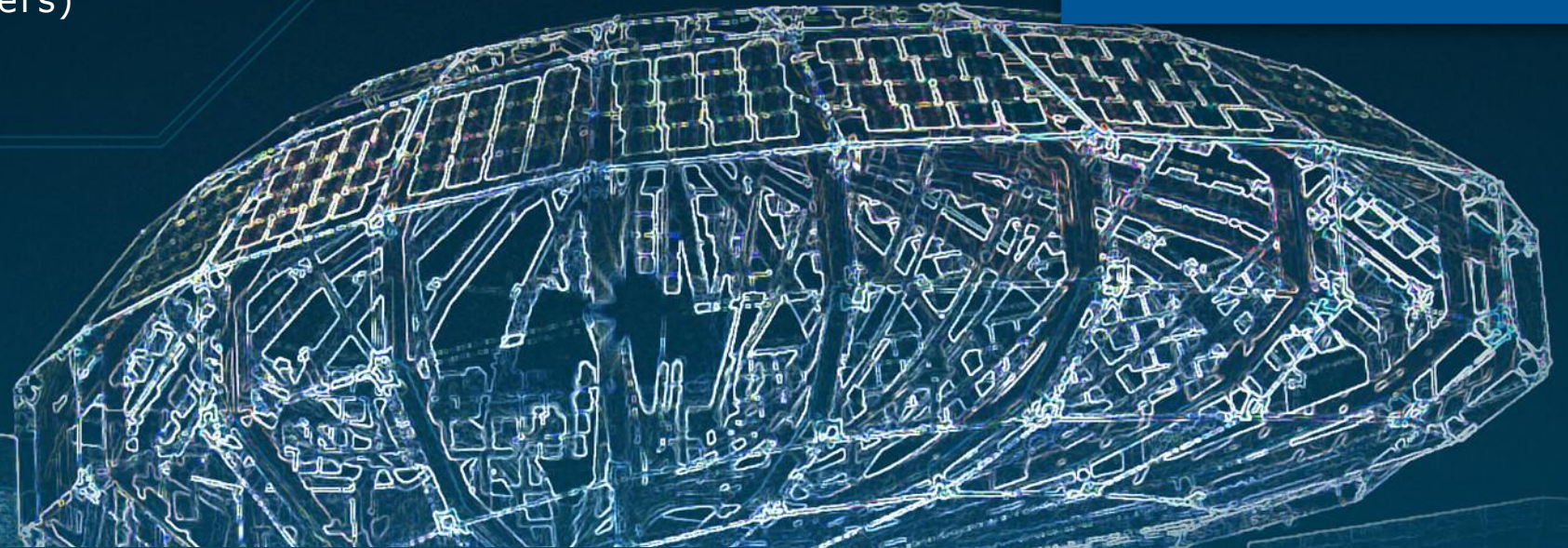


AVL



AVL List GmbH (Headquarters)

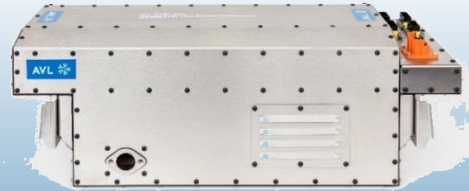


Solide Oxide Fuel Cell

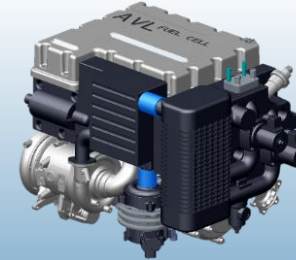
AVL Services Portfolio

Fuel Cell Systems

Two technology options for automotive industry



Solid Oxide Fuel Cell (SOFC)



Polymer Electrolyte Membrane Fuel Cell (PEMFC)

Range Extender



Efficiency: up to 55%

Both technologies can be used for passenger cars & commercial vehicles



Main Propulsion & Range Extender

Efficiency: up to 60%



Applications of SOFC APU

BEV Range Extender



©Nissan Motor Co

The system has two applications:

- 1) **Range extender:** for battery electric vehicles (passenger cars, commercial vehicles (LD and MD))
- 2) **Portable power generator:** for truck anti-idling, special purpose vehicles, marine and other mobile power generator applications



Truck Idling



Special Purpose



Marine/Leisure

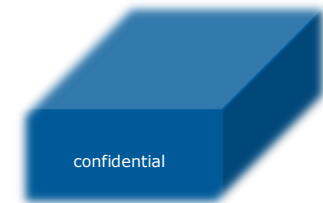
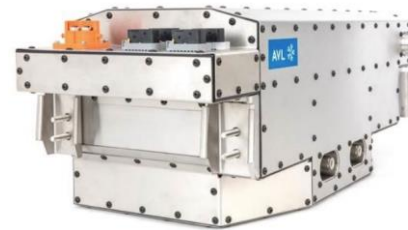
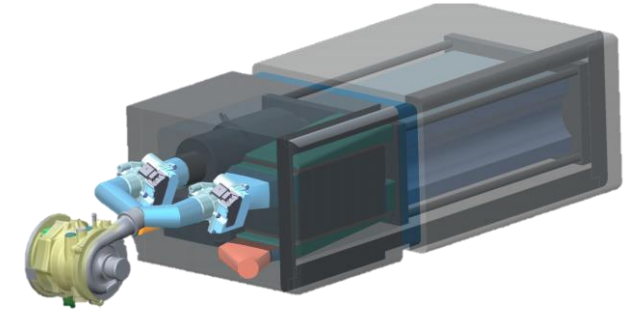
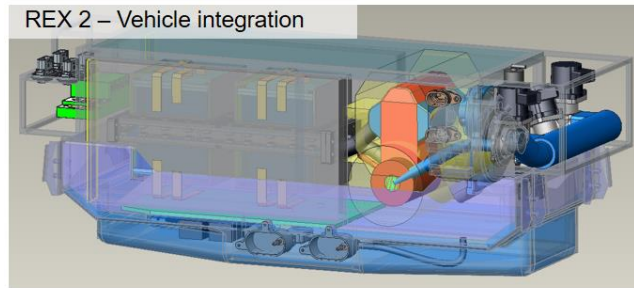


Development history SOFC REX

August 2016

December 2017

today



Fuel:	E100
Power output:	5kW
Efficiency:	~35-45%
Start-up time:	~40 min
Volume:	150L
Weight:	130kg
SOFC type:	ASC
Voltage:	85-150V
Current:	60A

Fuel:	E45
Power output:	5kW
Efficiency:	~45%
Start-up time:	~30 min
Volume:	142L
Weight:	115kg
SOFC type:	MSC
Voltage:	2x 60V
Current:	2x 80A

Fuel:	E45/CNG/eGas
Power output:	>10kW
Efficiency:	~55%
Start-up time:	~15 - 30 min
Volume:	145L
Weight:	110kg
SOFC type:	MSC
Voltage:	tbc
Current:	tbc

Project Example – SOFC Automotive

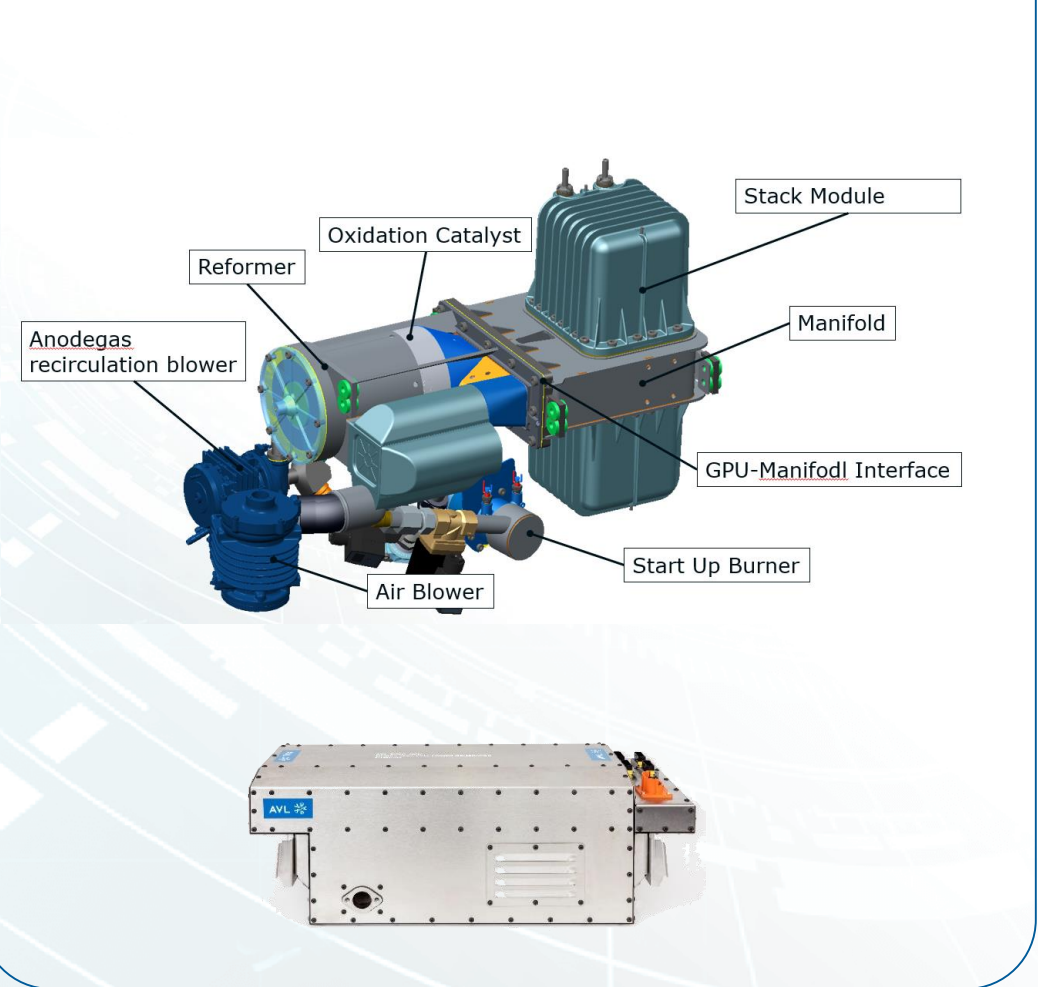


>600km Range

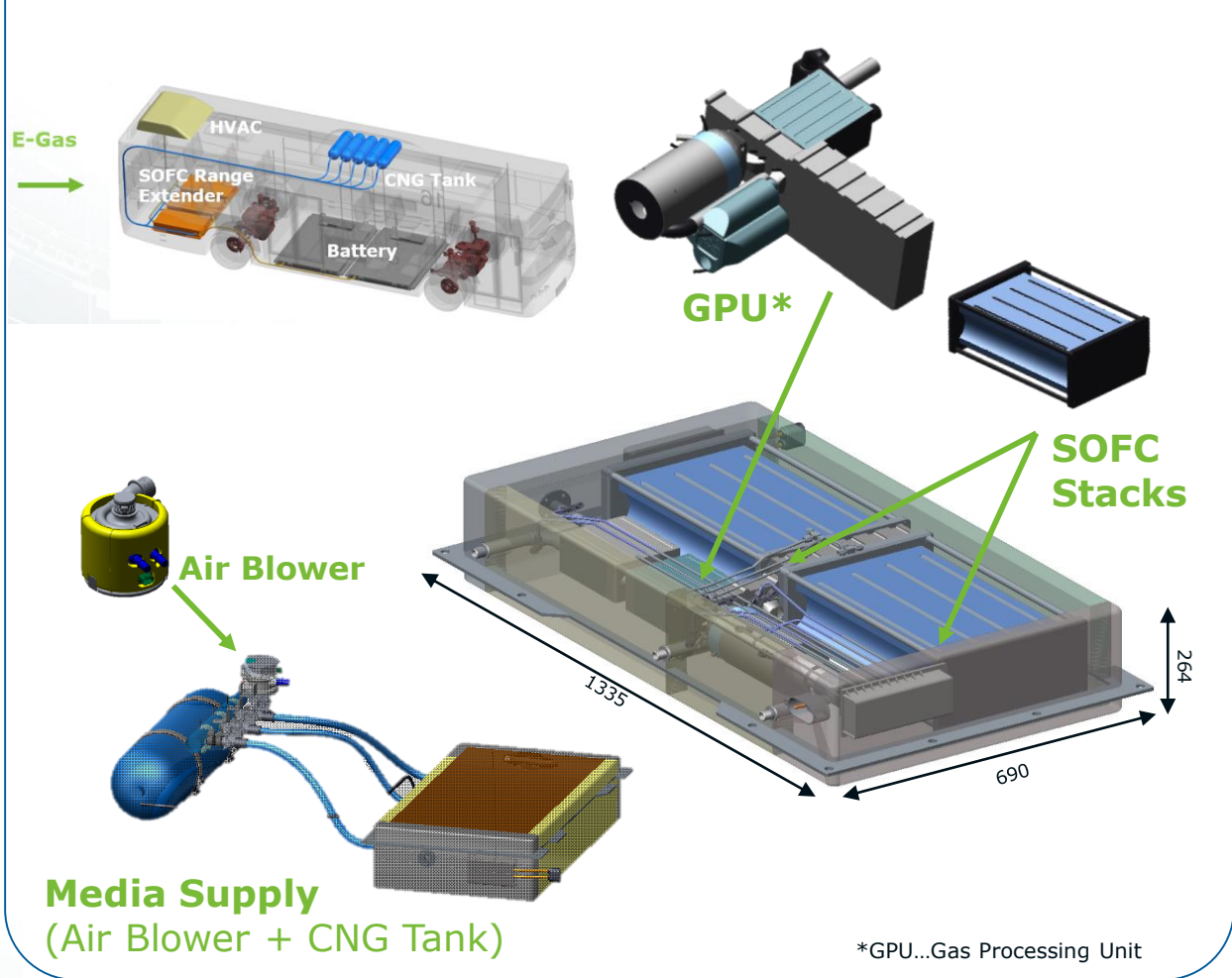
5kW SOFC REX

SOFC System

SOFC System Gen. III



SOFC System Gen. IV (10kW building block)



Applications for SOFC CHP

MULTI FAMILY HOMES



INDUSTRY



DATA CENTERS



HOTELS



HOSPITALS

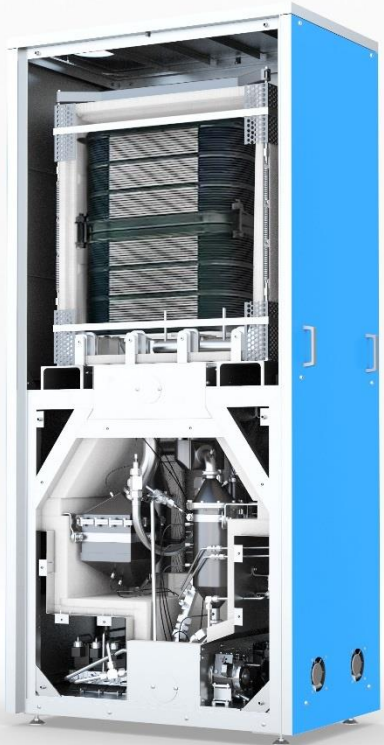


TELECOM STATIONS



AVL SOFC CHP

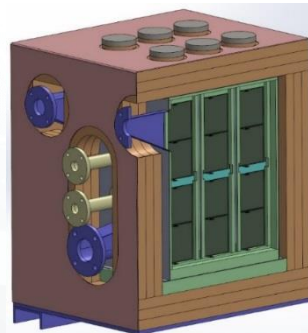
- 5-10kW System available on TRL7, Projects from 5kW to 1 MW
- MW powerplant concept design available
- Unique system designs for high efficiency, high durability and low cost



10kW



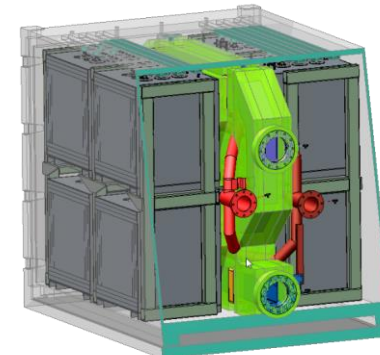
5kW



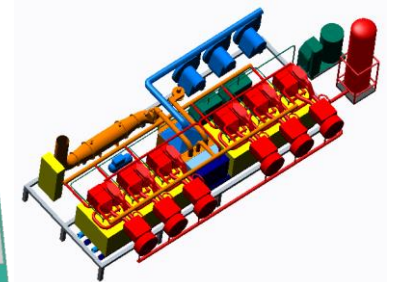
20kW



50kW



200kW



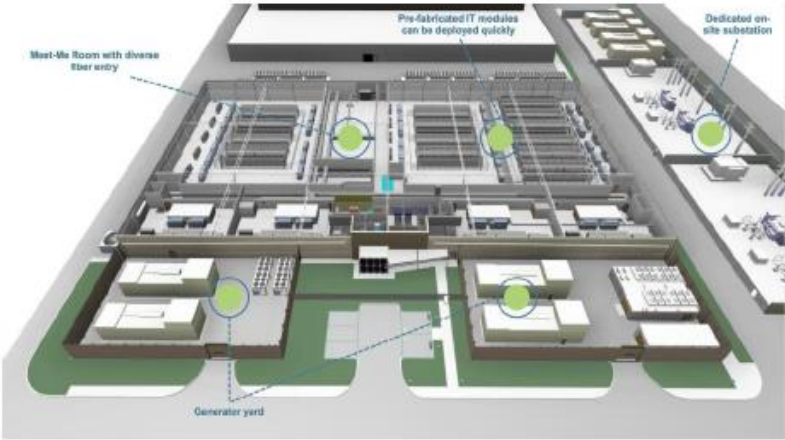
1000kW

Application in Data Centers

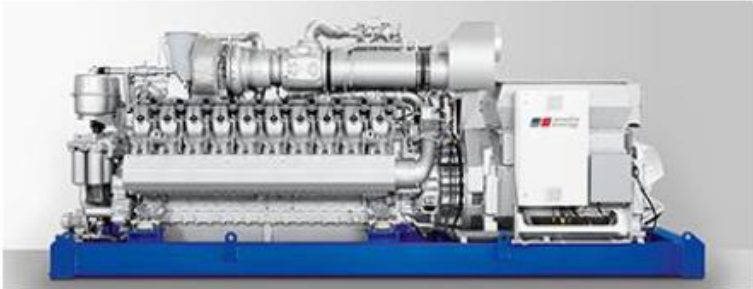


Grid

Compare different power supply scenarios for datacenters



Datacenter



Gas Genset



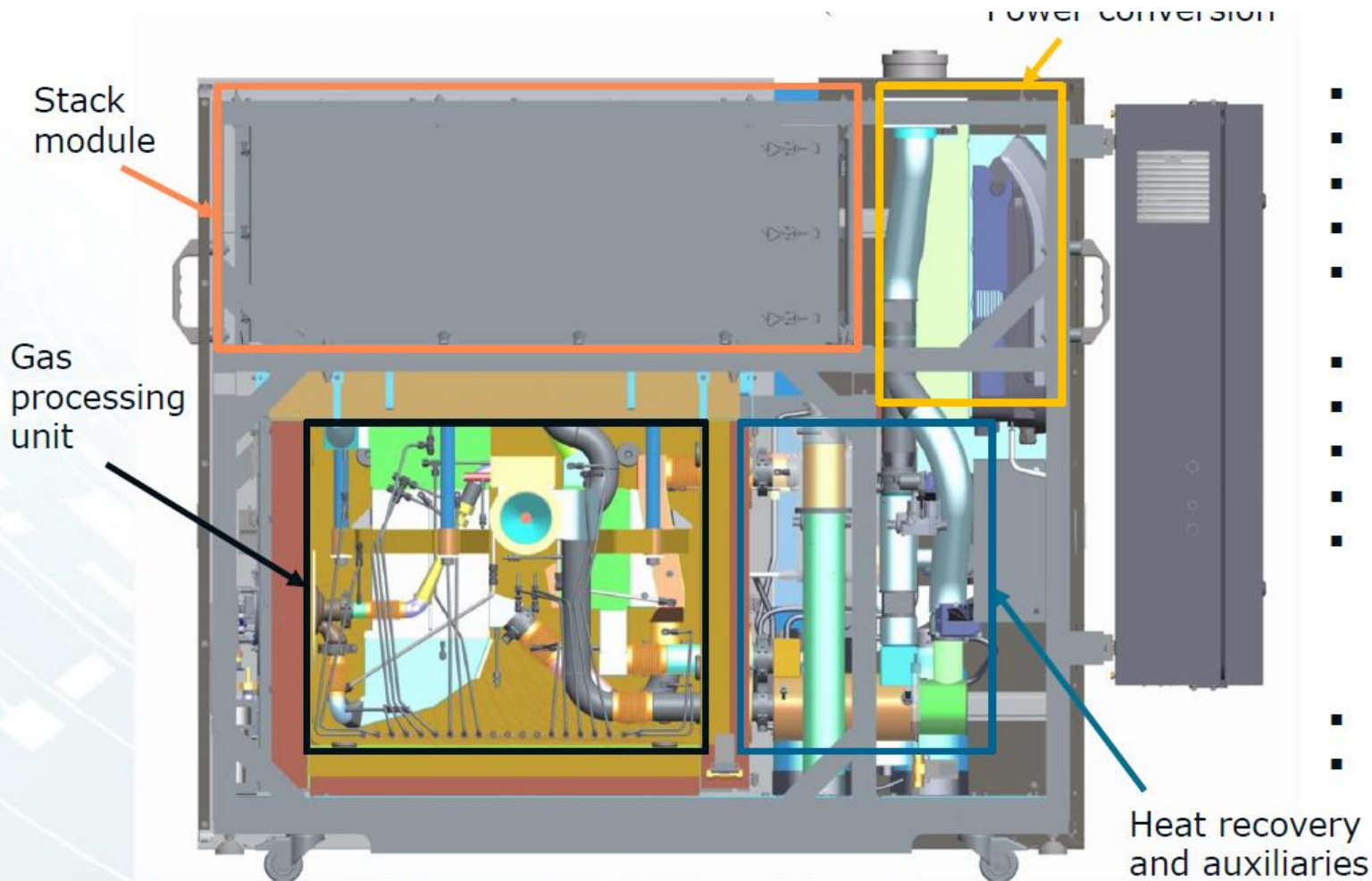
PEM

Efficiency, CAPEX, OPEX, TCO, CO₂, footprint, power supply



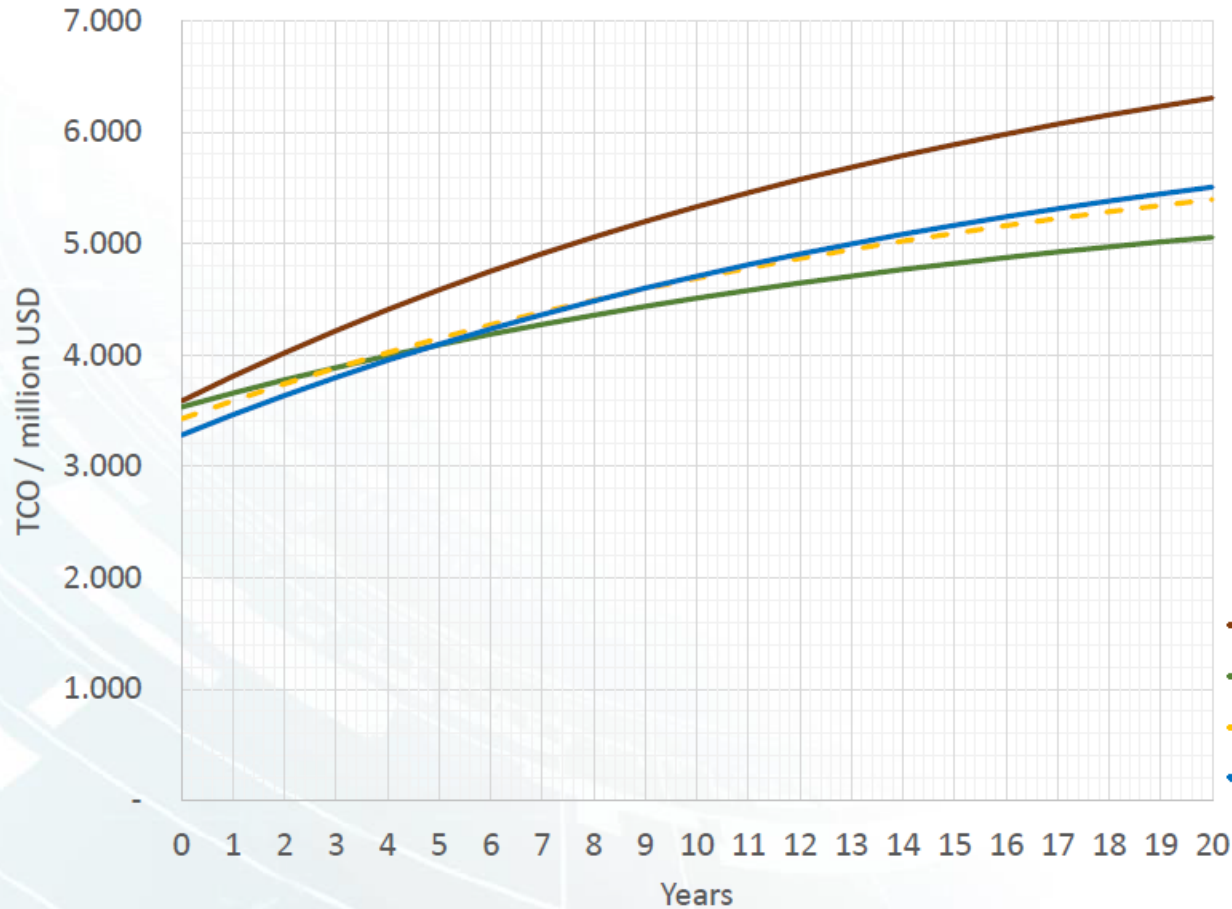
SOFC

AVL CHP Demonstration Unit



- 5 kW_{AC} nominal power
- 10 % overrating
- 0–100 % power modulation
- >55 % electrical efficiency
- >90 % total efficiency (30/65 °C)
- Natural gas from grid
- Desulfurizer included
- DC/AC power conversion
- Grid feed-in (3-phase)
- Water neutral by using exhaust gas condenser. No external water supply required.
- Condensate cleaning
- Underpressure system

TCO Comparison



- Grid solution by far the most expensive
- Lowest TCO with SOFC due to high electrical efficiency of power generation, conversion and distribution

— Case 1 - Grid, 230 VAC
 — Case 4.1 - SOFC, central, OR
 - - Case 4.2 - Genset Gas, central, OR
 — Case 5.2 - PEM, Integrated, OR