Batterie- und Brennstoffzellensysteme

BSZ-Systeme 1

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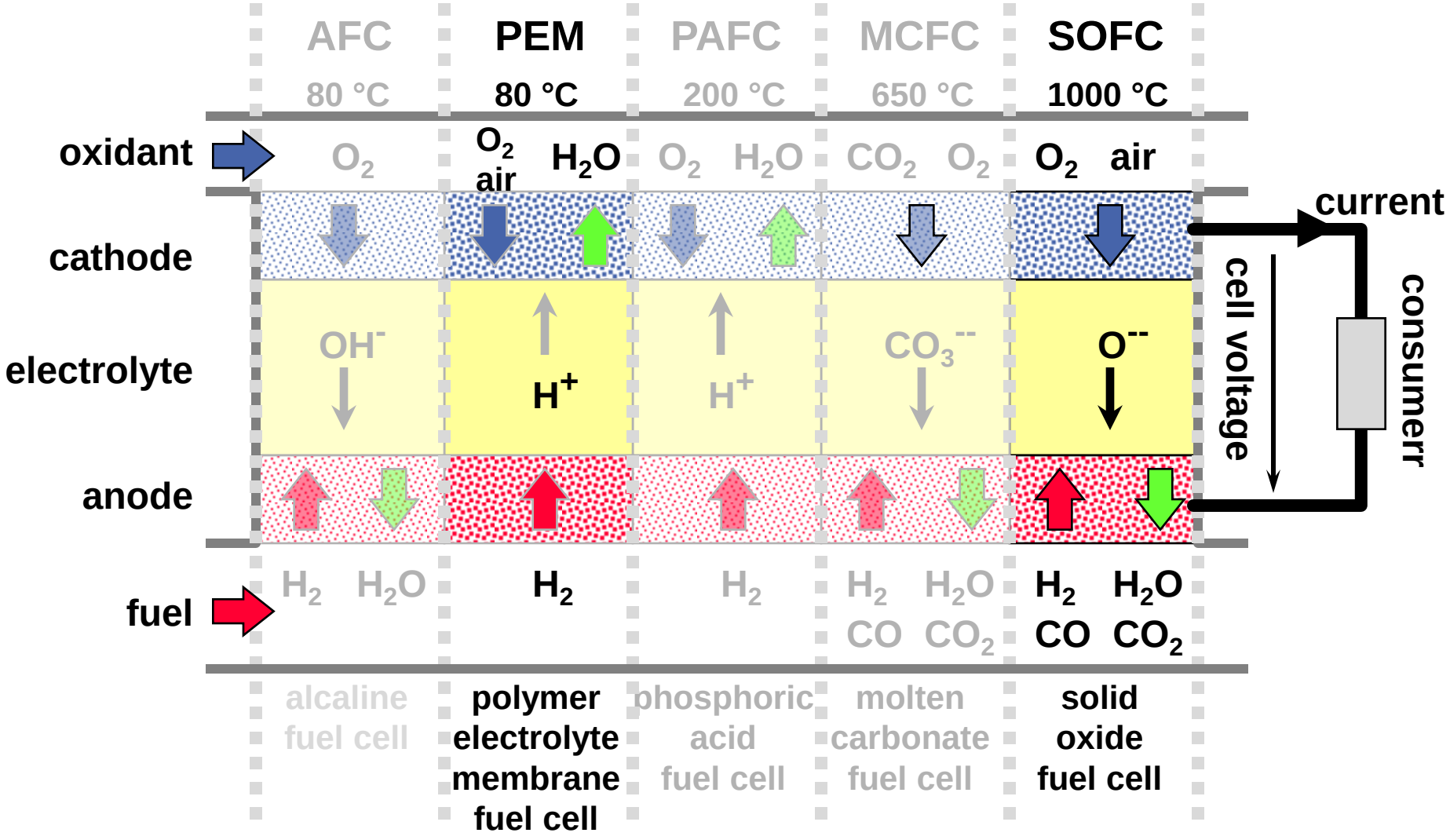
Inhalt

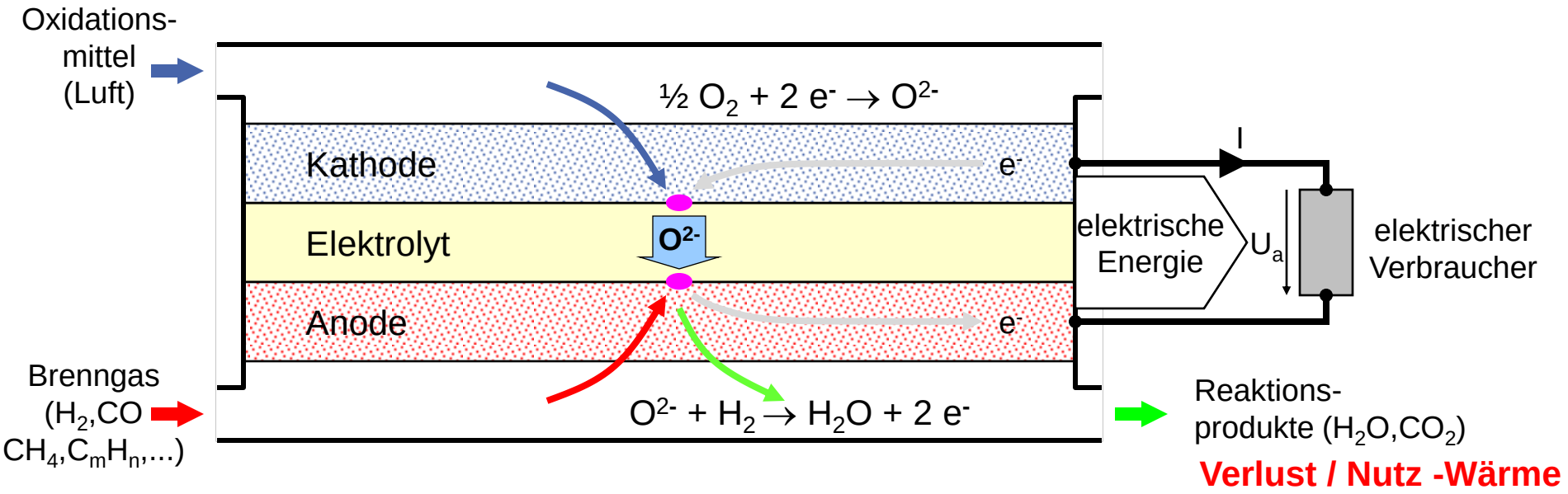
- Grundlagen
  - BSZ-Typen
  - Verluste und Wirkungsgrade
- BSZ-Systeme
  - stationäre (CHP-) Systeme (> 10 kW_{el})

Types of Fuel Cells

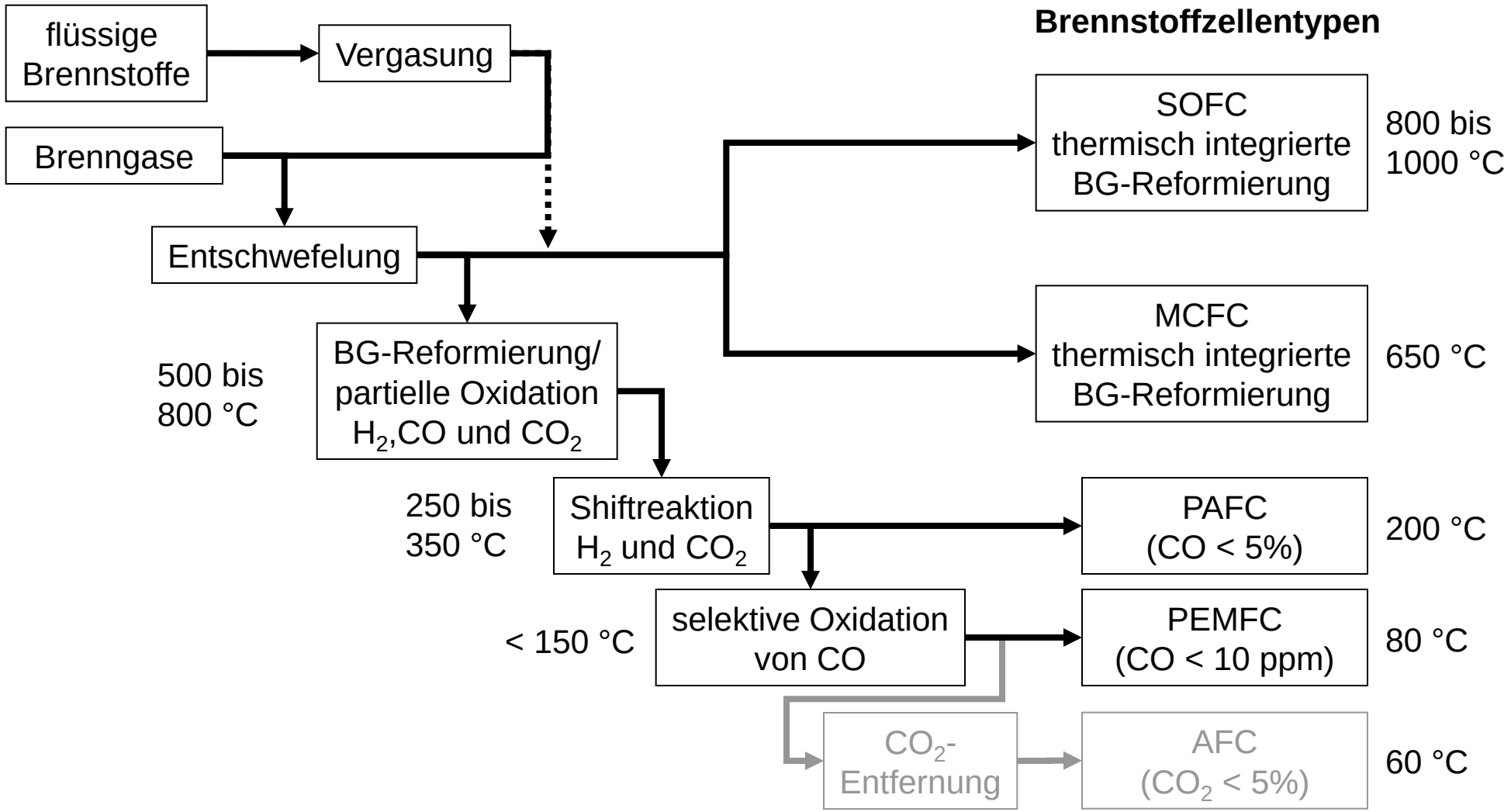


Elektrochemische Energiewandlung in Brennstoffzellen
Ideale und reale Brennstoffzelle

Reale Brennstoffzelle: $U_a = U_{th} - \sum_k U_{v,k}$; $U_L - I \times R_i(I)$ nichtlinearer Innenwiderstand R_i



Brennstoffaufbereitung für verschiedene BSZ-Typen



Elektrochemische Energiewandlung in Brennstoffzellen
Wirkungsgrade im Brennstoffzellensystem

thermodynamischer WG:

$$\eta_{th} = \frac{\Delta G}{\Delta H} = 1 - \frac{T\Delta S}{\Delta H}$$

elektrochemischer WG:

$$\eta_{el} = \frac{U_{cell}}{U_{th}} = -\frac{nFU_{cell}}{\Delta G}$$

Brenngasausnutzung:

$$\beta_f = \frac{\text{umgesetzter Brennstoff}}{\text{zugeführter Brennstoff}}$$

Faraday WG:

$$\eta_f = \frac{I}{I_m}$$

Reformerwirkungsgrad:

$$\eta_{ref} = \frac{\Delta H}{\Delta H_{fuel}}$$

el. Systemwirkungsgrad:

$$\eta_{elS} = \frac{W_{el}}{nFU_{cell}}$$

el. Nettowirkungsgrad

$$\eta_{electrical} = \eta_{th} \cdot \eta_{el} \cdot \eta_f \cdot \beta_f \cdot \eta_{Ref} \cdot \eta_{elS} = \frac{\text{produzierte el. Energie}}{\text{zugeführte chem. Energie}}$$

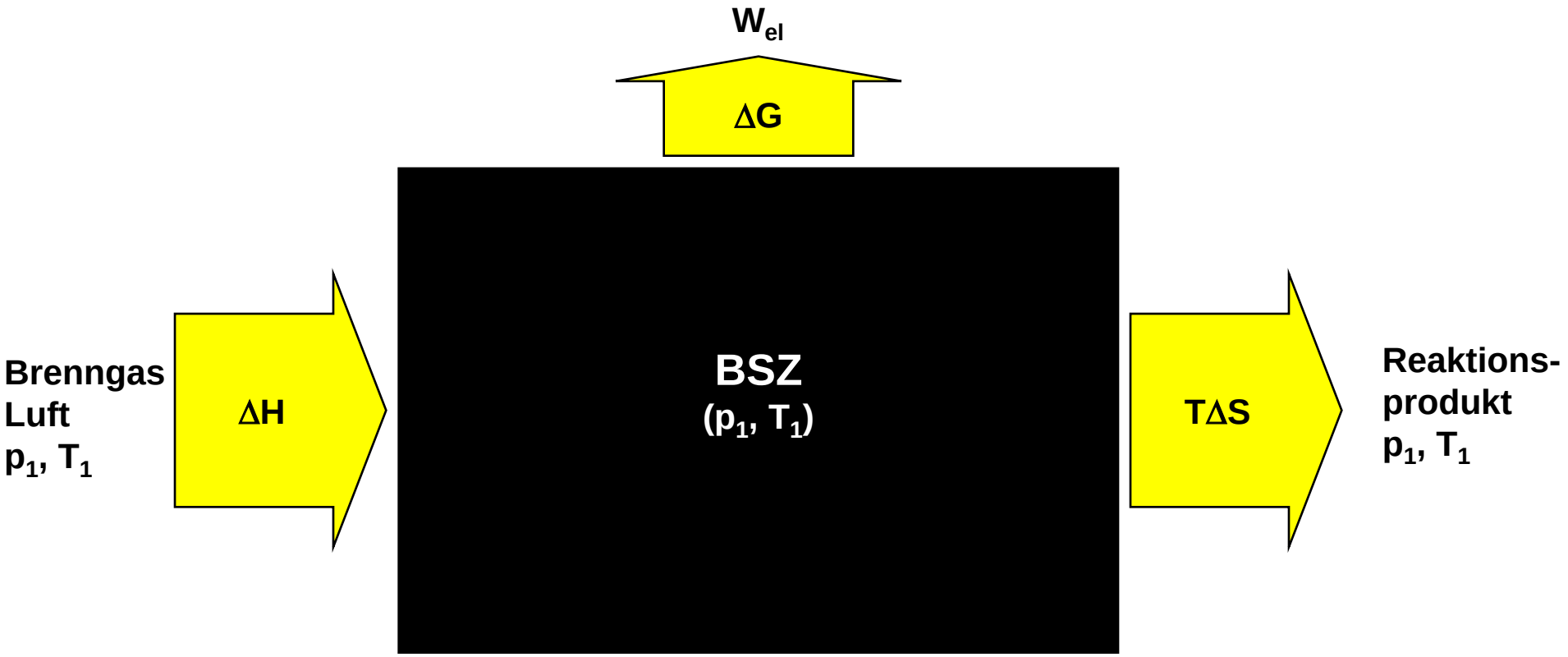
therm. Nettowirkungsgrad

$$\eta_{thermal} = \frac{\text{Nutzwärme}}{\text{zugeführte chem. Energie}}$$

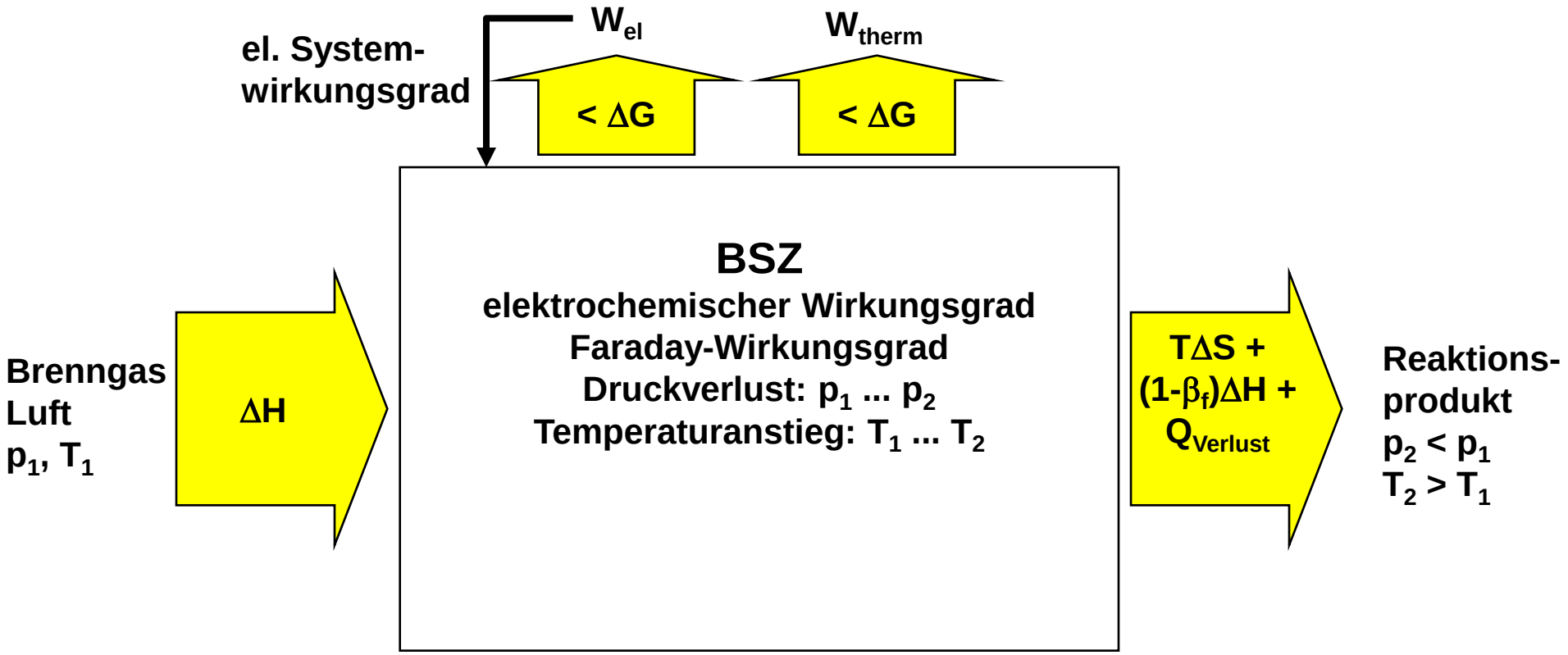
Gesamtwirkungsgrad

$$\eta_{tot} = \eta_{electrical} + \eta_{thermal}$$

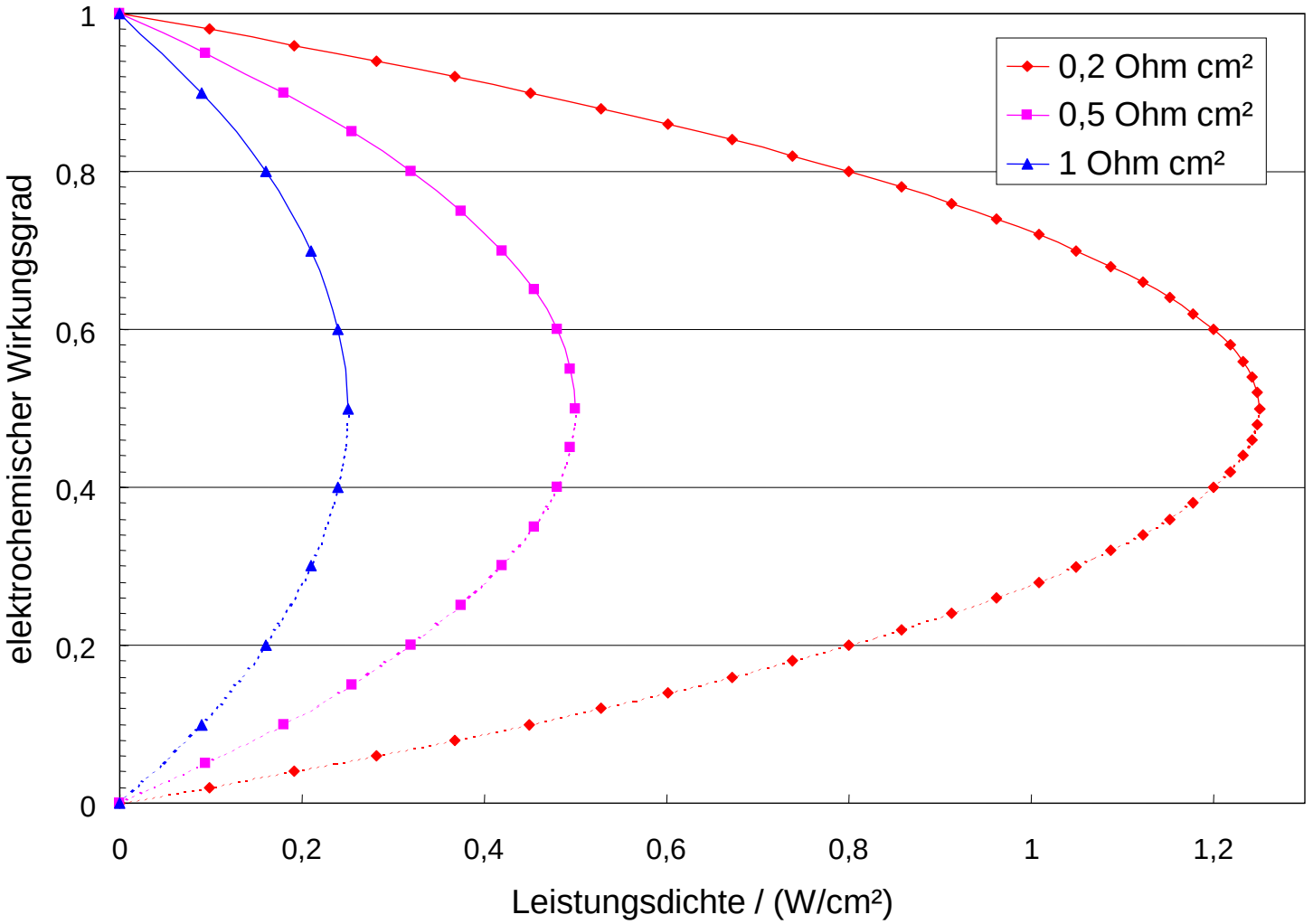
Ideale verlustfreie BSZ



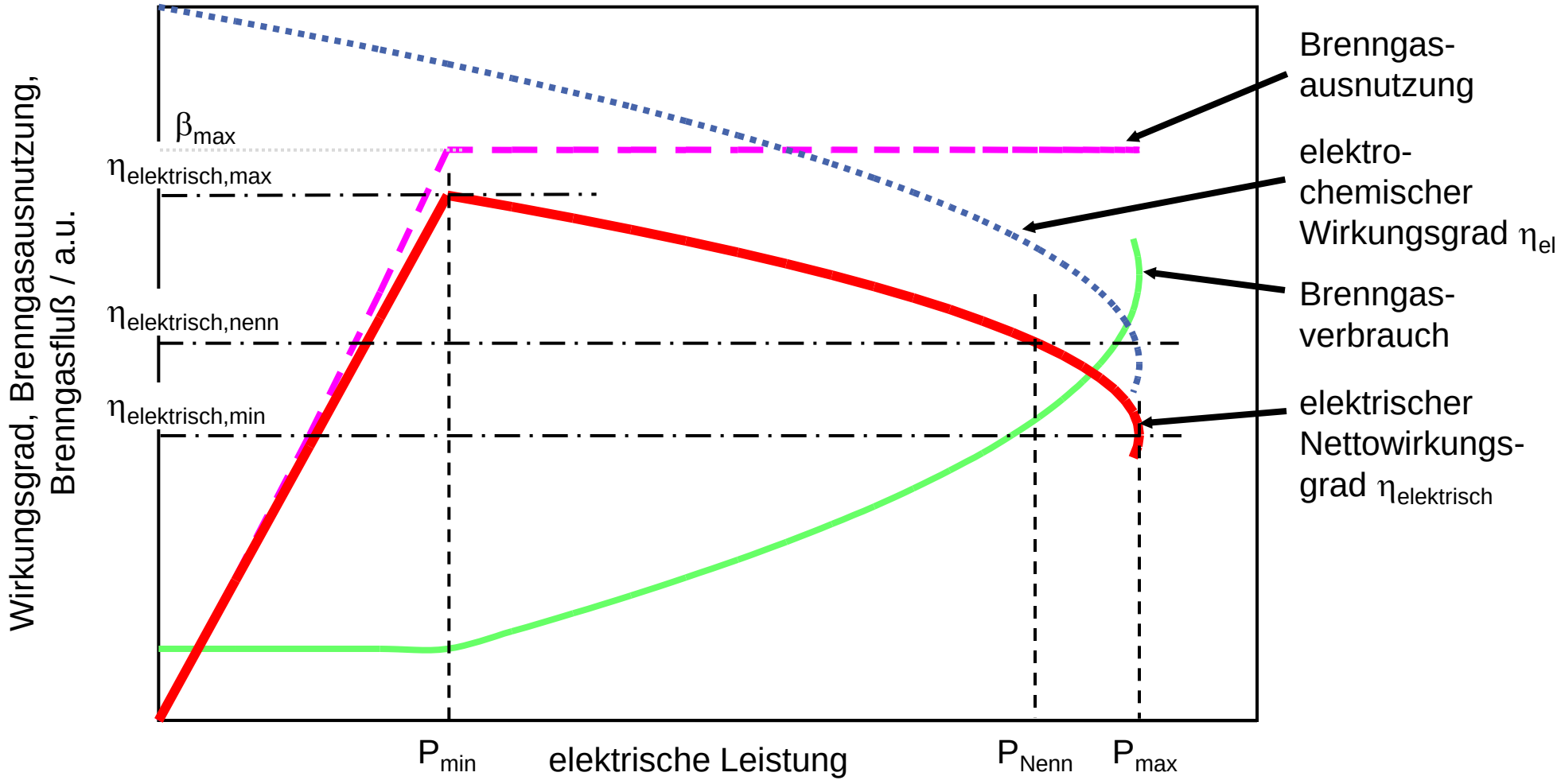
Verlustbehaftete BSZ



Elektrochemischer Wirkungsgrad in Abhängigkeit der Leistungsdichte



BSZ - Stand der (System-) Technik
Elektrischer Nettowirkungsgrad als Funktion der Leistung

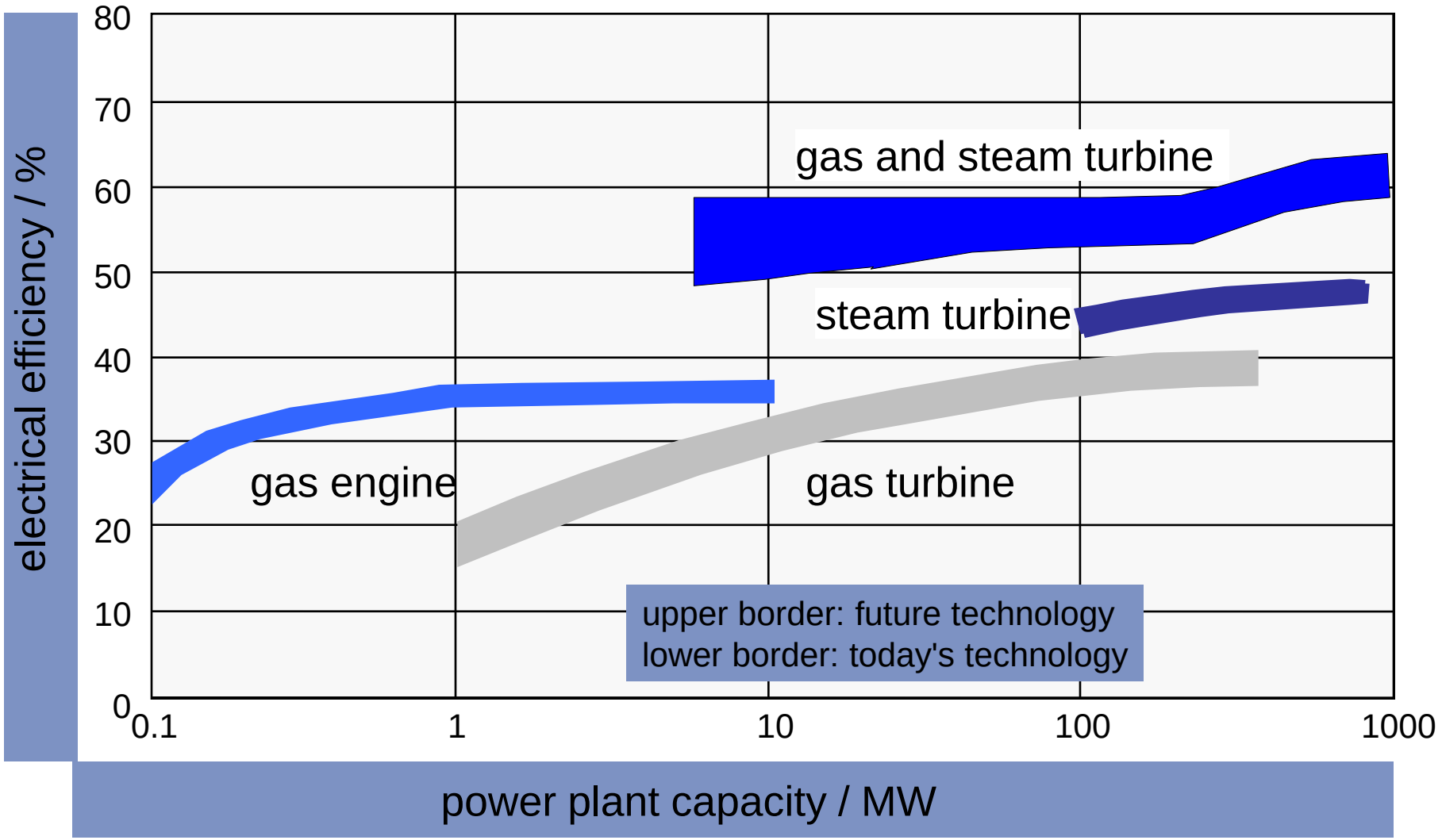


Anwendungen für stationäre BSZ-Systeme

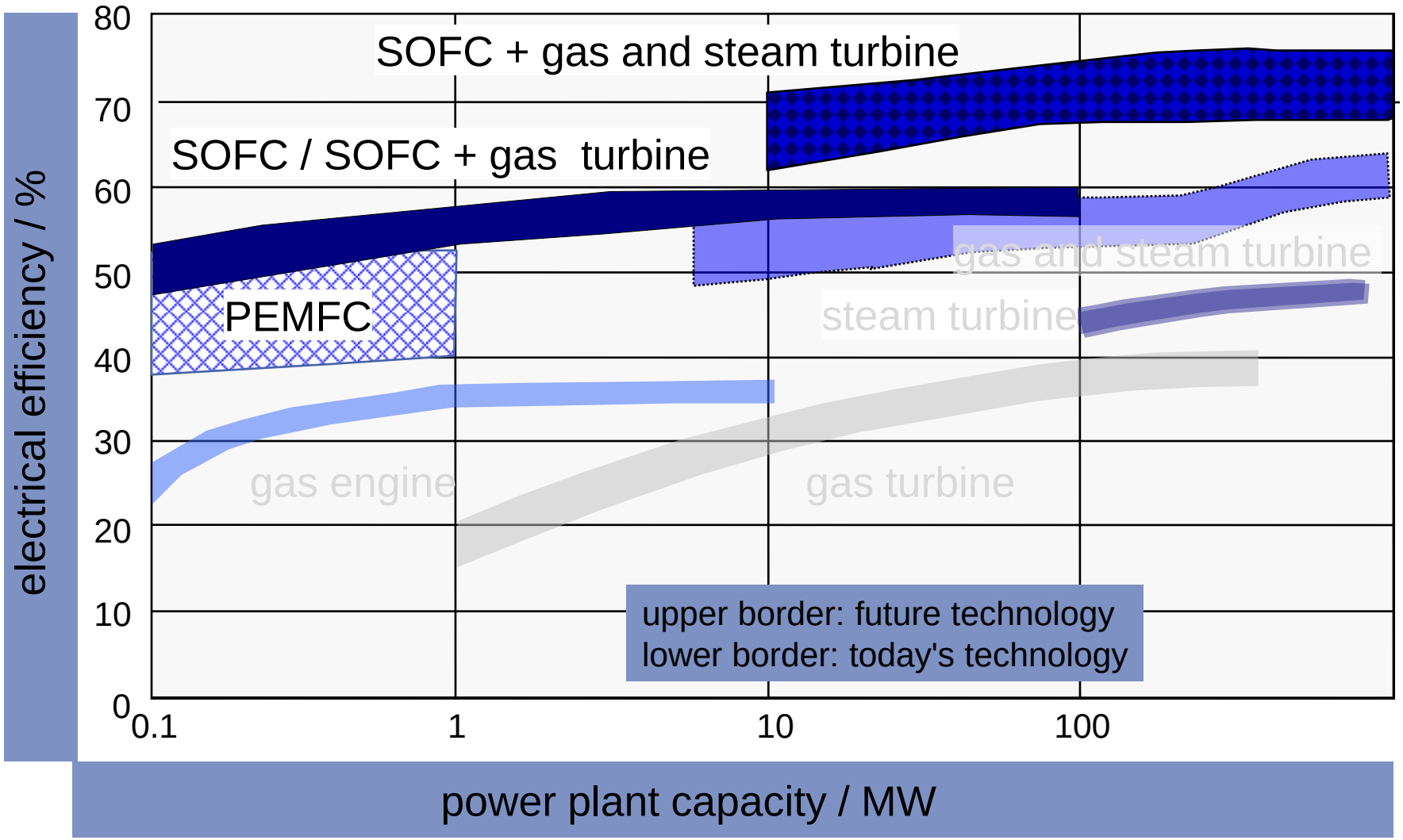
Anlagentyp	**P_{el}**	**Einsatz/Standort**	**Produkte***	**BSZ-Typ**
Kraftwerk	> 1 MW	Stromerzeugung	el. Energie, Fernwärme	PAFC/MCFC/SOFC
ind. Kraftwerk	> 100 kW	Industrie	Prozeßdampf, el. Energie	PAFC/MCFC/SOFC
Chemischer Reaktor	> 100 kW	chem. Industrie	H_2, CO, ... , el. Energie	SOFC
BHKW	> 100 kW		el. Energie + Nahwärme	PAFC/MCFC/SOFC
BSZ-Heizgerät / BHKW	5 - 100 kW	Mehrfamilienhaus, Bürogebäude	Nahwärme, el. Energie (Kälte)	PEMFC/SOFC
BSZ-Heizgerät	1 - 3 kW	beheiztes EFH	Nahwärme, el. Energie	PEMFC/SOFC
BSZ	1 - 5 kW	klimatisiertes EFH	el. Energie (+ Kälte)	PEMFC/SOFC
netzunabhängige BSZ	3 -10 kW	Gebäude	el. Energie	PEMFC/SOFC
BSZ	~ 1 kW	EFH	el. Energie	PEMFC/SOFC

* Reihenfolge entsprechend Wichtigkeit/Vorrang

Net electrical efficiencies of power generating systems (using natural gas)



Net electrical efficiencies of power generating systems (using natural gas)

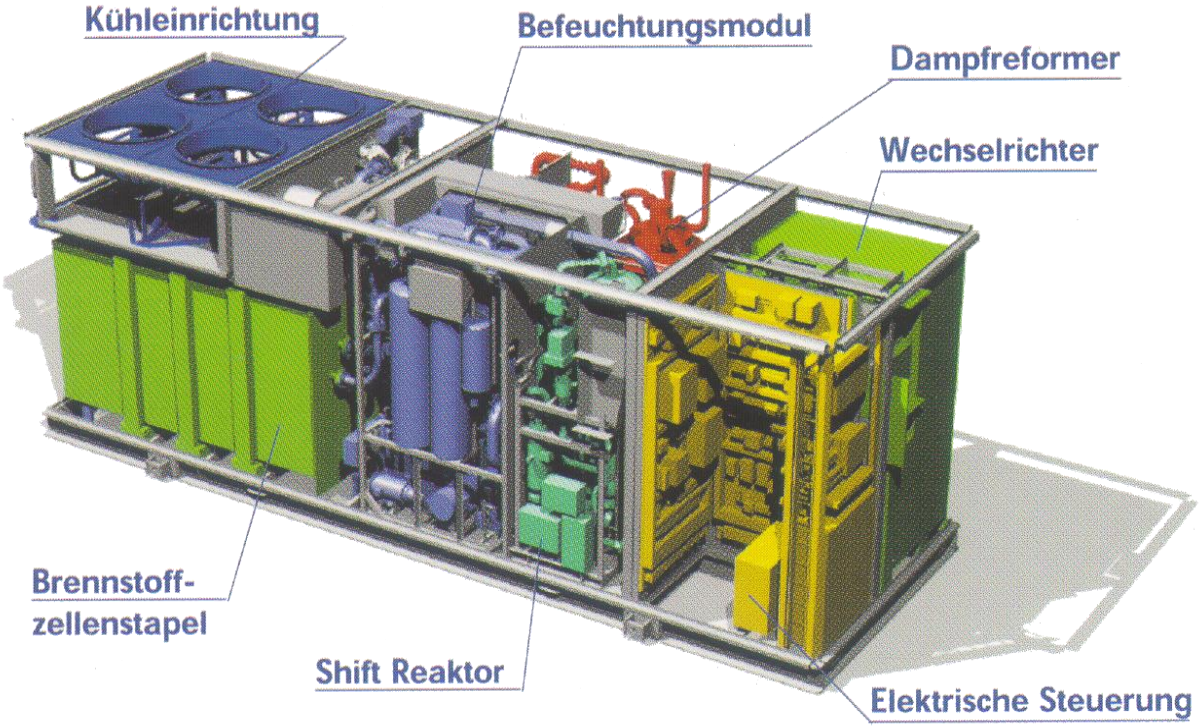


Brennstoffzellensysteme für die dezentrale Energieversorgung

Alstom/Ballard

Brennstoffzellen-Typ:	PEMFC
Betriebstemperatur:	80°C
elektrische Leistung:	250 kW
thermische Leistung:	237 kW
el. Nettowirkungsgrad*:	35 - 40%
Brennstoff:	Erdgas

*angestrebt



Alstom Ballard
Feldtest in Mingolsheim (EnBW)

Betriebsdaten zum 24. Oktober 2003:

- Inbetriebnahme 09.09.2002
- Betriebsstunden 2002 3.600 h
- Betriebsstunden 2003 3.500 h
- Betriebsstunden ges. 7.100 h

Energie:

- Elektrische Energie 786 MWh
- Thermische Energie 852 MWh

- Zeitl. Verfügbarkeit ca. 65 %
- Wirkungsgrad el. ca. 32-33 %
- Wirkungsgrad ges. ca. 60-70 %

Brennstoffzellensysteme für die dezentrale Energieversorgung
Parallel arbeitende PC25**-Systeme (Hersteller: IFC/ONSI, USA)

US Postal Service Mail Processing Center,

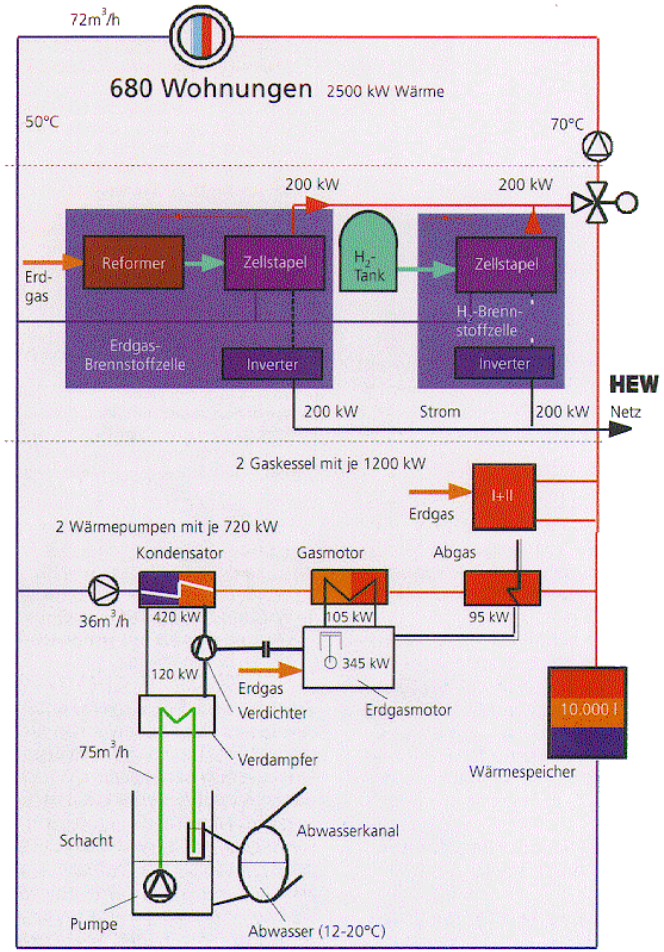
Anchorage, Alaska

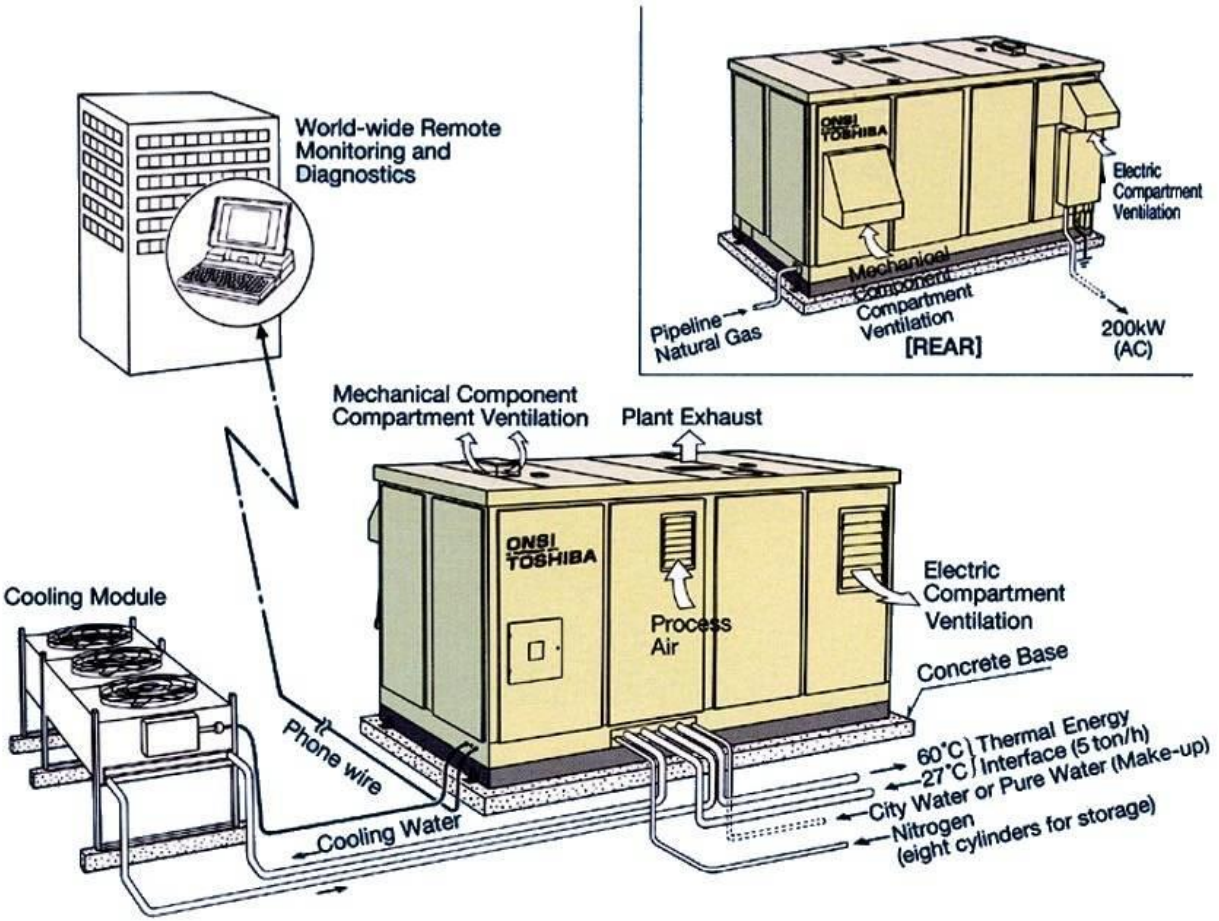
elektrische Leistung:	200 kW	
thermische Leistung:	200 kW	
Spannung:		450 V @ 50 Hz
dreiphasig		
el. Nettowirkungsgrad:	40%	
Systemwirkungsgrad:	85%	
Brennstoff:		Erdgas (u.a.)
Geräuschpegel:		60dB @ 10 m

** mehr als 200 Einzelsysteme weltweit installiert

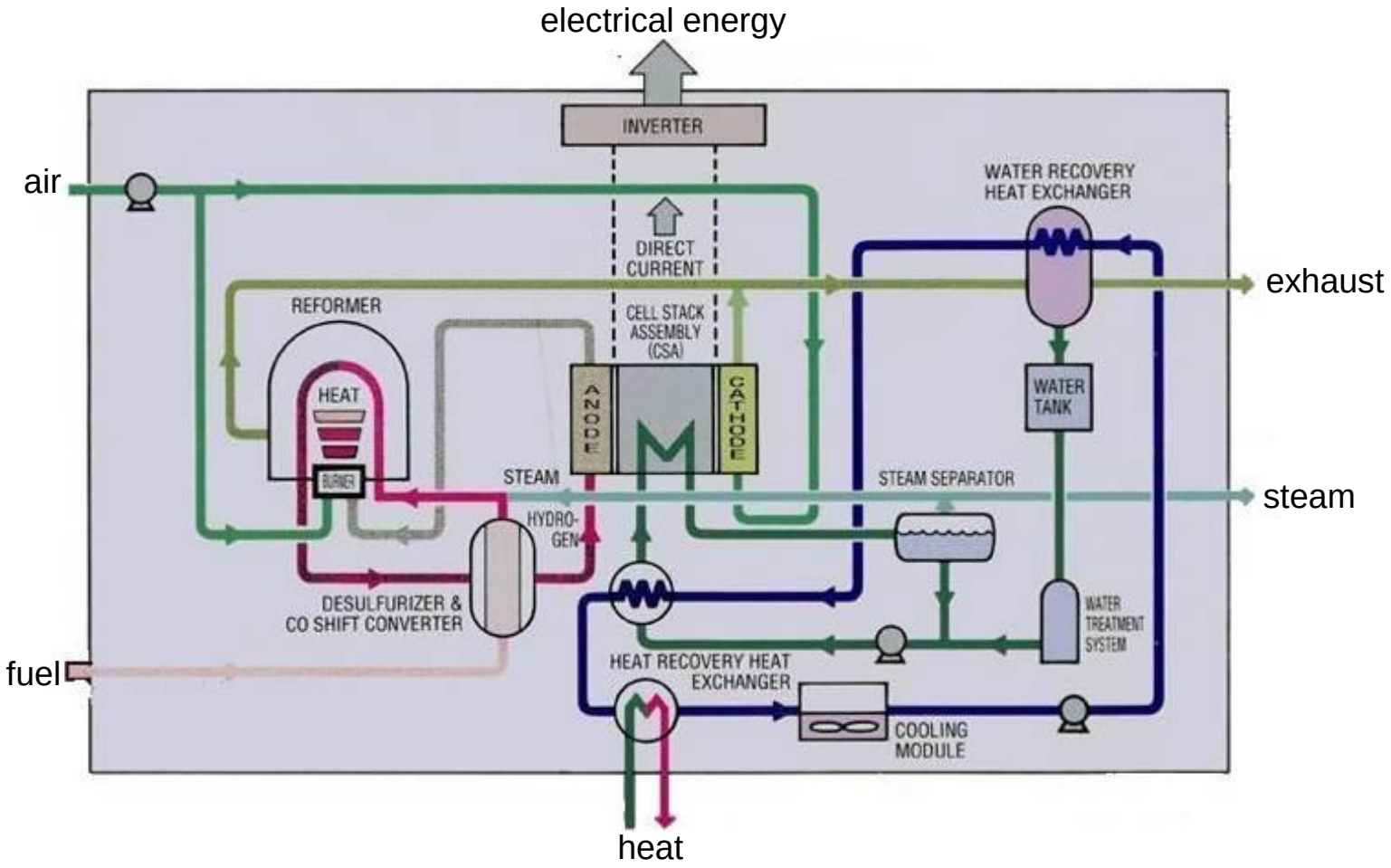
Quelle: IFC International Fuel Cells

BSZ - Stand der (System-) Technik
PC25™

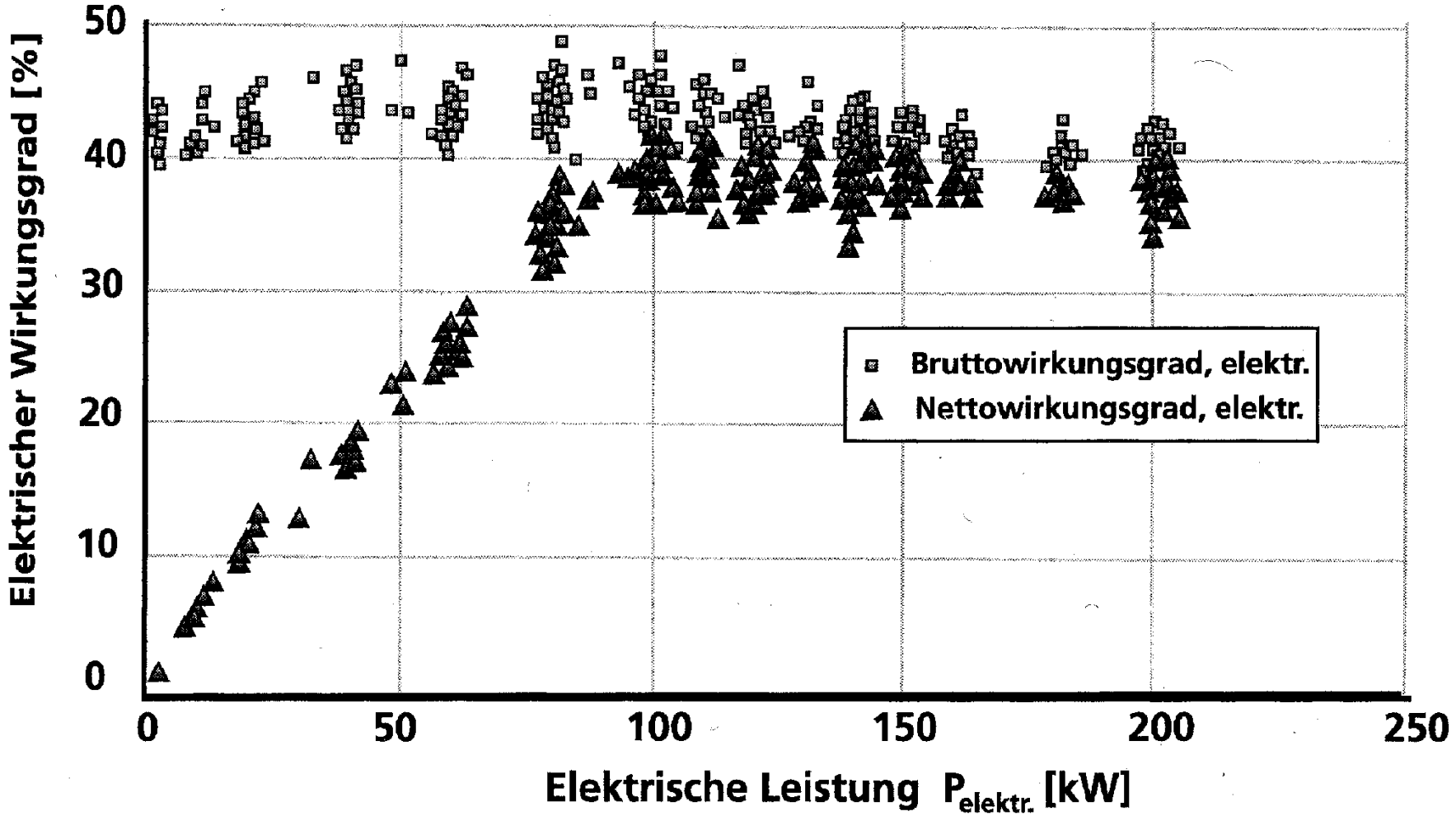




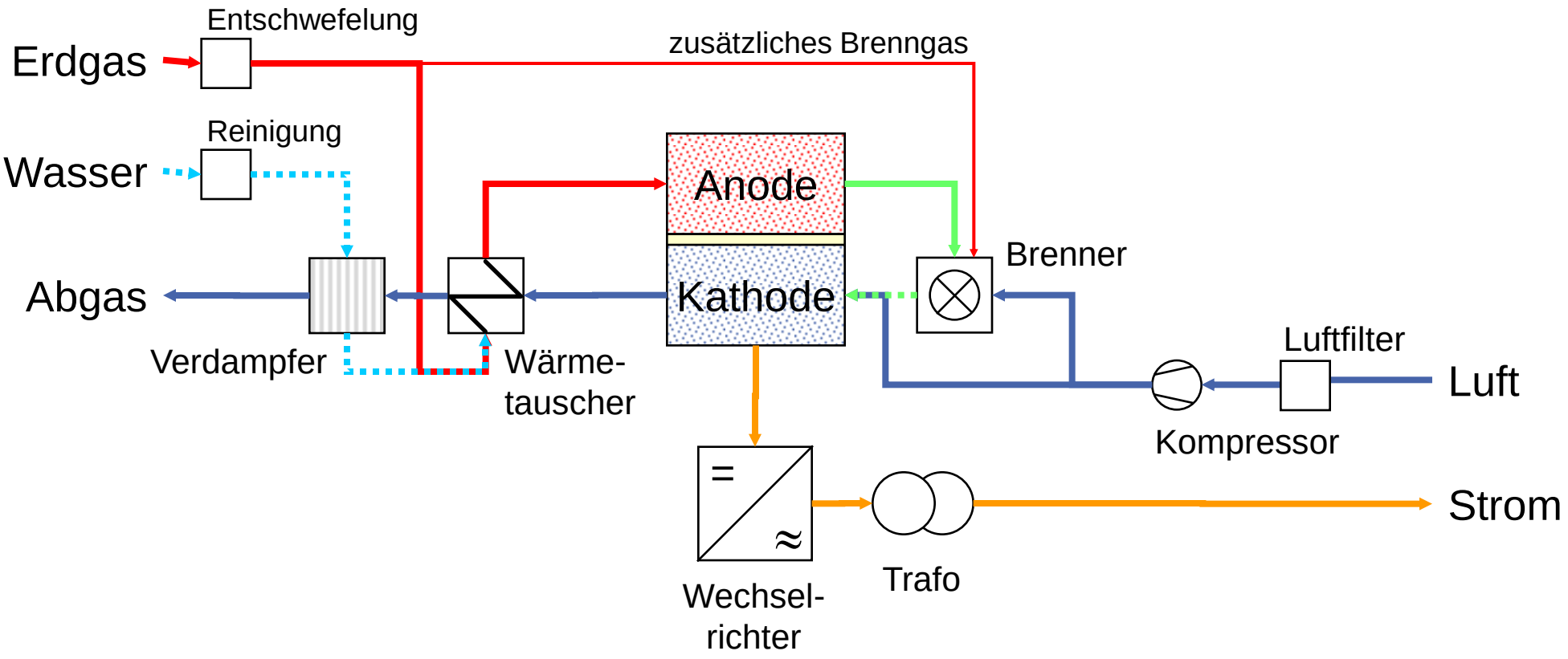
ONSI/Toshiba PC25



BSZ - Stand der (System-) Technik
PC25™ Wirkungsgrad als Funktion der Leistung

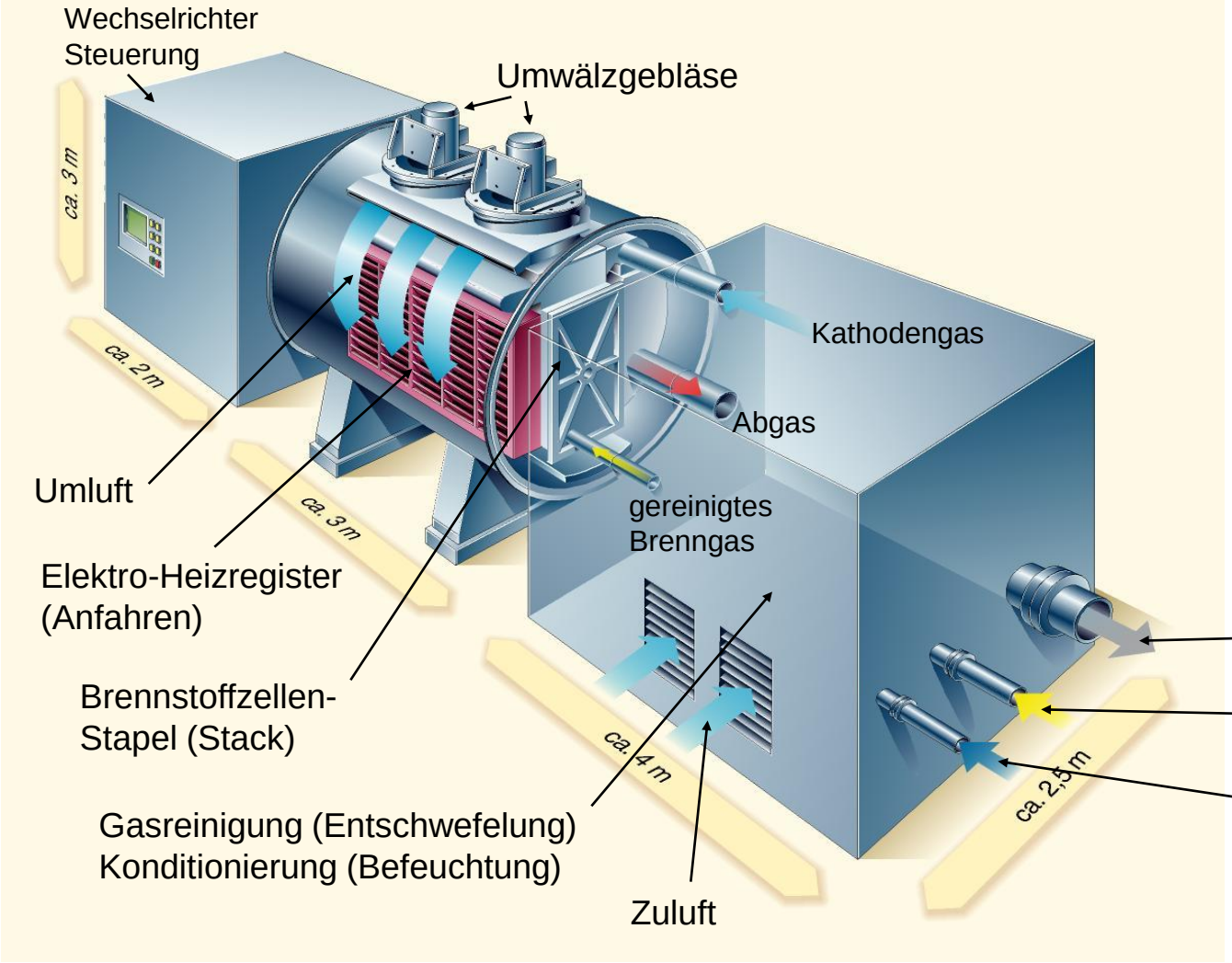


MCFC

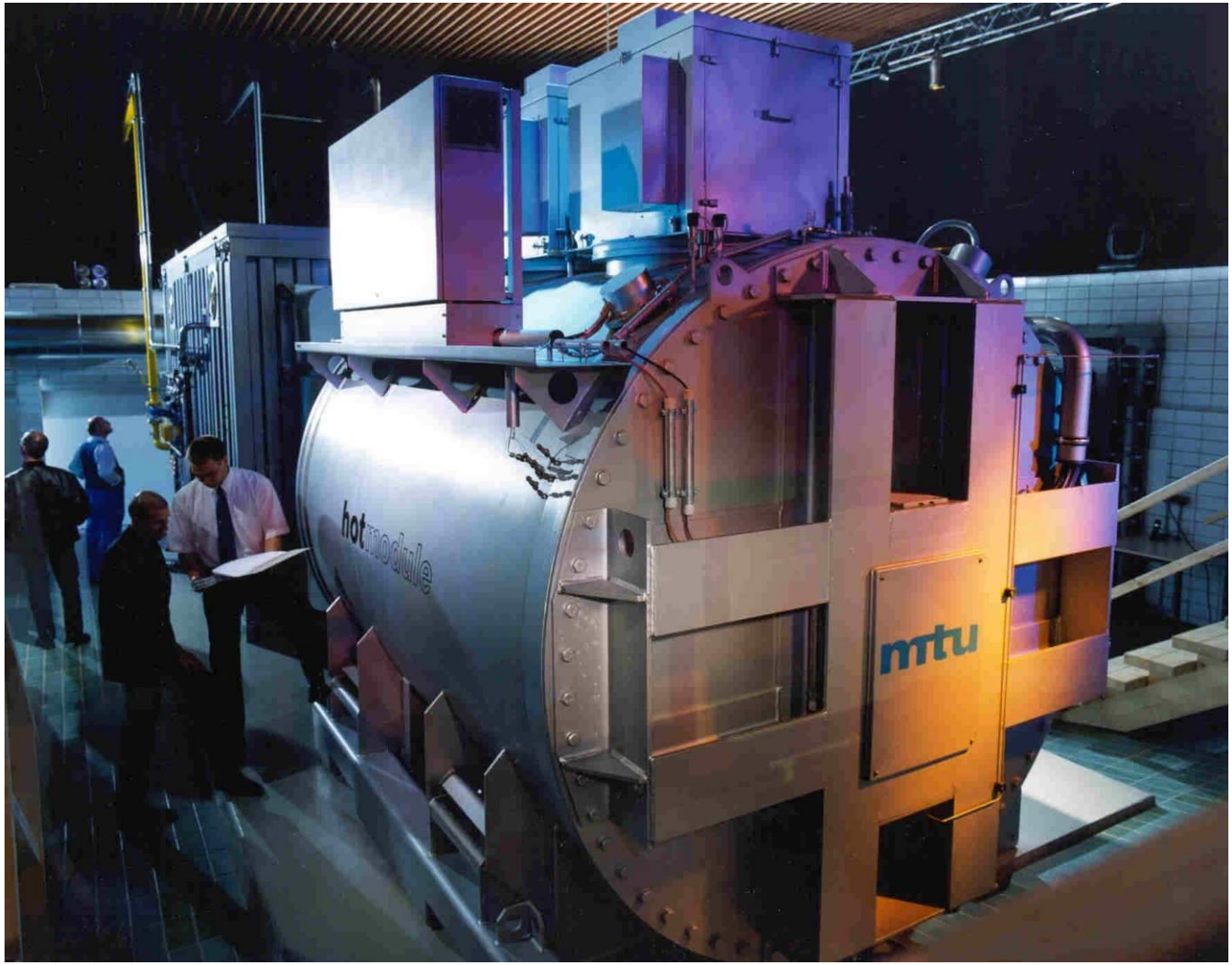

Entschwefelung
Erdgas
zusätzliches Brenngas
Reinigung
Wasser
Anode
Kathode
Brenner
Abgas
Verdampfer
Wärme-
tauscher
Luftfilter
Luft
Kompressor
=
≈
Strom
Trafo
Wechsel-
richter

BSZ - Stand der (System-) Technik
2 MW MCFC-Kraftwerk in Santa Clara (USA)

MCFC Systemtechnik
Hot Module



MCFC Systemtechnik
Hot Module



Fuel Cell Energy Solutions (MCFC)

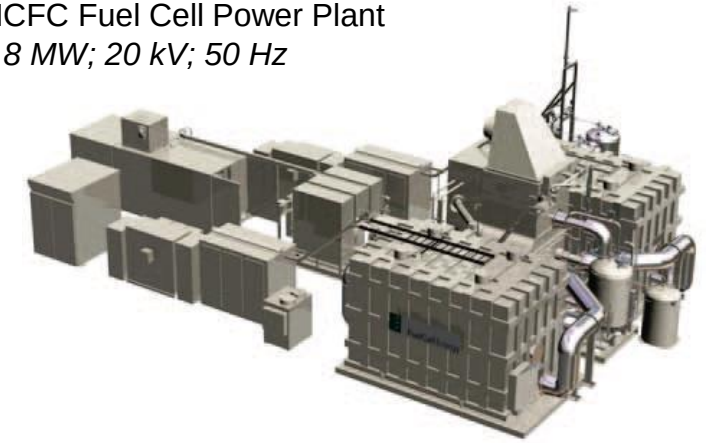
DFC®250 EU
MCFC-Fuel Cell Power Plant
250 kW; 400 V; 50 Hz

DFC®300 EU
MCFC-Fuel Cell Power Plant
300 kW; 400 V; 50 Hz

DFC®400 EU
MCFC-Fuel Cell Power Plant
400 kW; 400 V; 50 Hz

DFC®1500 EU
MCFC-Fuel Cell Power Plant
1,4 MW; 20 kV; 50 Hz

DFC®3000 EU
MCFC Fuel Cell Power Plant
2,8 MW; 20 kV; 50 Hz

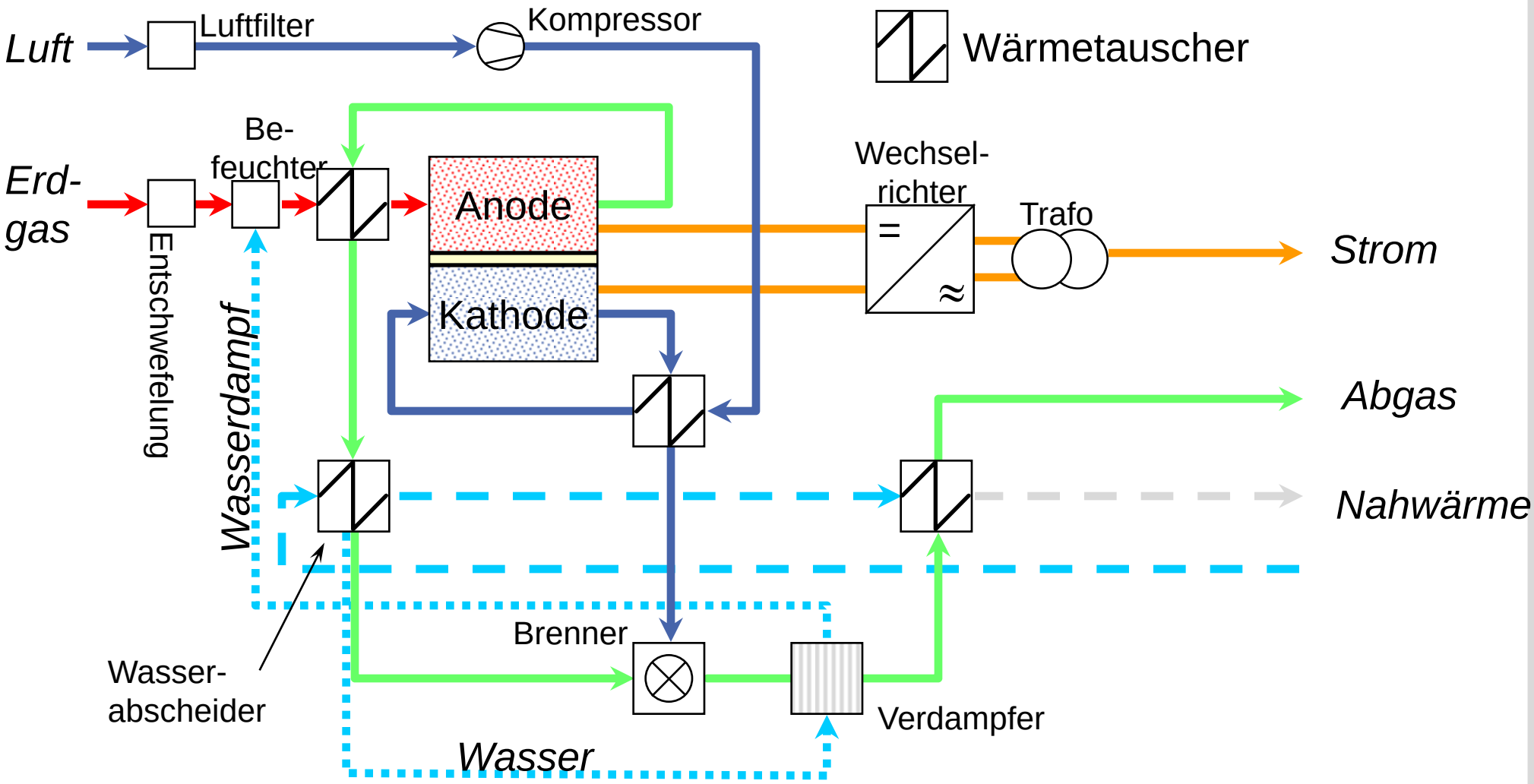


FuelCell Energy
Ultra-Clean, Efficient, Reliable Power

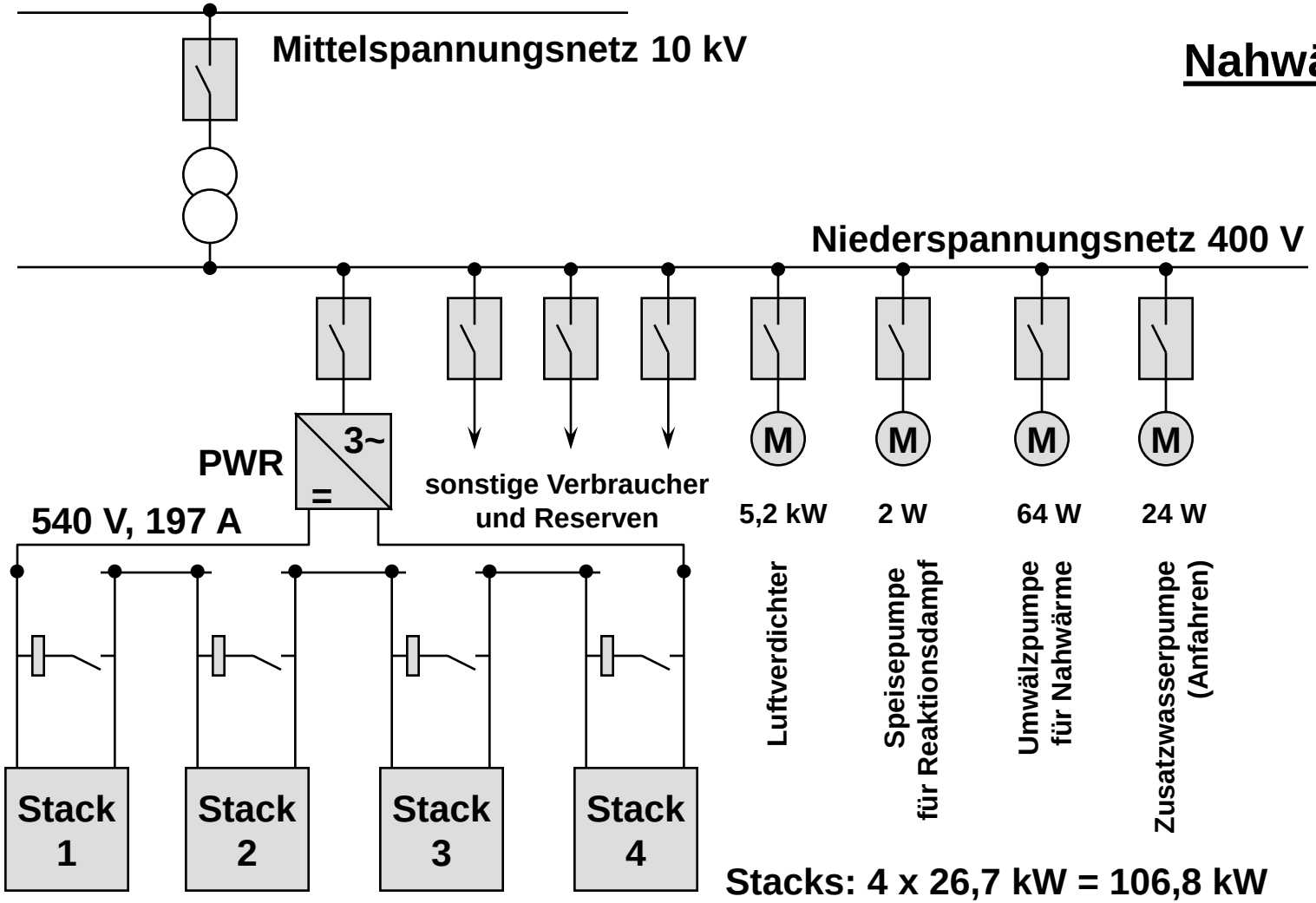
59 MW Fuel Cell Park

- **59 MW fuel cell park**
  - Construction period only about one year
  - 21 power plants: 2.8 MW DFC3000®
- **Ownership**
  - 49% by electric utility KHNP
  - 21% by financial investors
  - 15% by gas company Samchully
  - 15% by POSCO Energy

100 kW-SOFC-BHKW-Anlage



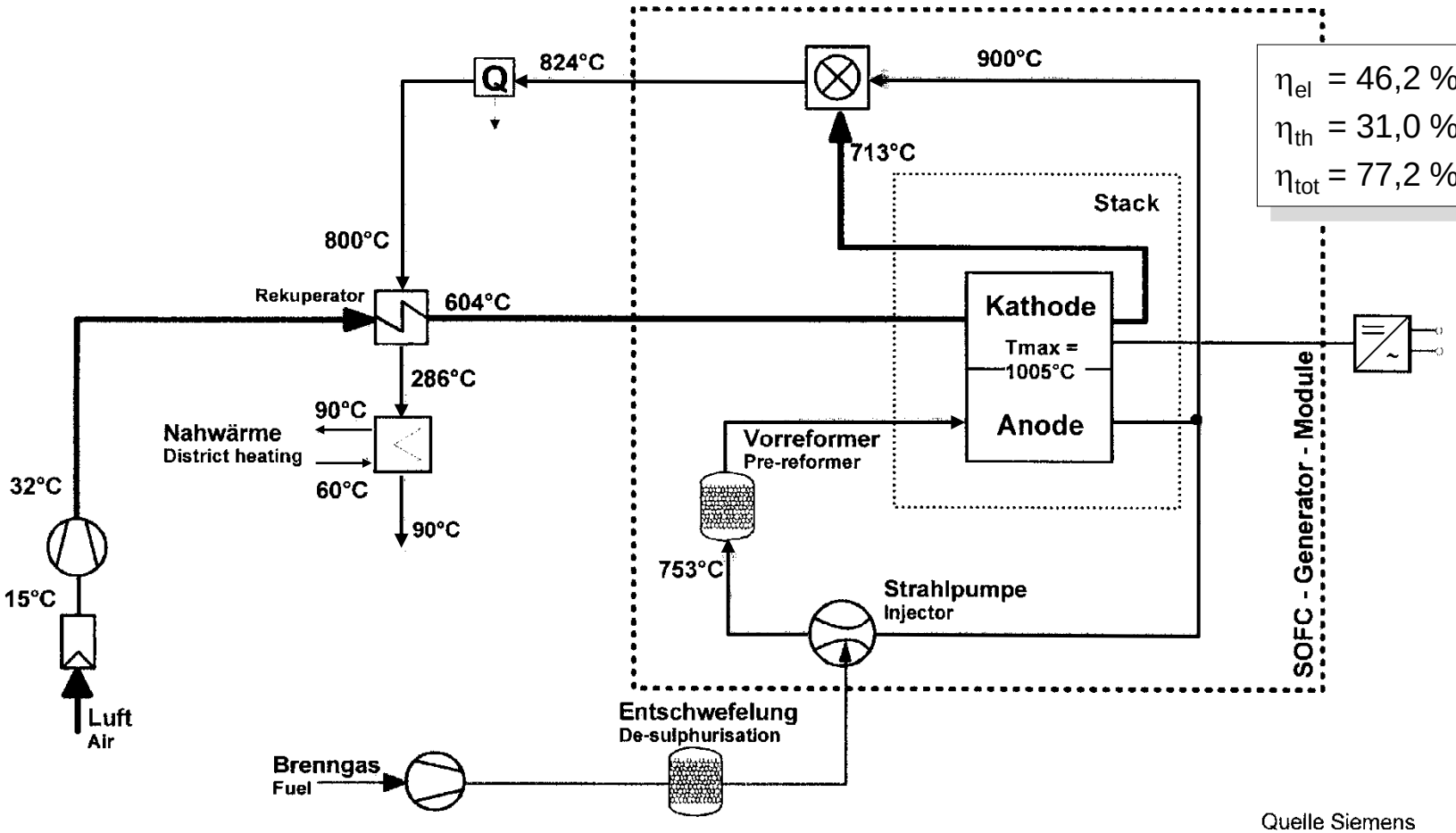
100 kW - SOFC - BHKW - Anlage
E-Schaltanlagenkonzeption mit netzgeführtem Wechselrichter



Nahwärme-Variante

250 kW BHKW (CHP)

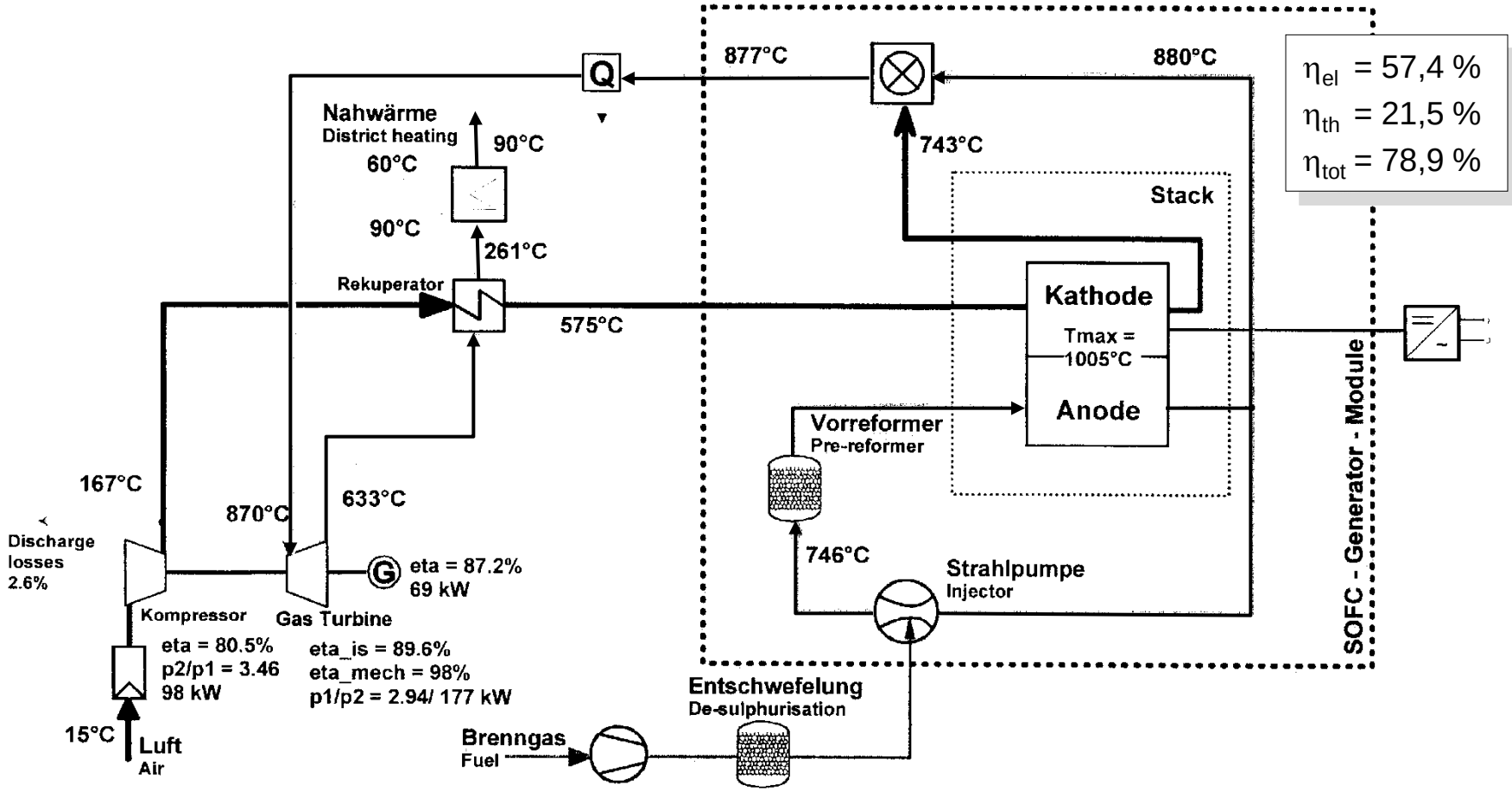
(Brenngasnutzung 84%, Zellspannung 0,65 V)



Quelle Siemens

320 kW Druck-Hybrid-Anlage

(Brenngasnutzung 84%, Zellspannung 0,63 V)



Quelle Siemens

BSZ - Stand der (System-) Technik
Siemens Westinghouse 100 kW SOFC-BHKW

P_{el}: 100 kW_{el}

P_{th}: 65 kW_{th}

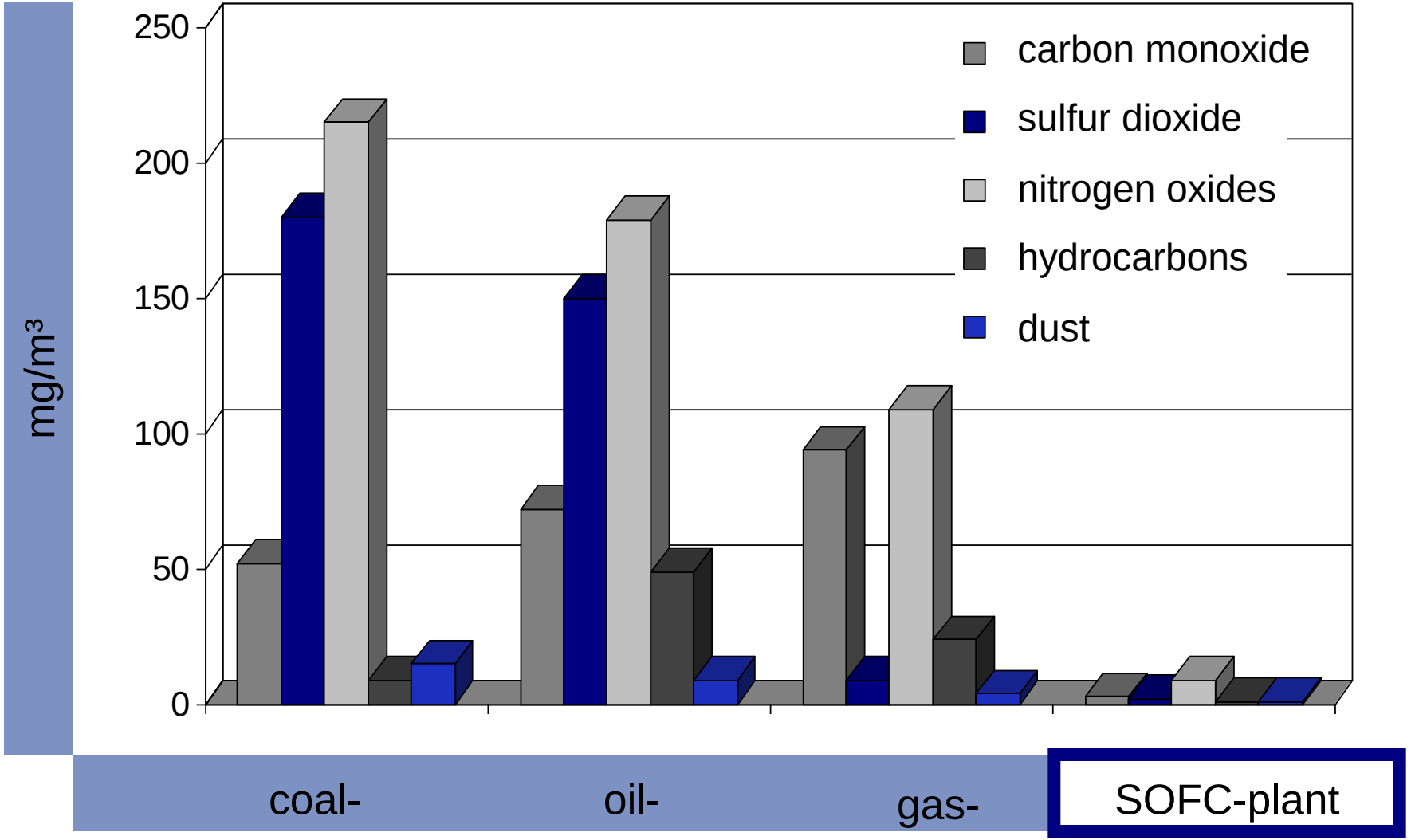
Brennstoff: Erdgas

$\eta_{elektrisch}$: 46 %

$\eta_{thermisch}$: 29 %

η_{gesamt}: 75 %

Pollutant emissions of different generators



BSZ - Stand der (System-) Technik
Siemens Westinghouse 220 kW SOFC-Hybridsystem

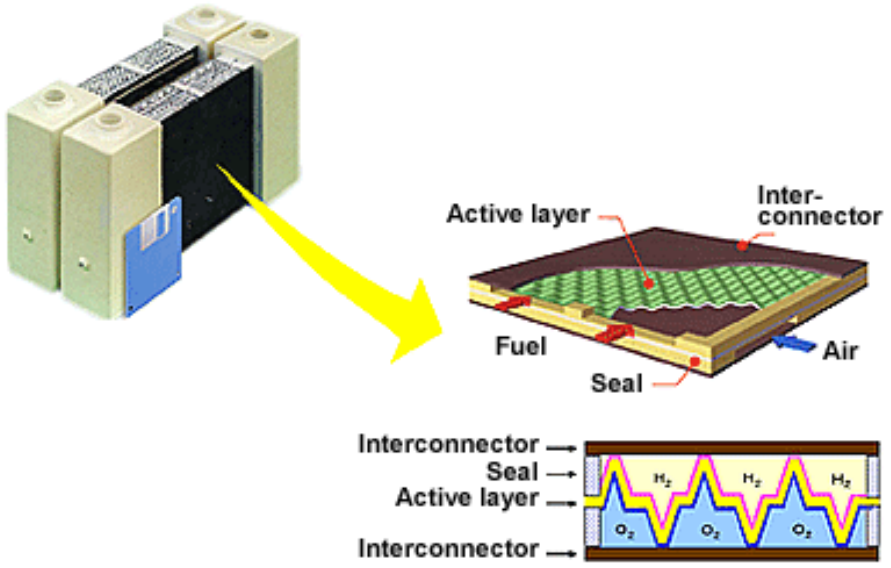
Siemens Westinghouse

Brennstoffzellen-Typ	SOFC
Betriebstemperatur	1000°C
Leistung BSZ	173 kW_{el}
Leistung Mikroturbine	47 kW_{el}
thermische Leistung	65 kW_{th}
Brennstoff	Erdgas
el. Nettowirkungsgrad	55%

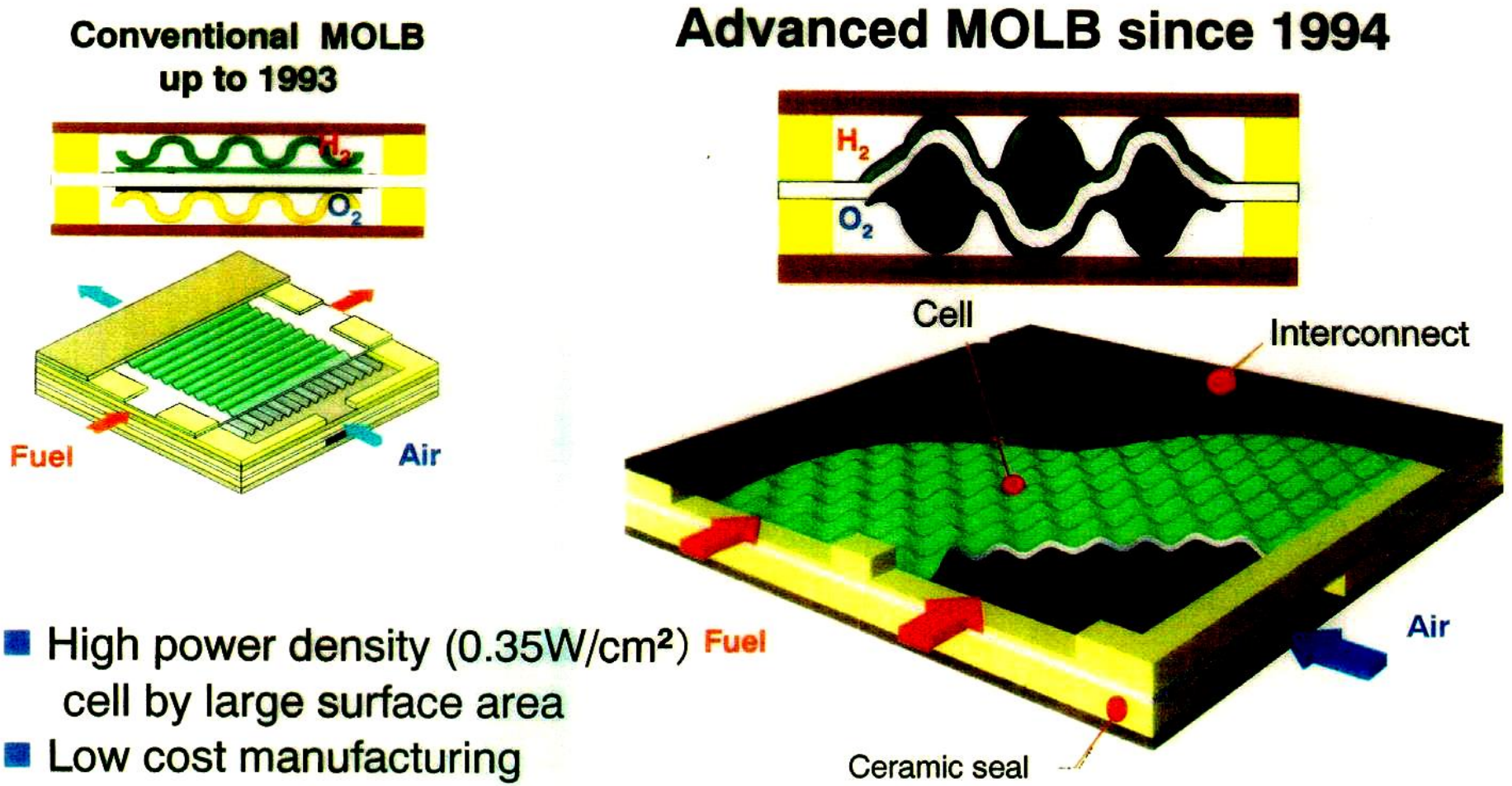
Betrieb durch Southern California Edison Co. an der University of California, Irvine.

Mitsubishi Heavy Industries
MOLB-Type

- several systems (1 kW ... 1 Stack unit .... 50 kW) under operation/construction
- 10 kW_{el} system operated from July 2000 to Oct. 2001 (total 7500h, 2437h with direct internal reforming), 0,24 W/cm², max power 15 kW_{el}, stack consisting of 10 cells (20x20cm², 1 kWel / Stack), operating temp. 950°C (up to1000°C)
- thermal and load cycling is no problem
- several kW systems running on desulfurized NG (3-4 ppm), complete internal reforming realized by fuel circulation
- planned 50 kW system (3x3x6m³)



Structure of MOLB type SOFC
(MOLB: M..... O.....L ..... B)



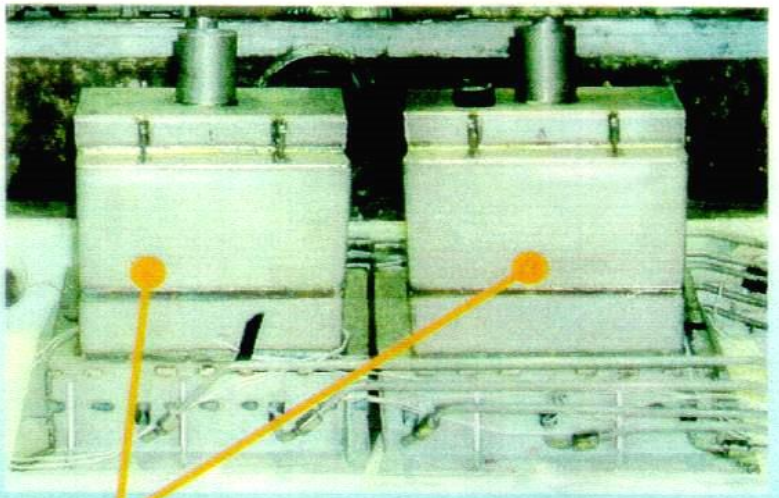
- High power density (0.35W/cm²) cell by large surface area
- Low cost manufacturing by wet fabrication process

Development of Module Components
NEDO project

Development items in 2001 - 2002

- Integrated air pre-heater
- Automated control of module operation
- Automated startup, power control and shutdown

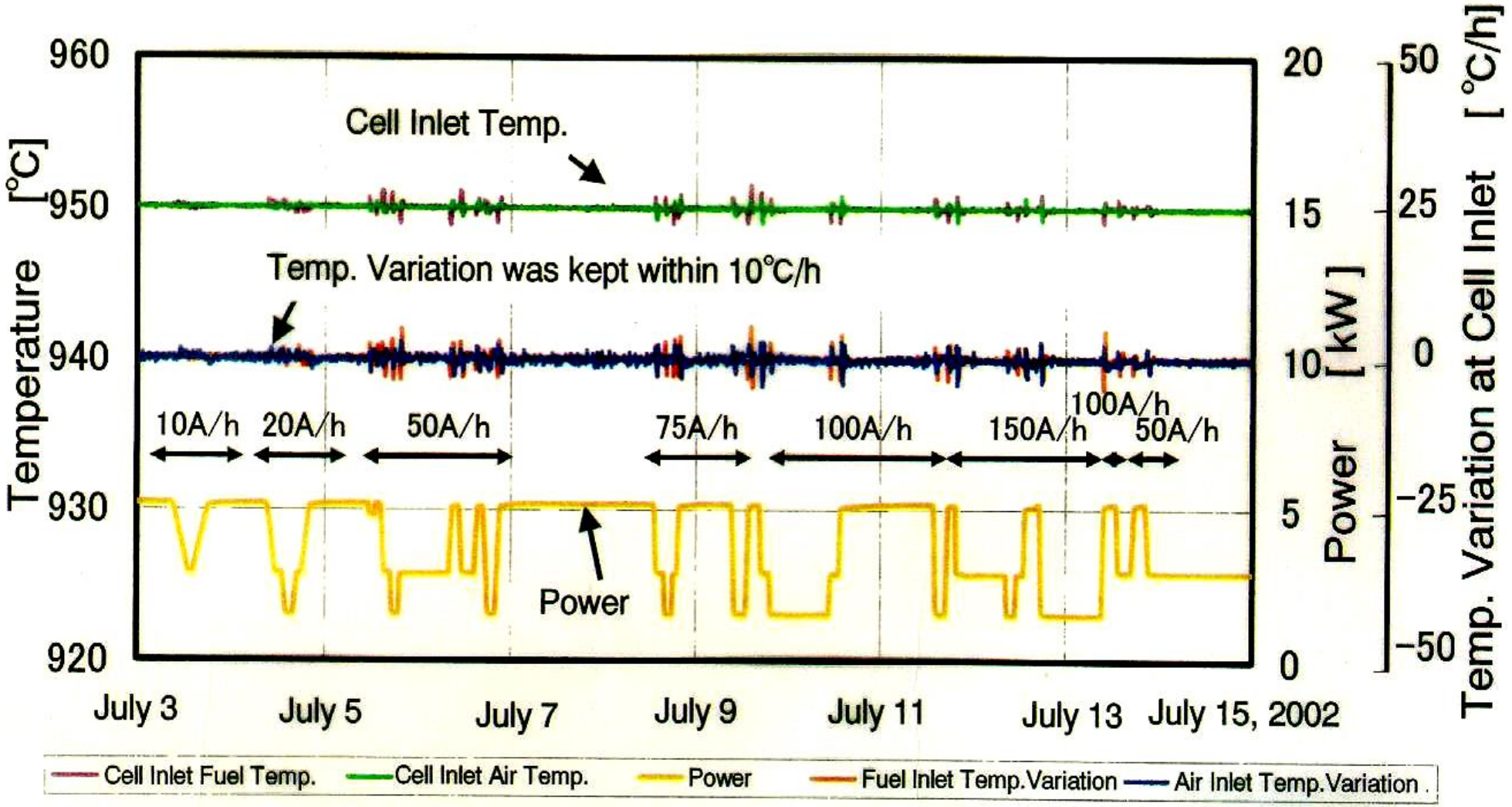
SOFC module



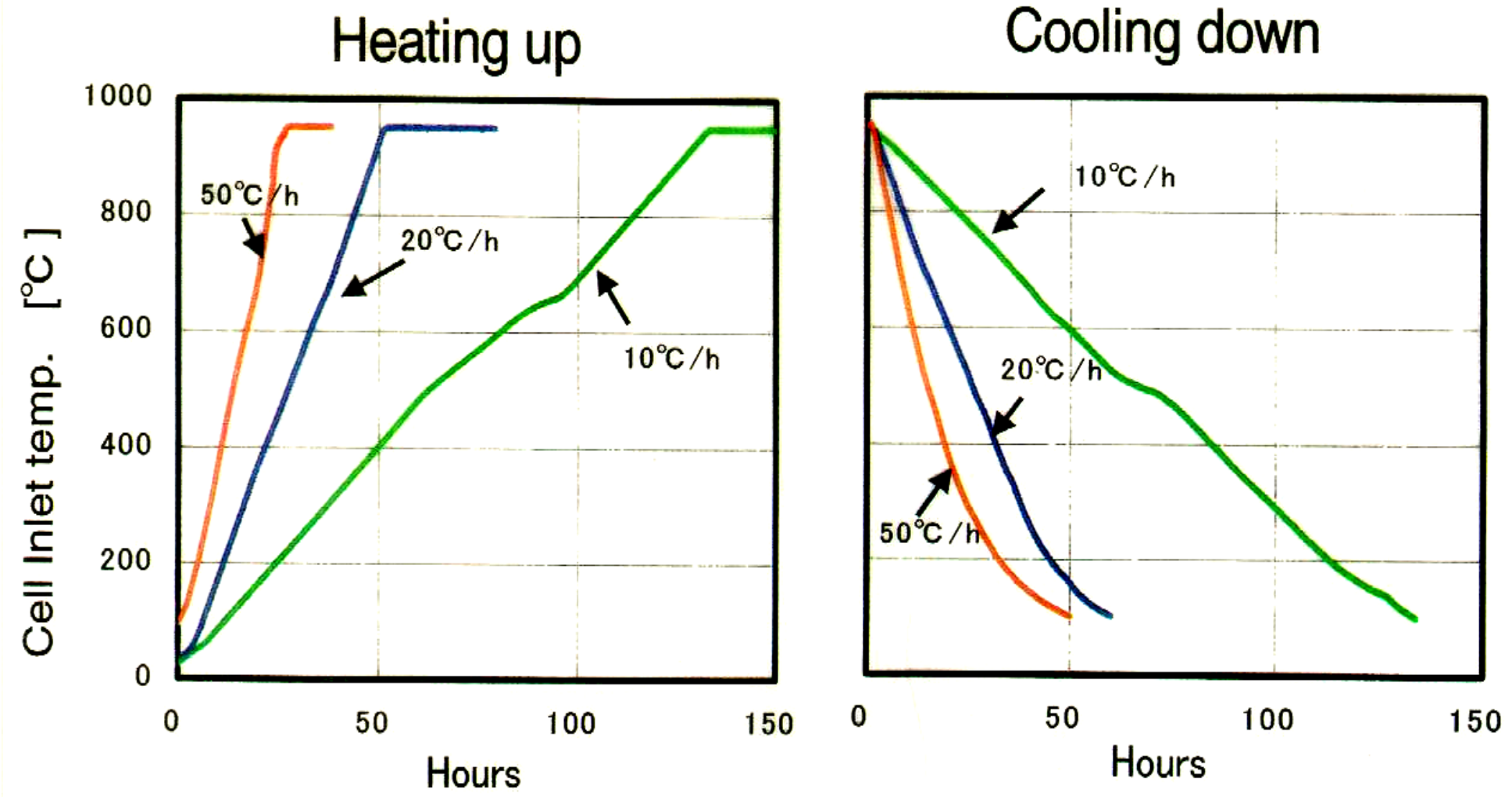
Integrated air pre-heater
- two heaters for 10 stacks

Automated control panel
- digital control system

Load change Test
NEDO project

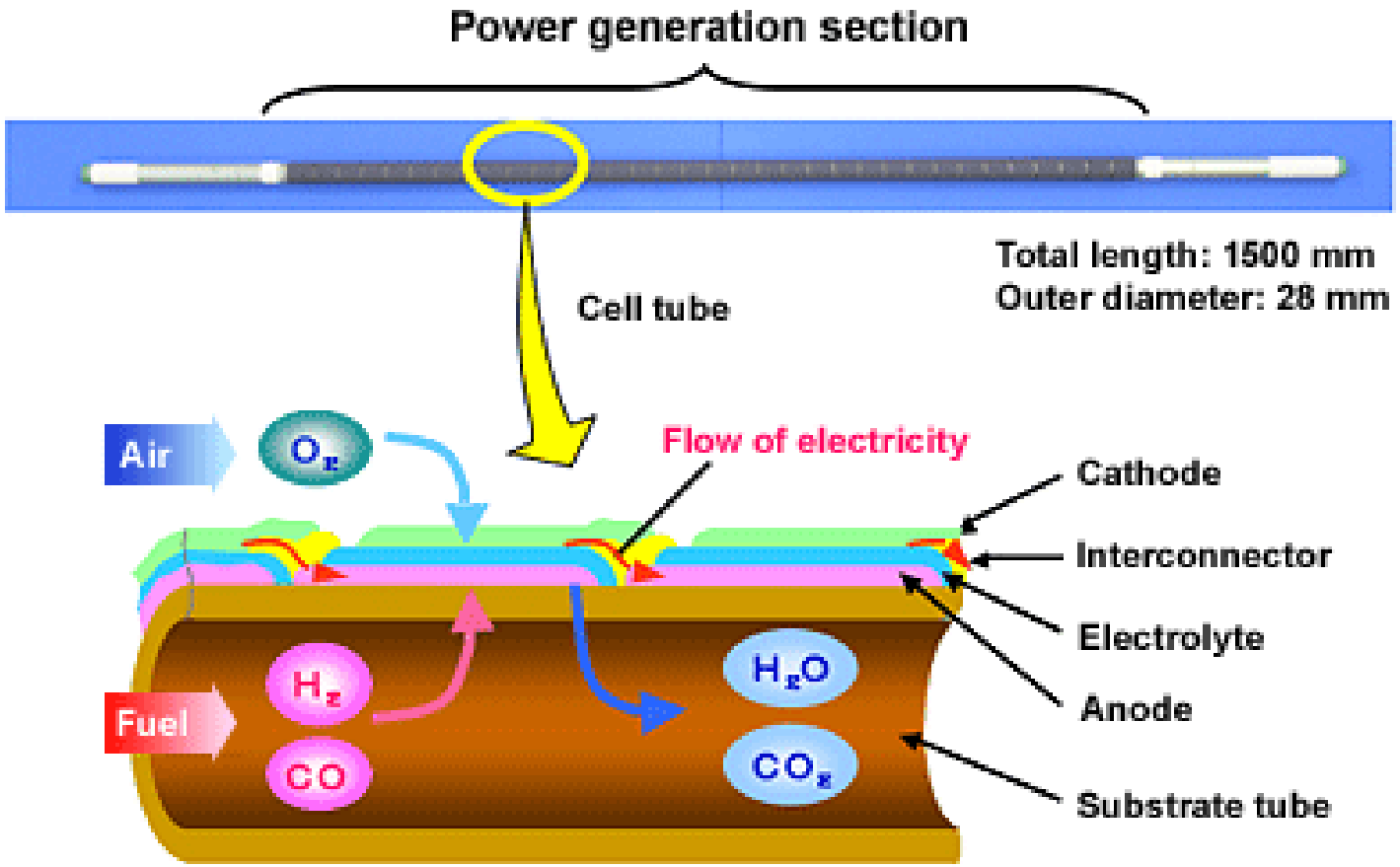


Automated Startup and Shutdown Operations
NEDO project

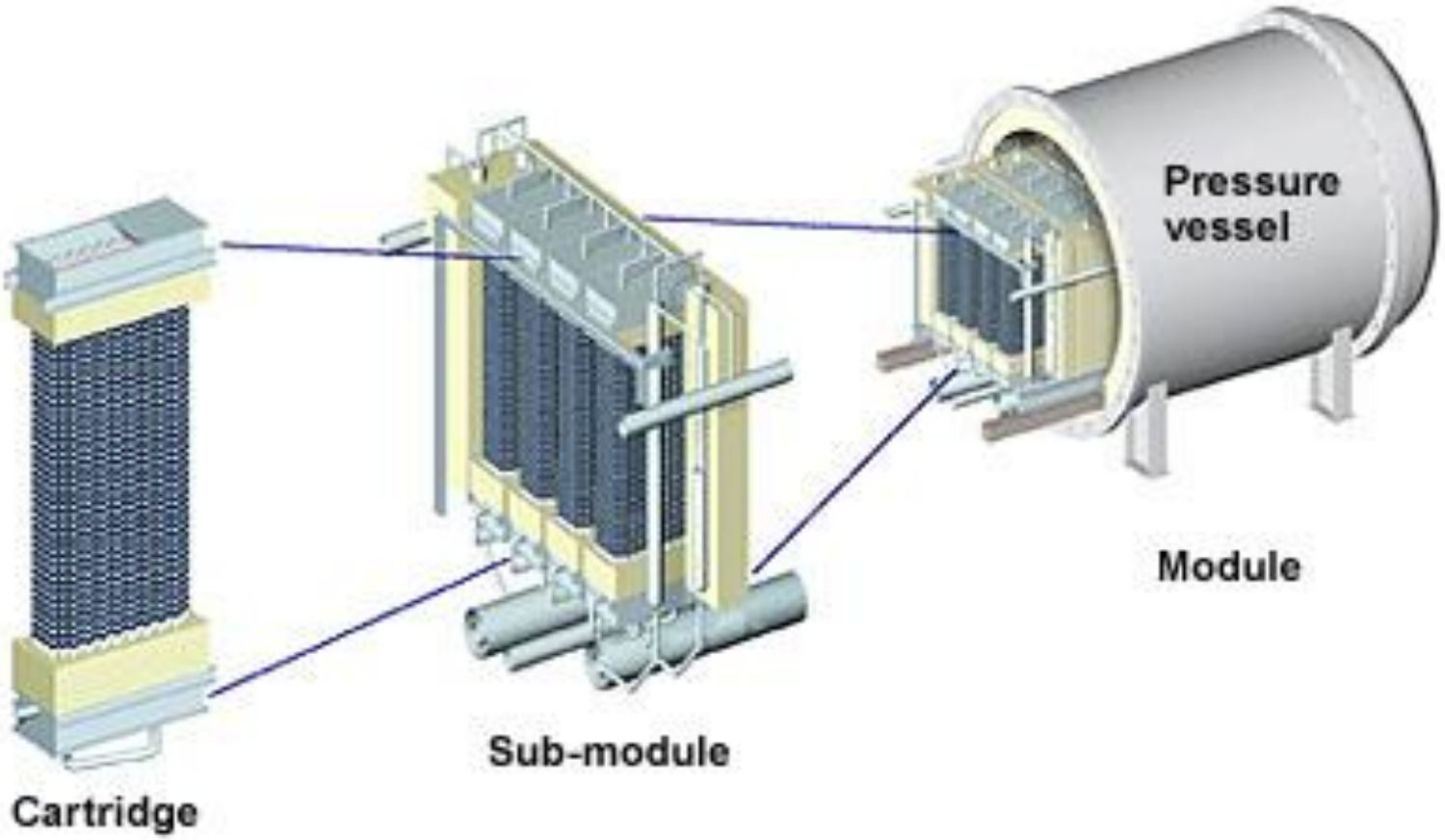


Mitsubishi Heavy Industries
30 kW Molb-Type SOFC System

Mitsubishi Heavy Industries
Tubular Type SOFC



Mitsubishi Heavy Industries
Tubular Type SOFC



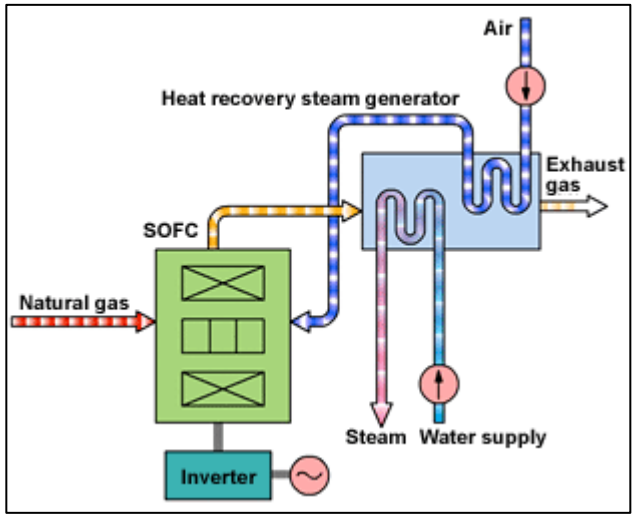
Mitsubishi Heavy Industries
Tubular Type SOFC

MHI

Brennstoffzellen-Typ	SOFC
Betriebstemperatur	>900°C
Leistung	229 kW_{el}
Brennstoff	Erdgas
el. Nettowirkungsgrad	52 %

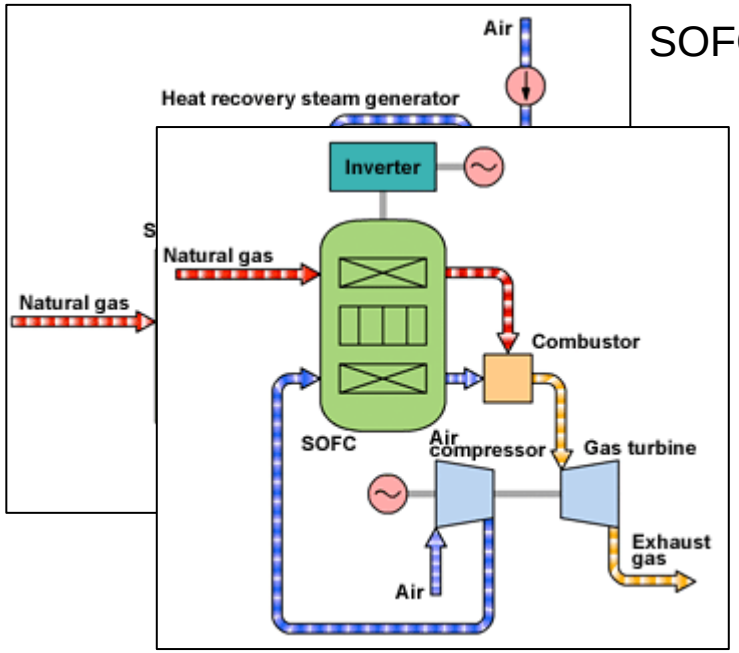
Quelle: MHI

Mitsubishi Heavy Industries
Tubular Type SOFC



SOFC-CHP

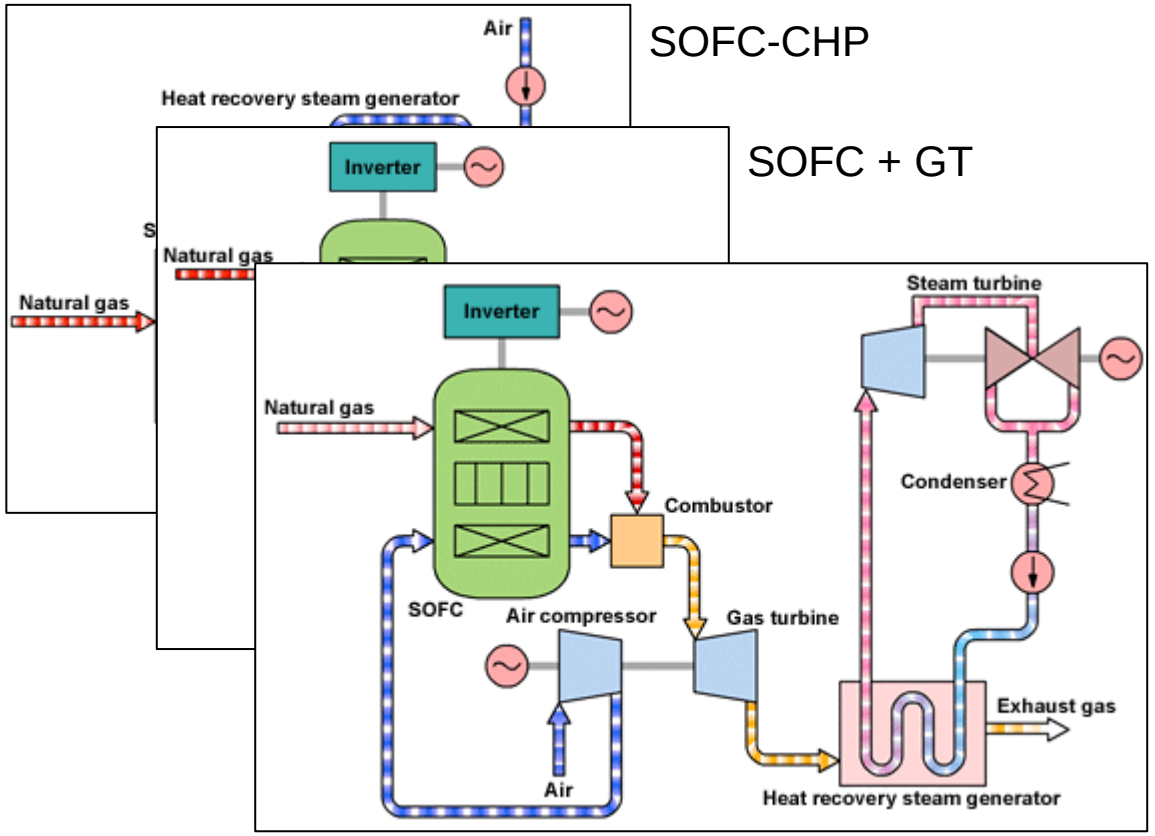
Mitsubishi Heavy Industries
Tubular Type SOFC



SOFC-CHP

SOFC + GT

Mitsubishi Heavy Industries
Tubular Type SOFC

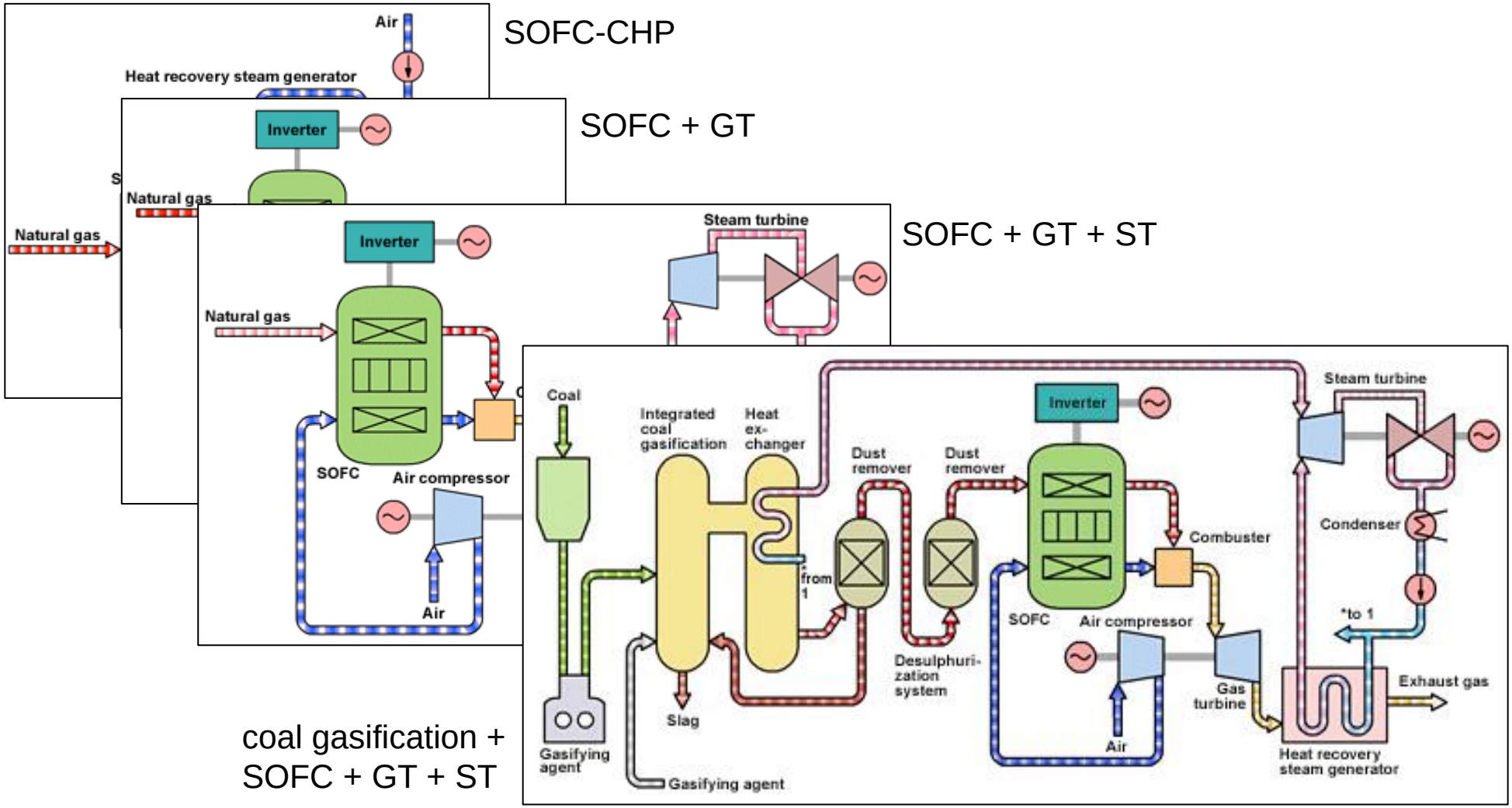


SOFC-CHP

SOFC + GT

SOFC + GT + ST

Mitsubishi Heavy Industries
Tubular Type SOFC



Rolls Royce Fuel Cells Systems

Bloom Energy

	ES-5700	ES-5710
Outputs		
Nameplate power output (net AC)	210 kW	262.5 kW
Base load output (net AC)	200 kW	250 kW
Electrical connection	480 V, 3-phase, 60 Hz	480 V, 3-phase, 60 Hz
Inputs		
Fuels	Natural gas, directed biogas	Natural gas, directed biogas
Input fuel pressure	15 psig	15 psig
Water	None during normal operation	None during normal operation
Efficiency		
Cumulative electrical efficiency (LHV net AC)	52-60%	52-60%
Heat rate (HHV)	6,295-7,264 Btu/kWh	6,295-7,264 Btu/kWh
Emissions		
NOx	< 0.01 lbs/MWh	< 0.01 lbs/MWh
SOx	Negligible	Negligible
CO	< 0.10 lbs/MWh	< 0.10 lbs/MWh
VOCs	< 0.02 lbs/MWh	< 0.02 lbs/MWh
CO2 @ stated efficiency	735-849 lbs/MWh on natural gas; carbon neutral on directed biogas	735-849 lbs/MWh on natural gas; carbon neutral on directed biogas
Physical Attributes and Environment		
Weight	19.4 tons	19.4 tons
Dimensions	26' 5" x 8' 7" x 6' 9"	26' 5" x 8' 7" x 6' 9"
Temperature range	-20° to 45° C	-20° to 45° C
Humidity	0% - 100%	0% - 100%
Seismic vibration	IBC site class D	IBC site class D
Location	Outdoor	
Noise	< 70 dBA @ 6 feet	< 70 dBA @ 6 feet
Codes and Standards		
Complies with Rule 21 interconnection and IEEE1547 standards		
Exempt from CA Air District permitting; meets stringent CARB 2007 emissions standards		
Product listed by Underwriters Laboratories Inc. (UL) to ANSI/CSA America FC 1-2004		
Additional Notes		
Access to a secure website to monitor system performance & environmental benefits		
Remotely managed and monitored by Bloom Energy		
Capable of emergency stop based on input from the site		