

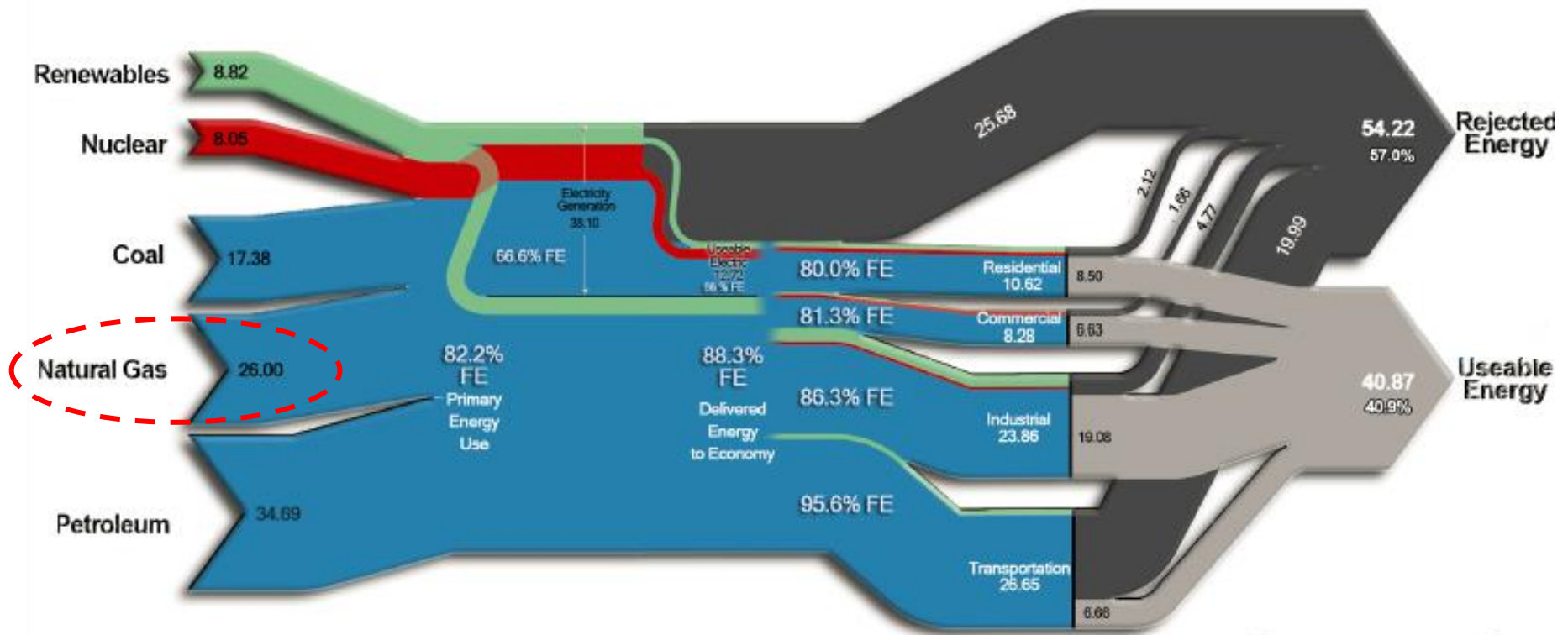
Natural Gas Based Stationary Power Generation

Panel Discussion Agenda

- Introduction (10-15 minutes)
- Introduction and overview by panelists (each 5-7 minutes)
- Panel discussion starts (60 minutes)
- Open questions from audience (7-10 minutes)

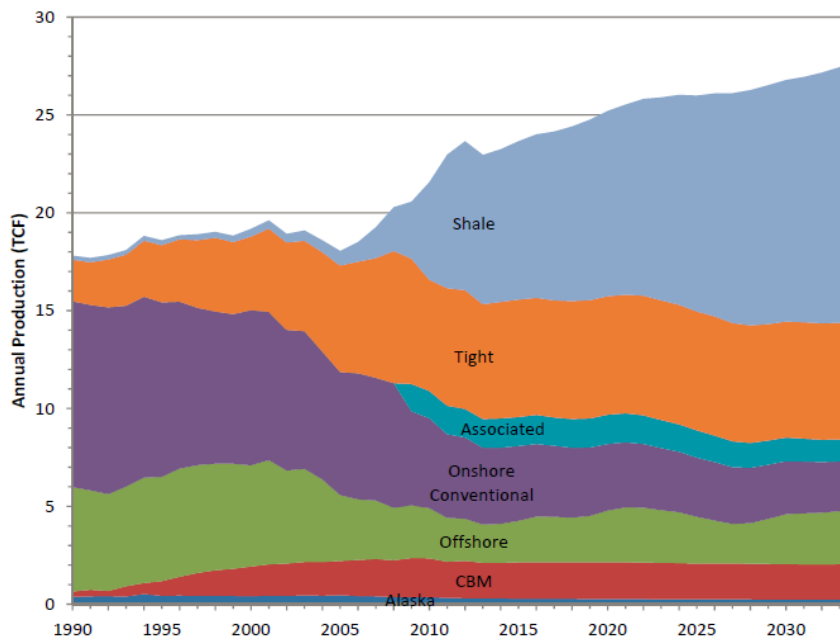
Estimated U.S. Energy Use in 2012: 95.1 Quads

Contributions of Major Energy Sources

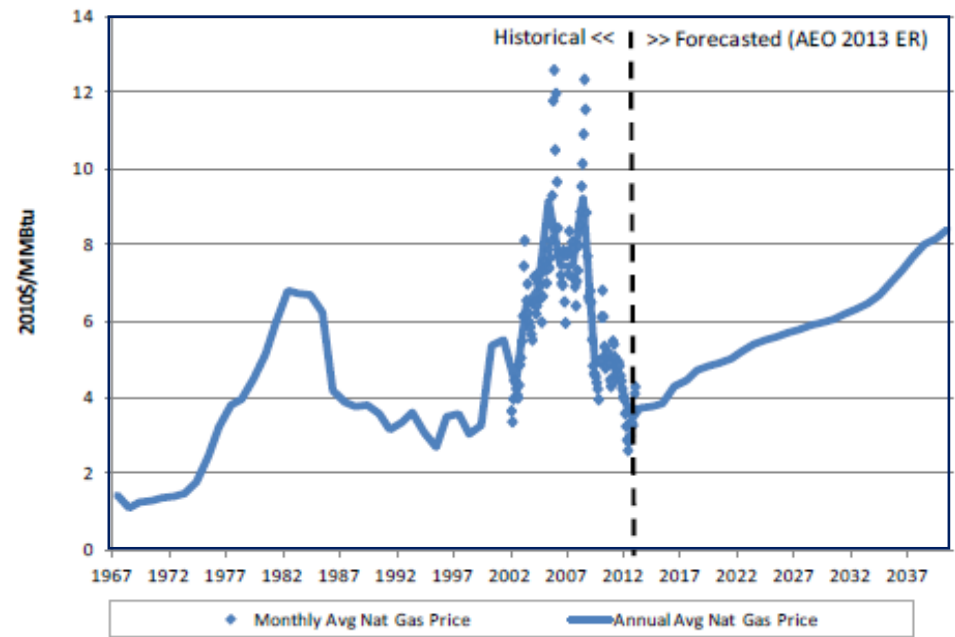


Source: DOE EIA-0035 (2013/05)

NG: The Rise of Production and Fall of Price



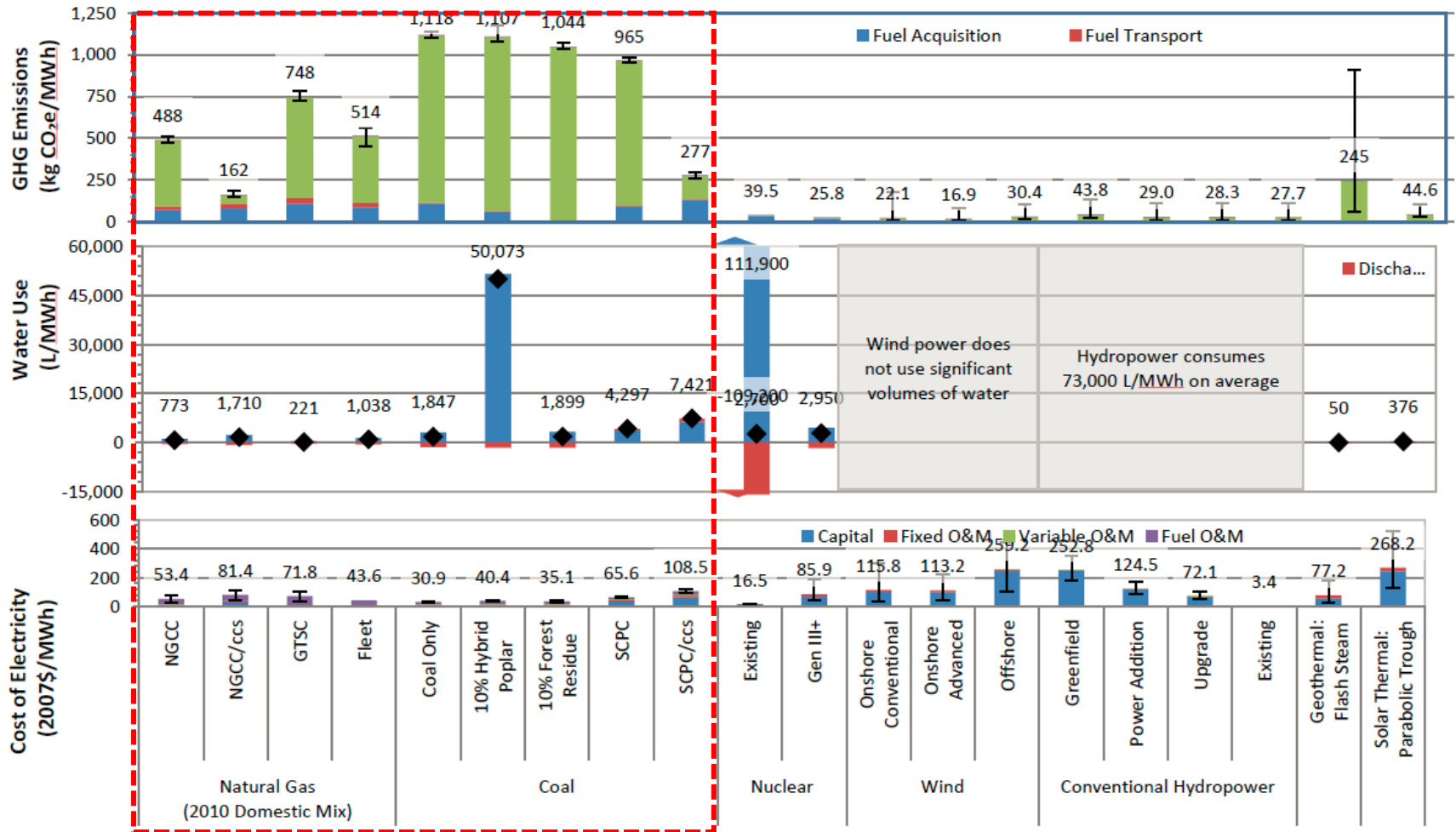
Source: DOE EIA-0035 (2013/05)



Source: EIA - AEO 2013ER [8,9]

Source: DOE/NETL-341/061013

Power Plants Performance

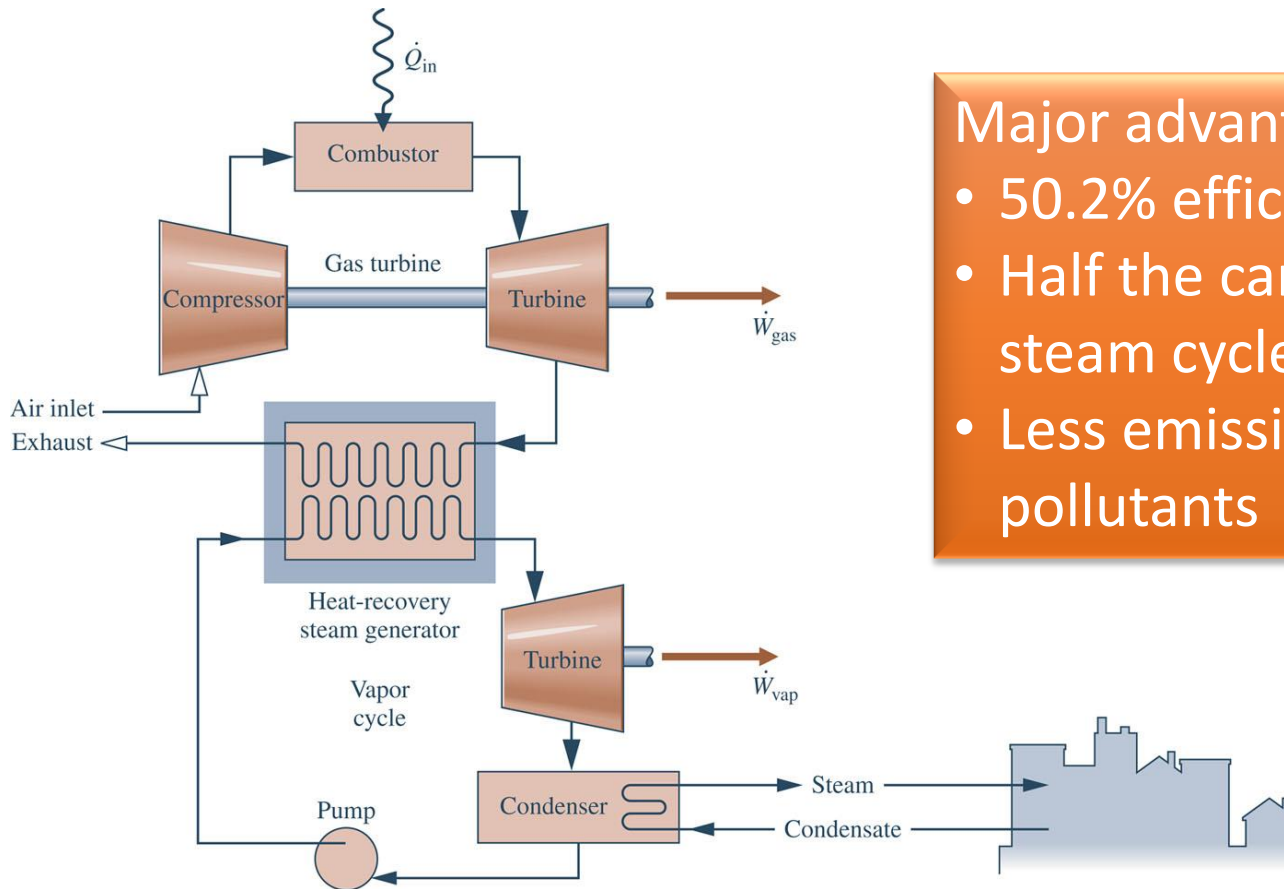


Source: DOE/NETL Fact Sheet, NETL program/product Identification: Life Cycle Analysis

Major NG Applications

- Power generation
 - Centralized: NGCC
 - Distributed: GTSC, NGFC, reciprocal engines, microturbines
- Chemical synthesis
 - H₂ production
 - Fertilizers
 - Refinery
 - Transportation fuels

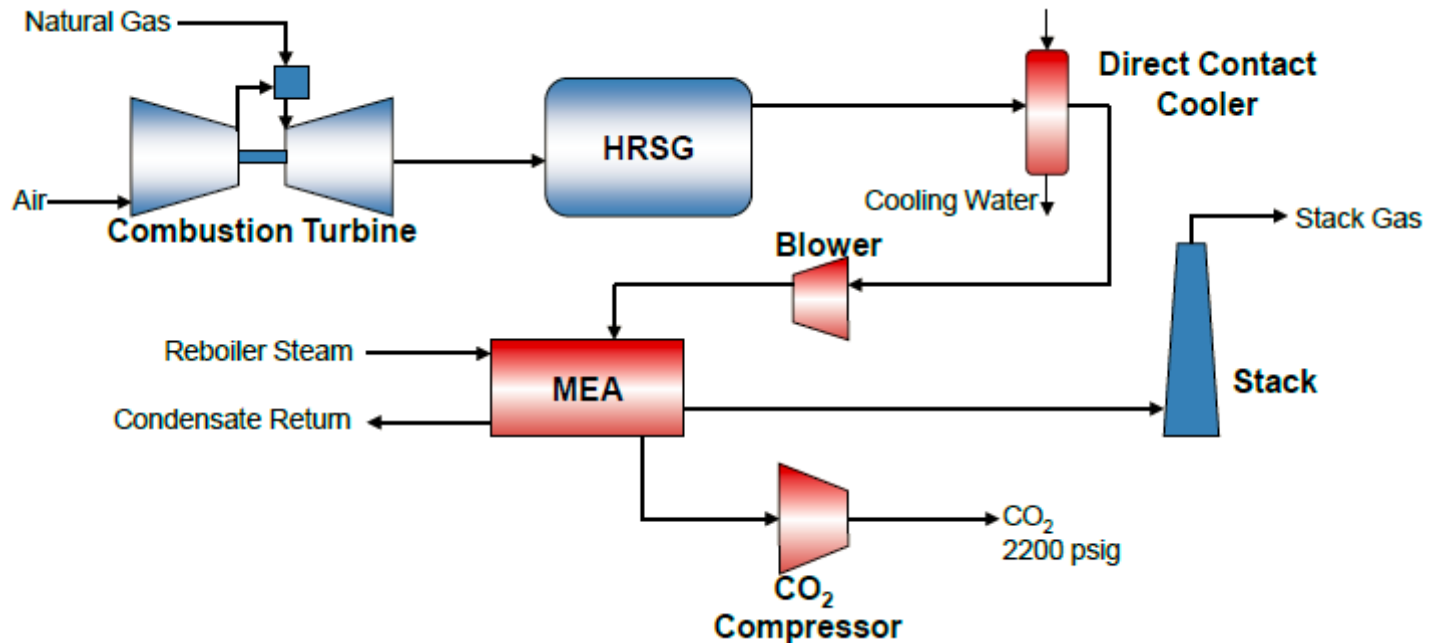
Centralized NGCC



Major advantages:

- 50.2% efficiency
- Half the carbon emission of steam cycle
- Less emission of other air pollutants

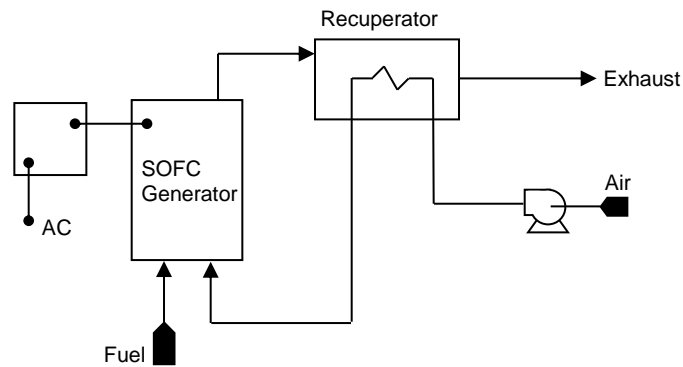
NGCC with CCS



NO_x Control: LNB + SCR to maintain 2.5 ppmvd @ 15% O₂

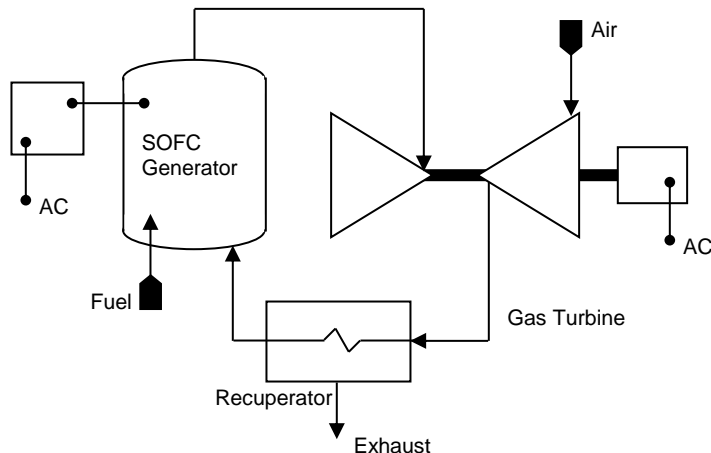
Steam Conditions: 2400 psig/1050°F/950°F

NGSOFC for DG



Atmospheric Pressure

- Efficiency: 45-50%
- Heat/Power Ratio= 0.8
- Exhaust temp: 600F
- Ideal for CHP



Pressurized Hybrid

- Efficiency: 55-60%
- Heat/Power Ratio= 0.5
- Exhaust temp: 500F
- Suitable for CHP

Westinghouse EDB/ELSAM 100 kW SOFC-CHP



100 kWe SOFC Power System Operation Summary

- 20,350+ hours
 - 4035 hours Pittsburgh/Netherlands in 1998
 - 12,577 hours in The Netherlands in 1999 & 2000 (95% availability)
 - 3,500+ hours at Essen, Germany
- Major performance:
 - 46% [Net ac/LHV] at 109 kWe AC to the Grid
 - 65 kWth to district heating system
 - $\text{NO}_x < 0.2$ ppmv, undetectable SO_x , CO, VOCs
 - No detectable cell degradation

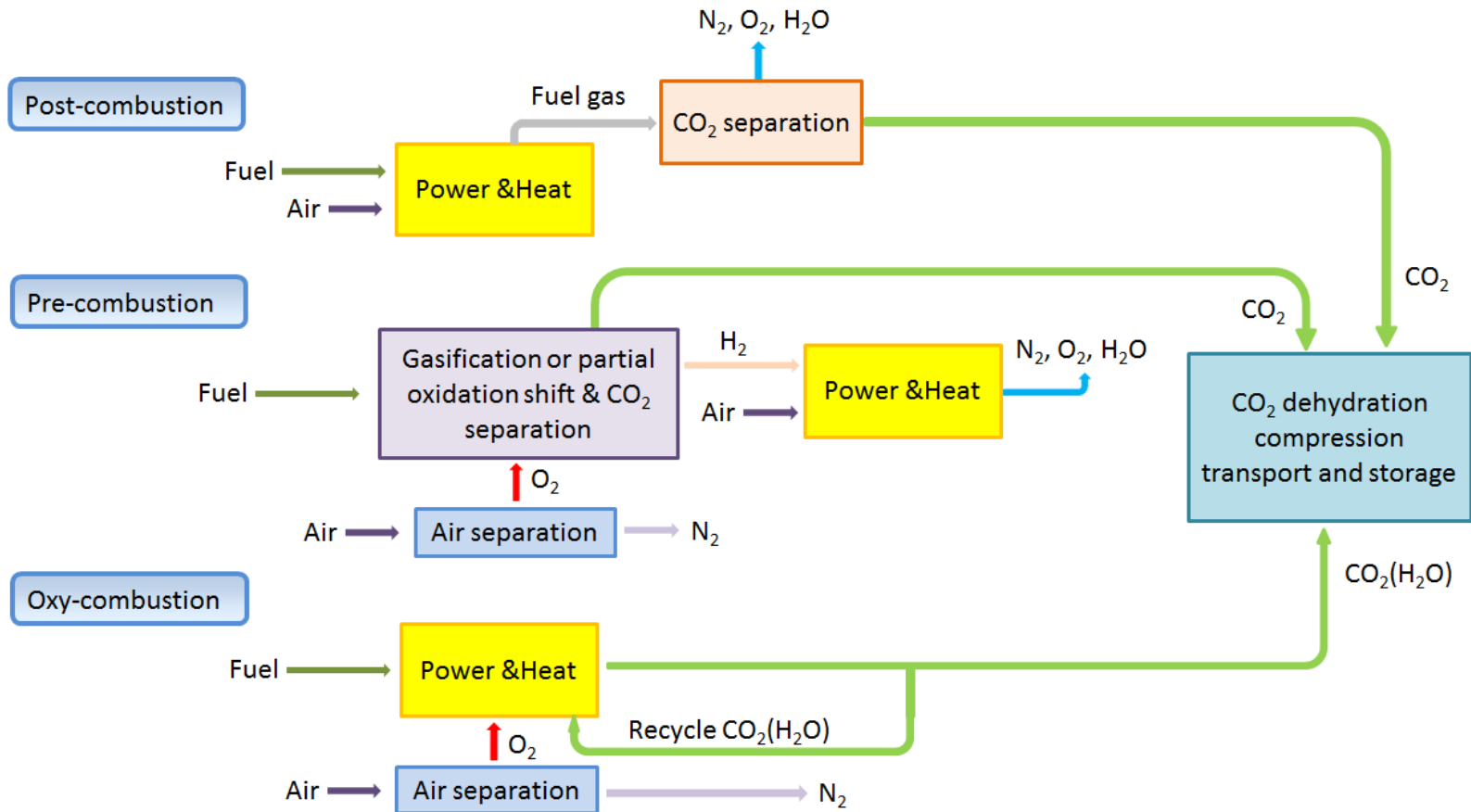
Siemens/Westinghouse 220 kW Pressurized SOFC/Gas Turbine Hybrid System



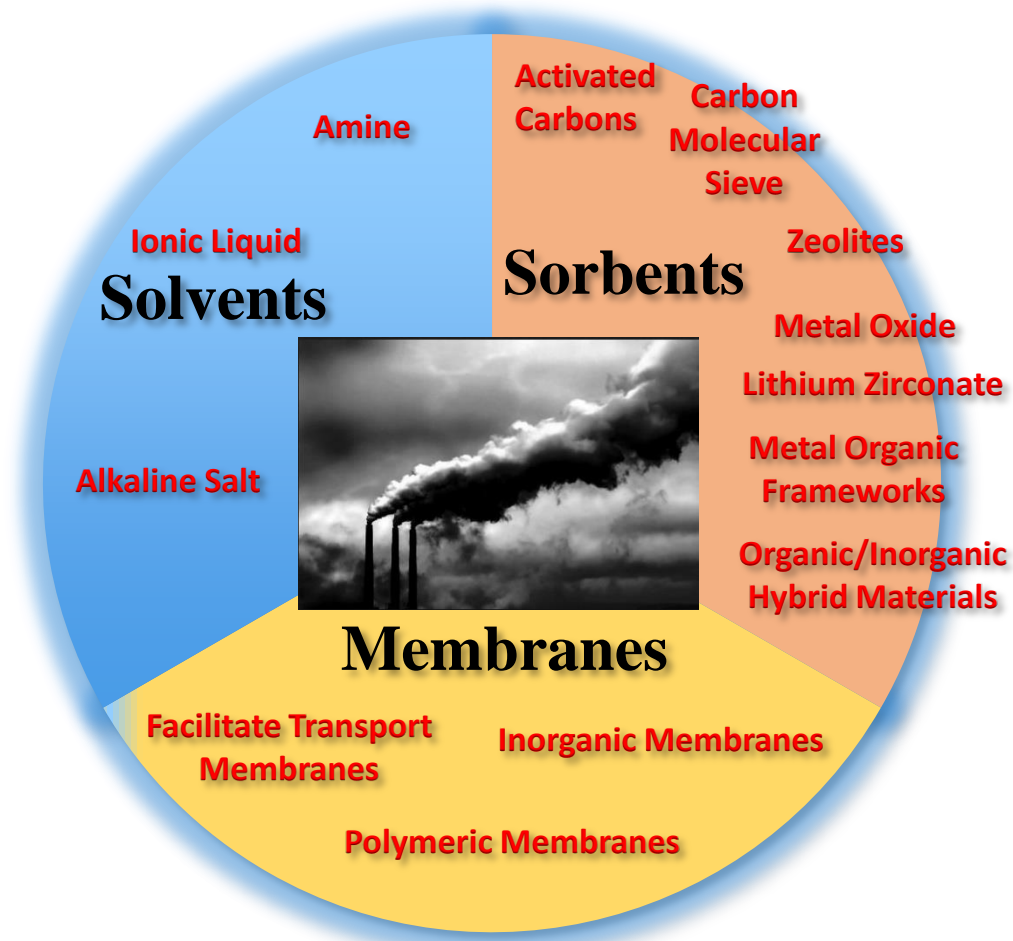
Performance Summary

- 774+ hours
 - 110 hours FAT
 - 150 hours SAT + operation
 - 514 hours operation
- 188 kW total
 - SOFC - 166 kW
 - MTG - 22 kW
- 52% (net ac/LHV)

CCS Technology

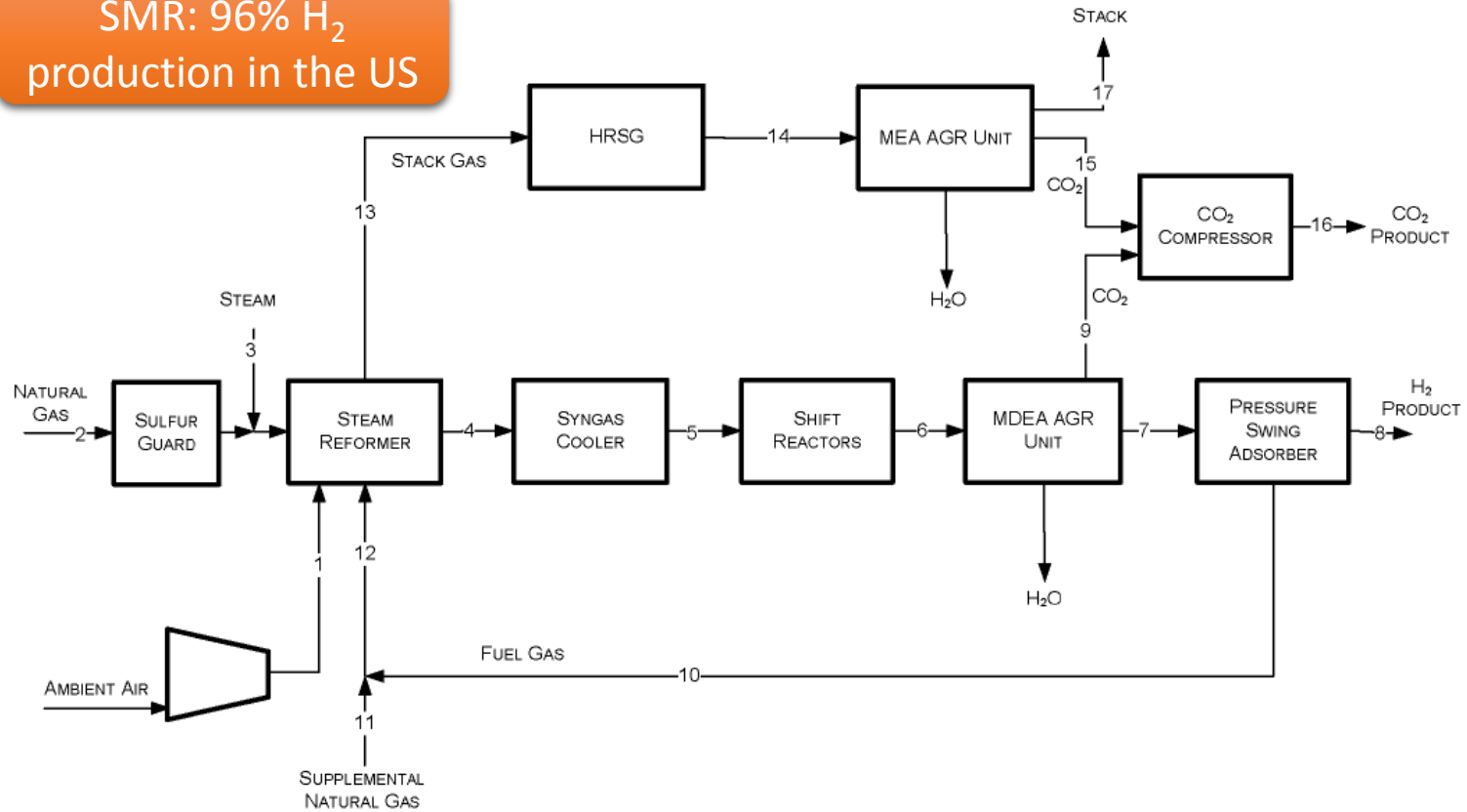


Carbon Capture Technologies



H₂ Production

SMR: 96% H₂ production in the US



H₂ Utilization

- Fuel cells
- Fertilizers
- Refineries
- Transportation fuels

Barriers to Implementation

- NGCC
 - High-temperature corrosions
- NGSOFC
 - Cost, durability and performance
- CCS
 - Cost, energy and efficiency penalty
- HCU
 - Cost and performance

Questions to be Discussed

- What are *potential areas for expansion* for NG in stationary energy generation?
- What are the major *technical, regulatory, or other barriers* or roadblocks that prevent growth of NG in stationary energy generation?
- What are the primary *technical gaps* inhibiting wider NG utilization?

Questions to be Discussed

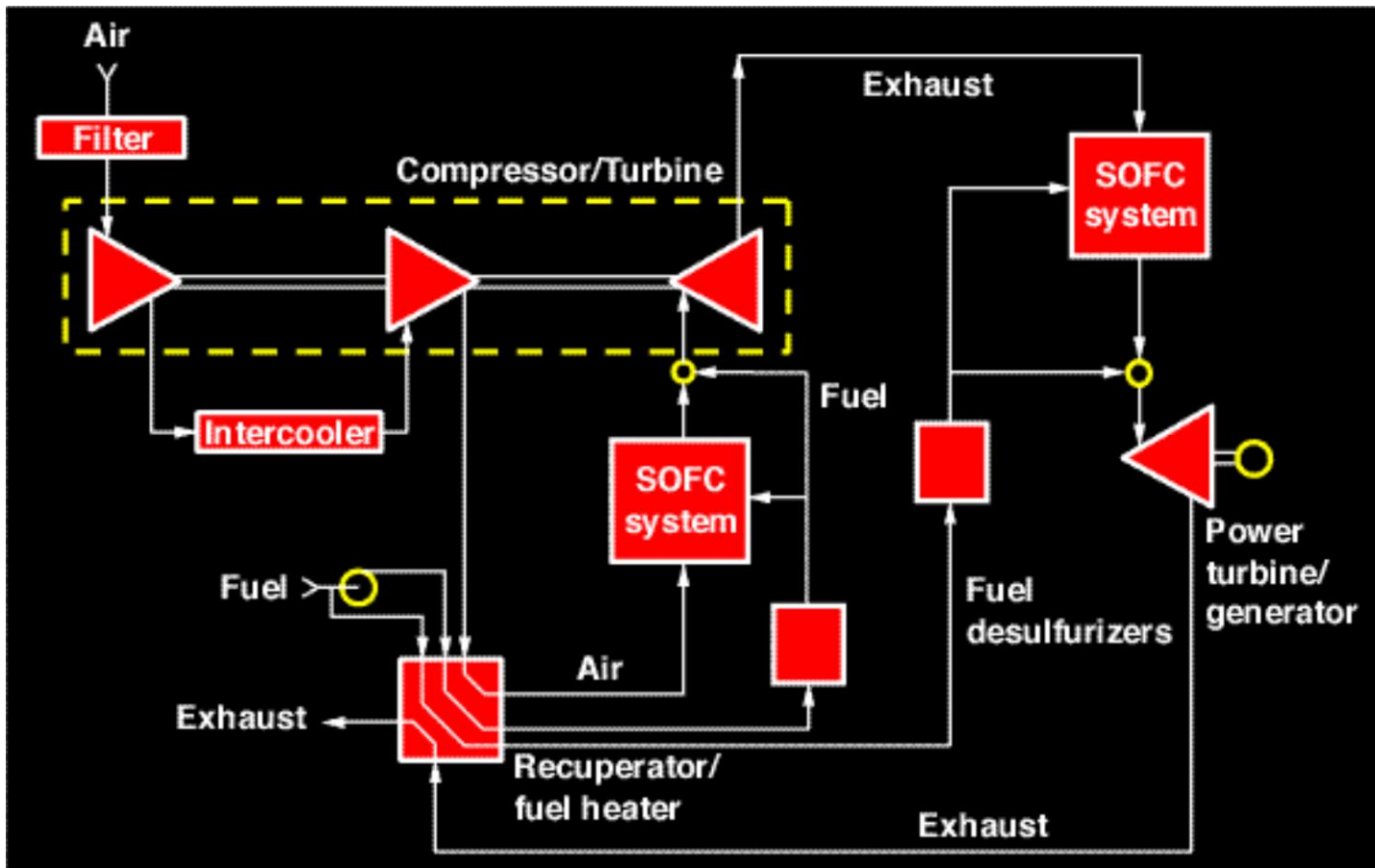
- What science or engineering research and development programs should be expanded to address these gaps?
- What is the magnitude or the *level of impact of the technology gaps*?
- What *role should the Government (i.e., federal and state) play* in addressing potential technology or policy gaps?

Backup Slides

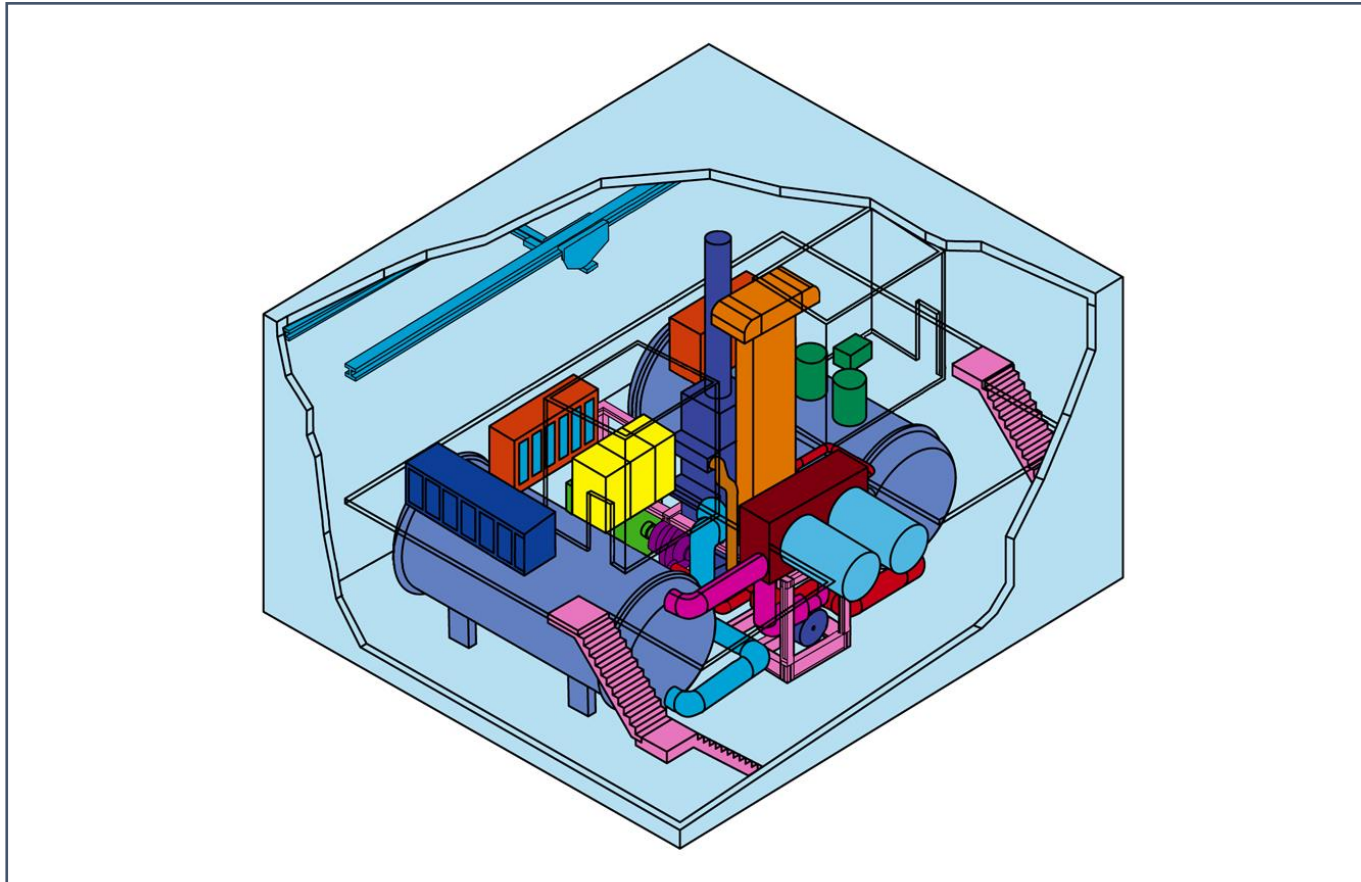
Westinghouse Field Test Units

Time Year	Customer	Stack Rating (kWe)	Cell Length (cm)	Cell Number	Oper. (Hrs.)
1986	TVA	0.4	30	24	1760
1987	Osaka Gas	3	36	144	3012
1987	Osaka Gas	3	36	144	3683
1987	Tokyo Gas	3	36	144	4882
1992	JGU-1	20	50	576	817
1992	UTILITIES-A	20	50	576	2601
1992	UTILITIES-B1	20	50	576	1579
1993	UTILITIES-B2	20	50	576	7064
1994	SCE-1	20	50	576	6015
1995	SCE-2	27	50	576	5582
1995	JGU-2	25	50	576	13,194
1998	SCE-2/NFCRC	27	50	576	5380+
1997	EDB/ELSAM - 1	100	150	1152	4035
1999	EDB/ELSAM - 2	100	150	1152	12,577
2001	RWE 100kW	100	150	1152	3500+
2000	SCE	200	150	1152	774+

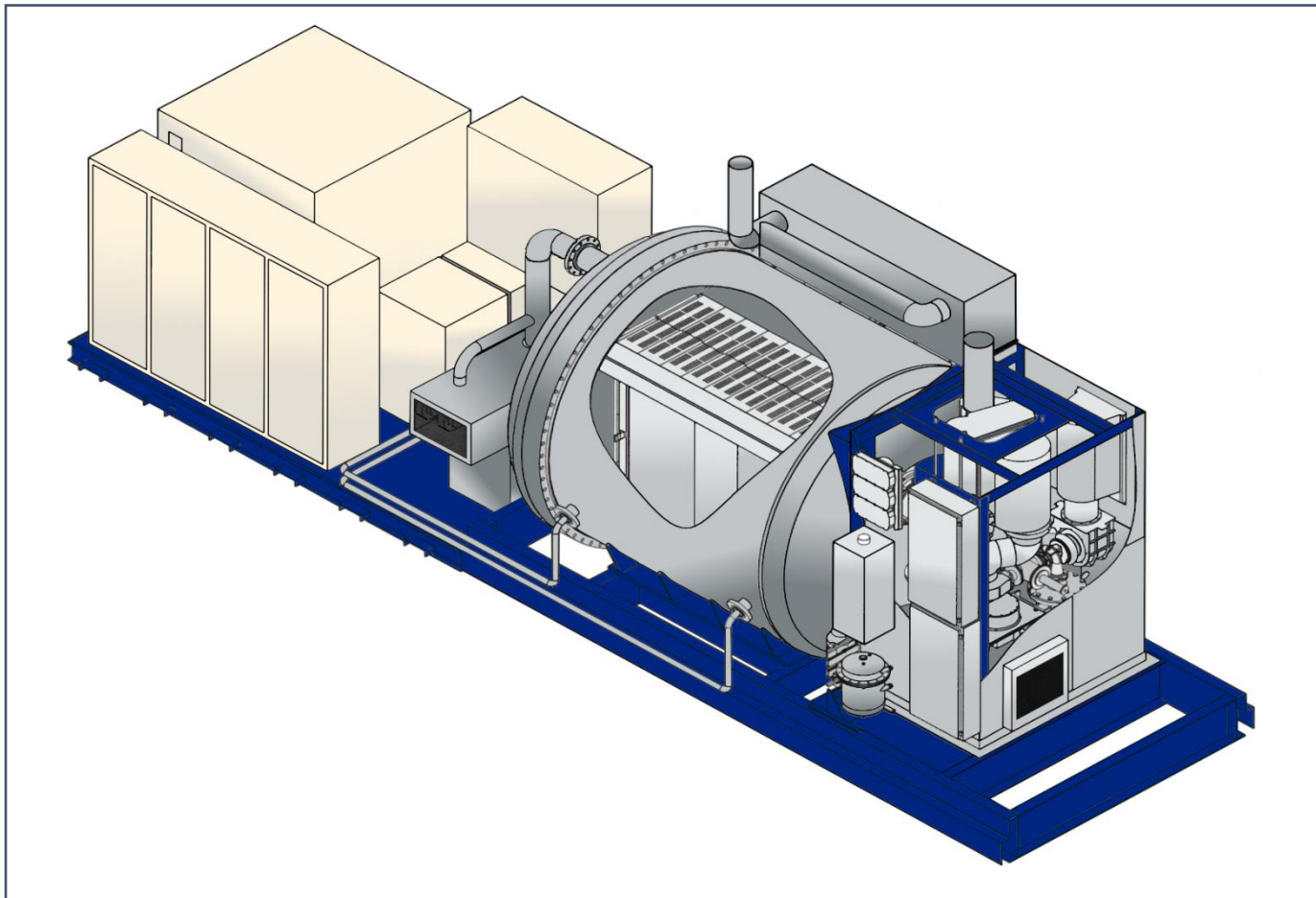
3 MW SOFC/GT Hybrid - 70% Electrical Efficiency



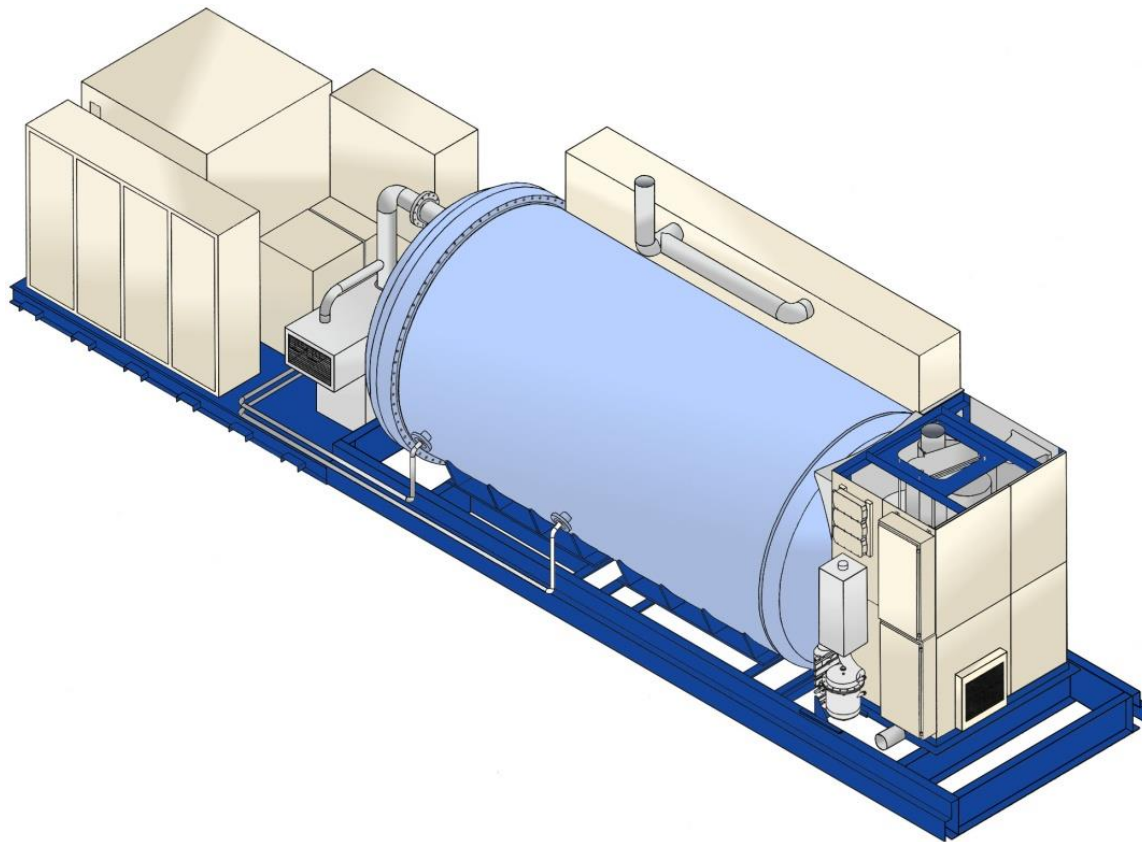
3 MW Power System Layout



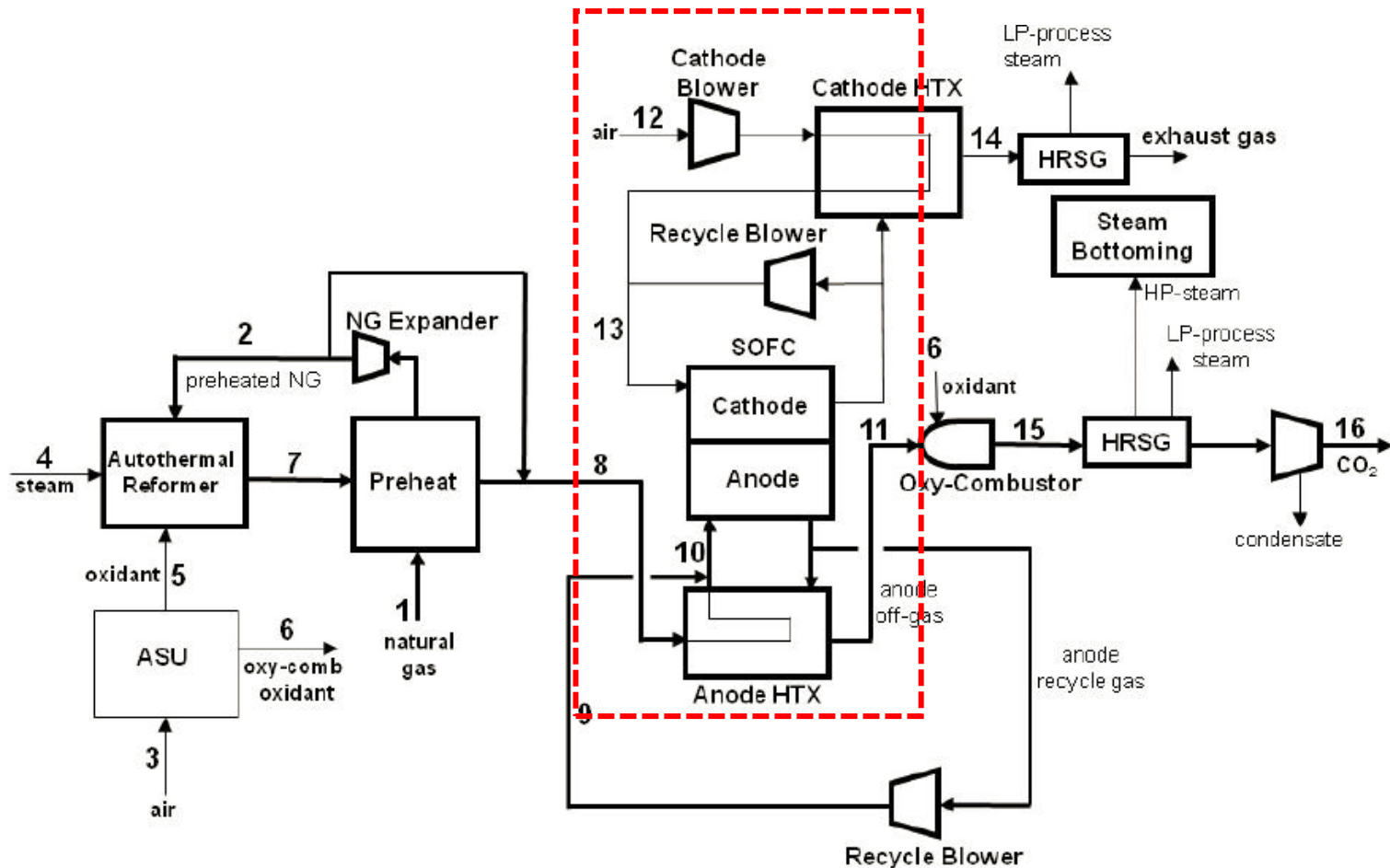
300 kWe-Class Hybrid PSOFC



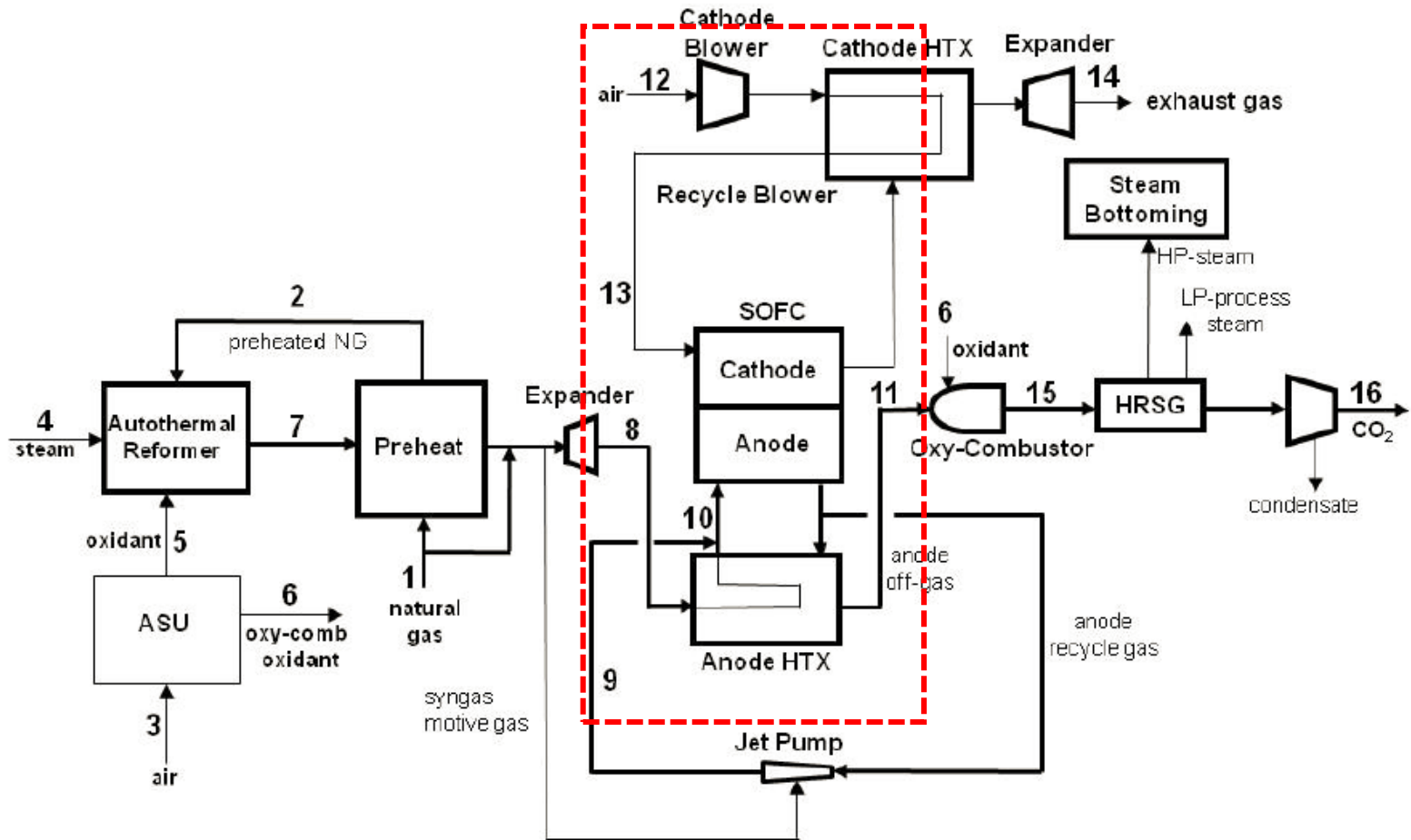
500 kW SOFC/GT Hybrid System



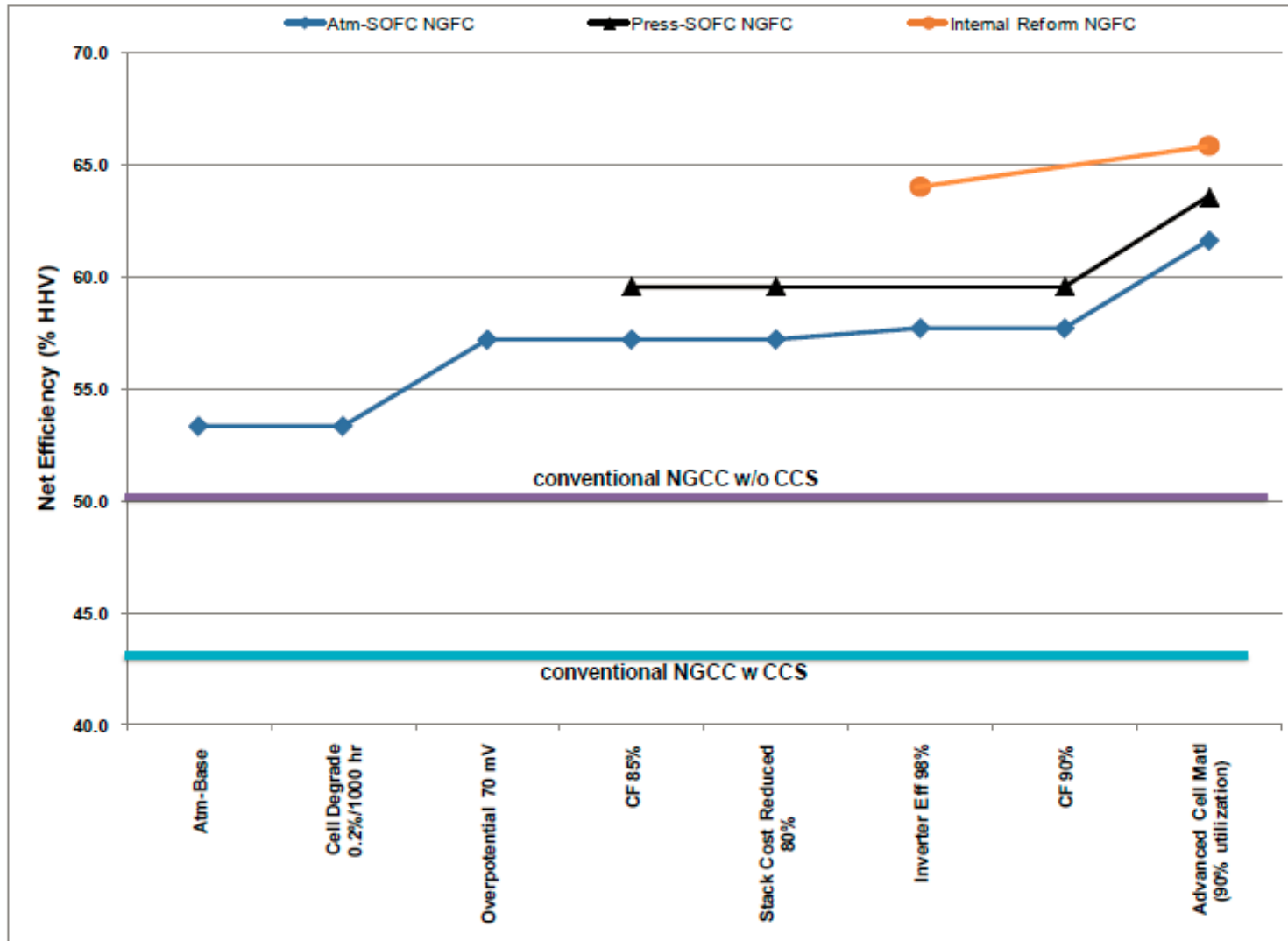
NGFC Configuration – Ambient Pressure SOFC



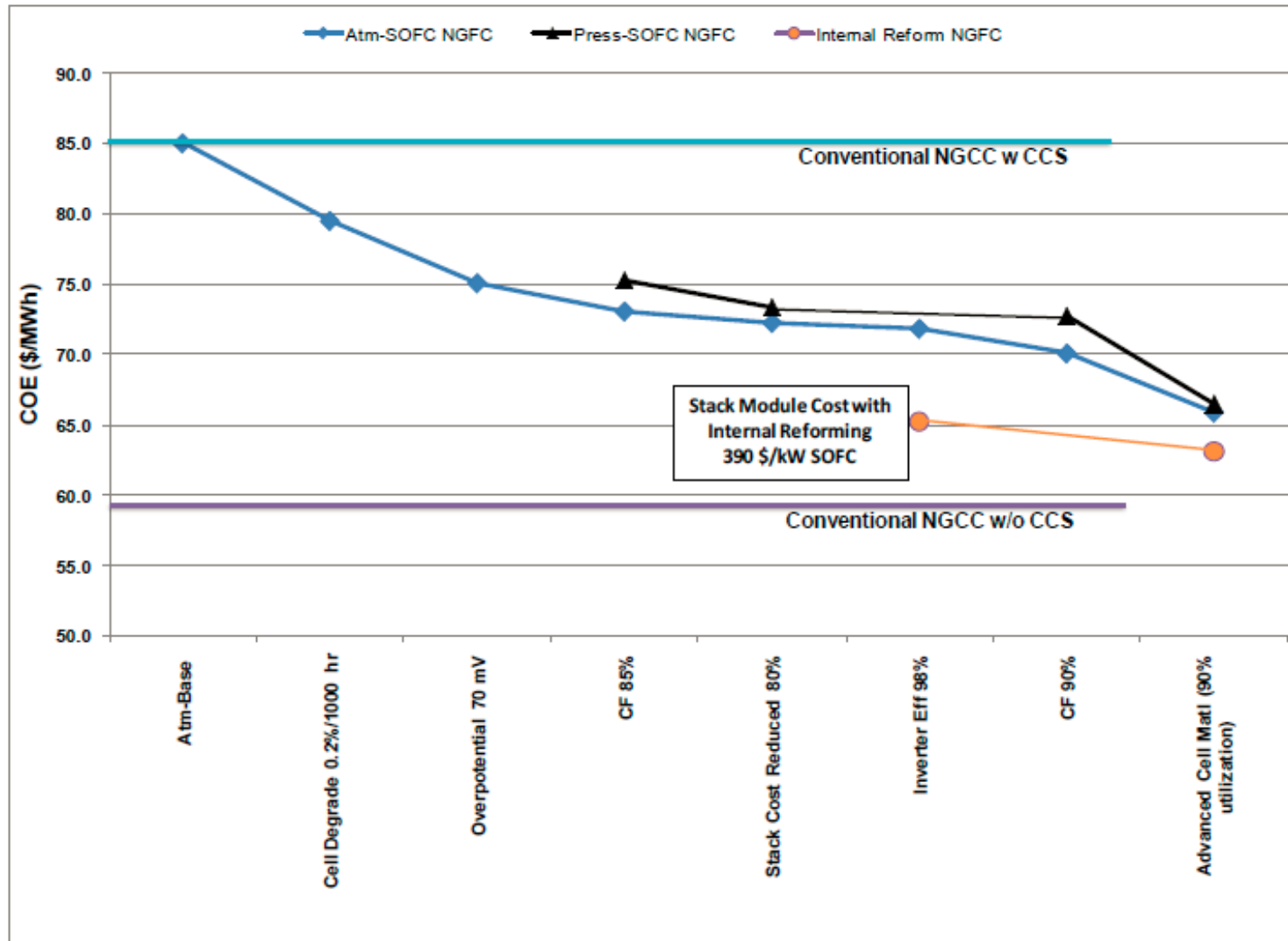
NGFC Configuration – Pressurized SOFC



NGFC Performance



NGFC Performance



SOFC for DG

