Technology



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INVESTOR DAY 2022

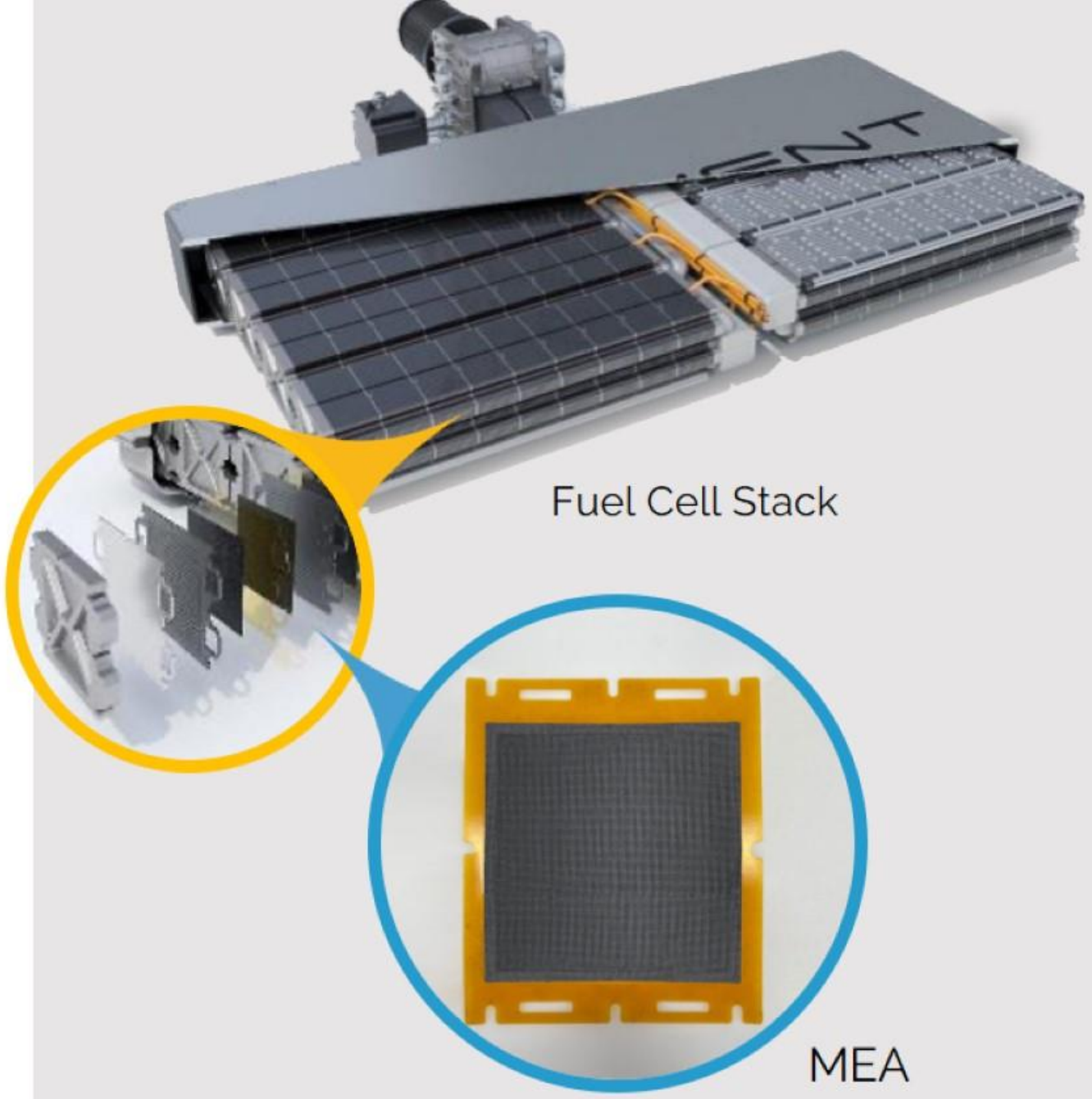
ADVENT

HT-PEM Fuel Cell Technology

HT-PEM fuel cells run hot (120-160°C)

Competitive Advantage: Low TCO

- **Multifuel**: can use any H2 fuel or biofuel
- **Lifetime:** performs at extreme conditions
- **Efficiency:** suitable for heavy-duty applications



Multifuel = Opex & Capex Reduction

Technology

PRODUCTION



SUN



WIND



WASTE

Green H2





CONVERT FOR TRANSPORTATION



eMethanol
LOHC

Ammonia

Renewable Natural Gas

Biomethane
Biomethanol

Green H2

ADVENT

HT-PEM FUEL CELLS

APPLICATIONS

Trucks



Marine



Aviation



Off-Grid



Buildings

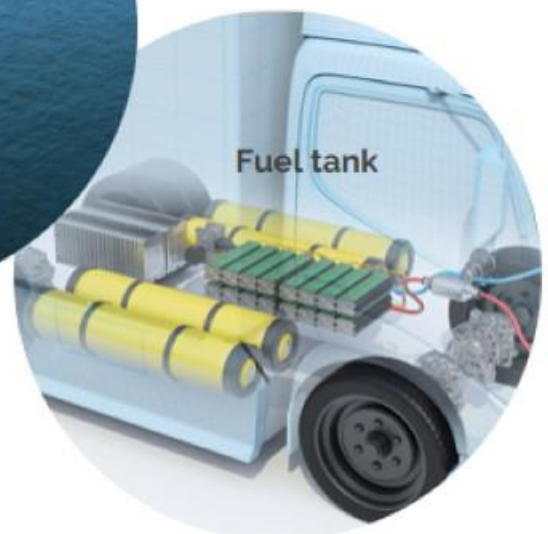




Multifuel capability enables wide and immediate market

- Marine will use eMethanol or Ammonia. Cannot Pack the H2 needed in a ship. Same for Aviation. Liquid hydrogen is 2.6 kWh/liter while methanol is 4.3
- HD-Automotive & Trains would benefit from fuel flexibility to reduce cost per mile
- Buildings can move from NG to NG/H2 blend to pure H2 gradually with same technology
- Off-grid power, remote & portable power for defense, infra and surveillance need liquid clean fuel like eMethanol for logistics





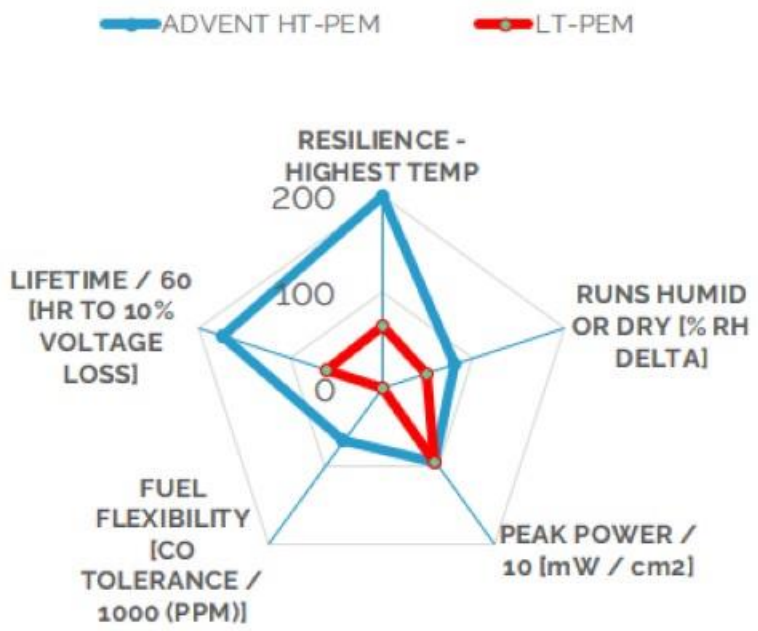
eMethanol fuel cartridge



Best in Class for HD Transportation

	SOFC	MCFC	PAFC	LT PEM	ADVENT HT PEM
Efficiency	High	Medium	Medium	Medium	High
Startup time	Long	Long	Moderate	Fastest	Fast
Fuel flexibility	Medium, low sulphur tolerance	High	High	Low	High
Power Density	Medium	Low	Medium	High	High
Water needed / run dry	Start up/yes	Yes / no	None	No / No	No / No
Cost reduc potent.	Medium	Low	Low	High	High

HT-PEM = Long Lifetime.



Wet- Dry
HT PEM: 80% RH DELTA
LT PEM: 50% RH DELTA

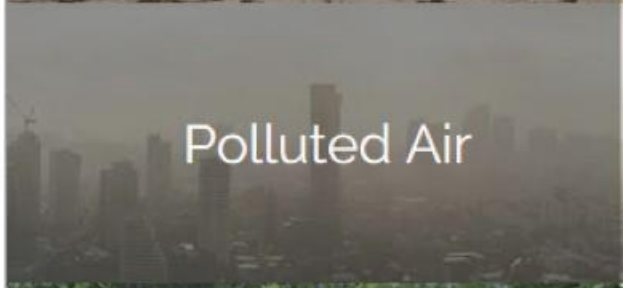
Reliance to heat
HT PEM: upper operating T = 200-240 °C
LT PEM: upper operating T = 80 ° C

Lifetime (time to 10% voltage drop)
HT PEM: 10,800 hrs
LT PEM: 3,600 hrs

Resistance to pollution and hydrogen impurities
HT PEM: can function with up to 4% carbon monoxide
LT PEM: 10 parts per million

Works ANYWHERE









Technology

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High Temperature = High Efficiency

- **Aviation:** We cannot fly unless we go HT-PEM. Heat-exchange inefficiency will make flight impossible
- **Trucks:** Radiators to run big trucks in the desert, (and any hot environment) are not existent or efficient
- **Buildings:** with HT-PEM we have quality heat and hot water.
  Cannot do this with lt-pem

High Temp Operation = Efficiency and Simple Design

Anywhere means the fuel cell has fewer, more simple sub systems, lower maintenance, and lower MTBF



How Advent Developed the HT-PEM Technology

Technology

ADVENT

1960s — First LT-PEM fuel cells



2006 — Advent HT-PEM Gen 1



2012 — R&D with NASA, ESA, DoE

DoE

ESA

NASA

2013 — Advent-BASF HT-PEM Gen 2

BASF

2018 — DoE selects Advent for L'Innovator Joint Dev. Program

LOS ALAMOS

BROOKHAVEN

NREL

2021 — HT-PEM Gen 3 launch with LANL



2021

Acquisition of UltraCell, Serenergy and fischer eco solutions GmbH



Silicon valley product dev for next gen fc system



New Boston & Europe production facilities under construction



Successfully demonstrates ion pair alone and in system Honey Badger



Mobility next-gen Fuel Cell under development



Enters into tech assessments and aims to bring ht-pem to all key markets with partnerships scale up production to GWs



New tech in HB and Serene (own systems) will drop cost and increase lifetime massively

Technology

ADVENT

Advent Has Assembled a 200-Strong Team of Top Materials Scientists and Fuel Cell Engineers

- ✓ For the last decade and more we are solely focused on developing the next generation of fuel cell technology
- ✓ Development/manufacturing hubs in Boston, Silicon Valley, Denmark, Germany, Greece
- ✓ 190 patents issued, licensed, or pending
- ✓ Strategic Partner of the U.S. Department of Energy (DoE) and U.S. Department of Defense (DoD).
- ✓ Awarded exclusive program with Los Alamos, Brookhaven, National Renewable Energy Laboratories to commercialize game-changing materials (MEAs, Catalyst)









Advent FC Systems

SereneU: Stationary Power systems

- ✓ *Replace the Diesel Generator*



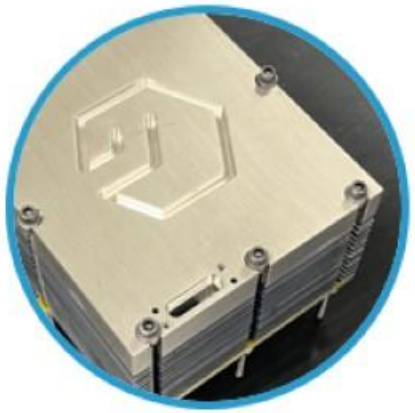
Honeybadger

- ✓ *Surveillance, Infrastructure, Defense*



DIGI-TRONIC: Mobility

- ✓ *Trucks*
- ✓ *Aviation*
- ✓ *Marine*



M-Zero

- ✓ *Remote Area Power System*
- ✓ *Mission-Critical Applications*



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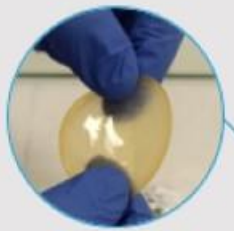
Fuel Cell Supply Chain

We design and manufacture systems for different market needs

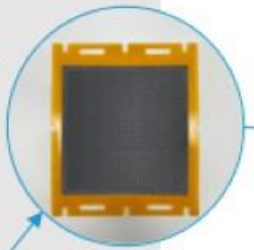
We make the MEAs
The "heart" of the fuel cell



Membrane



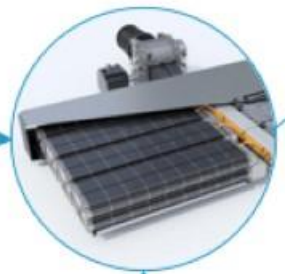
Electrode



MEA

Design and manufacture the fuel cell stacks

Fuel Cell Stack





Reformer-HT-Stack



Bipolar Plate

The complete fuel cell system that is ready to ship



Core Unit



Electro-mechanical Unit



Power Electronics / Control Unit

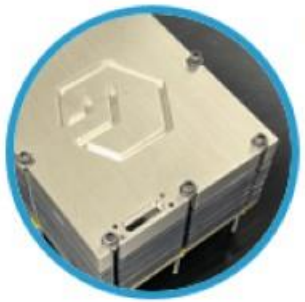
Stationary Power



Portable & Remote Power



Mobility



Systems

ADVENT

Serene Power Systems

Technology

- HTPEM fuel cell operated on methanol

System

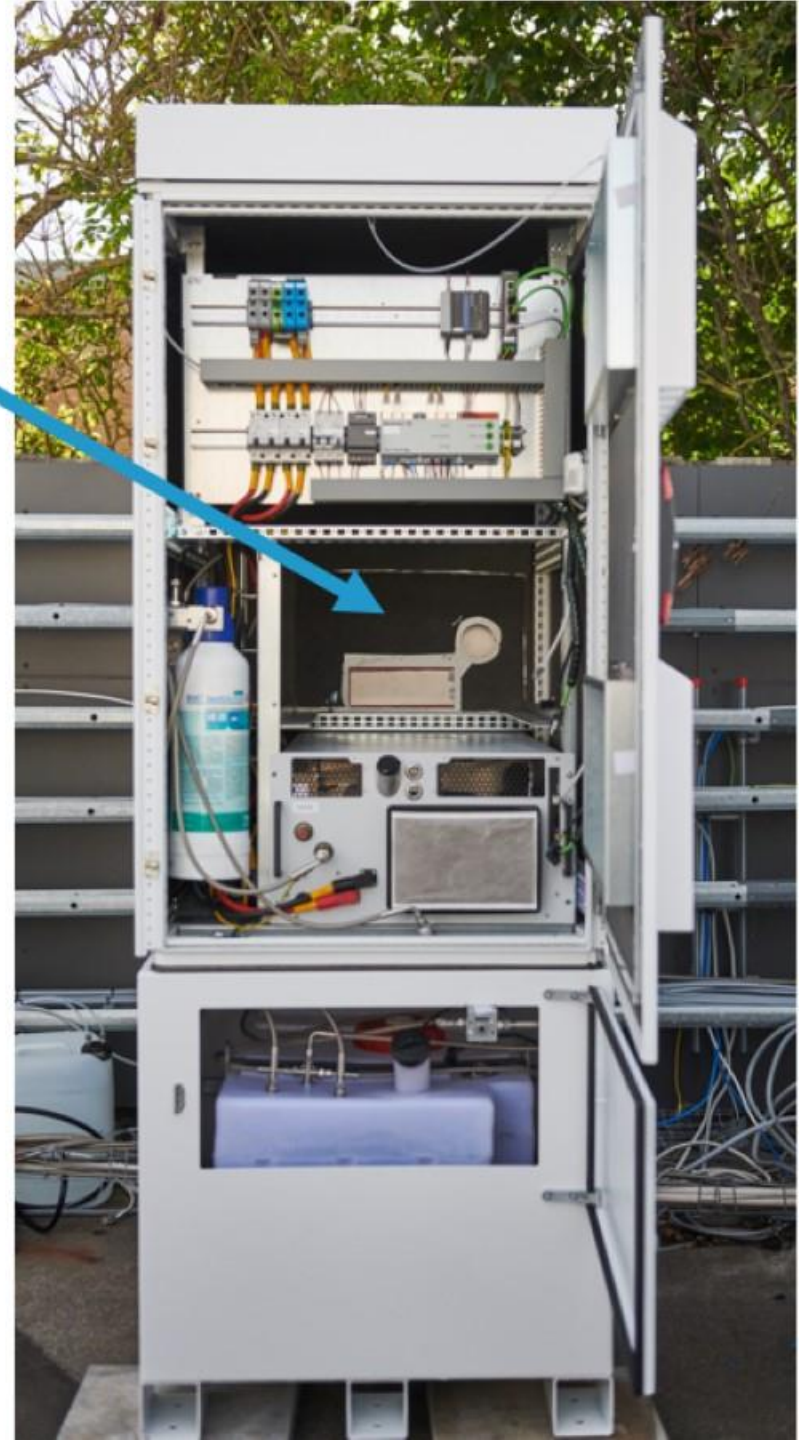
- Modular system in building block of 5 kW.
- System availability: 5-20 kW
- Tank size is 200L to 4,000L equivalent to 220kWh to 4,400 kWh of electrical energy.



5 kW Unit

Why a modular system?

- Having a modular system enables easy replacement, in case of repair/service.
- Easy mount and un-mount units for simplified field service. No fuel cell experience needed.
- Service and repair can do done at a certified local service center.



5 to 20 kW System

Systems

ADVENT

Advent's MEA Team Are Electrochemistry Specialists

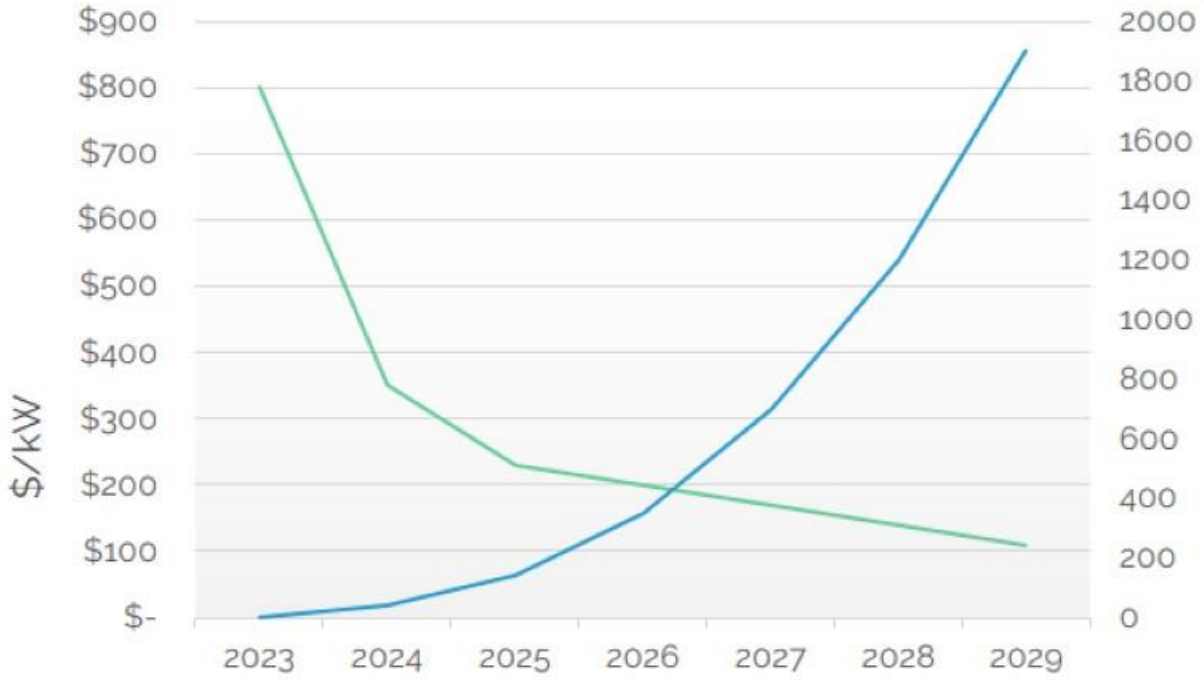
1. **Membrane**: highly selective synthesis and machine casting of performance polymers
2. **Electrode:** creating optimum structures for high current and catalyst utilization
3. **Lamination:** automation team for high-speed assembly of membrane electrode assemblies and stacks



Scale-up

Scale-up Manufacturing of MEA

Steep decline in price as volume increases







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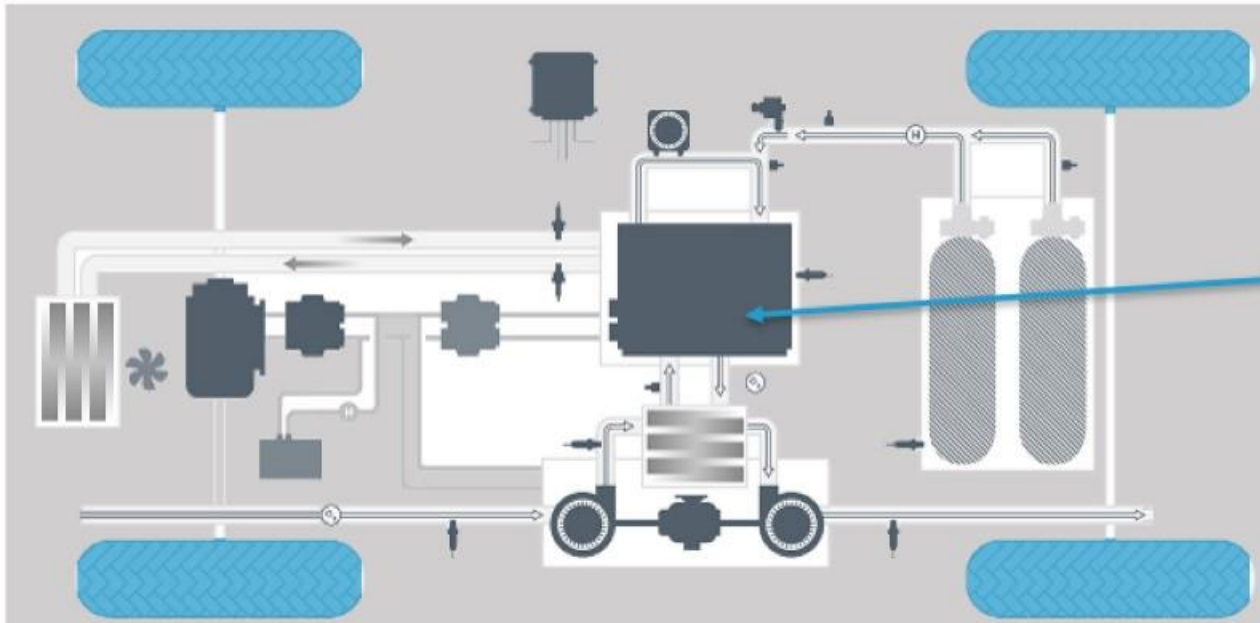
DIGI-TRONIC

ADVENT

DIGI-TRONIC: Simple Design & Low-cost Manufacturing

- ✓ HIGH-VOLTAGE 350V-800V
- ✓ INDIVIDUALLY DIGITALLY CONTROLLED CELLS FOR LONG LIFETIME AND REDUNDANCY
- ✓ SKATEBOARD DESIGN – FLEXIBLE FORM FACTOR



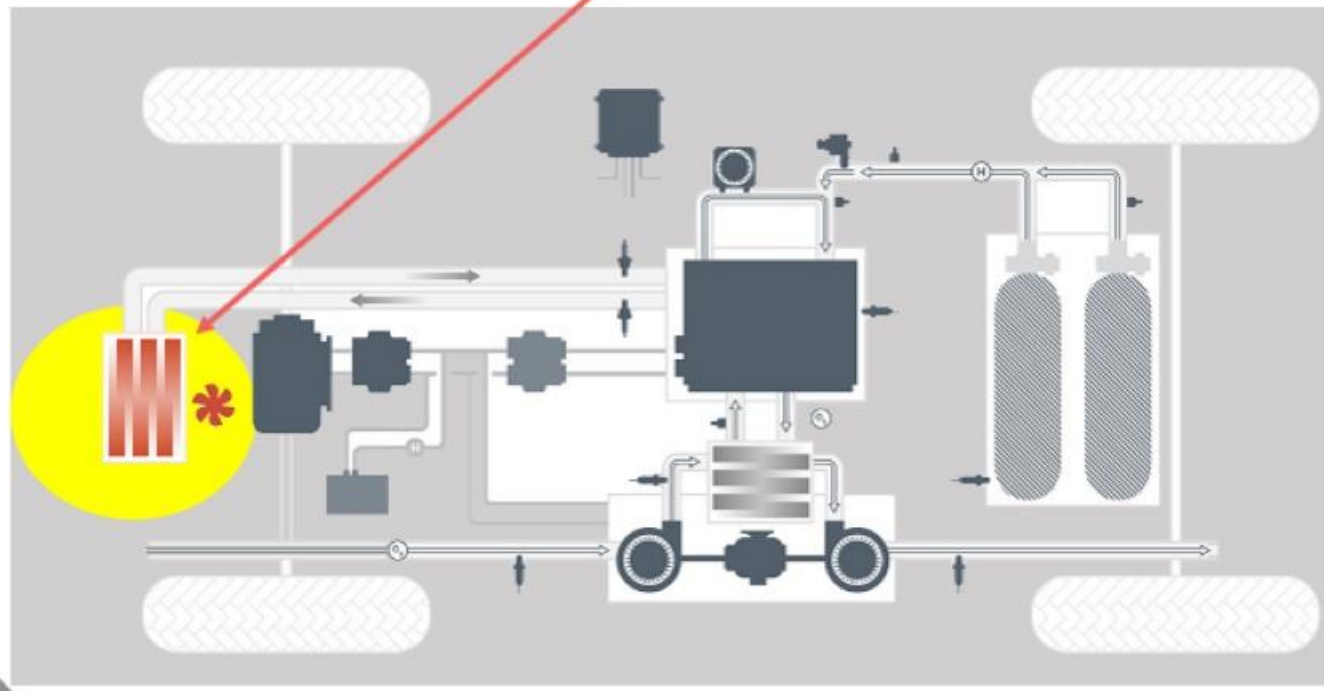


CONFIGURABLE TO MARKET AND APPLICATION NEEDS:

- EMOTOR+FUEL CELL -H_2 AS FUEL
- EMOTOR+FUEL CELL+REFORMER - EFUEL TANK
- EMOTOR-EV BATTERY-FUEL CELL RANGE EXTENDER

Efficiency: Superior Heat Management /Removal

- ✓ Advent fuel cell operates at 80°C-200°C: Innovative thermal controls are used including smaller radiators and compact cooling circuits for stack and system.





DIGI-TRONIC

ADVENT

From Innovation to TCO

Higher Power Density Higher Lifetime

TCO 6X Lower





Summary

- Advent's HT-PEM fuel cell technology is multifuel capable, can perform at ambient conditions, and is particularly suitable for heavy-duty applications.
- The multifuel capability enables wide and immediate market adoption.
- Advent is jointly developing the new Advent MEA in collaboration with the U.S. Department of Energy.
- Advent's HT-PEM has significant advantages over LT-PEM, SOFC, MCFC, and PAFC.
- Advent aims to revolutionize mobility by replacing the diesel generator and the internal combustion engine with DIGI-TRONIC.
- Advent's Boston-based team is working on the MEA manufacturing scale-up.
- Advent has assembled a 200-plus team of top material scientists and fuel cell engineers.
- Advent now covers the full supply chain of its products.