



Hydrogen for Industrial Energy and Mobility

AVL at a Glance



1948

Founded



29

Countries
Represented



12,200

Employees Worldwide



10 %

Of Turnover Invested
in Inhouse R&D

75+

Years of Experience

50+

Global Tech and
Engineering Centers

68 %

Engineers and
Scientists

2,200

Granted Patents
in Force

H₂ for Industrial Energy and Mobility



Commercial Share

200 Mio€



Patents

>250



Locations & People

6/650



Share outside automotive

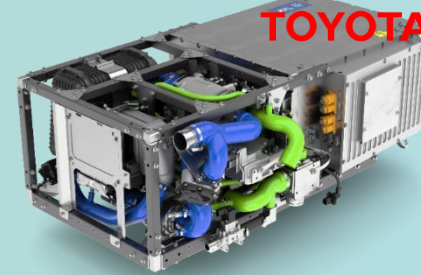
~60%

Lighthouse projects

Mobility



TOYOTA



Leading PEM System Development



SOP Marine Fuel Cell System Development



AIRBUS

Introducing Airbus **ZEROE**



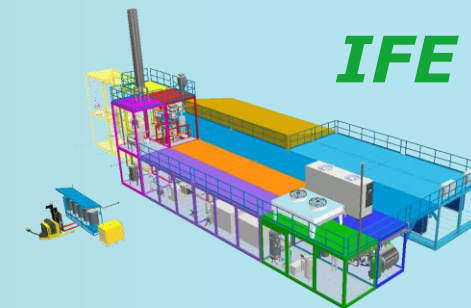
Fuel Cell System Development Partner



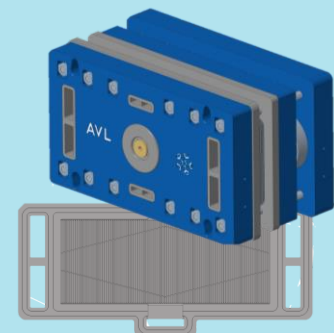
1MW SOEC Industrial H₂ Production

Energy

IFE



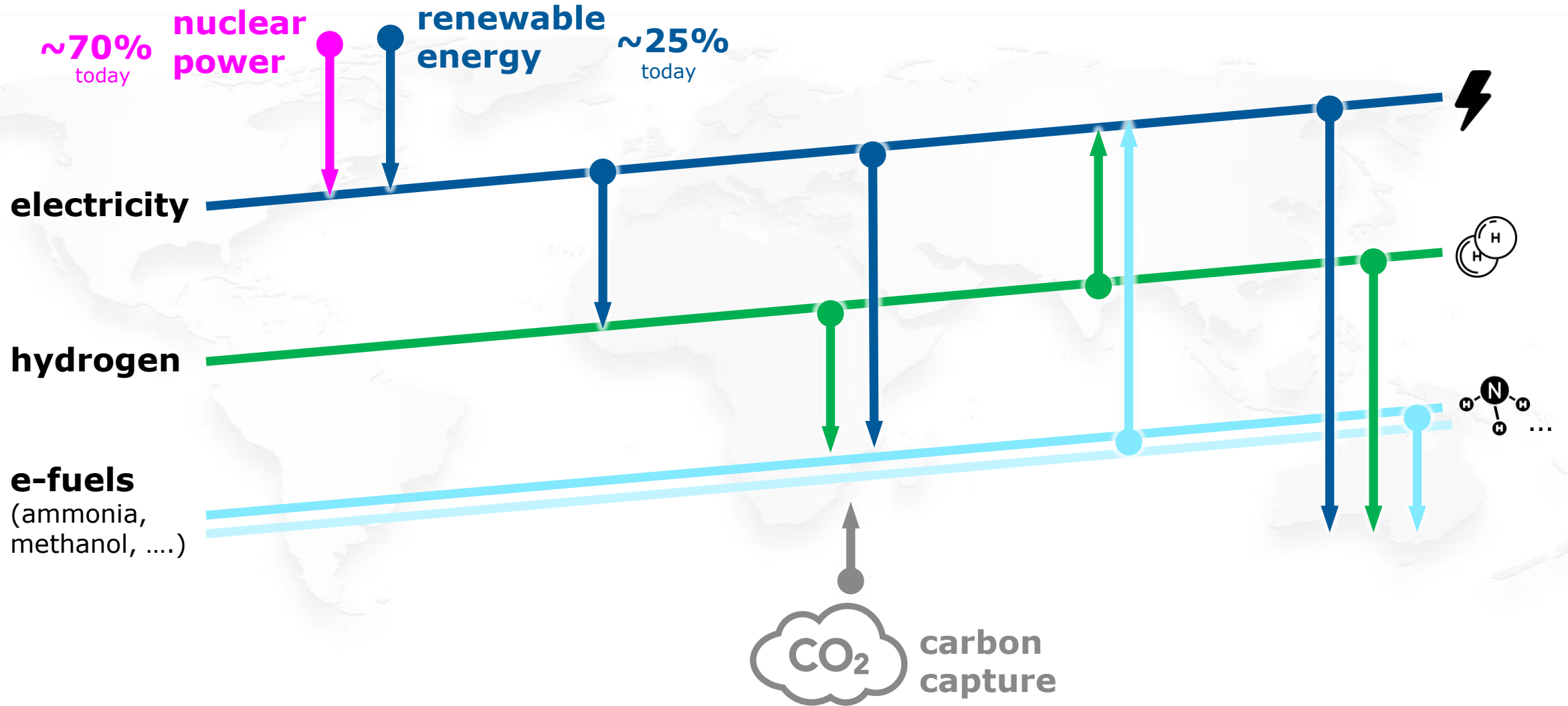
SOEC based PtL Plant for SAF Production



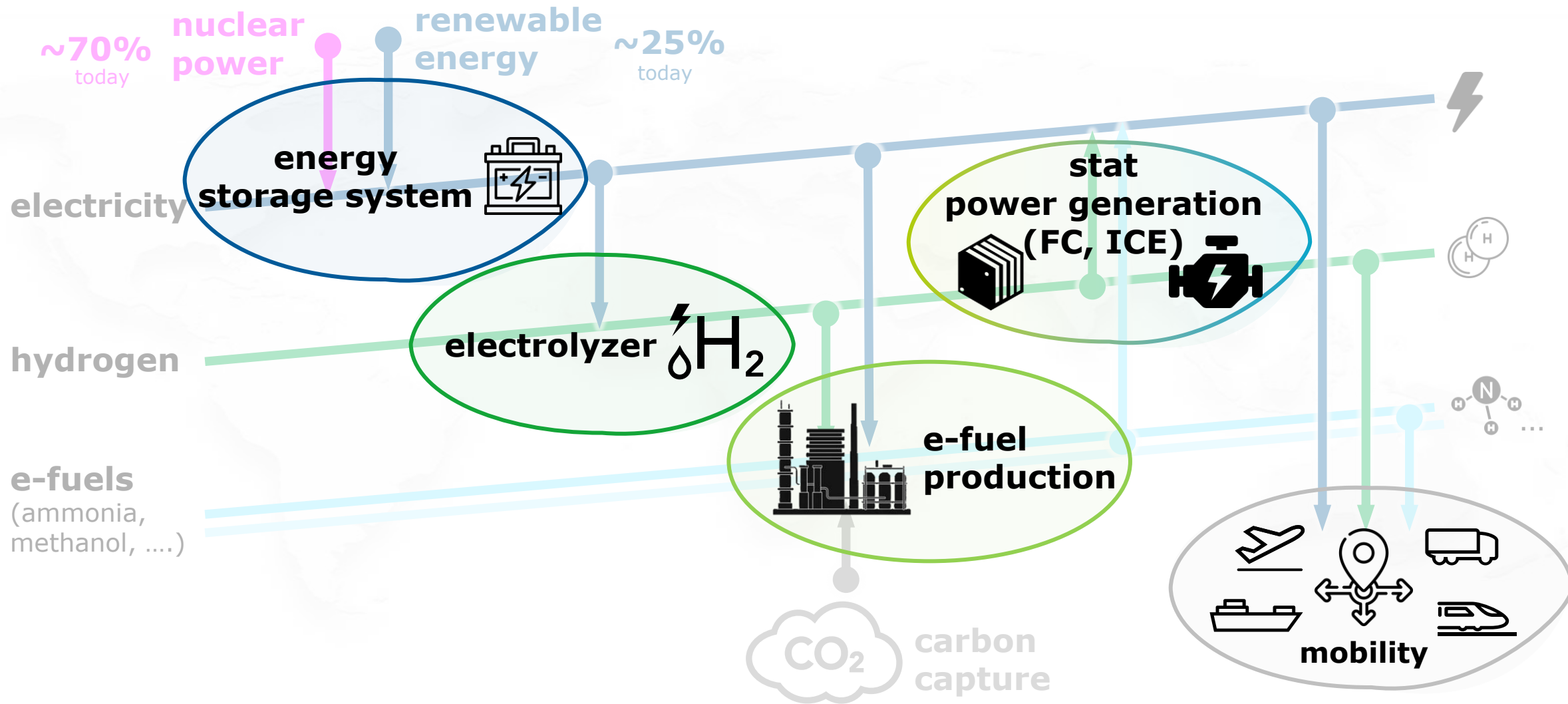
Next Generation PEM EL Stack

CCS - Carbon Capture Storage
DAC - Direct Air Capture
ESS - Energy Storage System
FC - Fuel Cell
ICE - Internal Combustion Engine

France Energy Vectors for Decarbonisation



Future Energy Vectors and AVL Focus Areas



AVL AEE-1 PEM Electrolyzer Stack Benchmark

Efficiency

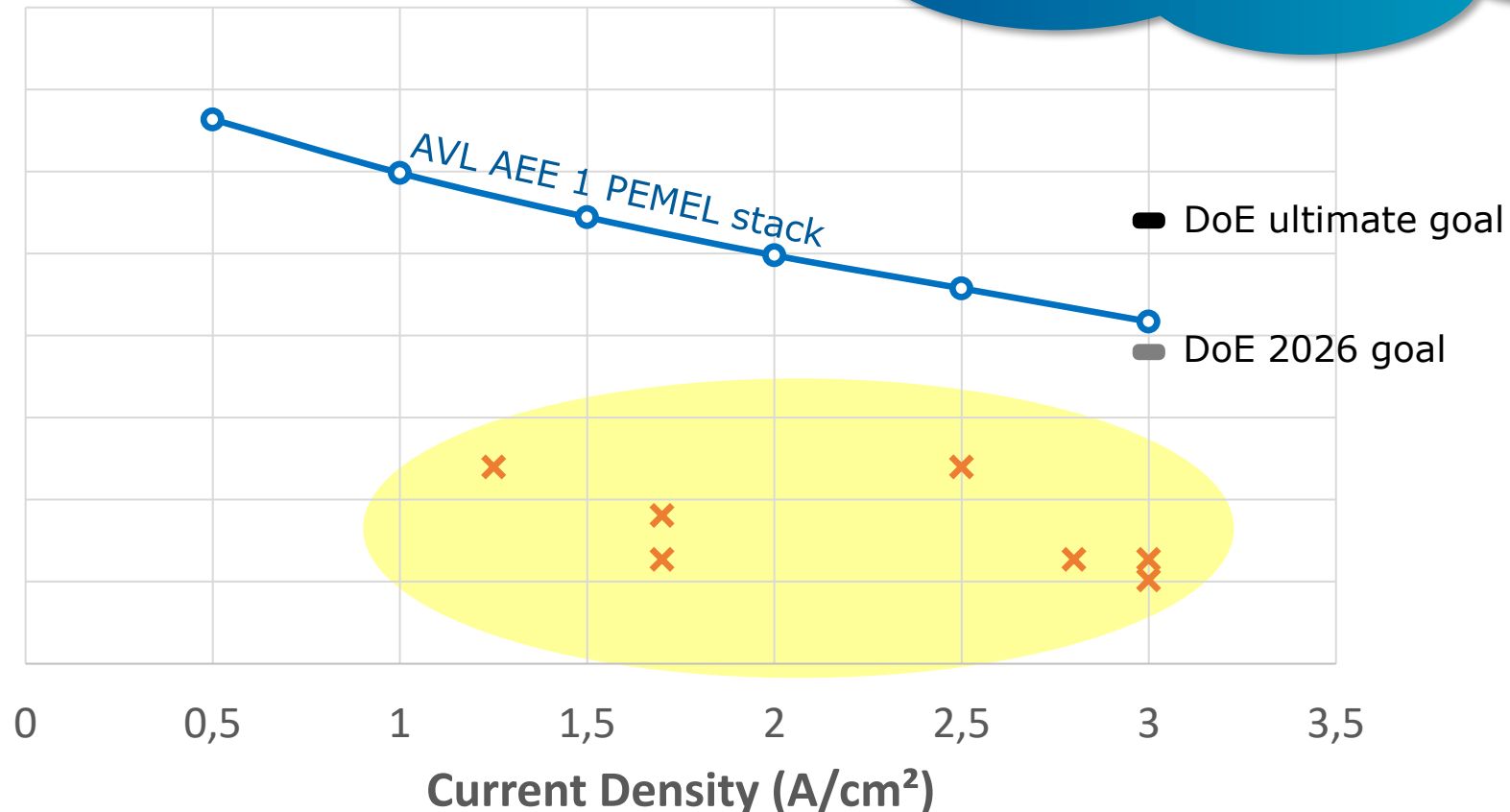
90 %LHV
37.0 kWh/kgH₂

80 % LHV
41.6 kWh/kgH₂

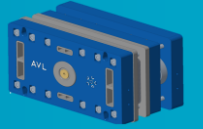
70 %LHV
47.6 kWh/kgH₂

60 %LHV
55.5 kWh/kgH₂

50 %LHV
66.6 kWh/kgH₂



AVL AEE 1 is more efficient than commercial stack designs and more efficient than DoE 2026 goal



AVL Fuel Cell and Electrolyzer Stack Development Competences

PEM Fuel Cell Stack

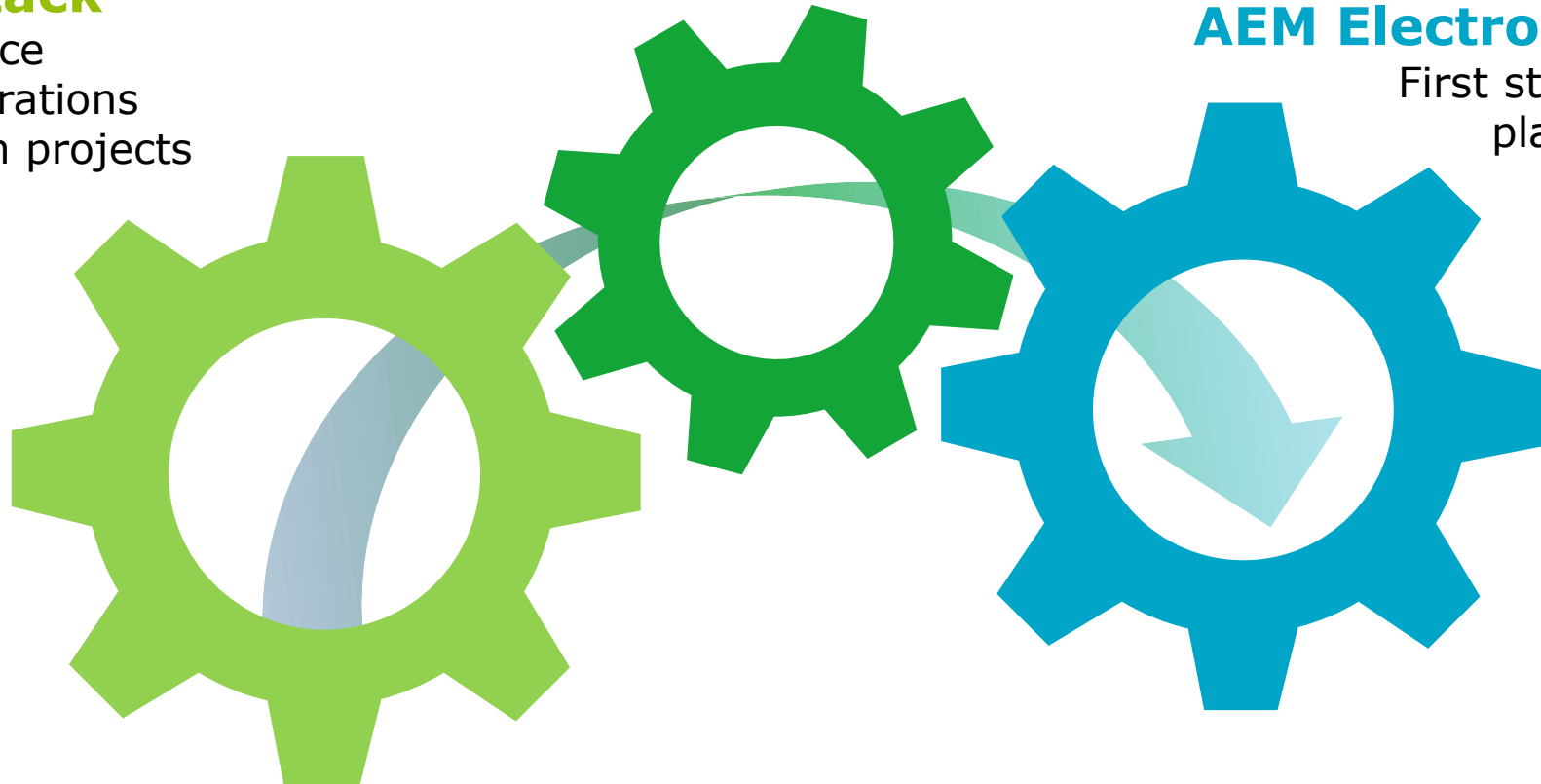
20+ years of experience
3 in-house stack generations
Customer stack design projects

PEM Electrolysis Stack

2+ years of experience
1 in-house stack generation
Customer stack design projects

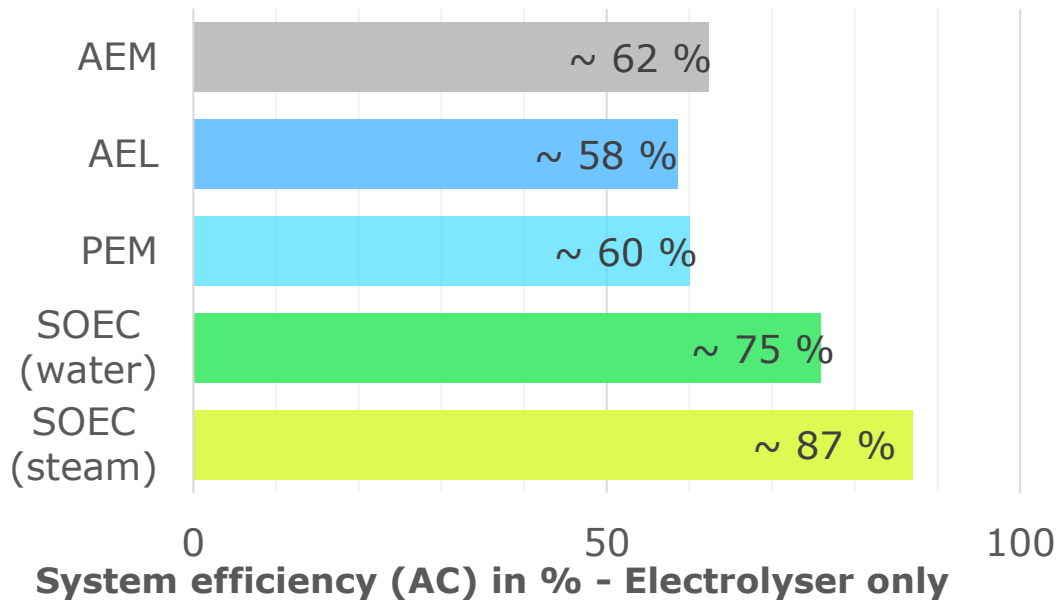
AEM Electrolysis Stack

First stack generation
planned for 2025



Hydrogen Production by SOEC

Electrolyzer Technologies Efficiencies:



20-30%*
savings in
hydrogen
production costs
using AVL-SOEC
technology

* cost outlook maturity 2035+,
depending on system and
plant/system layout

Recent SOC Market Trends

Delta Secures License to Hydrogen Energy Technology from UK-listed Ceres to Develop its Fuel Cell and Electrolysis Solutions

Delta Electronics, Inc. (hereinafter referred to as "Delta"), a global leader in power and thermal management and provider of IoT-based Smart Green Solutions, today announced the signing of a long-term collaboration agreement, which includes technology transfer and licensing, with Ceres Power Limited, subsidiary of London Stock Exchange-listed Ceres Power Holdings plc (hereinafter referred to as "Ceres") to access Ceres' Hydrogen energy stack technology portfolio for approx. GBP43 million. Ceres is a global leader in solid oxide fuel cell and electrochemical technology.



[Delta Secures License to Hydrogen Energy Technology from UK-listed Ceres to Develop its Fuel Cell and Electrolysis Solutions - Ceres](#)

Thermax Partners with Ceres for Green Hydrogen Production with Large-Scale Solid Oxide Electrolysis (SOEC) Manufacturing in India

Thermax, a leading energy and environment solutions provider and a trusted partner in energy transition, has announced a strategic collaboration with Ceres Power Holdings plc (CWRL), a leading developer of clean energy technology. The two companies have entered a non-exclusive, global licence agreement for Thermax to manufacture, sell and service stack array modules (SAM) based on Ceres' advanced solid oxide electrolysis (SOEC) technology. Thermax will also develop, commercialise and sell SAM balance of modules (SBM) and multi-megawatt SOEC electrolyser modules. The partnership marks a significant step towards accelerating the deployment of SOEC technology in India and worldwide that will enable cost-effective green hydrogen production.



[Thermax Partners with Ceres for Green Hydrogen Production with Large-Scale Solid Oxide Electrolysis \(SOEC\) Manufacturing in India - Ceres](#)



[HD Hyundai makes a Strategic Investment in Elcogen - Affordable Green Hydrogen](#)

thyssenkrupp nucera and Fraunhofer IKTS agree on a strategic partnership in SOEC technology

Press release / March 13, 2024

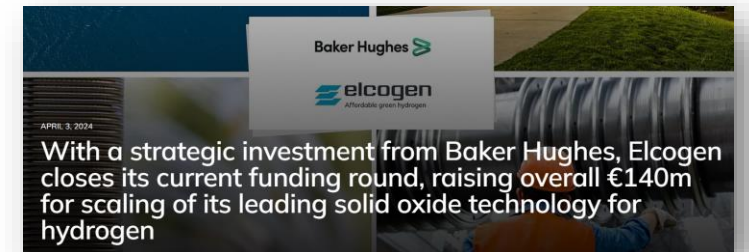


- Strengthening thyssenkrupp nucera's hydrogen technology portfolio for industrial applications through highly innovative high-temperature electrolysis (SOEC)
- Technology transfer of the electrolysis CFY stack technology developed at Fraunhofer IKTS
- Major cost advantage of SOEC technology in the application areas due to high efficiency
- Design for a later production ramp-up depending on the results of the pilot production line to test the existing technology status and achieve the necessary economic efficiency

[13.03.2024 Press release: thyssenkrupp nucera and Fraunhofer IKTS agree on a Strategic Partnership in SOEC Technology - Fraunhofer IKTS](#)

Significant momentum in the SOC market in 2024

Big Players start to heavily invest in SOEC technology



With a strategic investment from Baker Hughes, Elcogen closes its current funding round, raising overall €140m for scaling of its leading solid oxide technology for hydrogen

[With a strategic investment from Baker Hughes, Elcogen closes its current funding round, raising overall €140m for scaling of its leading solid oxide technology for hydrogen - Affordable Green Hydrogen](#)

Topsoe confirms FID to build world's largest SOEC electrolyzer plant; company's biggest single investment

02 September 2022

The Board of Topsoe has made the final investment decision (FID) to begin construction of the world's largest SOEC electrolyzer manufacturing plant in Herring, Denmark. Plant manufacturing capacity is 500 MW per year with an option to expand to 5 GW.

[Topsoe confirms FID to build world's largest SOEC electrolyzer plant; company's biggest single investment - Green Car Congress](#)

Next Generation Electrolyzer Technologies

1MW 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

NEWS

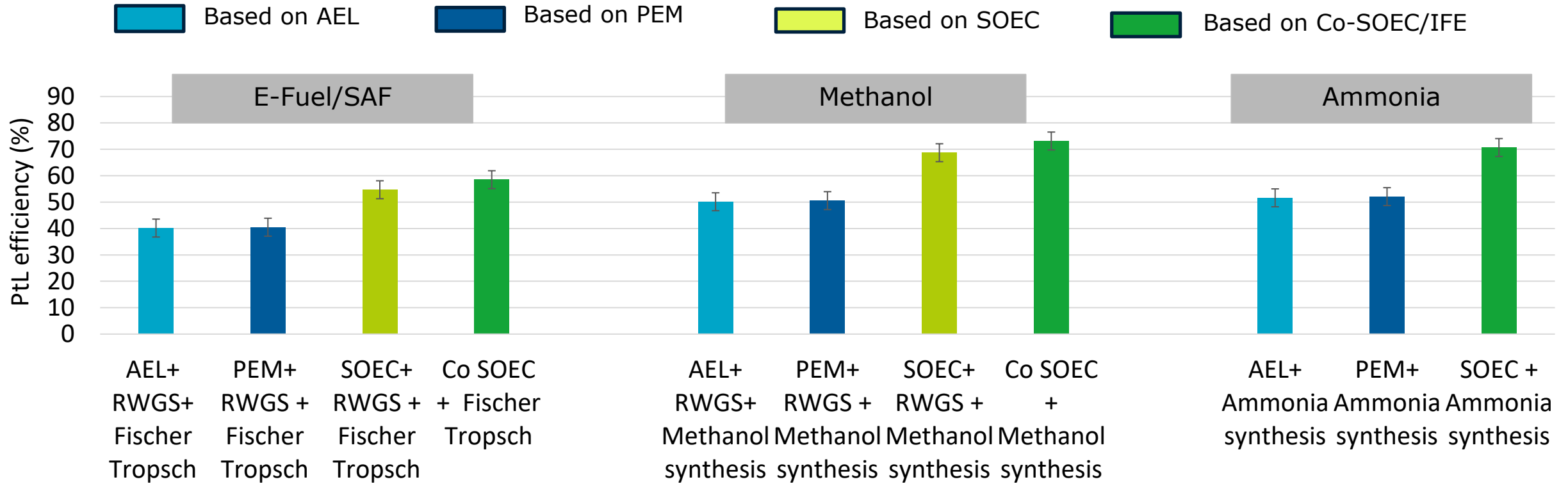
Ceres and Shell sign agreement for green hydrogen

28 June 2022

- Megawatt scale demonstrator to be located in Bangalore, India
- Aim to deliver low-cost green hydrogen for industrial decarbonisation



E-Fuel Production Routes



E-Fuel Production is >30% more efficient using SOEC technology

Executive Project Summary

Main targets

- Co-SOEC development and integration
- ~55% overall PtL efficiency (LHV)
- 200kW (2x100kWel) Co-SOEC systems
- Focus: SAF (~100.000 liters of syncrude)
SAF ... sustainable aviation fuels

Program timeline

- 2019/2020 Concept Study
- 2021 - 2023 Design of a 200 kW Power-to-Liquid Plant
- 2024 – 2026 Build-up and operation



Hydrogen and Fuel Cell

Shift of Focus

NEW APPLICATIONS introduce NEW CHALLENGES in the development

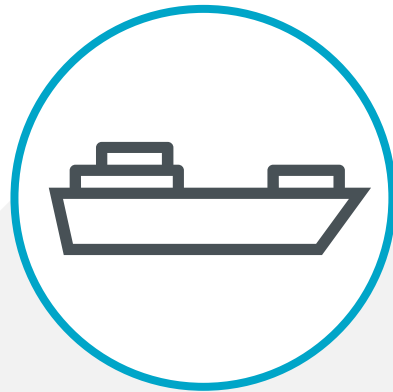
Shift of Focus

Automotive



- Heavy Duty Transport
- Bus (City, Inter-City, Transit)
- Light Commercial Vehicles

Marine



- Local shipping
- Super-Yacht
- Short-sea RoPax / Cargo
- Cruise

Stationary



- Off-grid power generation
- Mobile power generation
- Backup power generation

Aviation

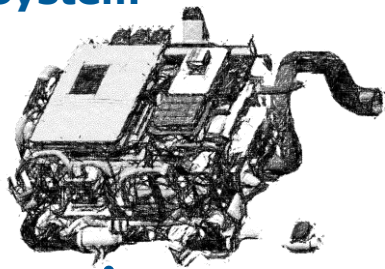


- Urban air mobility
- Small aircraft
- Commuter
- Regional aircraft

AVL PEM Fuel Cell System Development – A Timeline of Competence in Mobility



90 kW Fuel Cell System



AVL
Fuel Cell
Demo Car

Fuel Cell Demo Cars



325 kW Marine Fuel Cell System



Class 8 Truck Conversion



2017

AVL

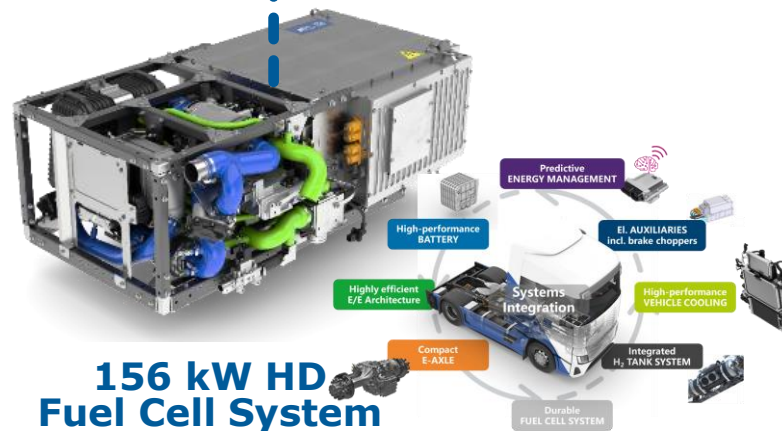
AVL

AVL

2024



35 kW Range Extender System



156 kW HD Fuel Cell System



Fuel Cell Ineos Granadier



Aviation Fuel Cell System Development

Fuel Cell Propulsion for Aviation

Introducing Airbus **ZEROe**

Turboprop		 <100 Passengers	 1,000+nm Range
		 Hydrogen Hybrid Turboprop Engines (x 2)	 Liquid Hydrogen Storage & Distribution System
Blended-Wing Body		 <200 Passengers	 2,000+nm Range
Turbofan		 Hydrogen Hybrid Turbofan Engines (x 2)	 Liquid Hydrogen Storage & Distribution System

AIRBUS



AVL is supporting Airbus in the framework of the EU Clean Aviation Project „FAME“ in the fuel cell propulsion system development

Thank you



www.avl.com