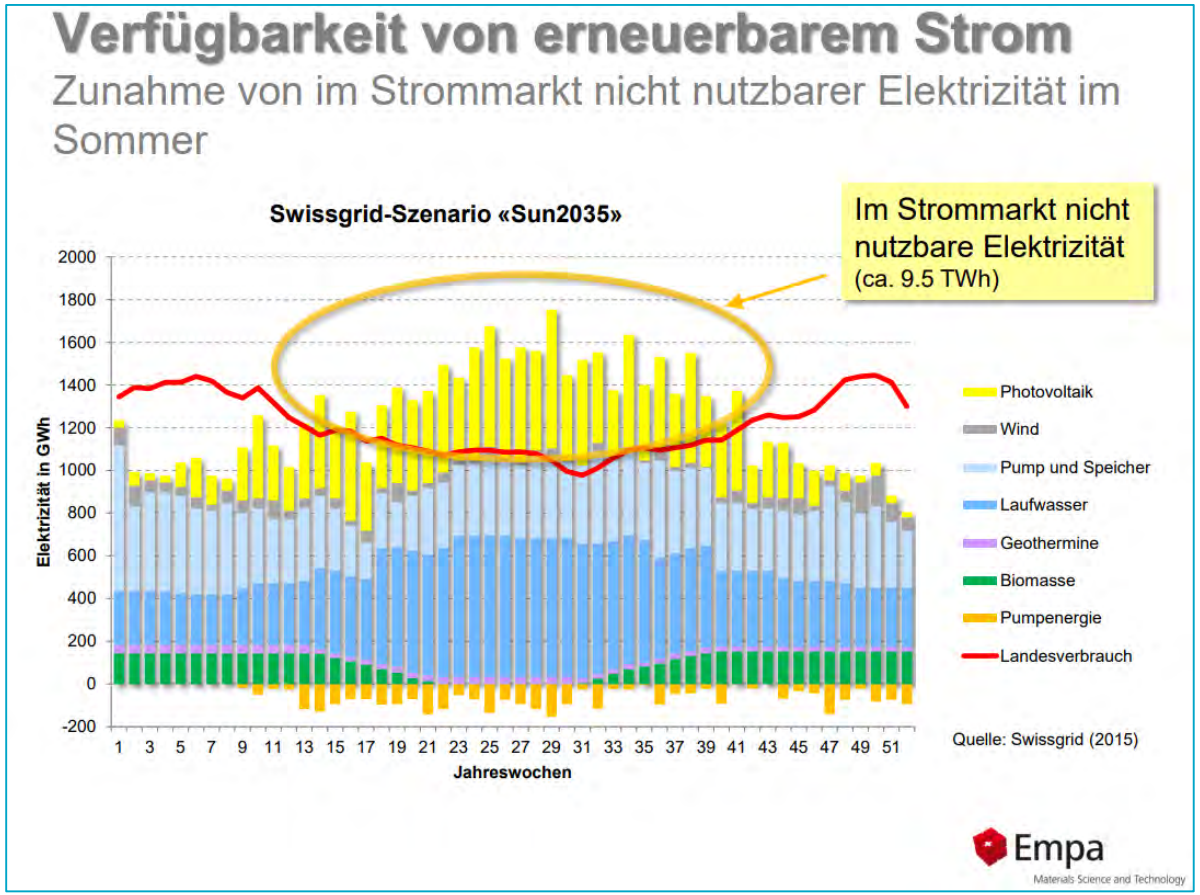
Future Electricity Market

e.g. 71 GWh
energy surplus for one day in Austria (13.6.21)

ONE DAY

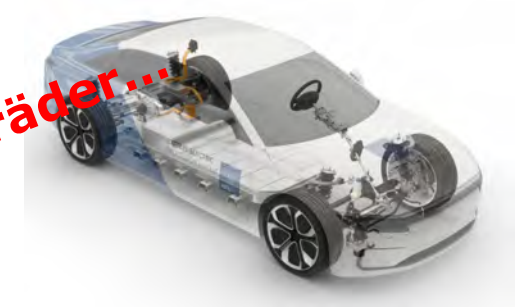
Storage option

Example Switzerland



Source Christian Bach – Electro fuels as an alternative to electrification – an energetic and economic analysis; MK Baden- Baden 2018

Abstellen der Windkräfträder...



Assuming 635.000 BEVs in 2030 in Austria, average battery capacity of 50kWh

BEV fleet Austria 2030: **32GWh**

Speicherkraftwerk Kaprun (eine vollständige Befüllung): **280GWh**

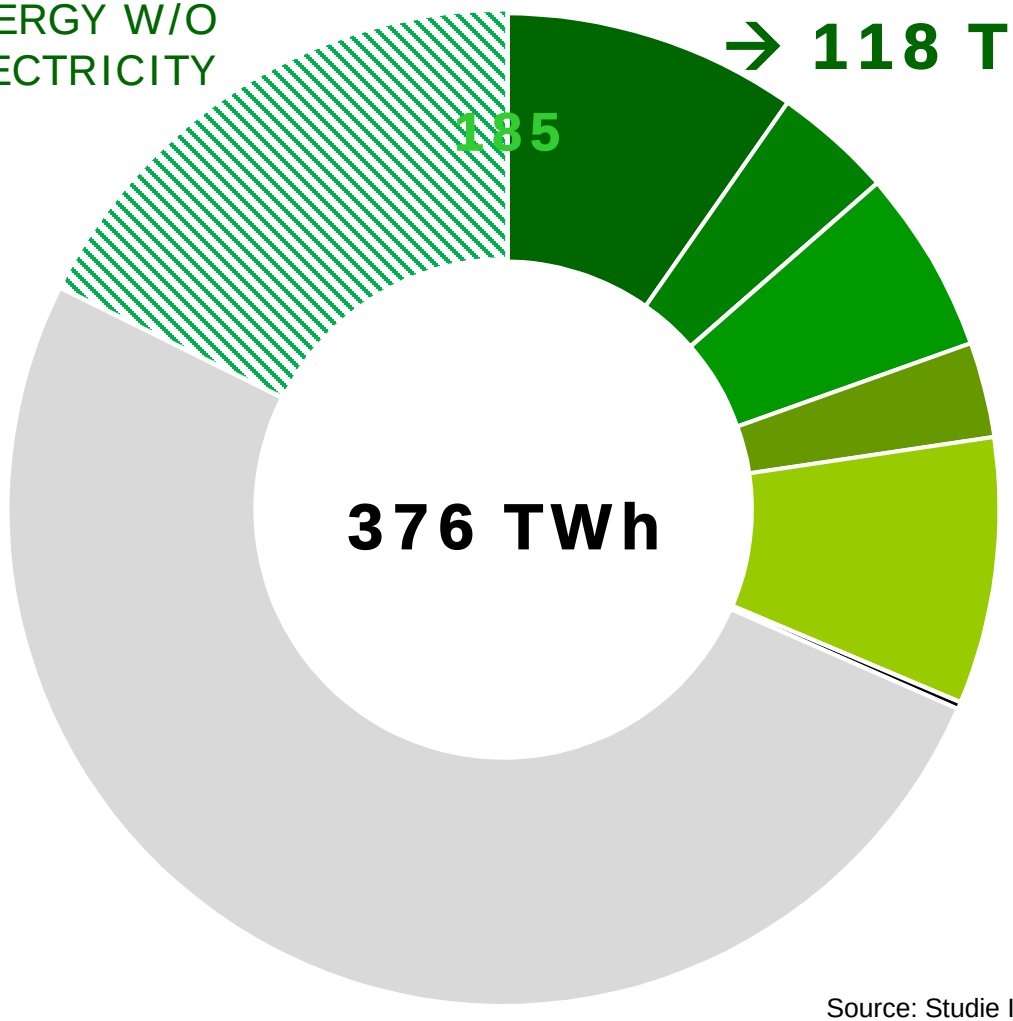
https://www.verbund.com/de-at/ueber-verbund/kraftwerke/unsere-kraftwerke/kaprun-oberstufe-limberg-3

Share of electricity of energetic GROSS end consumer [TWh]
POTENTIAL

RENEWABLE ENERGY W/O ELECTRICITY

RENEWABLE: 54,4

→ 118 TWh



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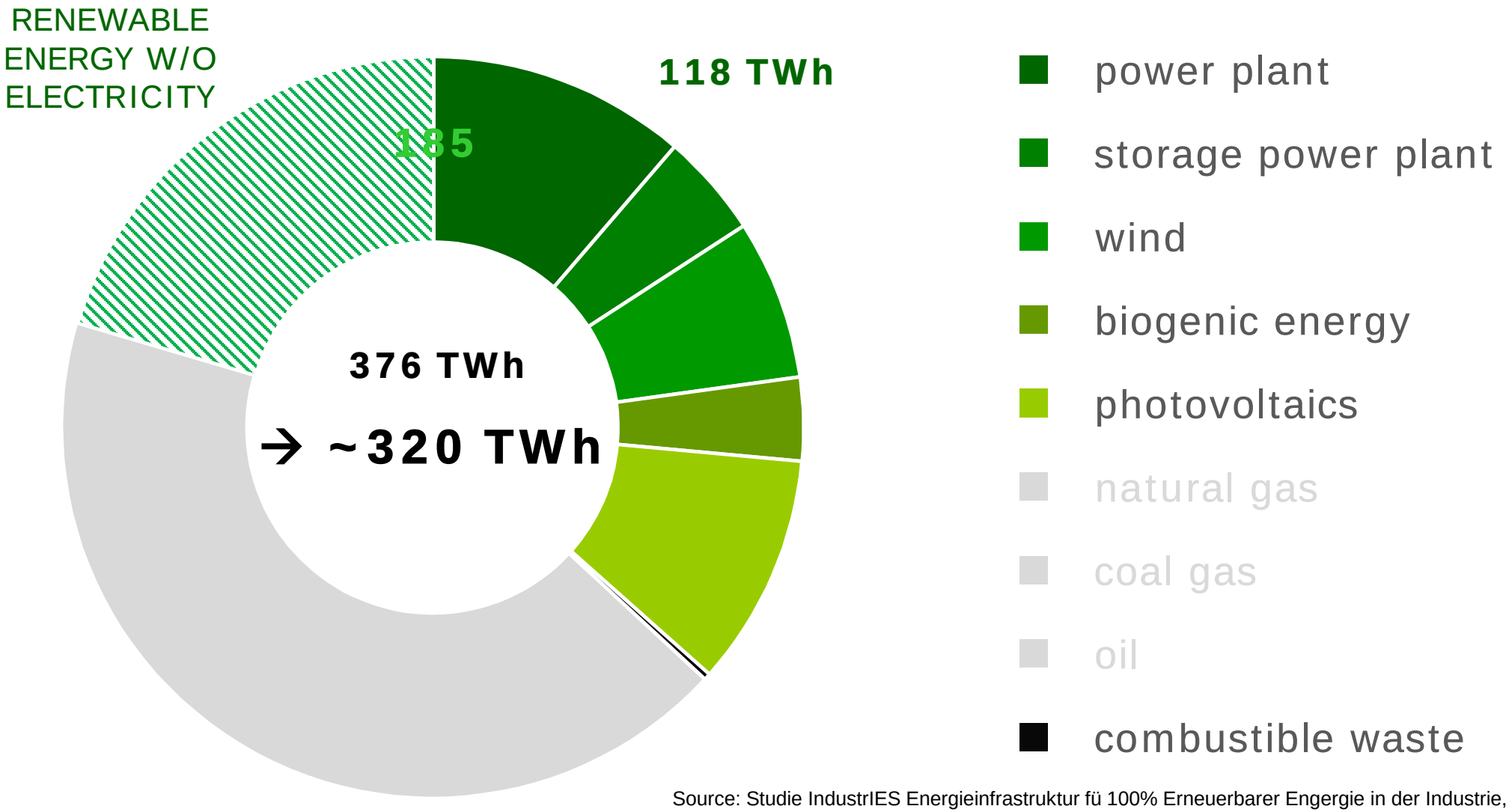
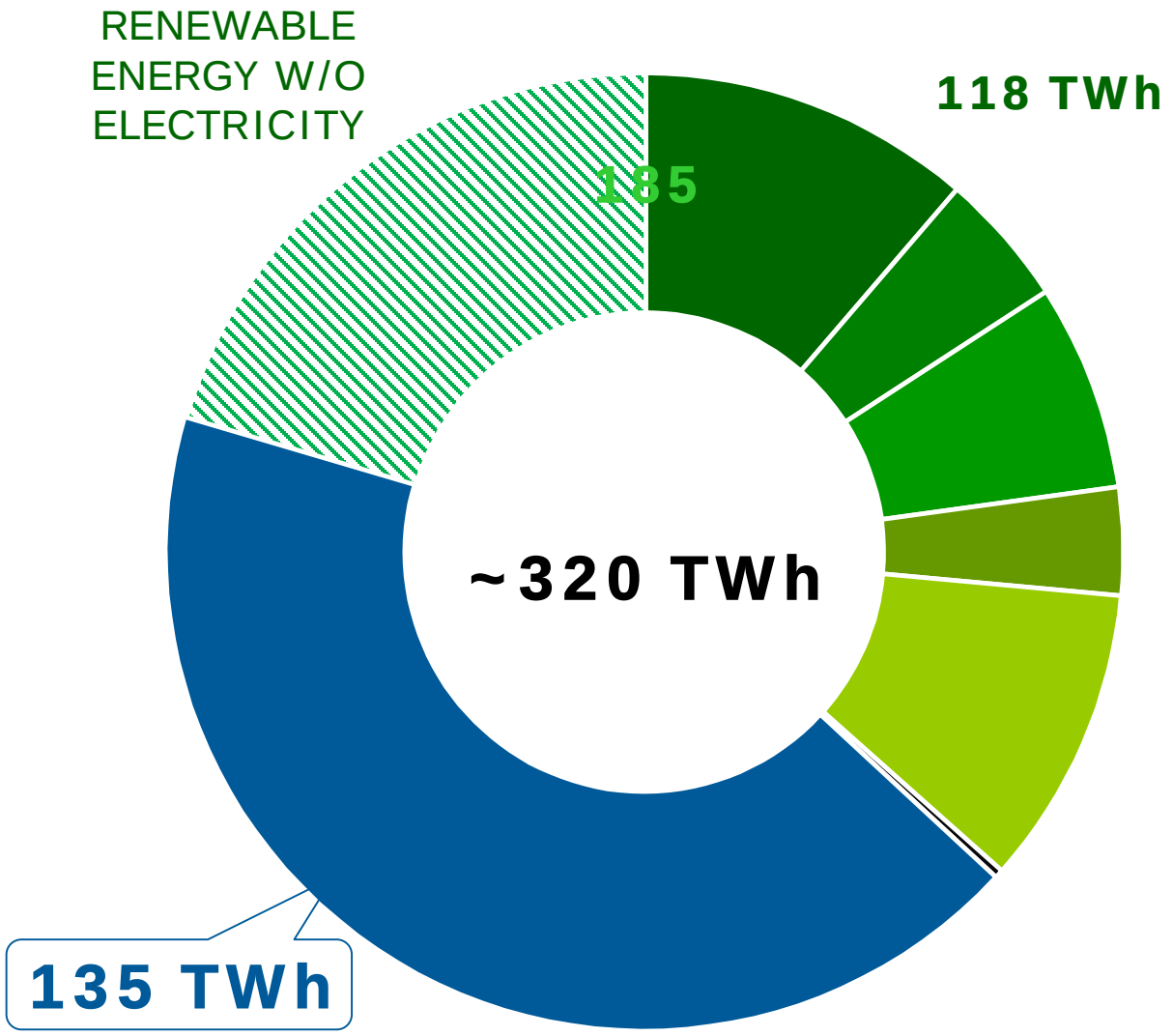
Source: Studie IndustrIES Energieinfrastruktur fü 100% Erneuerbarer Engergie in der Industrie, Wien 2019

Share of electricity of energetic GROSS end consumer [TWh]
POTENTIAL Consumption reduction through efficiency



Source: Studie IndustrIES Energieinfrastruktur fü 100% Erneuerbarer Engergie in der Industrie, Wien 2019

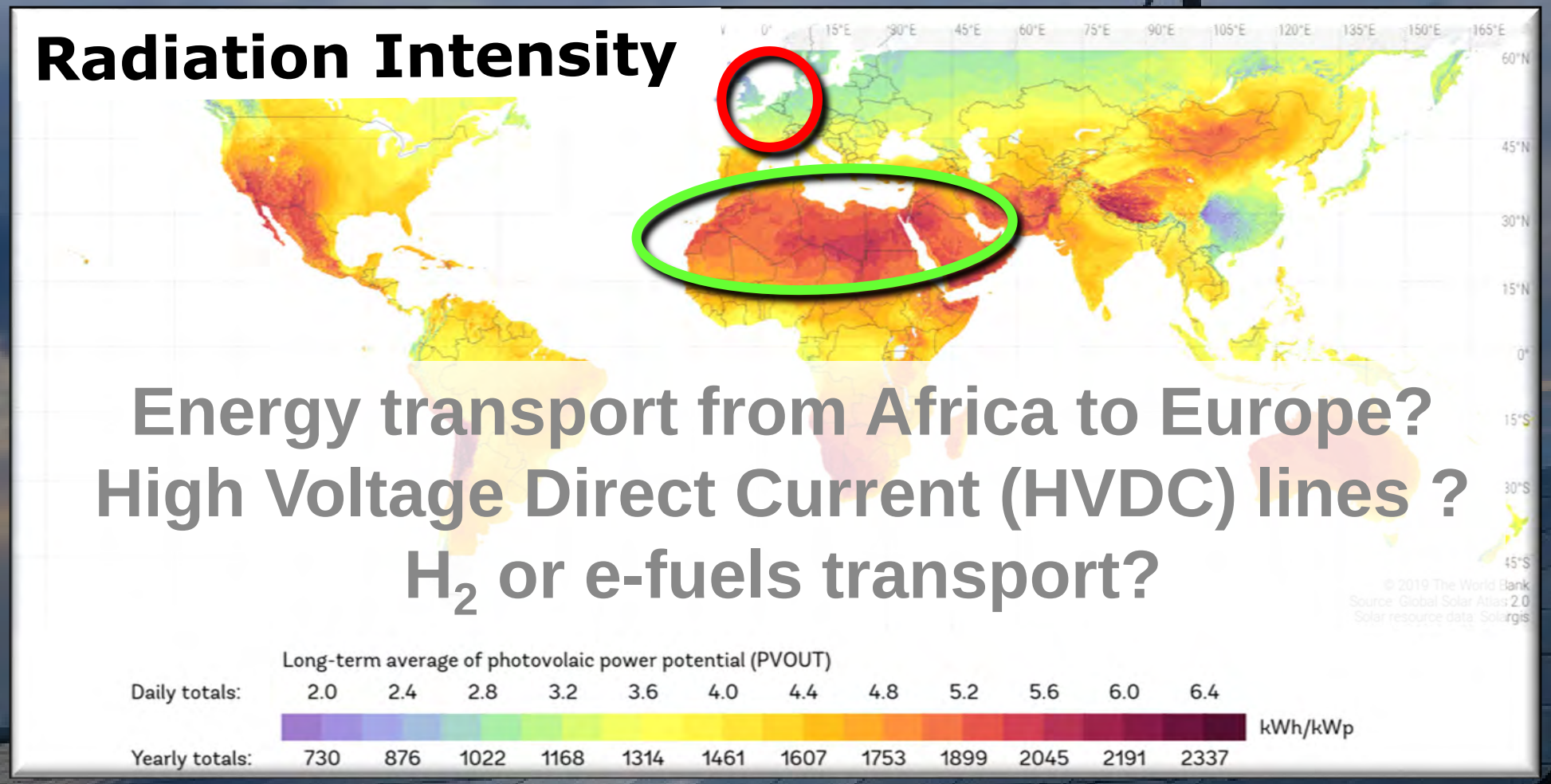
Share of electricity of energetic GROSS end consumer [TWh] **POTENTIAL**



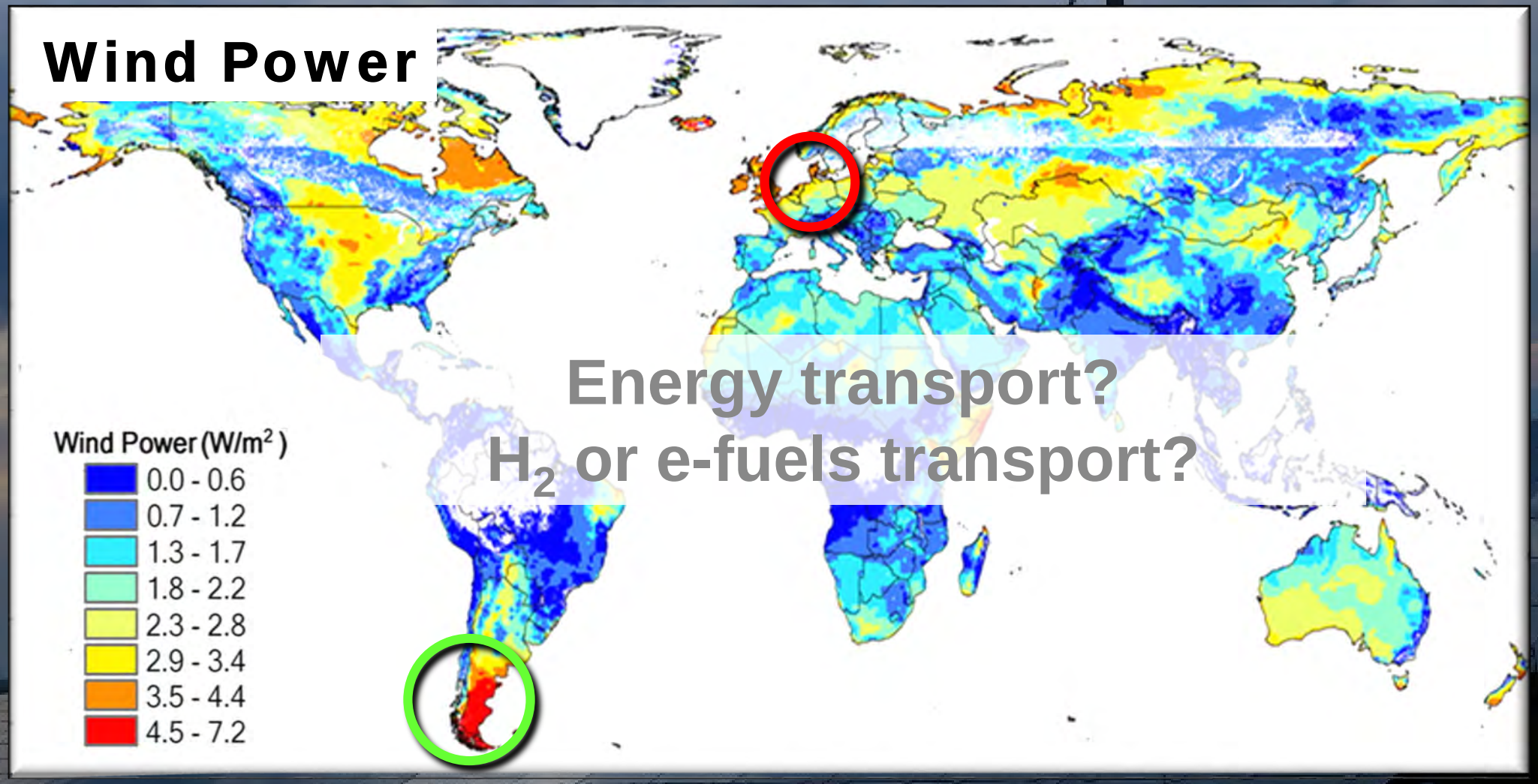
„Even under the most optimistic assumptions, a substantial portion of the energy demand must still be imported“

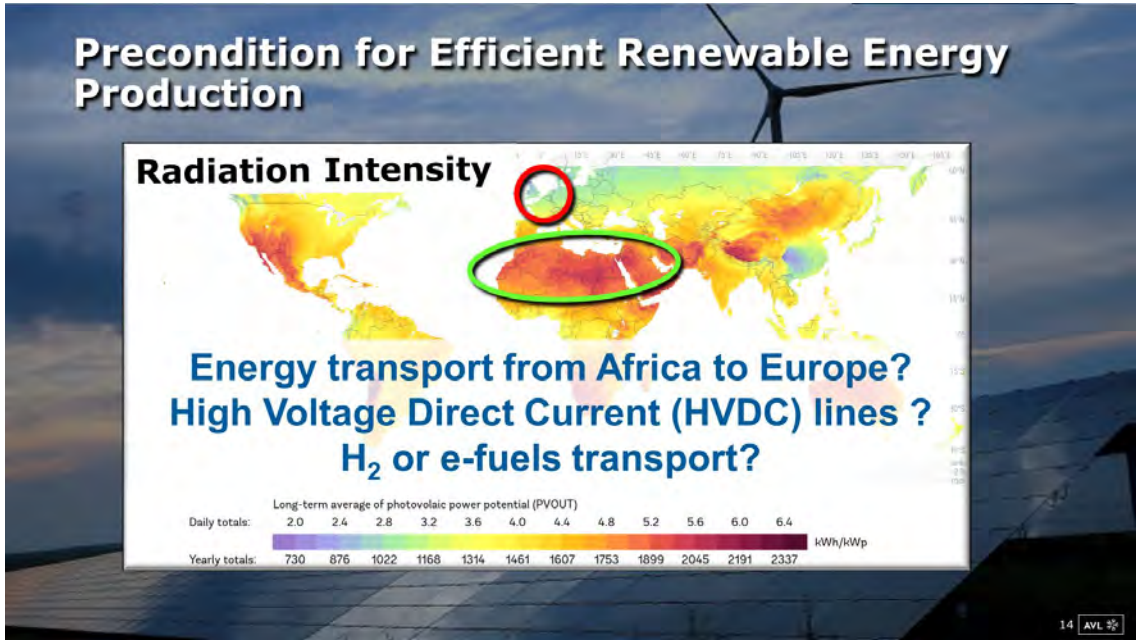
„This energy must be renewable!“

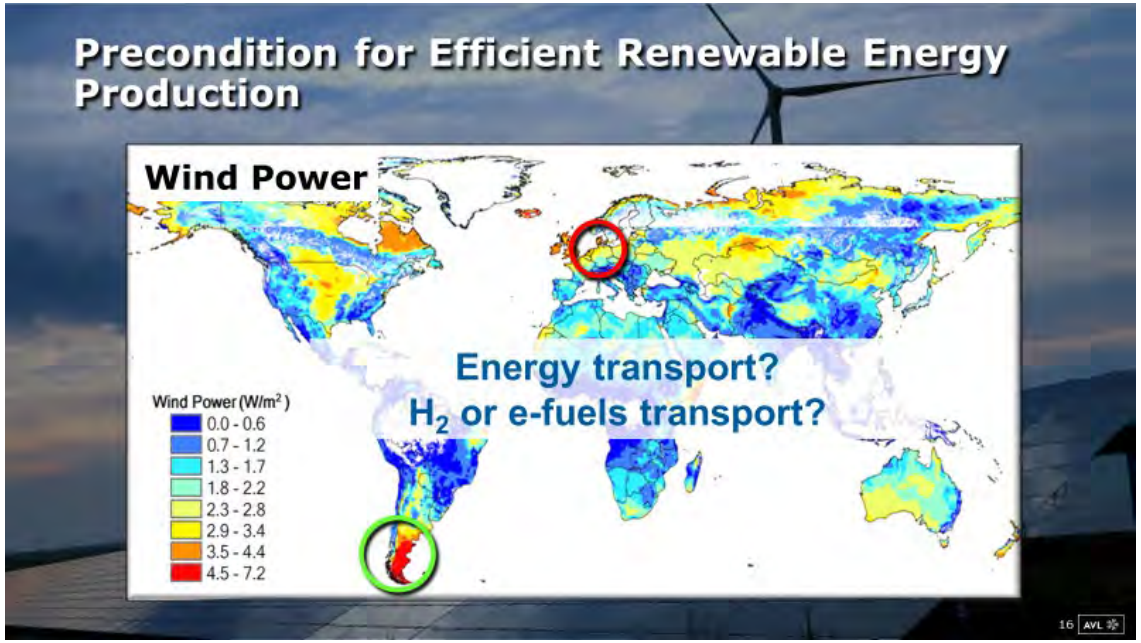
Precondition for Efficient Renewable Energy Production



Precondition for Efficient Renewable Energy Production



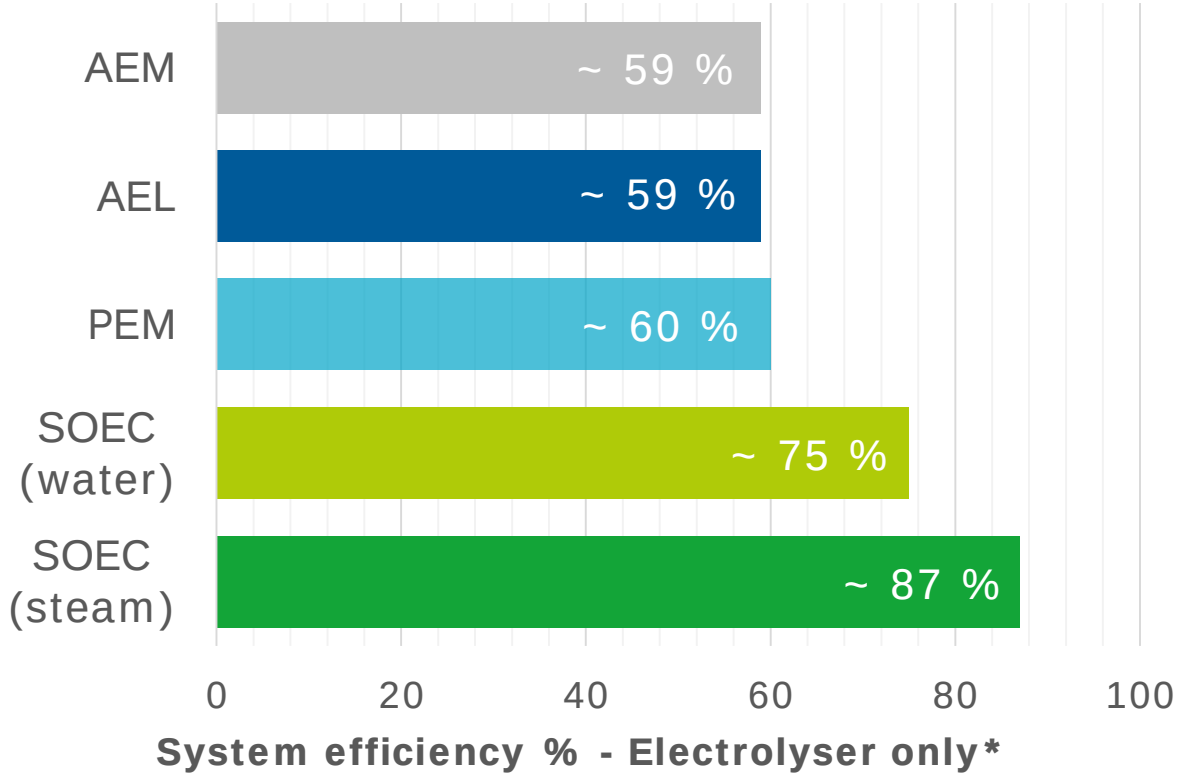




The import of renewable energy will be primarily in chemically bound form!

Electrolyzers comparison – Water to Hydrogen

Electrolyzer Technologies Efficiencies:



AEM ...	Anion Exchange Membrane
AEL ...	Alkaline Electrolyzer
PEM ...	Polymer Electrolyte Membrane
SOEC ...	Solid Oxide Electrolyzer Cell
SOFC ...	Solid Oxide Fuel Cell

Project Reference:

Next Generation Electrolyzer Technologies

- 1 MW 40ft Container Solid Oxide Electrolysis System
- 87% efficiency demonstrated – water steam electrolysis on SOEC module level
- Module Integration, Container Build Up, Testing, Commissioning by AVL

Comparison of options

E-Energy Carrier	Energy density	Infrastructure / Transport / Storage	Production efficiency*
Not compressed Hydrogen	0,01 MJ/l (@ 1bar, 20°C)	-	~ 85 %
Compressed Hydrogen (700bar)	6,8 MJ/l	-	~ 68 %
Liquid Hydrogen (-252°C)	9,5 MJ/l	-	~ 55 %
Ammonia (-35°C)	12,8 MJ/l	o	~ 70 %
Methanol	15,8 MJ/l	+	~ 70 %
E-fuel (e.g. e-diesel)	36,5 MJ/l	++	~ 55 %

*** ... SOEC used as basis electrolysis technology, values based on LHV**

Due to its energy density and infrastructure, e-fuels will have a significant share. Unquestionable is the undeniable importance for the aviation.

How to harvest one of the best wind locations worldwide?

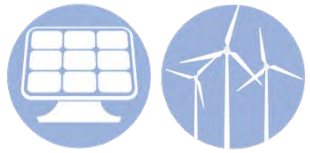
Efficiency equalization:

- **ICE car with e-fuel from "Patagonia" wind parks**
- **BEV with energy from German wind parks**

1 Fraunhofer IEE – Windmonitor: ca. 1800 FLH in 2018

Source: Alexander Temel (Siemens Energy); H2 for Large-Scale Energy Storage; ECPE Network Meeting 8.10.21

E-fuel Process



Renewable electricity

Water

SynGas Production

$H_2 + CO$

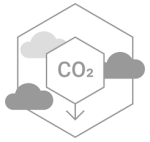
Fisher-Tropsch synthesis

C_xH_y syncrude

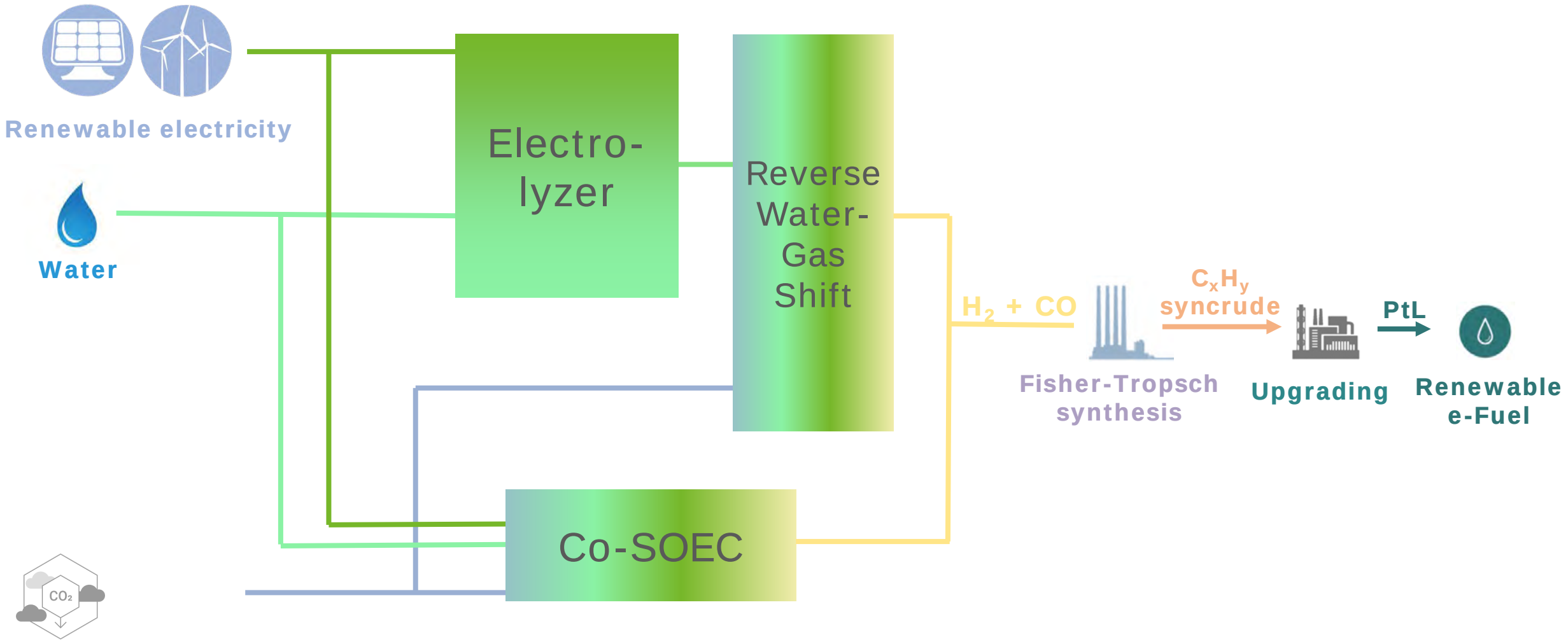
Upgrading

PtL

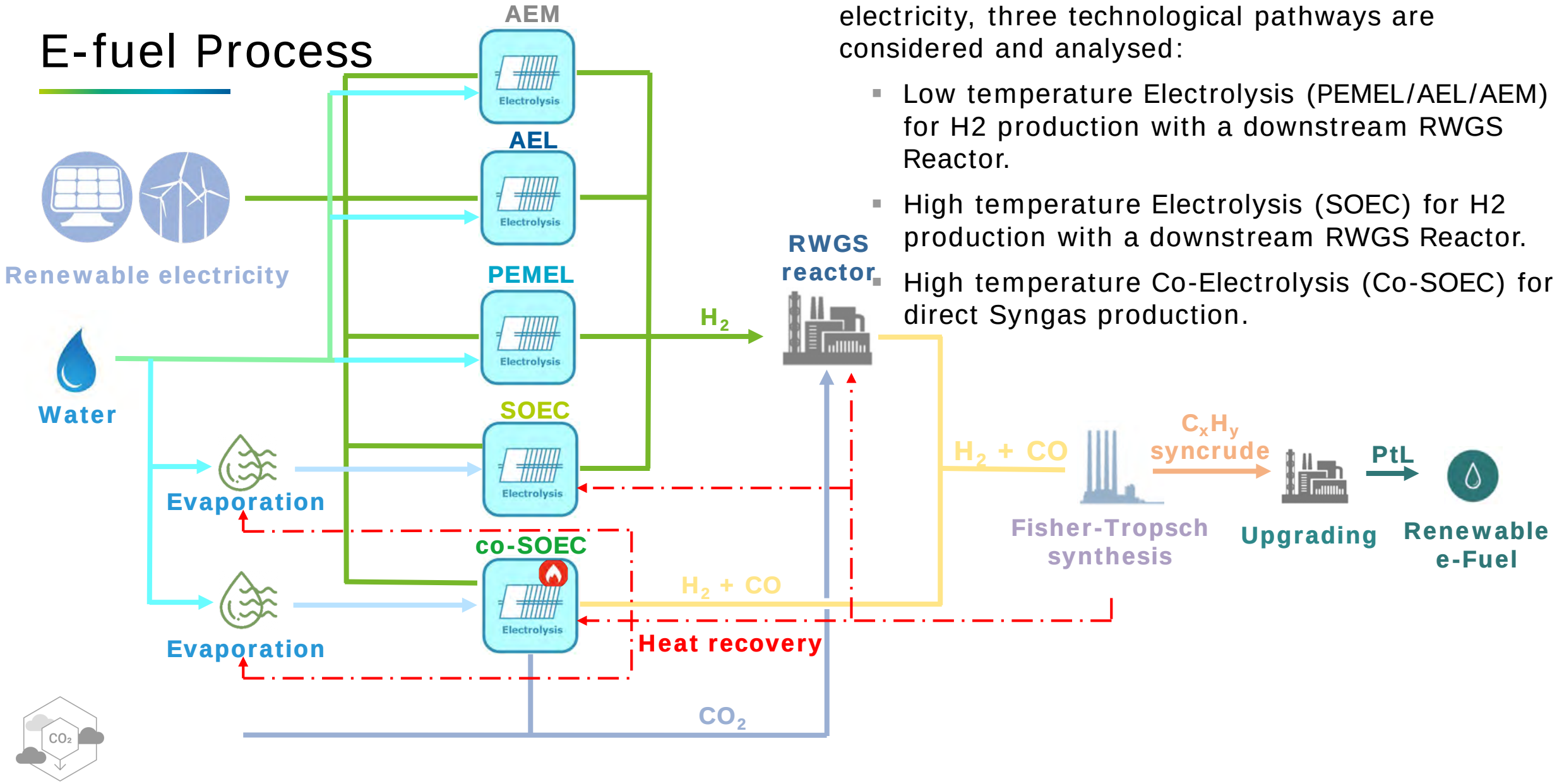
Renewable e-Fuel



E-fuel Process



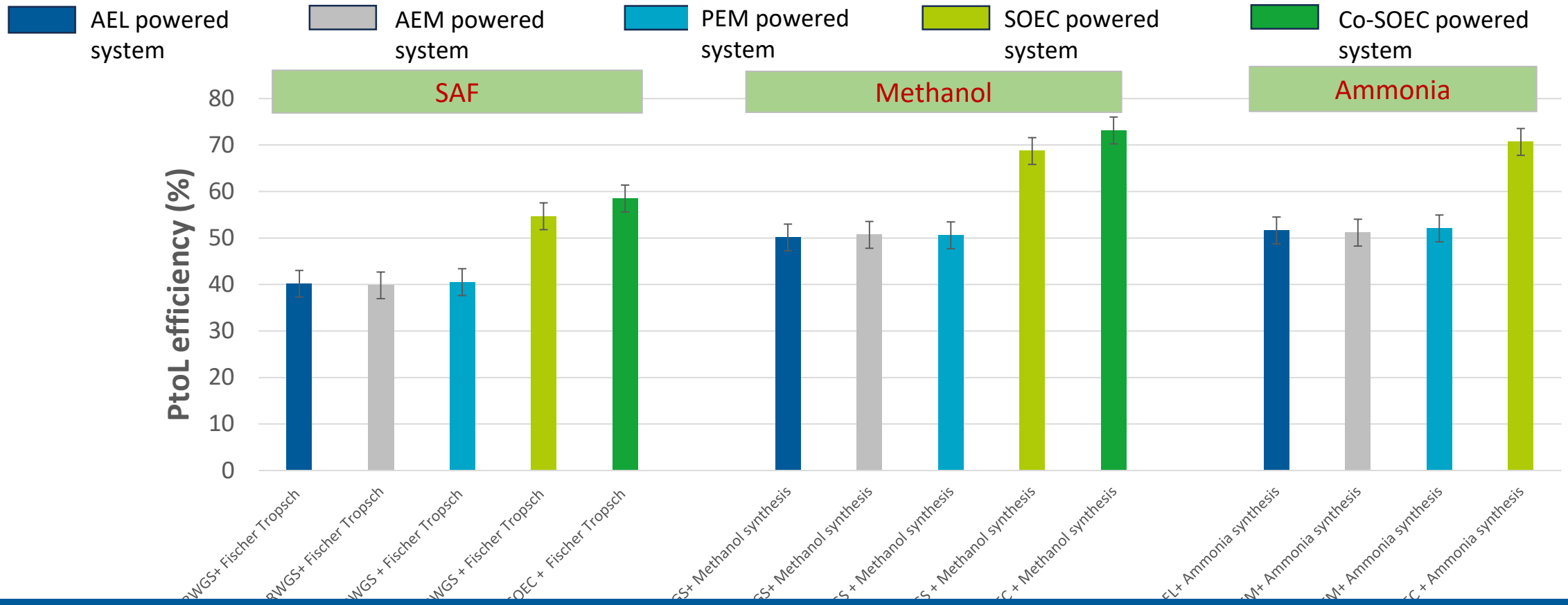
E-fuel Process



To produce E-Fuels based on CO_2 and green electricity, three technological pathways are considered and analysed:

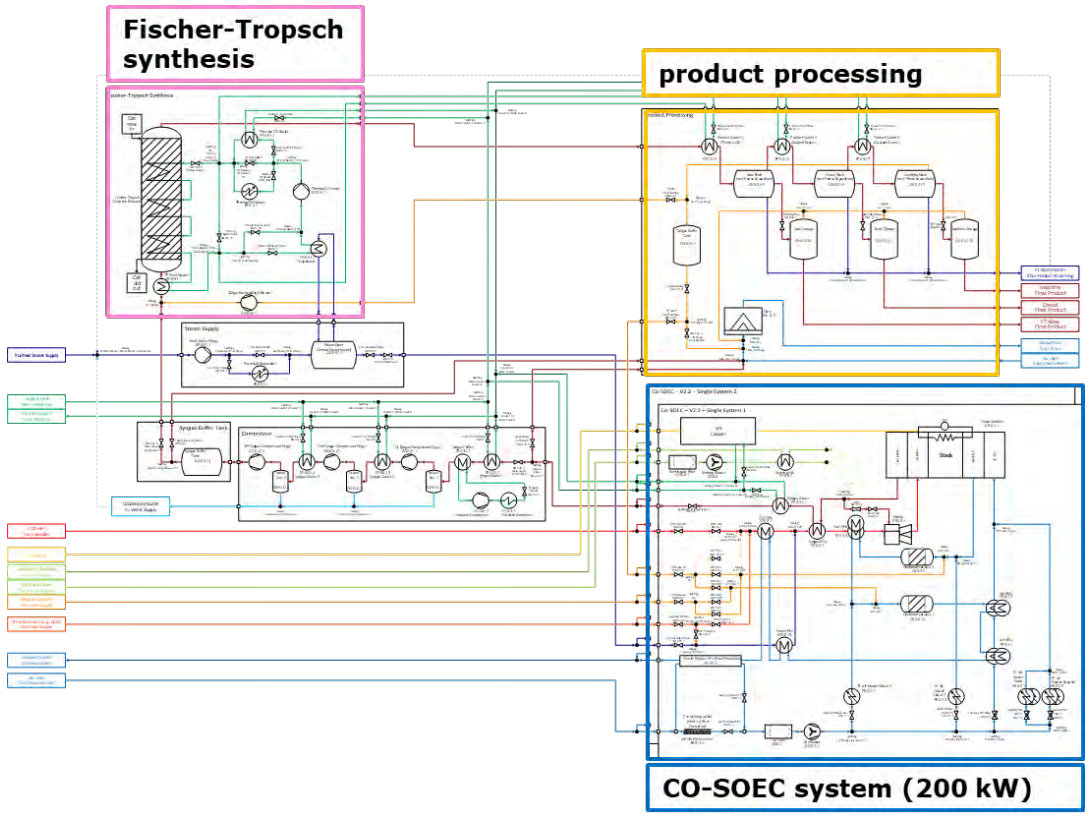
- Low temperature Electrolysis (PEMEL/AEL/AEM) for H2 production with a downstream RWGS Reactor.
- High temperature Electrolysis (SOEC) for H2 production with a downstream RWGS Reactor.
- High temperature Co-Electrolysis (Co-SOEC) for direct Syngas production.

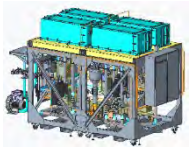
E-Fuel Production Routes

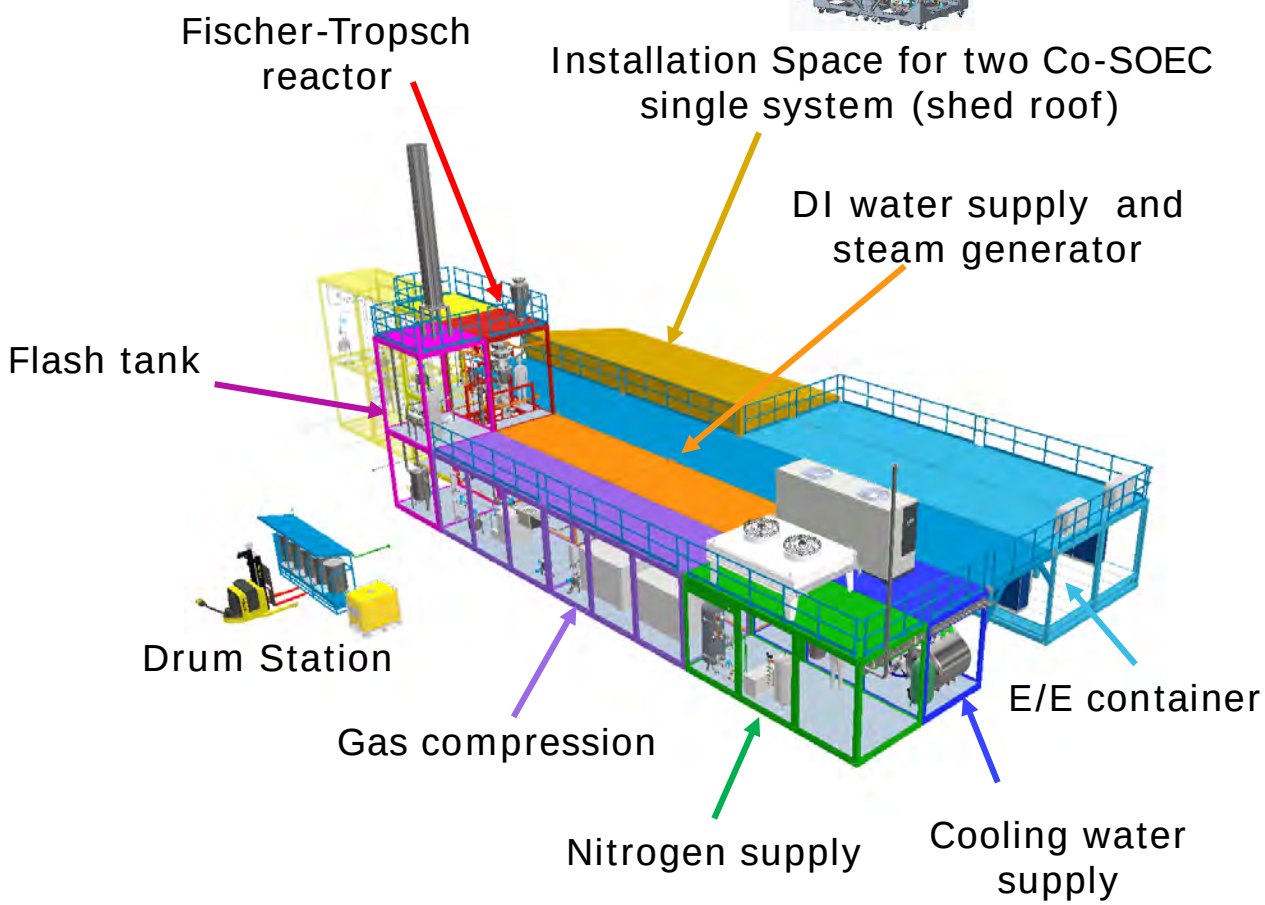


E-Fuel / Sustainable Aviation Fuel production with Co-SOEC has a 15 to 20 % higher potential compared with low temperature electrolysis

SOEC Power-to-Liquid Demonstration Plant

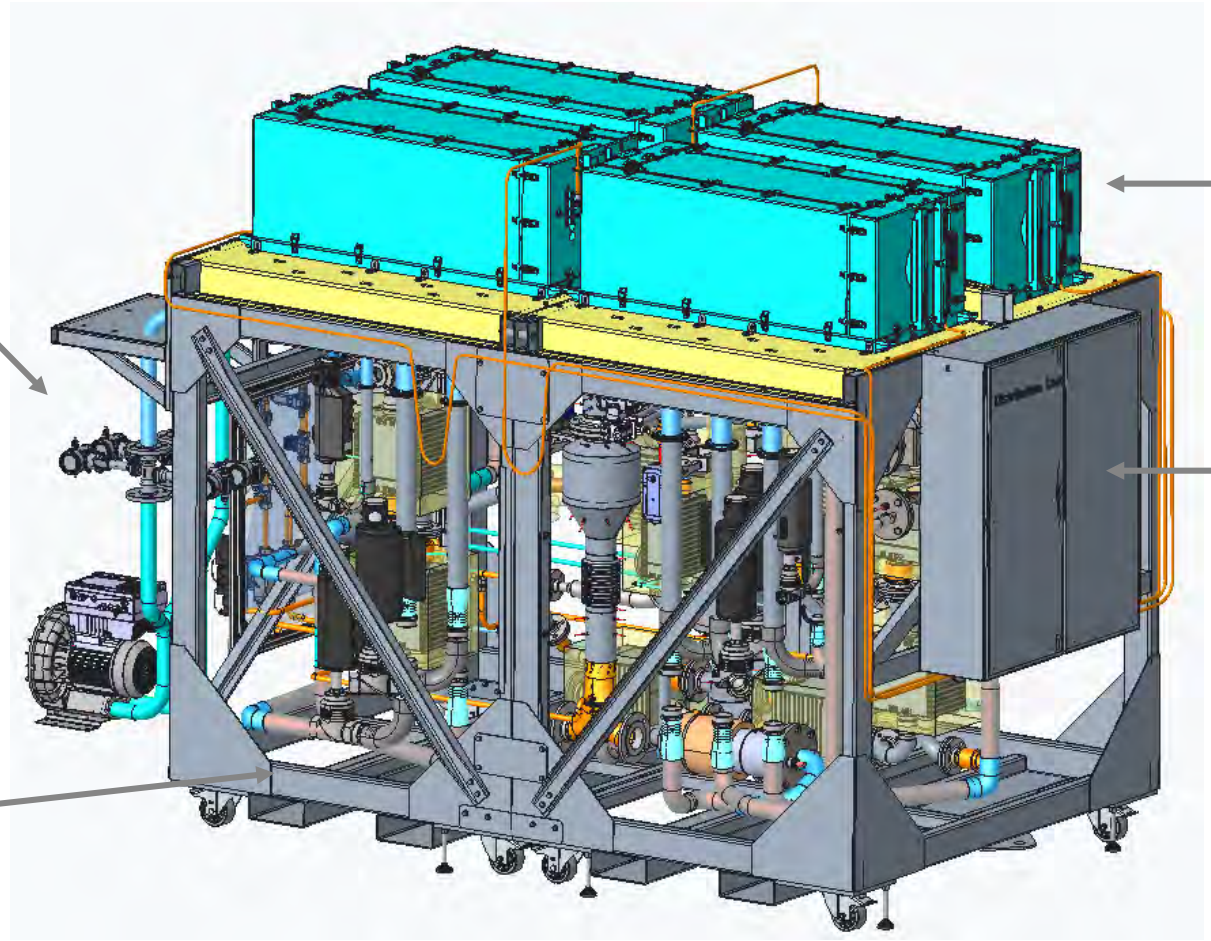






CO-SOEC Module

Cold BoP components:
- Blower
- Air filter
- Mass flow controllers
- Water supply + purifier
- Steam generator



Co-SOEC Stack modules

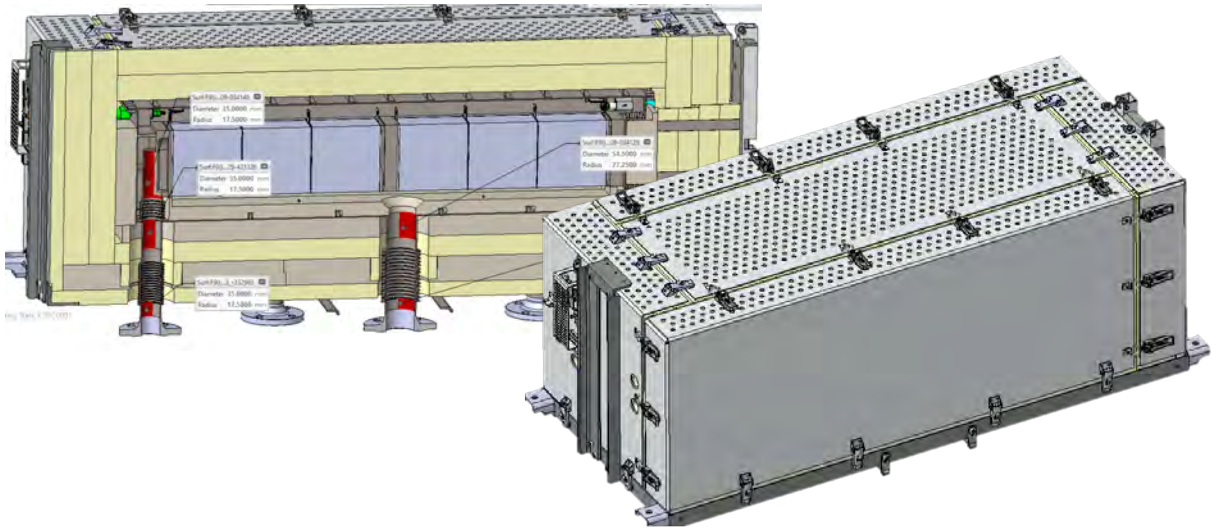
E-cabinet

Hot BoP components:
- Heat exchangers
- Ejector
- Afterburner/OxiCat
- Heaters

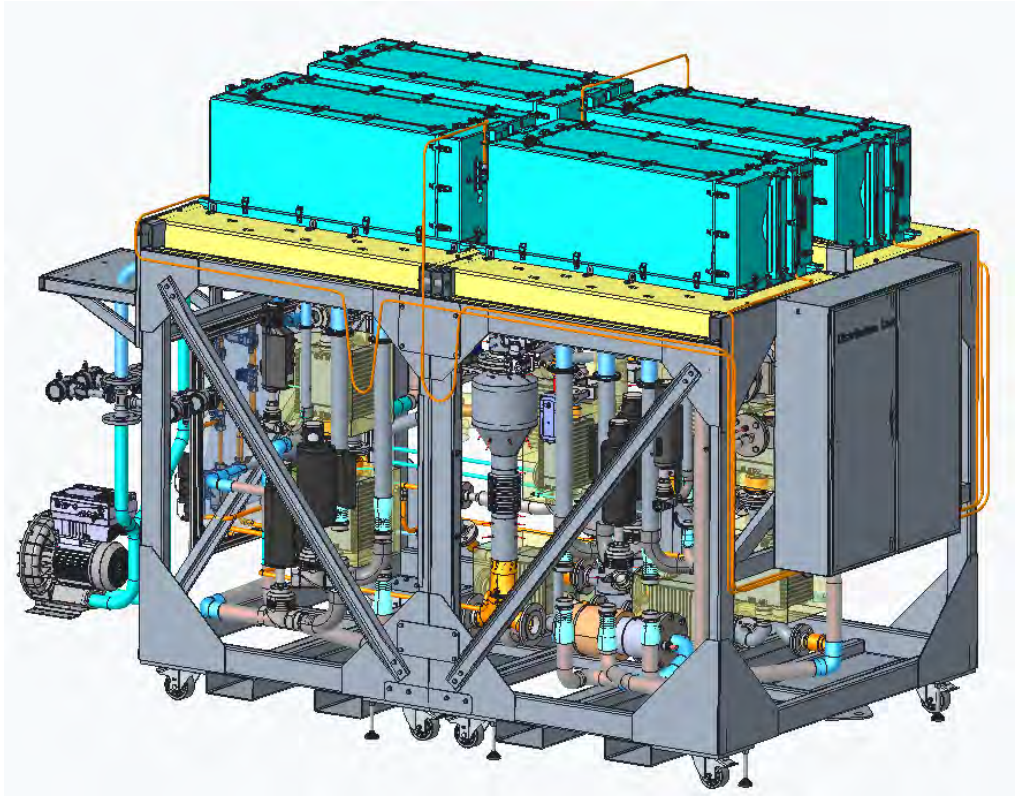
Power-to-Liquid Demonstration Plant

Stack Module & Short Stack Testing – **First Co-SOEC Demonstration globally**

1 kW IKTS MK355 Short Stack
Verification in IFE/HiPoLiq Design
Operation Point – 1000h durability test
→ finished ✓



25 kW Stack Module Verification in IFE/HiPoLiq Design
Operation Point – 250h test → finished ✓



100 kW Co-SOEC Module Verification, Calibration & Commissioning

Solution approach on the way to 100% green energy

Austrian energy demand

Options for energy import

SOEC Power-to-Liquid

Summary

Austrian energy demand

Options for energy import

SOEC Power-to-Liquid

The energy required in Austria must be converted 100% to renewable energy.

Everything points to the fact that a significant proportion of this renewable energy will have to be imported.

This energy will be imported in a chemically bound form.

SOEC technology will play a major role due to its high efficiency.

To demonstrate the potential, AVL is building a corresponding research demo plant with partners.