

Batterie- und Brennstoffzellensysteme

BSZ-Systeme 2

André Weber

Institut für Angewandte Materialien - Werkstoffe der Elektrotechnik IAM-WET

Adenauerring 20b, Geb. 50.40 (FZU), Raum 314

phone: 0721/608-7572, fax: 0721/608-7492

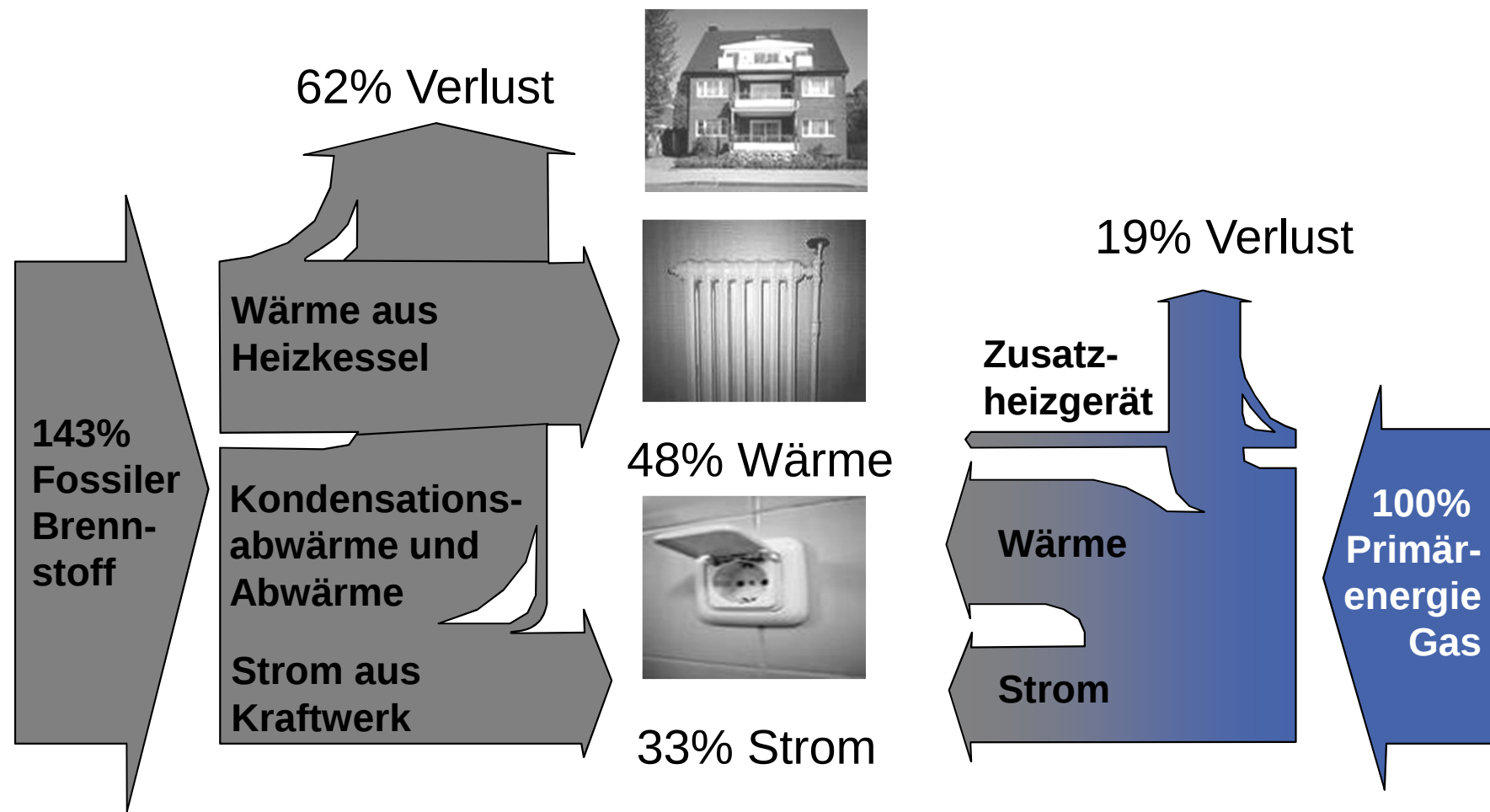
andre.weber@kit.edu

www.iam.kit.edu/wet



- BSZ-Systeme
 - μ CHP-Systeme
 - PEMFC
 - SOFC
 - SOFC für mobile Anwendungen
 - Auxiliary Power Units

CHP-Systeme (Brennstoffzellen-Heizgerät)



Die getrennte Erzeugung von Strom und Wärme erfordert 45% mehr Primärenergie als die gekoppelte Erzeugung mit einem Brennstoffzellen-Heizsystem.

Brennstoffzellen-Heizgeräte zur Strom- und Wärmeversorgung von Gebäuden

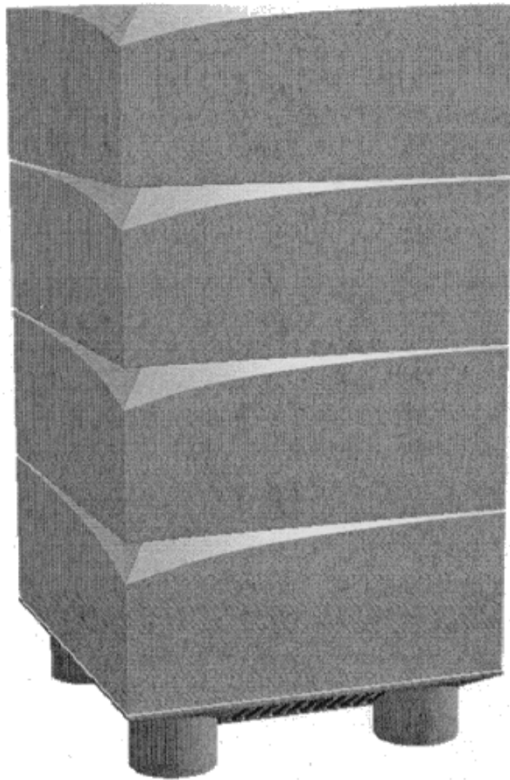


PlugPower/GE HomeGen 7000

Brennstoffzellen-Typ:	PEMFC
elektrische Leistung:	7 kW
thermische Leistung:	10 kW
Spannung:	120/240 V @ 60 Hz 100/230 V @ 50 Hz
el. Nettowirkungsgrad:	36% (2 kW), 29% (7 kW)
Systemwirkungsgrad:	>75%
Brennstoff:	Erdgas (u.a.)
Geräuschpegel:	60 dB @ 1 m

Brennstoffzellen-Heizgeräte zur Strom- und Wärmeversorgung von Gebäuden

Nuvera



Brennstoffzellen-Typ:	PEMFC
elektrische Leistung:	5 kW
thermische Leistung:	10 kW
Spannung:	120/240 V @ 60 Hz 100/230 V @ 50 Hz
el. Nettowirkungsgrad:	40 % (2 kW)
Systemwirkungsgrad:	>75%
Brennstoff:	Erdgas (u.a.)
Geräuschpegel:	<70dB @ 1 m

Brennstoffzellen-Heizgeräte zur Strom- und Wärmeversorgung von Gebäuden



Hpower RCU Fuel Cell

Brennstoffzellen-Typ:	PEMFC
elektrische Leistung:	4,5 kW
thermische Leistung:	k.A.
Spannung:	100/120/220 V _{AC}
el. Nettowirkungsgrad:	k.A.
Systemwirkungsgrad:	k.A.
Brennstoff:	Erdgas (u.a.)
Geräuschpegel:	k.A.

Vaillant / Plug Power

PEM : $4,5 \text{ kW}_{\text{el}}$ / 7 kW_{th} + Zusatzbrenner



Vailant Brennstoffzellen-Heizgerät

Brennstoffzellen-Typ: PEMFC
elektrische Leistung: $1 - 4,5 \text{ kW}_{\text{el}}$
thermische Leistung: $1,5 - 7 \text{ kW}_{\text{th}}$
Zusatzbrenner: 50 kW
el. Nettowirkungsgrad: $35 - 40\%$
Systemwirkungsgrad: $> 80\%$
Brennstoff: Erdgas



Mai 2000



November 2000

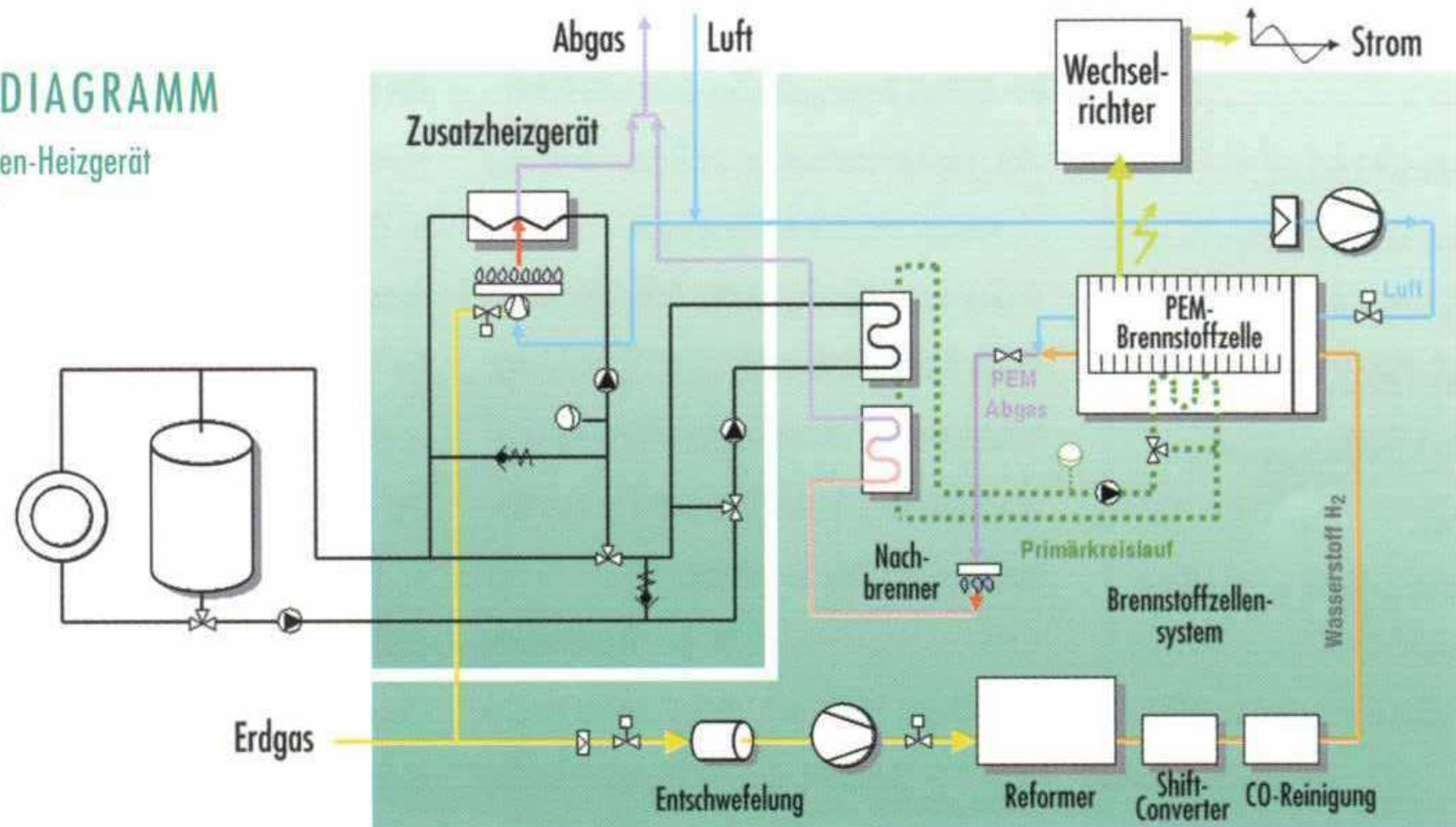


2005

Vaillant PEMFC-Heizgerät

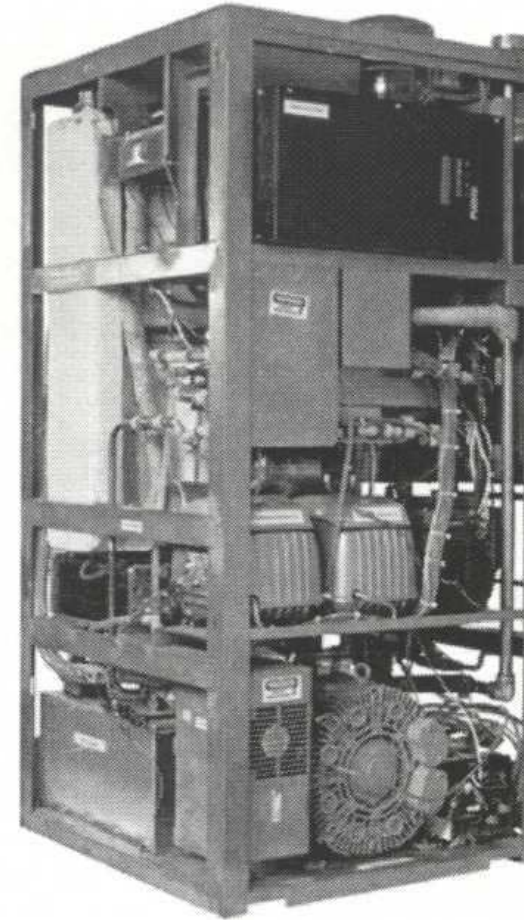
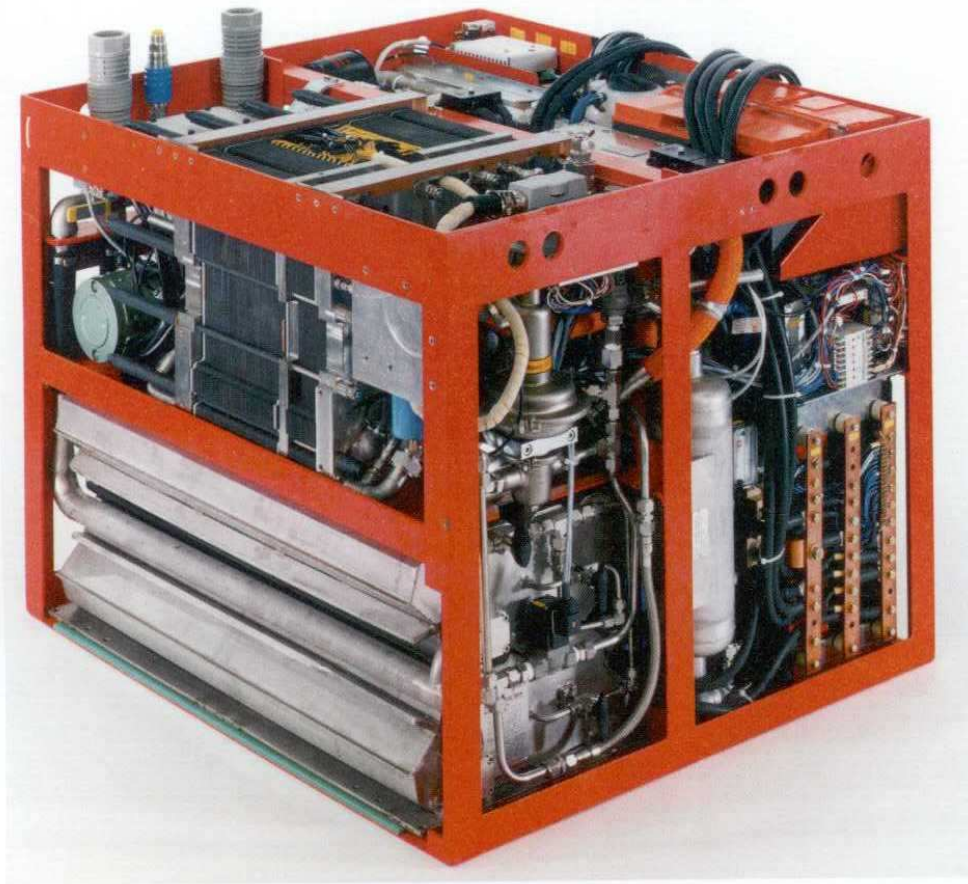
PROZESSFLUSSDIAGRAMM

Anlage mit Brennstoffzellen-Heizgerät
und Warmwasserspeicher



HGC Hamburg Gas Consult / Dais Analytic

PEM : 3 kW_{el} / 8 kW_{th} + Zusatzbrenner





Common Specifications:

Fuel:	Natural Gas or Commercial Grade LPG (7.5 – 27.5 mbarg)
Sound Level:	<55 dB @ 1 meter
Dimensions (DxWxH):	104 x 75 x 175 cm; 41" x 30" x 69"
Weight (approximate):	380 kg; 840 lbs.
Temperature Range:	2 to 40° C
Exhaust Temperature:	<50° C
Ventilation Requirement:	Must be vented to the outdoors
Operating States:	On-Idle-Off

Electrical Specifications:

Electrical:	0.8 kWe (Net minimum) – 4.6 kWe (Net maximum)
Thermal:	>7.0 kW _{th} (Net) based on 40° C inlet water temperature
Nominal Output Voltage:	220 VAC @ 60 Hz, Single Phase 230 VAC @ 50 Hz
Electrical Output Turn Down Ratio:	6:1

Panasonic ENEFARM



Separate type



Integrated type



In-door type

Fuel cell unit

Backup boiler

Hot water storage unit



		Separate type	Integrated type	In-door type
Fuel type			City gas (13A)	
Electric output	Rated output	700(W)		750 (W)
	Output range	200 - 700 (W)		200 - 750 (W)
Rated power generation efficiency		LHV:39.0% HHV:35.2%		
Rated heat recovery efficiency		LHV:56.0% HHV:50.6%		
Total efficiency		LHV:95.0% HHV:85.8%		
Hot water storage capacity		140 L		147 L
Dimensions (mm)	Fuel cell unit	Width:400 Depth:400 Height:1750		Width: 399 Depth: 395 Height: 1750
	Hot water storage unit	Width:560 Depth:400 Height:1750	Width:700 Depth:400 Height:1750	Width:400 Depth:560 Height:1850
	Backup boiler	Width:480 Depth:250 Height:750	(Built into the hot water storage unit)	Width:480 Depth:250 Height:750
Mass	Fuel cell unit	77 kg		99 kg
	Hot water storage unit	50 kg	88 kg	54 kg
	Backup boiler	44 kg		44 kg
Output during blackouts		Maximum 500(W)		

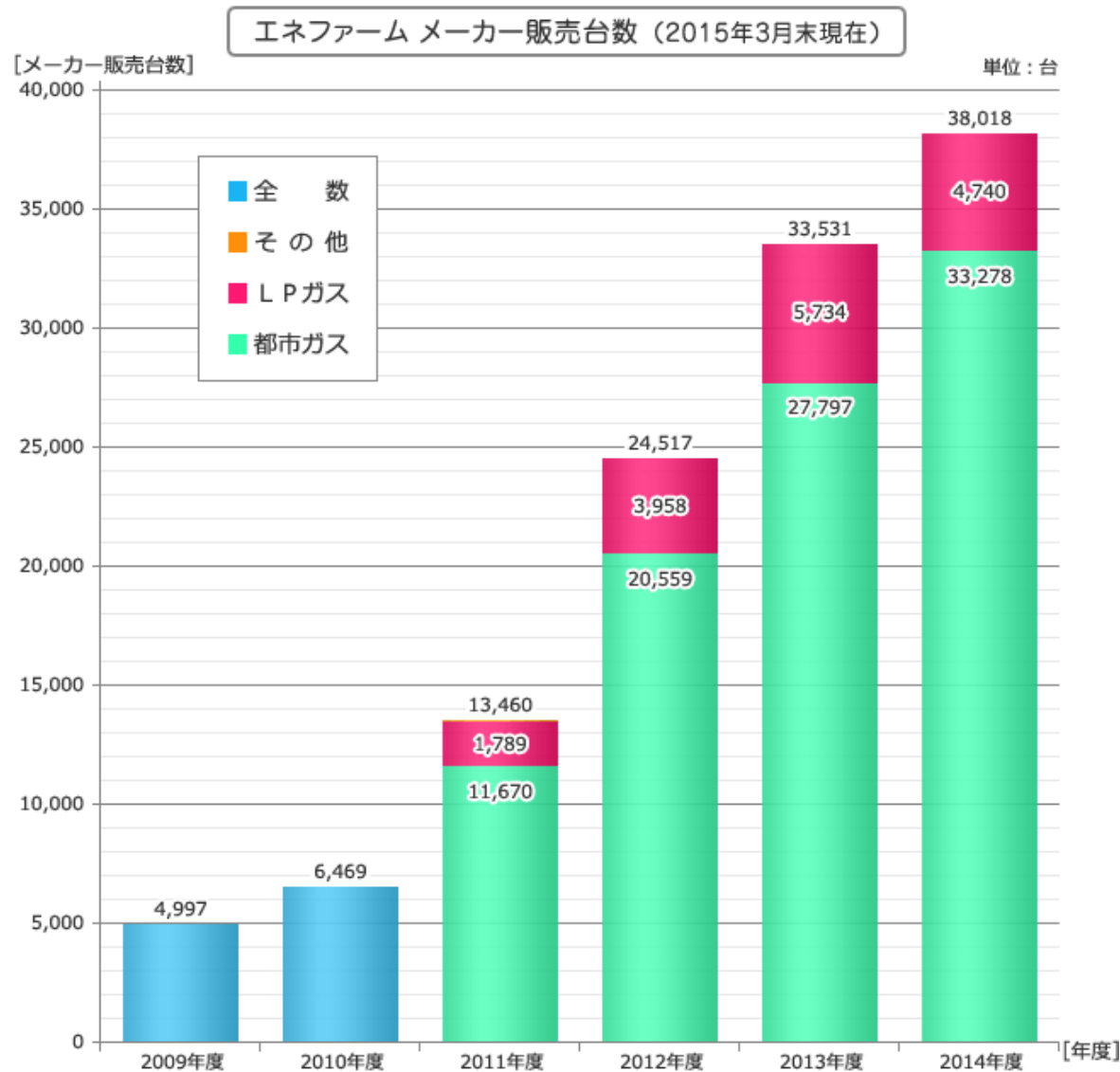
installed units: > 50000

price: < 15 k€

warranty: 10 years



ENEFARM μ CHP-FC in Japan (mainly PEMFC)



price:

PEMFC: ~ 11 k€

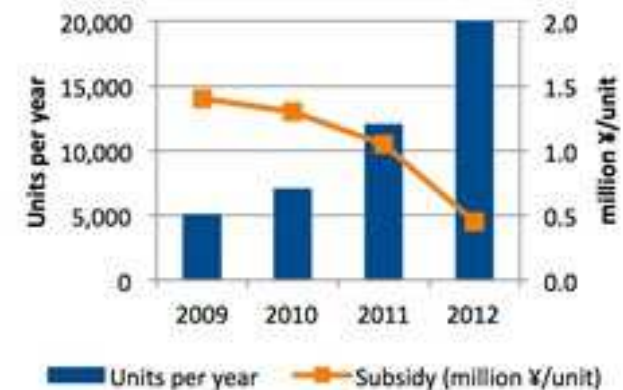
Tokyo Gas, Panasonic

750 W (39% / 95% el. / total eff.)

SOFC: ¥2,75 (~ 21 k€)

Osaka Gas, Aisin, Kyocera

700 W (46.5% / 90% el. / total eff.)



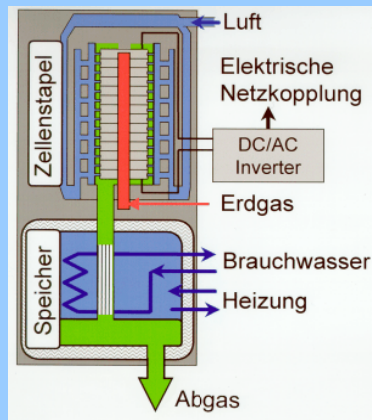
subsidy per unit (~ 700 W):

~ 10 k€ (2009) → ~ 3.4 k€ (2012)

→ 2.6 k€ (2014)

Solid Oxide Fuel Cell Application

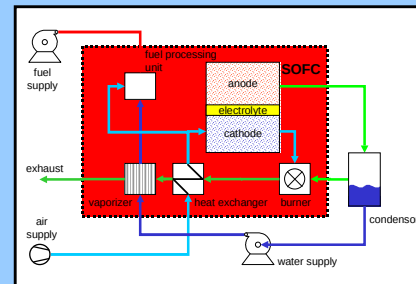
stationary



mobile

APU

auxiliary power units



electrical energy for
cars and trucks

Traction

SECA

Solid State Energy
Conversion Alliance

industry

military

solid state
fuel cell module
(5 kW)

automotive

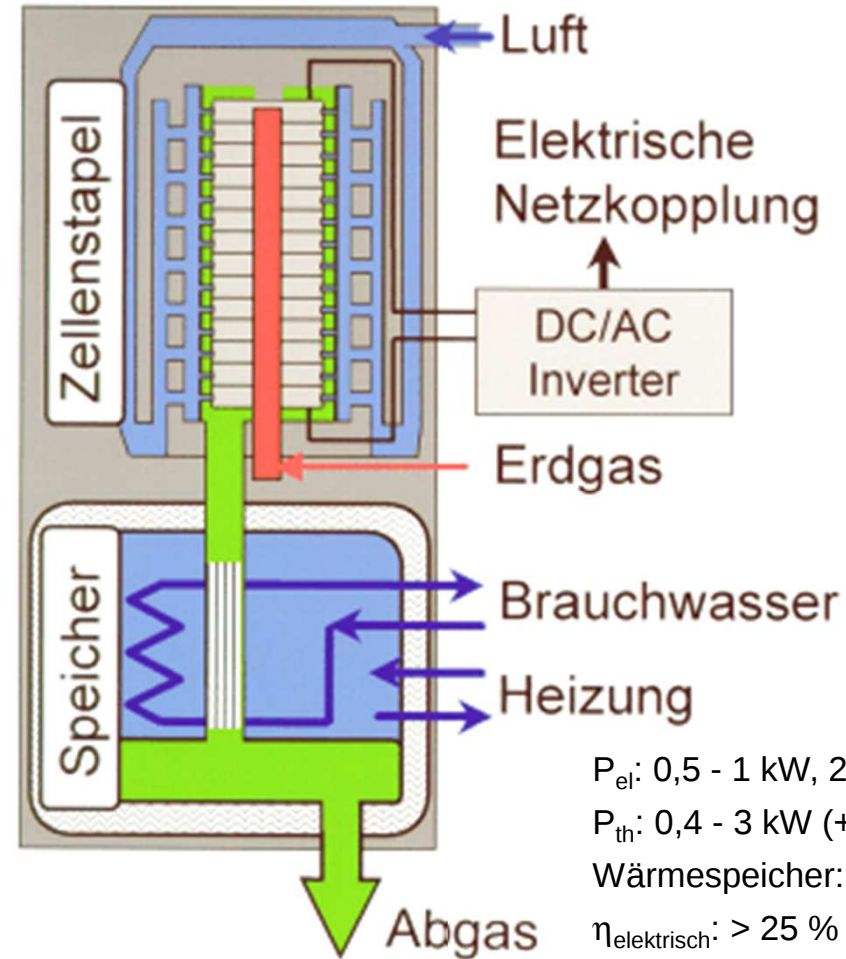
residential

Stationäre SOFC-Systeme

	Sulzer Hexis	FuelCell Technologies	ZTek	Siemens	Rolls Royce
					
Leistung el.	1kW	5kW	25kW	220kWhybrid 20kW Turbine	1MW hybrid 200kW Turbine
Leistung th.	2,5kW				
Entwicklungs- stand	Praxistest- erfahrungen mit Vorserien- anlagen	Prototyp	25kW Module in Demonstra- tionsprojekten	100kW/ 220kWhybrid/ 25kW/300kW hybrid/250kW getestet	60kW Module können beliebig kombiniert werden
Planung	Ab 2006 werden alte durch neue Geräte ersetzt	k.A.	200kW hybrid	250kW 500kW hybrid	2005 Prototypen
Marktreife	Ab 2008	k.A.	2010	2010	k.A.

BSZ - Systemtechnik

Sulzer HEXIS 1 kW SOFC-Heizgerät



P_{el} : 0,5 - 1 kW, 230 V_{50Hz}

P_{th} : 0,4 - 3 kW (+ 25 kW)

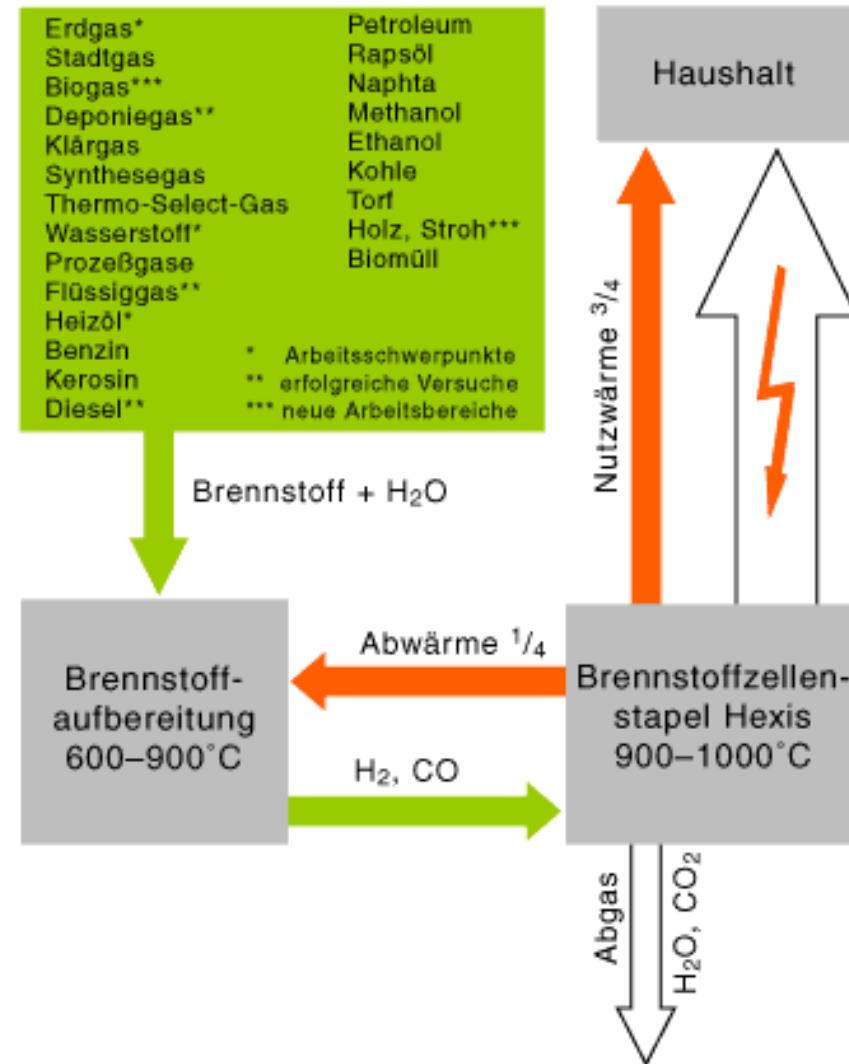
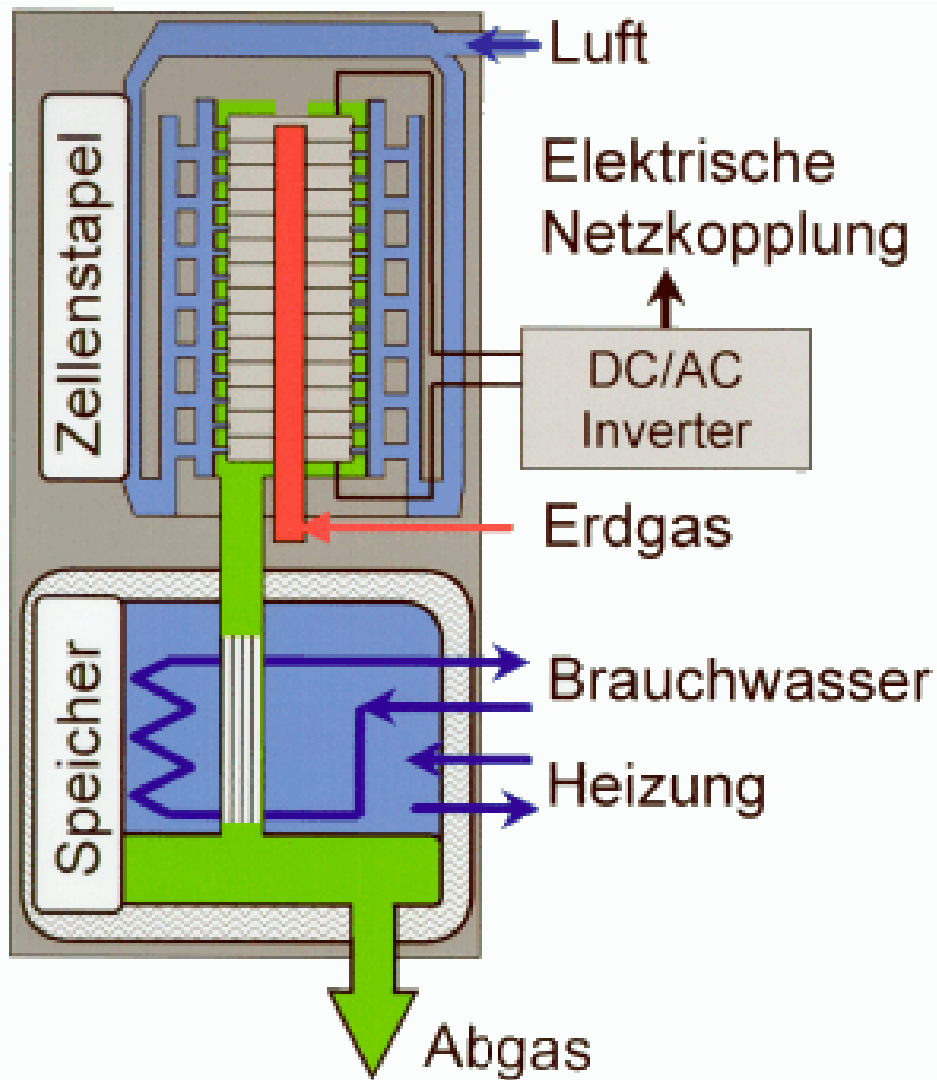
Wärmespeicher: 200 l

$\eta_{elektrisch}$: > 25 %

η_{gesamt} : > 80 %

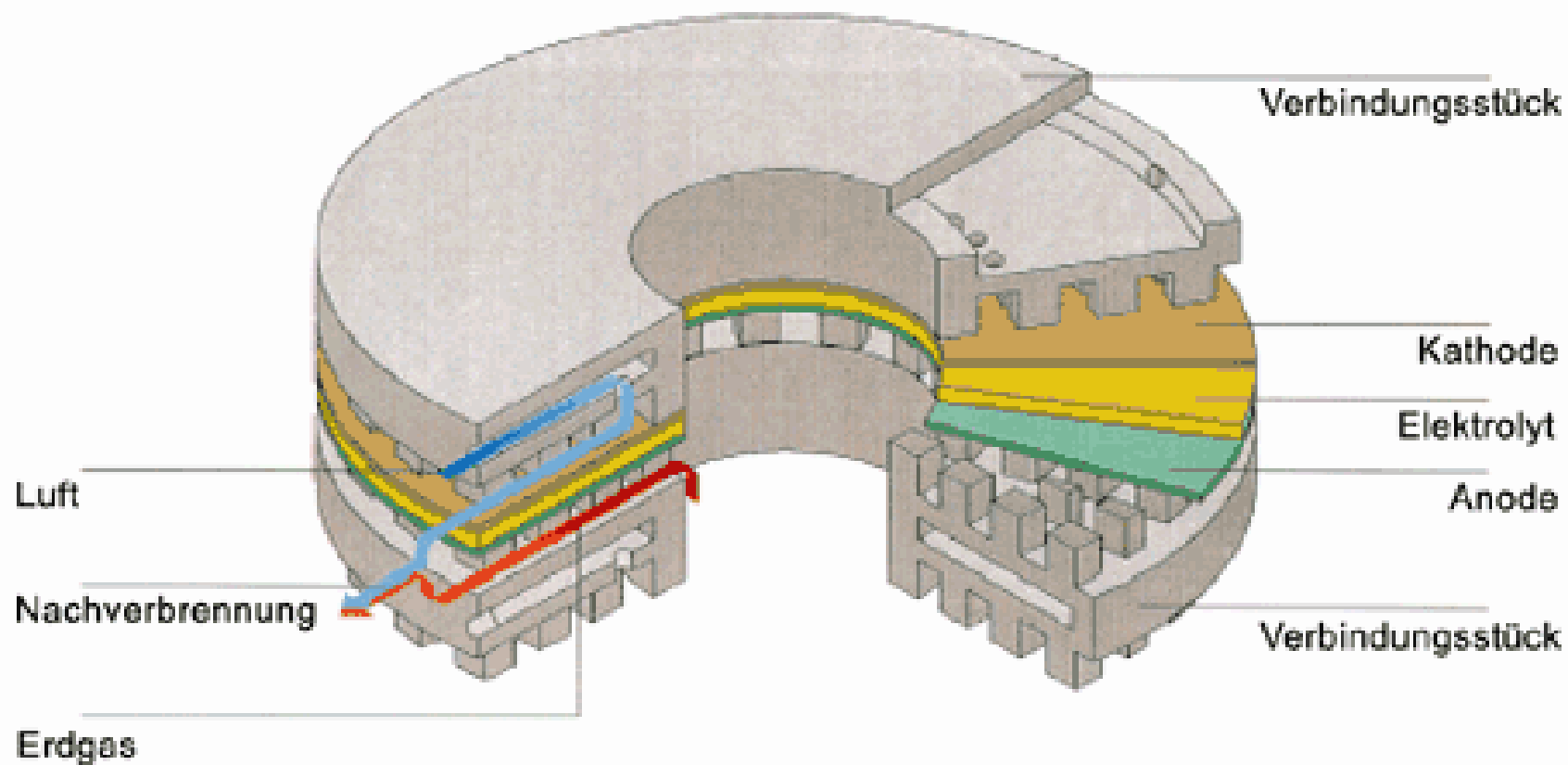
Brennstoff: Erdgas, Heizöl,
Biogas u.a.

Sulzer-Hexis 1 kW SOFC-System



BSZ – Stacktechnologie

Sulzer HEXIS Stackkonzept



Sulzer Hexis / Hoval

SOFC : 1 kW_{el} / 3 kW_{th} inkl. Zusatzbrenner



Sulzer Hexis HXS 1000 Premiere

Brennstoffzellen-Typ:	SOFC
Betriebstemperatur:	950°C
elektrische Leistung:	1 kW
thermische Leistung:	2,5 kW
Zusatzbrenner:	12 – 22 kW
el. Nettowirkungsgrad:	25 – 30%
Systemwirkungsgrad:	> 80%
Brennstoff:	Erdgas

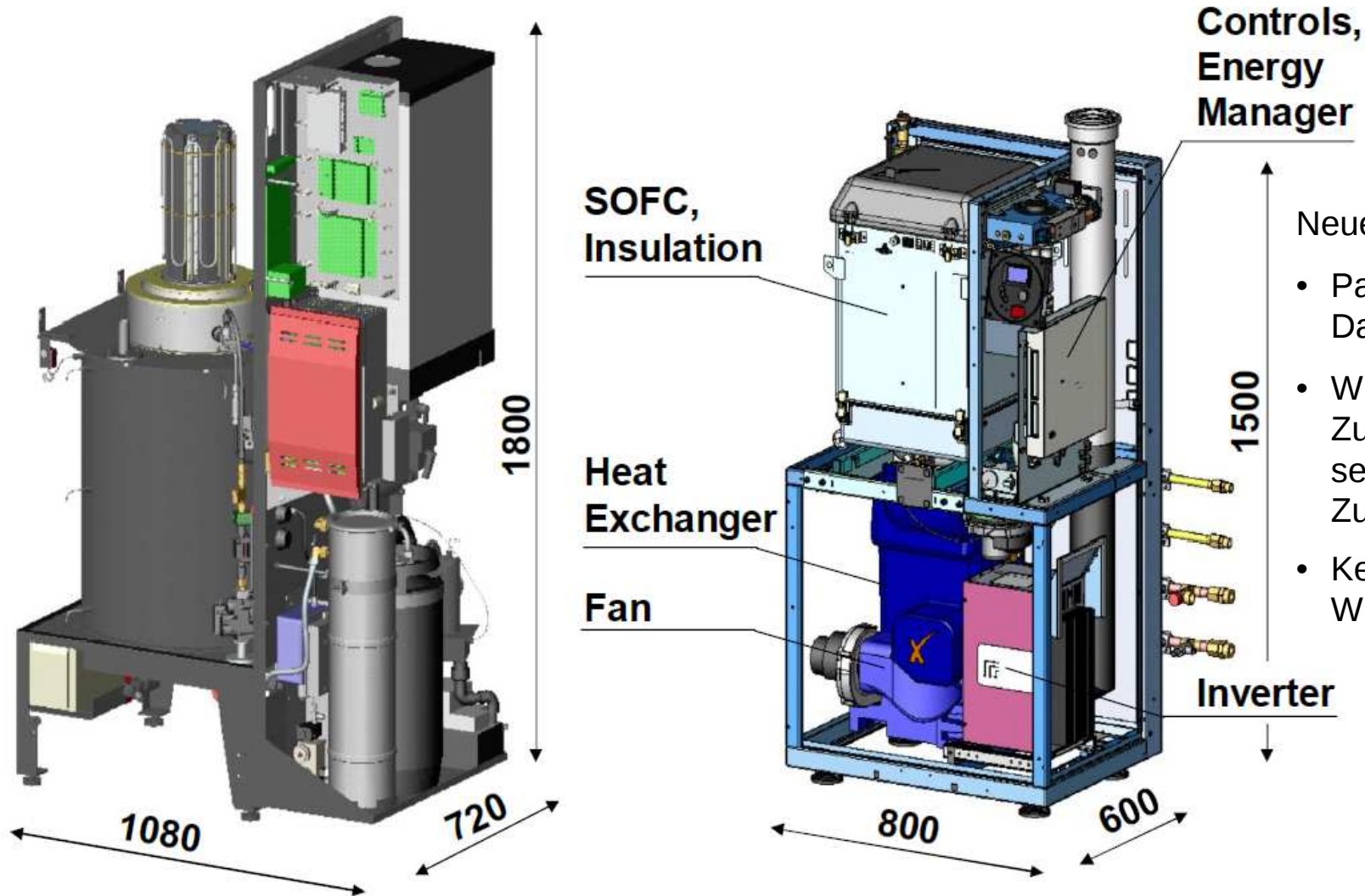
Installation von 55 Systemen in BW
durch die EnBW bis Ende 2004

Hexis

Galileo – 2. Generation in 2005



Brennstoffzelle	
elektrische Leistung:	1 kW max.
thermische Leistung:	2,5 kW max.
Zusatzbrenner:	20 kW
el. Wirkungsgrad:	ca. 25-30%; (Ziel: > 30%)
Gesamtwirkungsgrad:	ca. 85%
Brennstoffzellentyp:	Sulzer Hexis SOFC
Reformierung:	Partielle Oxidation
Brennstoff:	Erdgas
Abmessungen:	55 x 55 x 160 cm
Gewicht:	170 kg



Neuerungen :

- Partielle Oxidation statt Dampfreformierung
- Wärmetauscher mit Zusatzbrenner statt separatem Zusatzheizgerät
- Kein integrierter Wärmespeicher



**3 installierte Systeme
Siemens Westinghouse Stacktechnologie**

Kyocera 1 kW_{el} μ CHP SOFC-System

Fuel : City Gas(Natural Gas)

Operation: Automatic

Start up: Combustion of fuel

Main Unit:

SOFC module, Controller,
power conditioner
and safety device

Size:

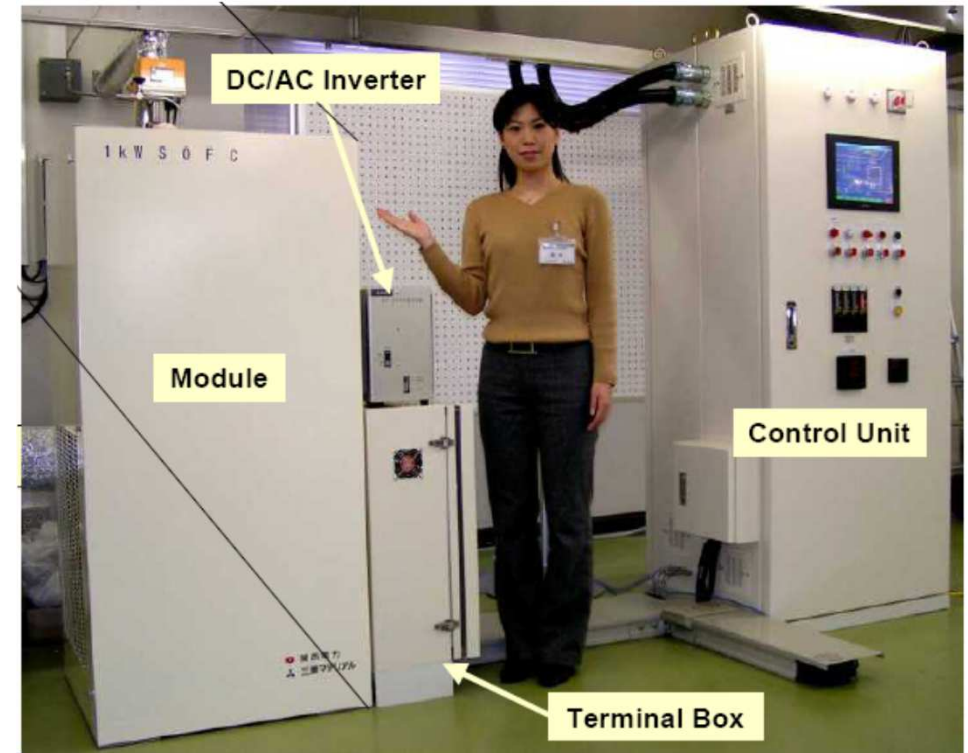
(W) 700 x (D) 480 x (H) 1000

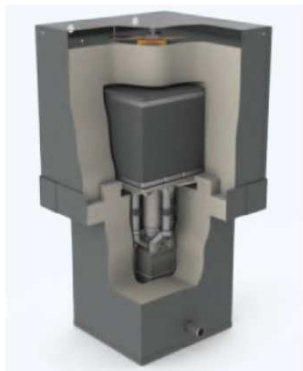
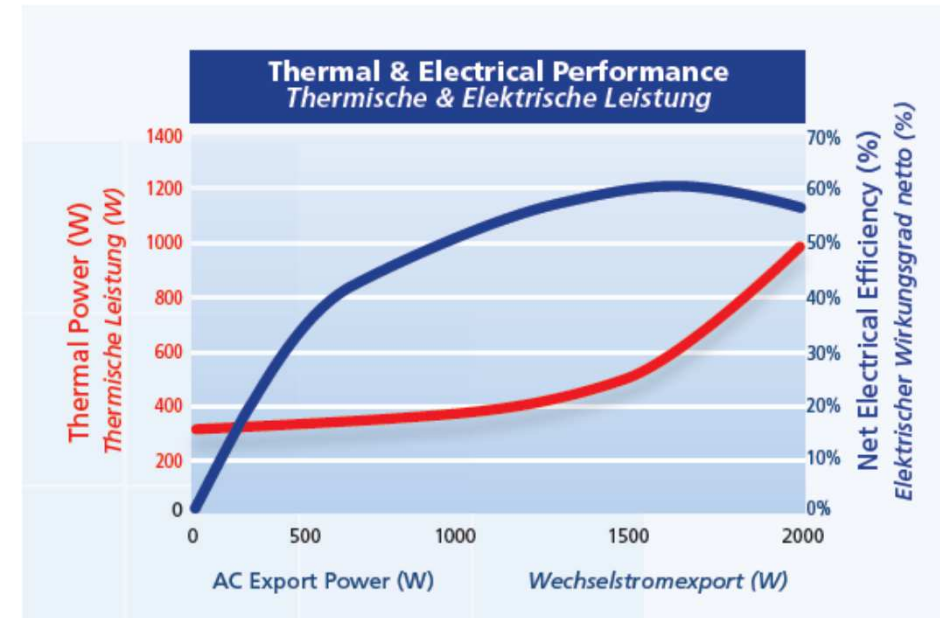
Hot water tank: 100L



Design Your Energy 夢をかなる明日を
OSAKA GAS

Mitsubishi 1 kW_{el} SOFC-System





Spezifikationen Blue Gen

Elektrische Leistung:

Max. elektr. Wirkungsgrad:

Thermische Leistung:

Gesamtsystemwirkungsgrad:

CO₂ Emissionen:

Abgastemperatur:

Verwendbares Wasser:

Lärmpegel:

Umgebungstemperatur:

Luftzufuhrtemperatur:

0 bis 2.000 W, einphasig: 230V ±10% 50Hz

60 % bei 1.500 W Leistung (AC netto; unterer Heizwert)

ca. 300 W bis 1.000 W

bis zu 85 %

340 g/kWh

max 200 °C

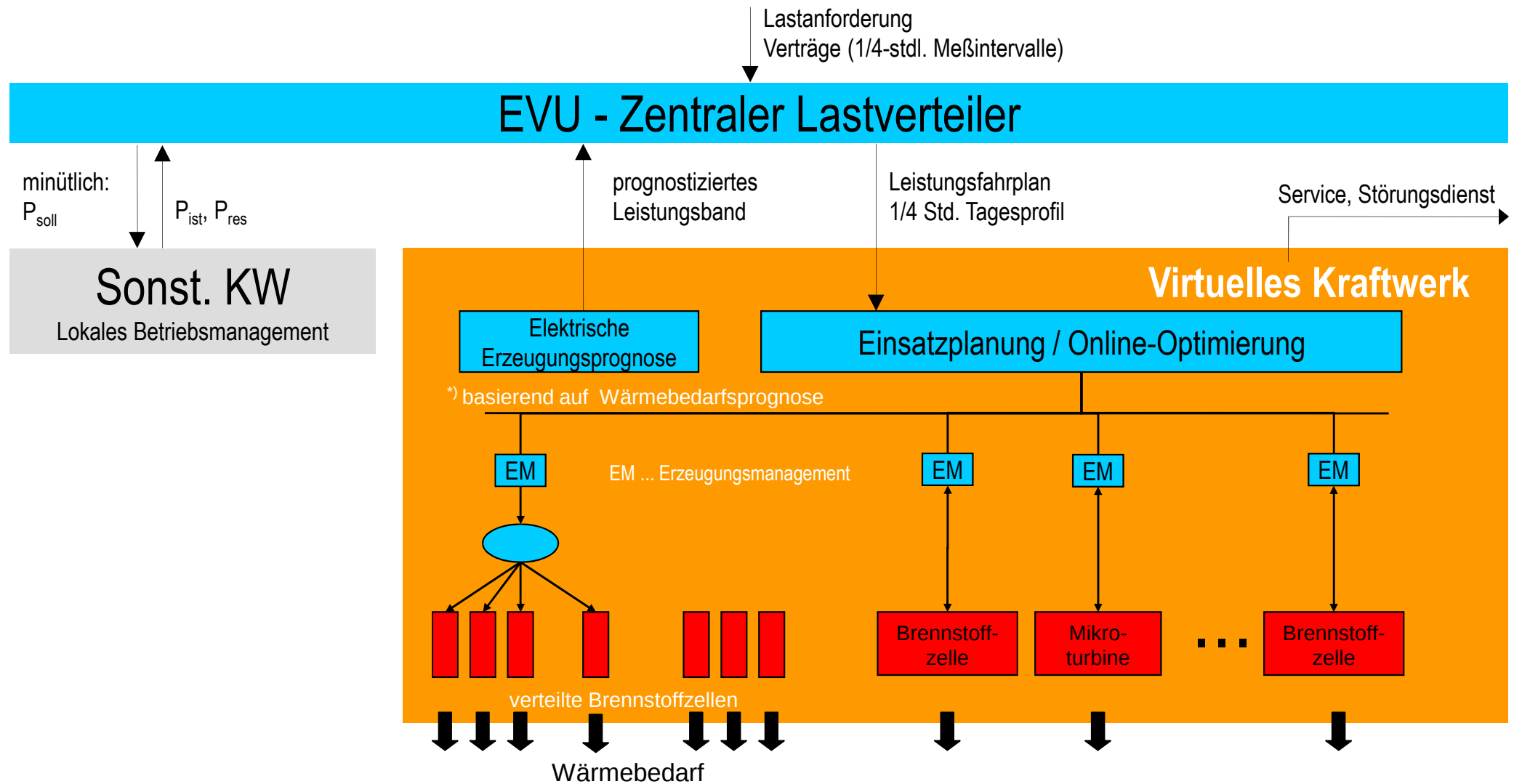
max 1.1 L/h.

< 45 dBA

+1 °C - +45 °C

-20 °C - +45 °C

IT-Infrastruktur bündelt dezentrale Erzeugungsanlagen zu "Virtuellen Kraftwerken"



Idatech FCS 1200



Common Specifications:

Fuel:	Methanol/De-ionized water mix
Fuel Mix Consumption (@ 1 kW):	1.4 Liters/hr
Fuel Mix Consumption (idle):	0.2 Liters/hr
Fuel Capacity:	11.2 Liters
Sound Level:	<55 dB @ 1 meter
Dimensions (LxWxH):	74 x 69 x 64 cm; 29" x 27" x 25"
Weight (varies w/options):	77-84 kg; 170-185 lbs.
Operating Temperature:	3 to 30° C
Storage Temperature:	-20 to 50° C
Exhaust Temperature:	<50° C
Ventilation Requirement (indoor use):	70 Liters / sec

AC Model Specifications: *

Continuous Output Power:	850 Watts (120 VAC or 240 VAC) True Sine Output
Peak Output Power (10 sec.):	2000 Watts
Voltage Output:	120 VAC, +/- 5%, 60 HZ +/- 0.1% or 240 VAC +/- 5%, 50 Hz +/- 0.1%

DC Model Specifications: **

Continuous Output Power:	1000 Watts (48 VDC nominal)
Peak Output Power (1 min.):	2000 Watts (48 VDC nominal)
Voltage Range:	44.0 - 56.0 VDC

* AC de-rating specifications are 17 W/100 meters & 17 W/deg C >30

**DC de-rating specifications are 15 W/100 meters & 15 W/deg C >30

Powered by **BALLARD™**

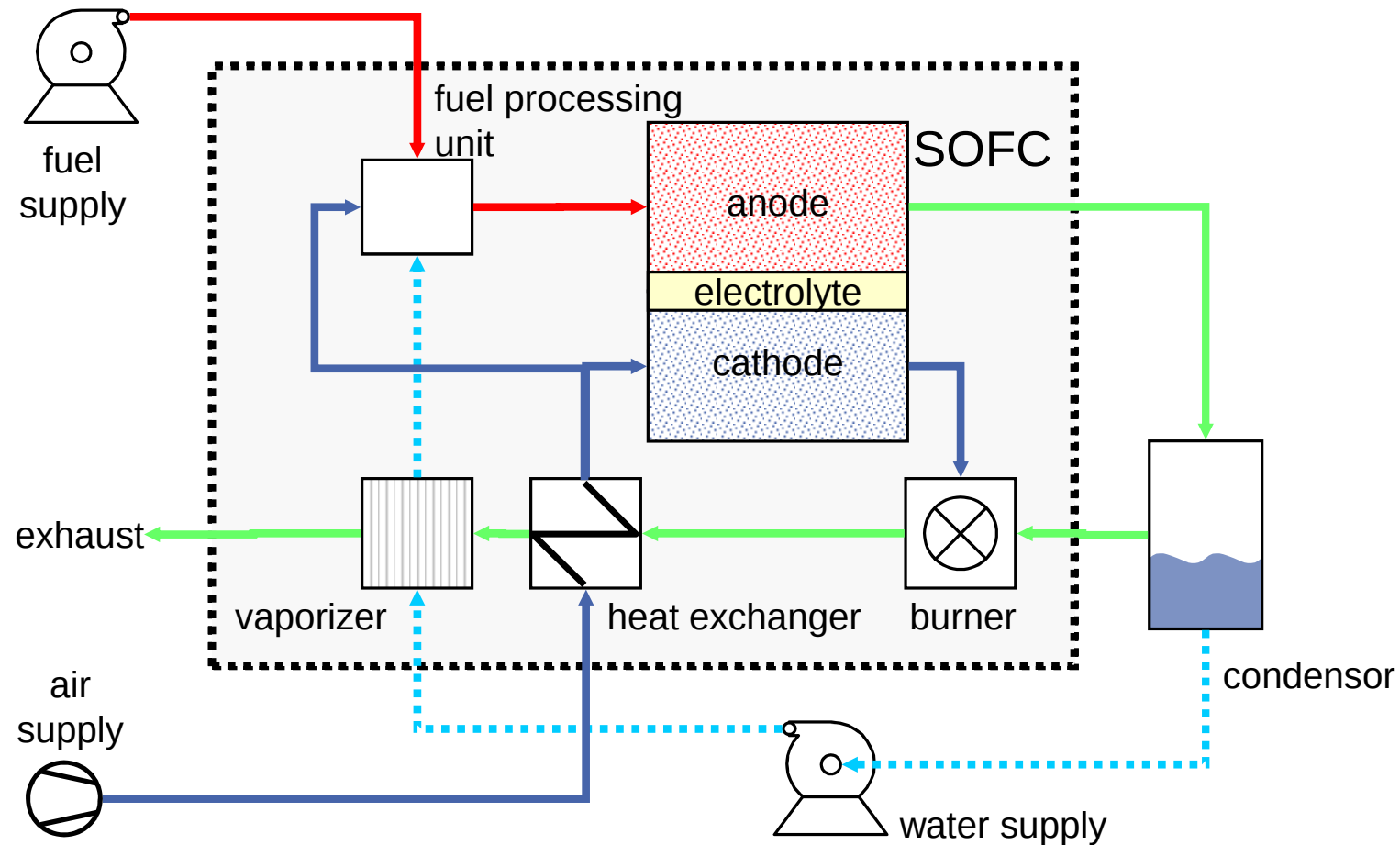
Military Solutions

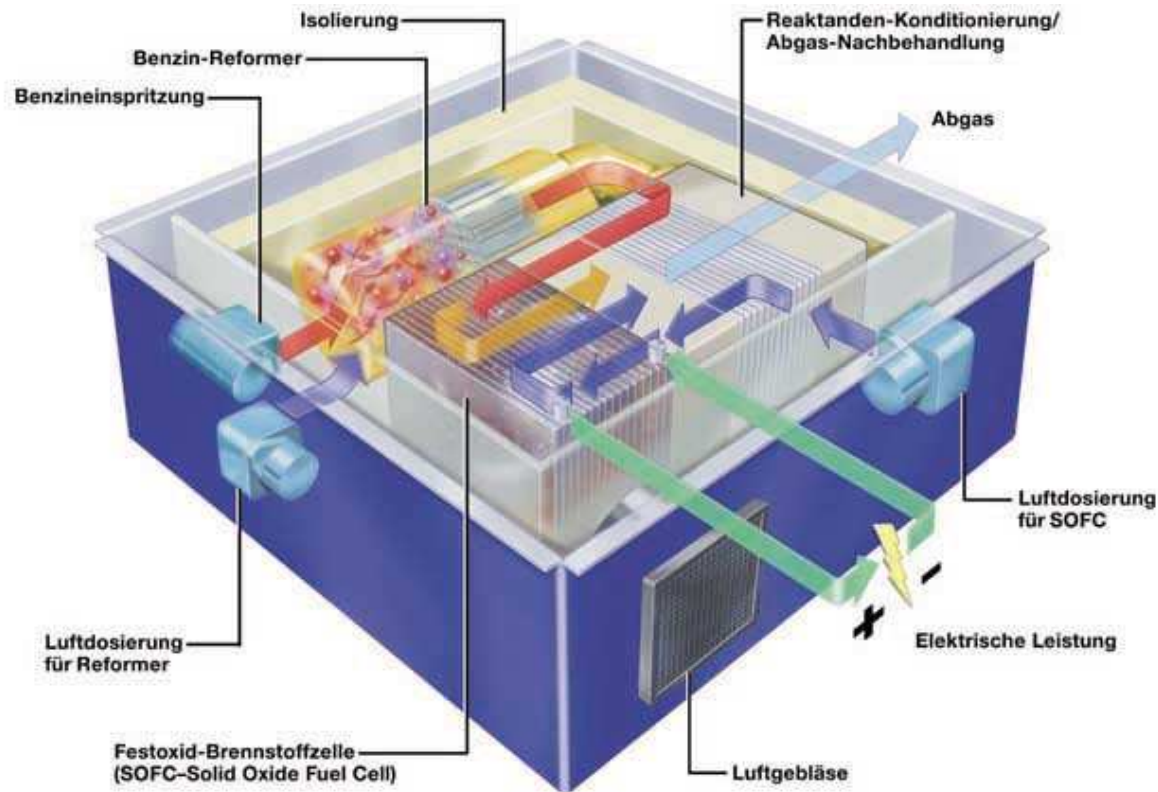


Army vehicle featuring Idatech scalable power solution.

Idatech Modular Fuel Cell Systems

Continuous Output Power:	1 kW and above
Power Outputs:	12 to 48 nominal VDC 120 VAC, +/- 5%, 60 Hz +/- 0.1 % or 240 VAC, +/- 5%, 50 Hz +/- 0.1 %
Sound Level:	<55 dB @ 1 meter
Fuel Types:	Various liquid fuels
Enclosures:	Indoor & outdoor options available





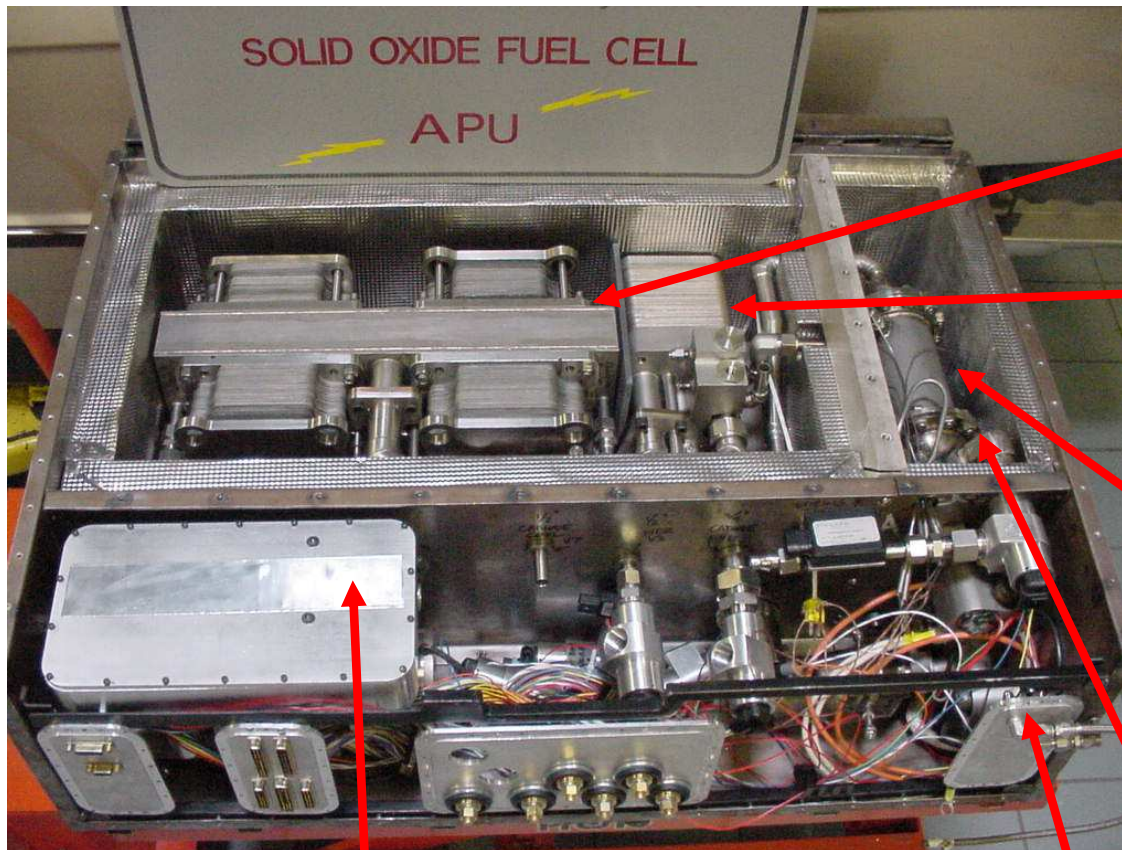
Spannung: 42 V
Leistung: 5 kW_{el}
Brennstoff: Benzin
Verfügbarkeit ab 2007

1 kW Generator: ~ 1,5 l Kraftstoff / 100 km
1 kW SOFC-APU: ~ 0,7 l Kraftstoff / 100 km



SOFC APU

Delphi 1,5 kW SOFC APU (1. Generation)



Brennstoffzellen-Stack
Erzeugung elektrischer Energie
aus Reformat (H_2 und CO)

Energie-Rückgewinnung
Restgasverbrennung,
Aufheizung Reaktionsluft

Hauptreformer
Aufheizung Stack,
Erzeugung von Reformat
(20% H_2 , 20% CO , 3% CH_4 ,
Rest N_2)

Mikroreformer
Start Hauptreformer

**Kraftstoff-
versorgung**

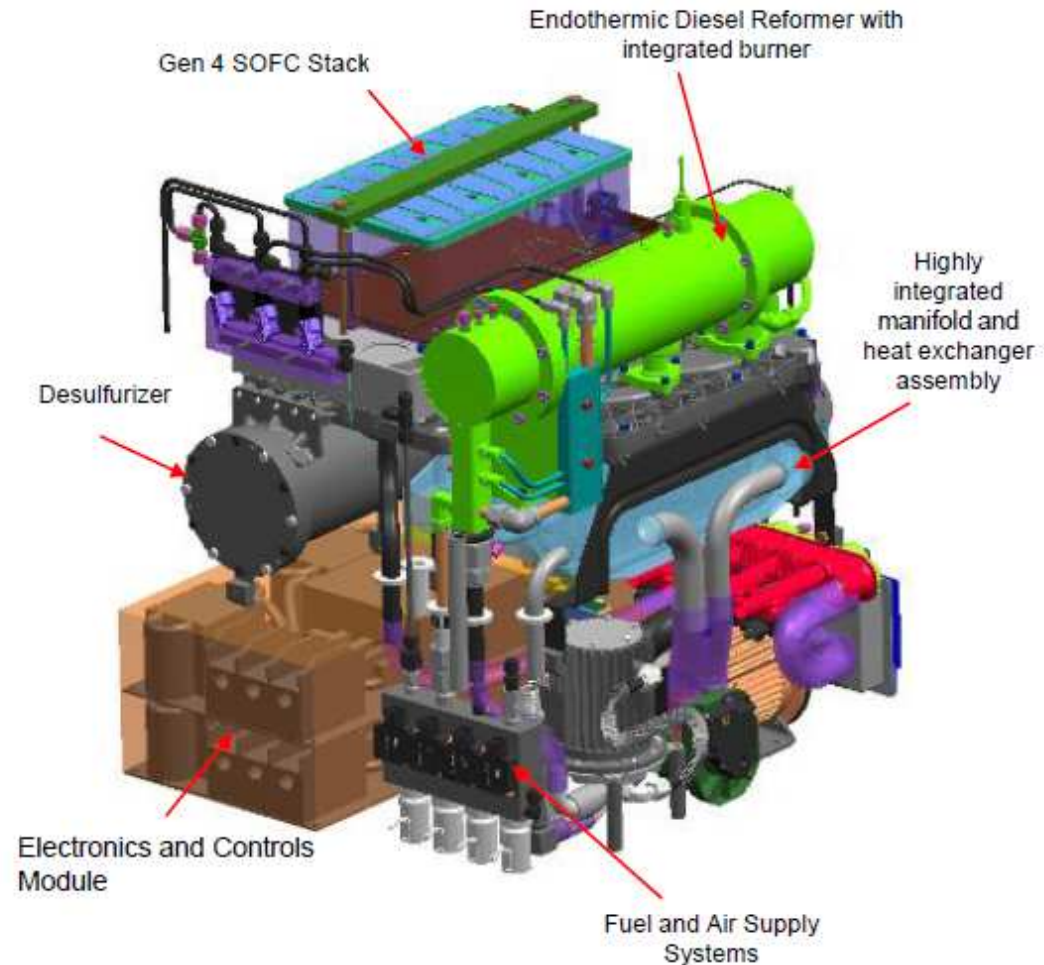
Luft-Gebläse
Reaktionsluft und
Kühlluft

SOFC APU

Delphi DPS 3000D



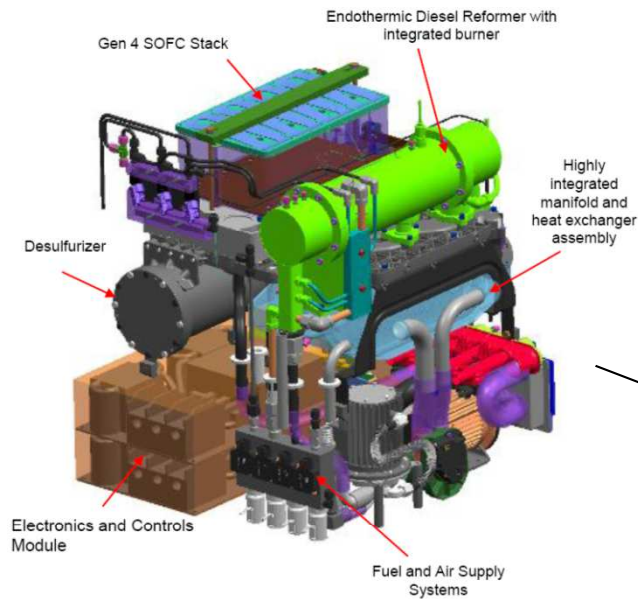
DPS 3000D
3 kW net output power



DELPHI

SOFC APU

Delphi DPS 3000D

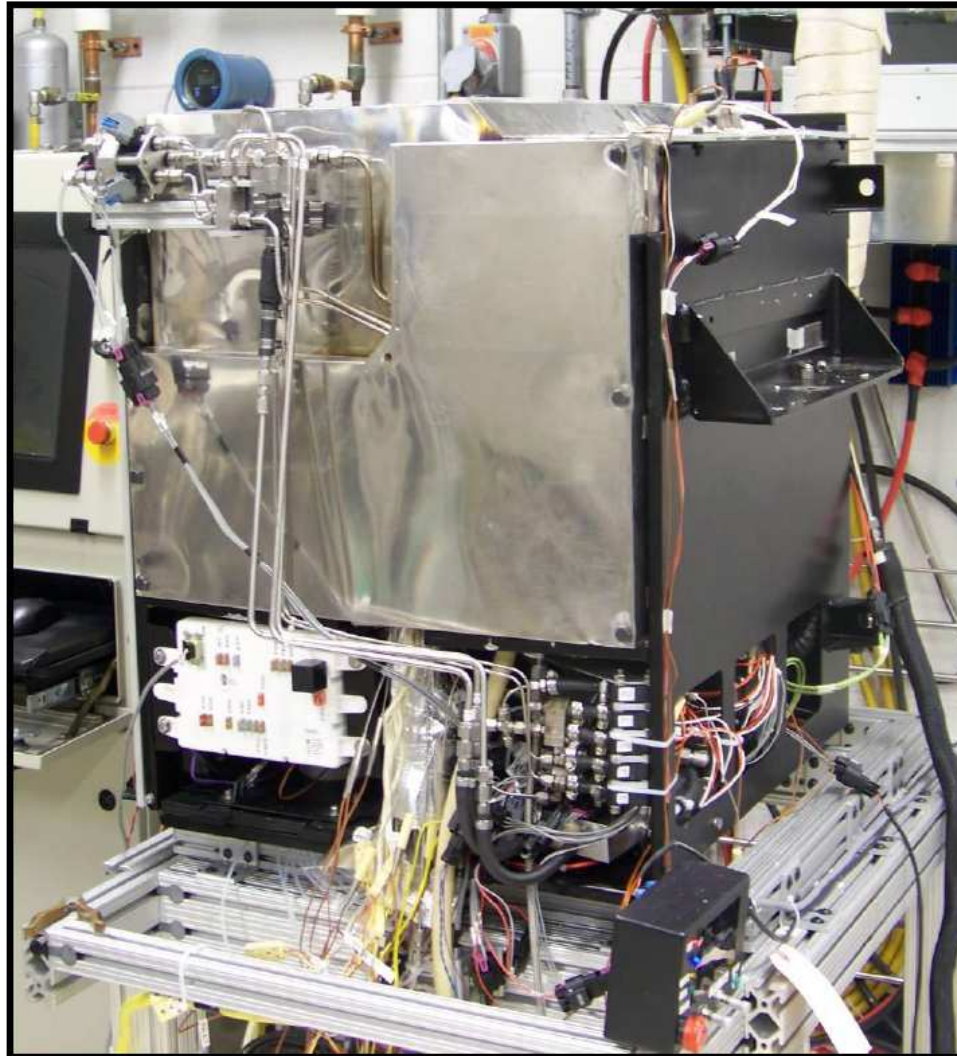


- High quality, reliable power: 110 V_{AC} and/or 12 V_{DC}
- High fuel efficiency: 40 to 50% higher than current gen set APUs
- Low noise: <60 dBA at 3 meters
- Ultra-clean, near zero emissions:
 - Meets Tier 4 Emissions standards for Non-Road Diesel Engines
 - For CO, less than 8 g/kWh
 - For NMHC and NO_x, less than 0.2 g/kWh
- On-board reforming capability

SOFC APU

Delphi DPS 3000D

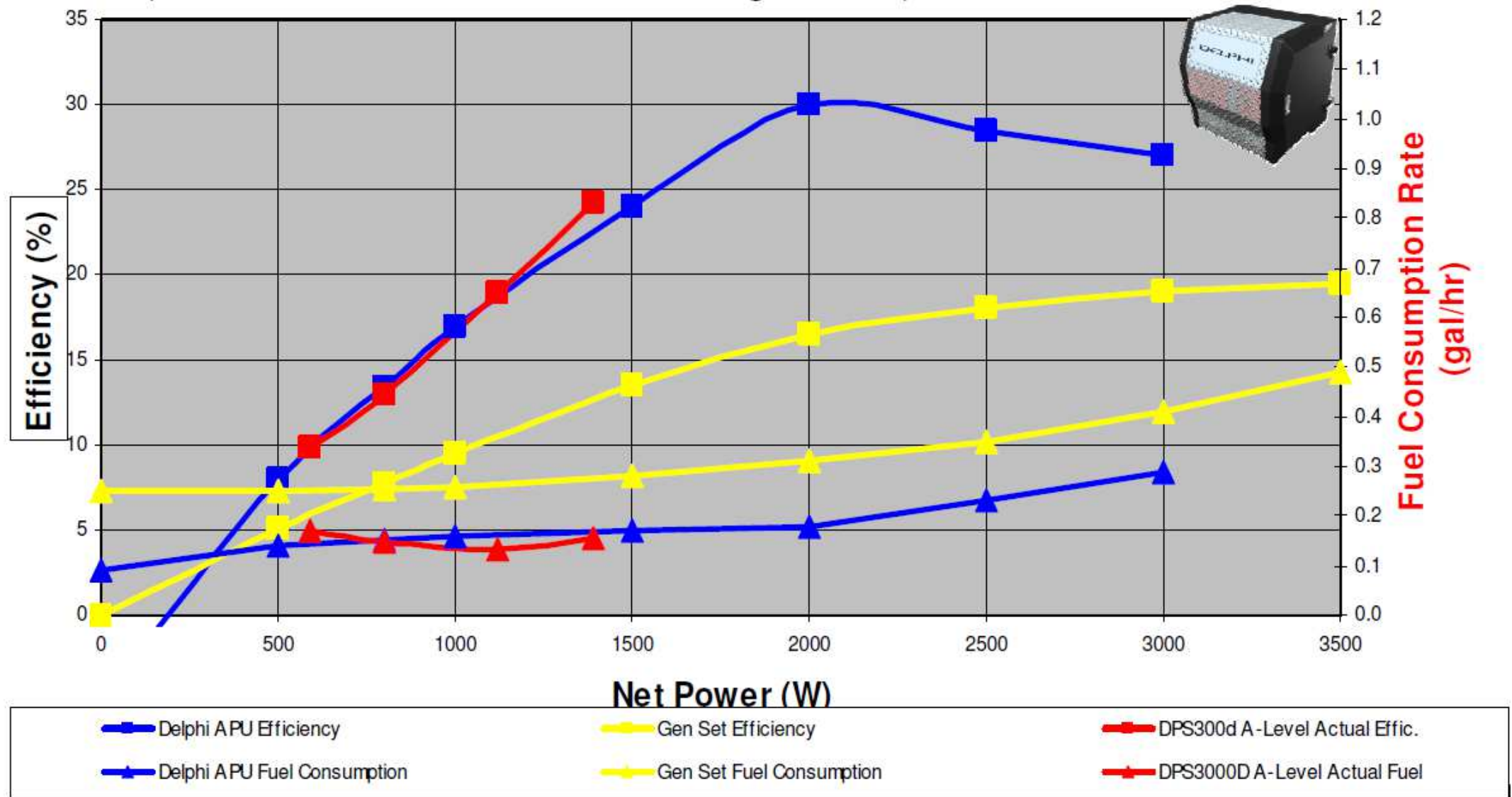
- ◆ First design engineered specifically as a truck APU
- ◆ Internal desulfurizer for ULSD
- ◆ ULSD cold-start capable



DELPHI

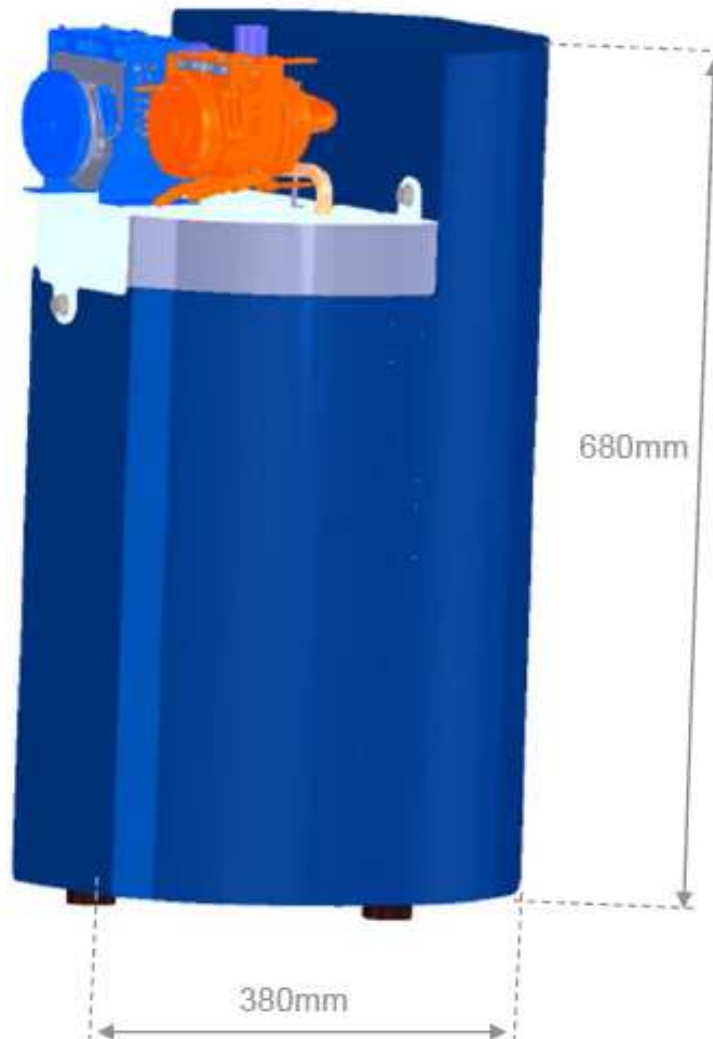
SOFC APU

Delphi DPS 3000D



AVL SOFC APU Generation I

STAND ALONE SOLID OXIDE FUEL CELL AUXILIARY POWER UNIT



Design Targets:

- 3kW electrical power
- 10kW thermal power
- el. efficiency ~35%
- Fuel: european road diesel (< 10 ppm S)
- 75L, 60kg
- ~ 55dB(A) noise

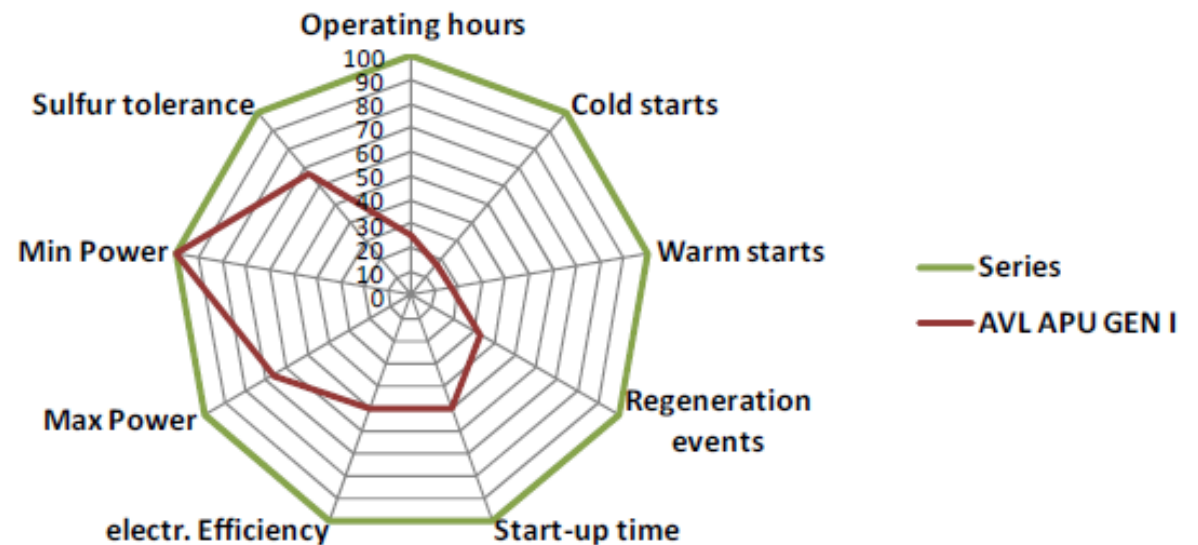
Technology:

- Solid Oxide Fuel Cell
- anode-supported stack
- hot-gas anode recirculation
- auto thermal reforming
- highly efficient radial-blowers for media supply
- system internal regeneration approaches

Status: Feb. 2011, Design Freeze AVL APU GEN I

REQUIREMENTS & DEVELOPMENT TARGETS

		AVL GEN I	
Operating Hours (>0A):	12000	3000	h
Operating Hours (T>100°C):	36000	-	h
Deep Thermal Cycles (T<100°C):	300	50	-
Medium Thermal Cycles (T>100°C):	3000	500	-
RedOx Cycles @Operat. Temp ⁽¹⁾	30	10	-
RedOx Cycles to Ambient Temp. ⁽²⁾	5	-	-
electr. Efficiency:	35	25	-
Heat up Time:	30	45	min
Maximum electrical Power:	3000	2000	W
Minimum electrical Power:	300	300	W
Sulphur Tolerance US (fuel):	15	10	ppm
Mass:	100	-	kg
Volume:	100	-	L



AVL SOFC APU – Packaging Concept

