NATIONAL ENERGY TECHNOLOGY LABORATORY

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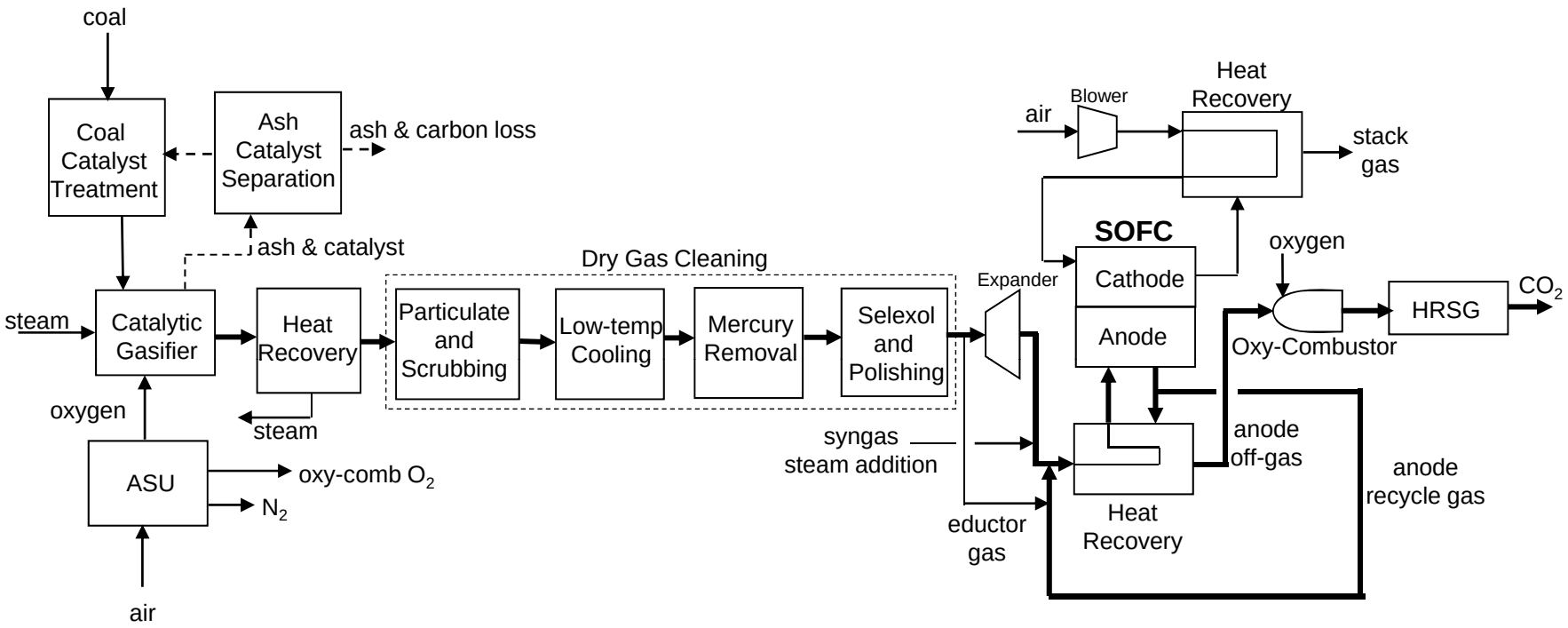
Innovative Coal / Fuel Cell Systems

Selecting System Design and Operating Parameters Critical for IGFC System Success

- **Sub-System Design Choices**
  - Gasifier
  - SOFC
  - Gas Cleaning
  - CO_2 Capture
- **Two Advanced IGFC Concepts Illustrated**
  - IGFC with atmospheric SOFC
  - IGFC with pressurized SOFC
- **Illustration of Parameter Sensitivity**
  - Catalytic gasifier operating conditions
  - Fuel utilization
  - Gas cleaning operating temperature

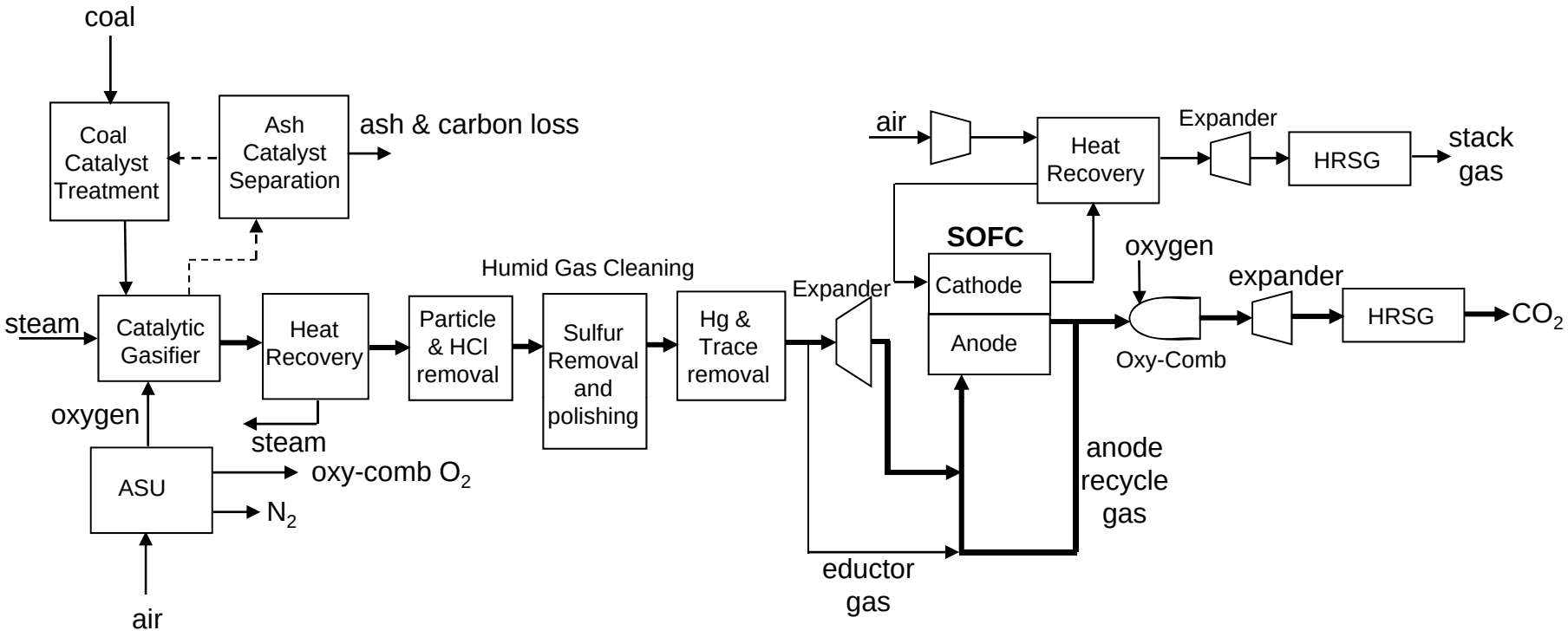
Advanced IGFC with Atmospheric SOFC and DGC



Advanced System Components

- **Catalytic gasifier**
- **Oxy-combustor**
- **Recycle gas eductor**

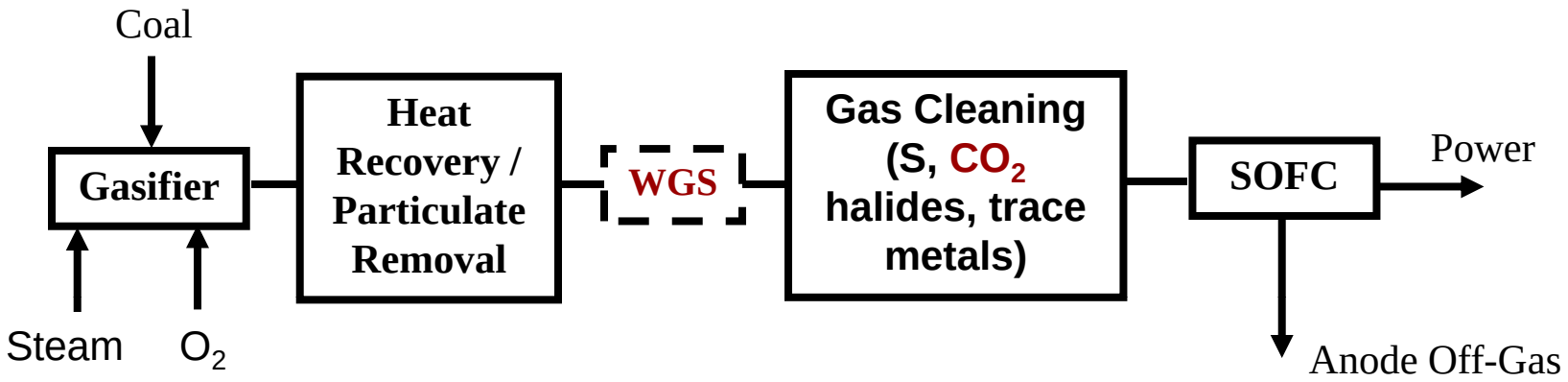
High Performance IGFC System



Advanced System Components

- Catalytic gasifier
- Humid gas cleaning
- Pressurized SOFC
- Oxy-combustor
- Recycle gas eductor

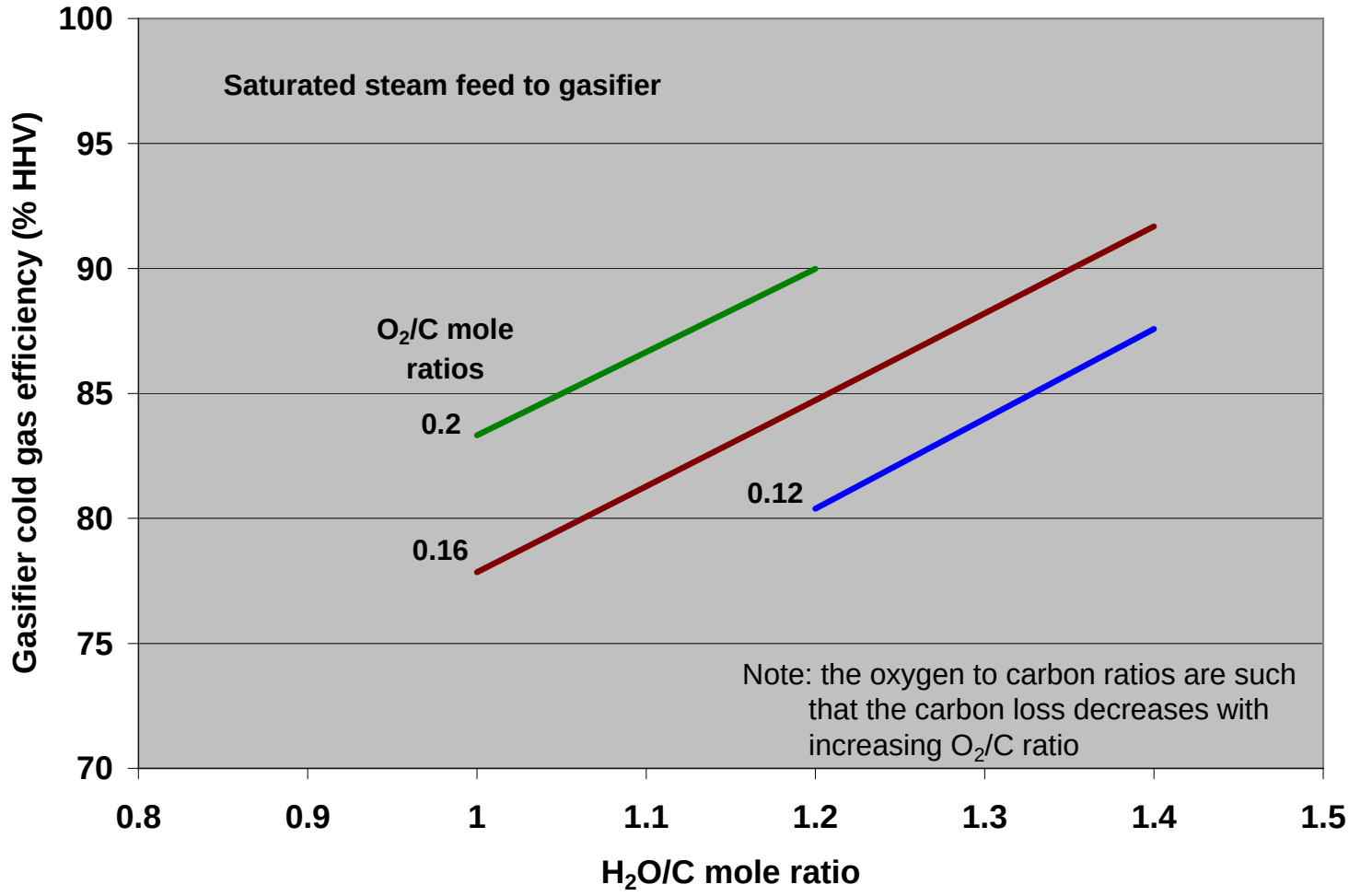
Integrated Gasification Fuel Cell System Choices



Gasifier Design Choices

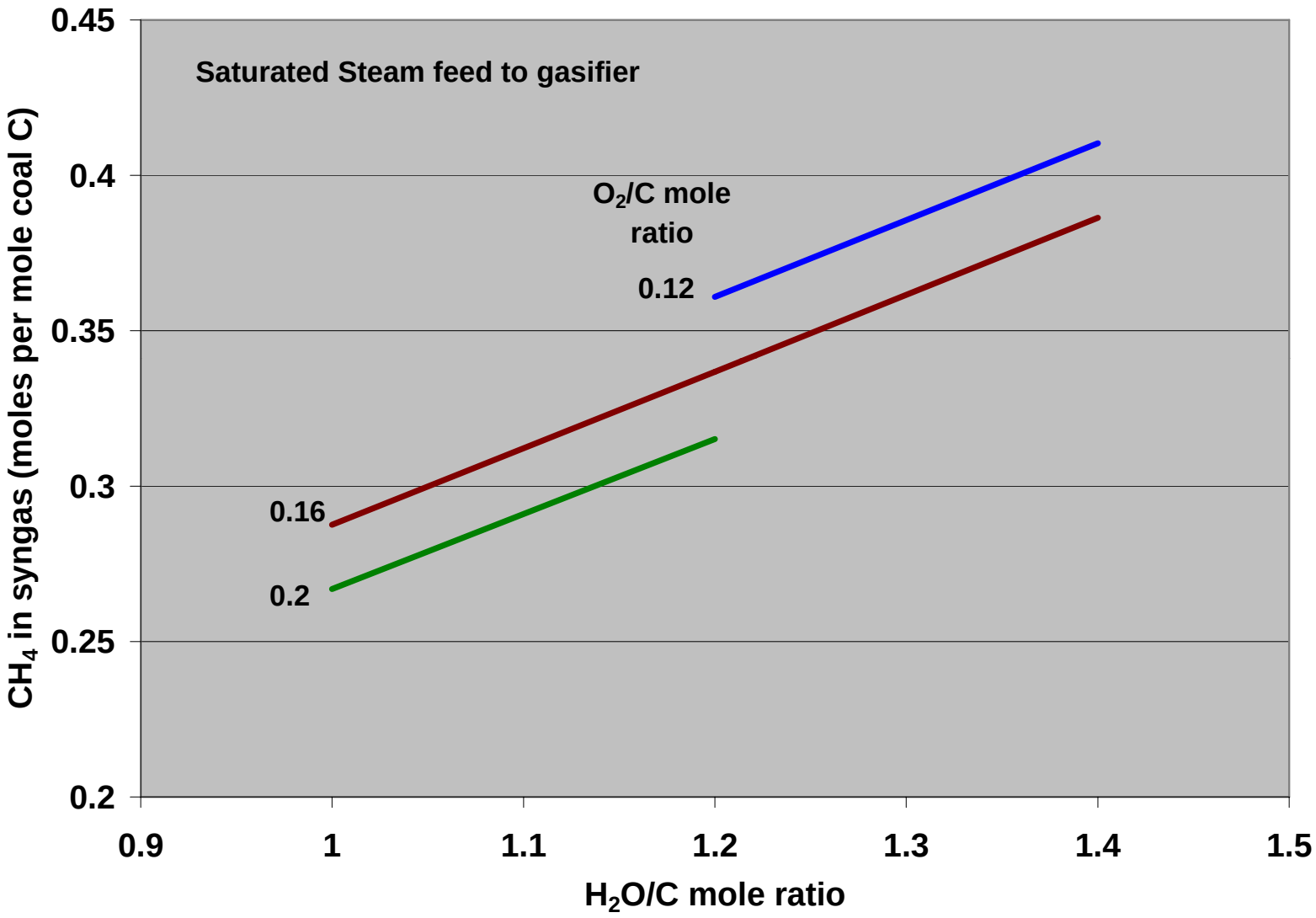
- Operating temperature: low T reduces O_2 requirement, favors methane; high T reduces higher HC in syngas and C losses
- Operating pressure: high pressure favors methane content
- Dry or slurry coal feed: function of coal and anode off-gas design
- Simplicity: gasifier feed choices

Catalytic Gasifier Cold Gas Efficiency

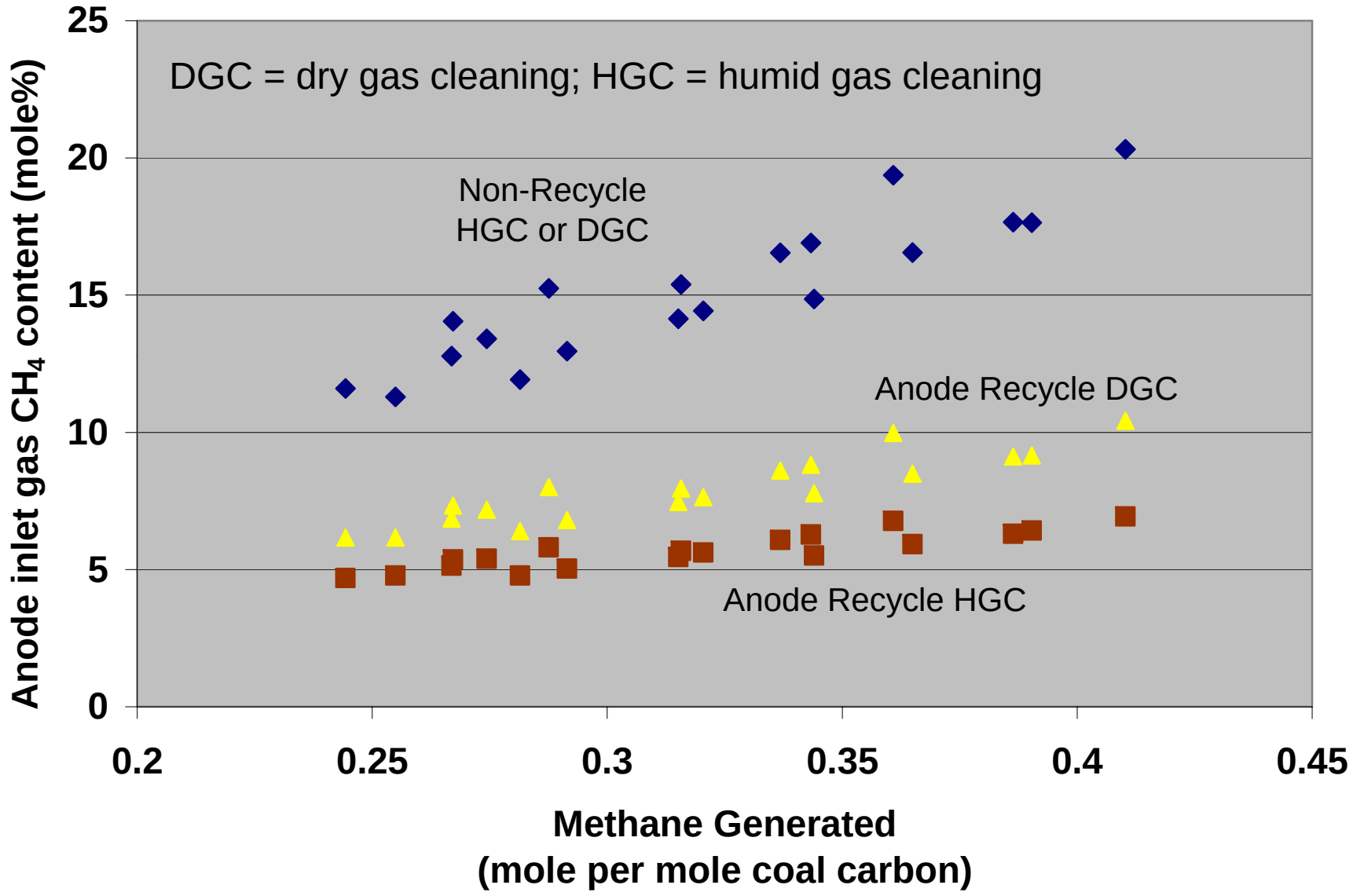


Cold gas efficiency for conventional entrained flow gasifiers: 75-80%

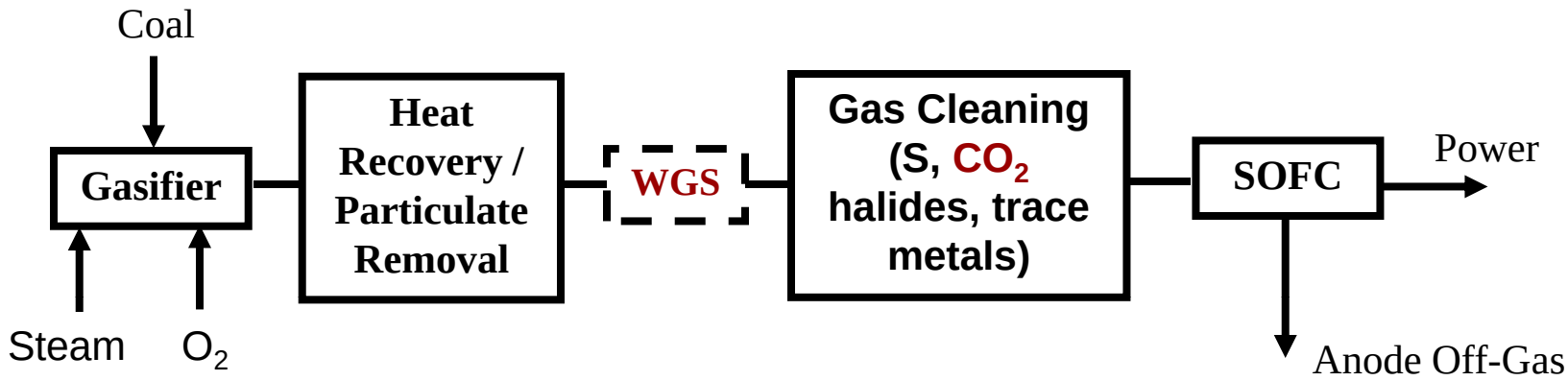
Catalytic Gasifier Methane Content



Anode Inlet Gas Methane Content



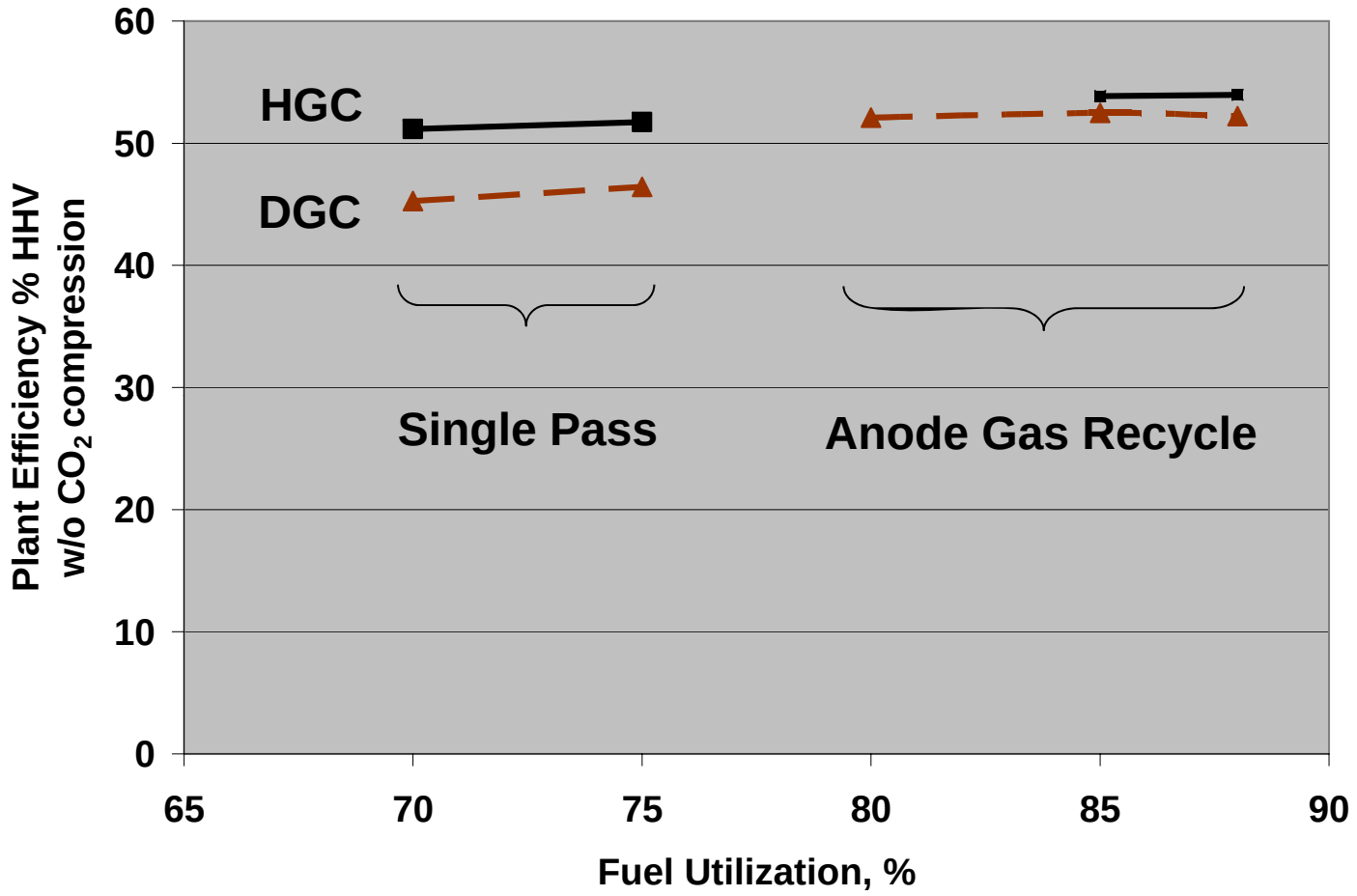
Integrated Gasification Fuel Cell System Choices



SOFC Design Choices

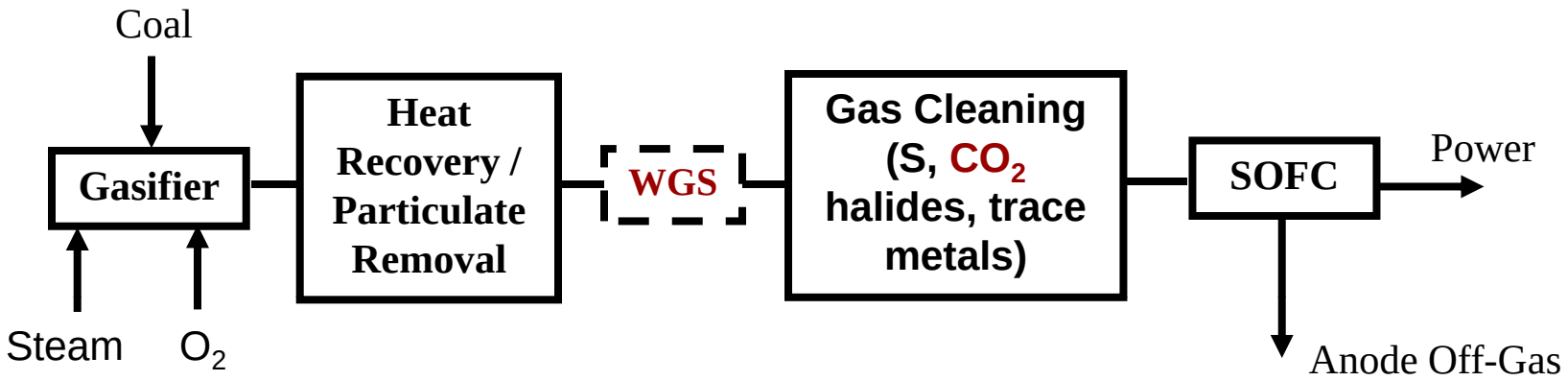
- SOFC design – combined or separate cathode / anode off-gas (separate allows for post SOFC carbon dioxide removal)
- Atmospheric or pressurized (increased efficiency with elevated pressure)
- Anode off-gas once-through or recycle (recycle enables higher efficiency)
- Syngas methane content (CH_4 reforming reduces cathode air requirement)

Illustration of SOFC Design Choices



System: Catalytic gasifier; atm pressure SOFC; temperature: 650/800°C; DGC (dry gas cleaning) and HGC (humid gas cleaning); 50 mV voltage loss; CO_2 compression is 3.5 % points

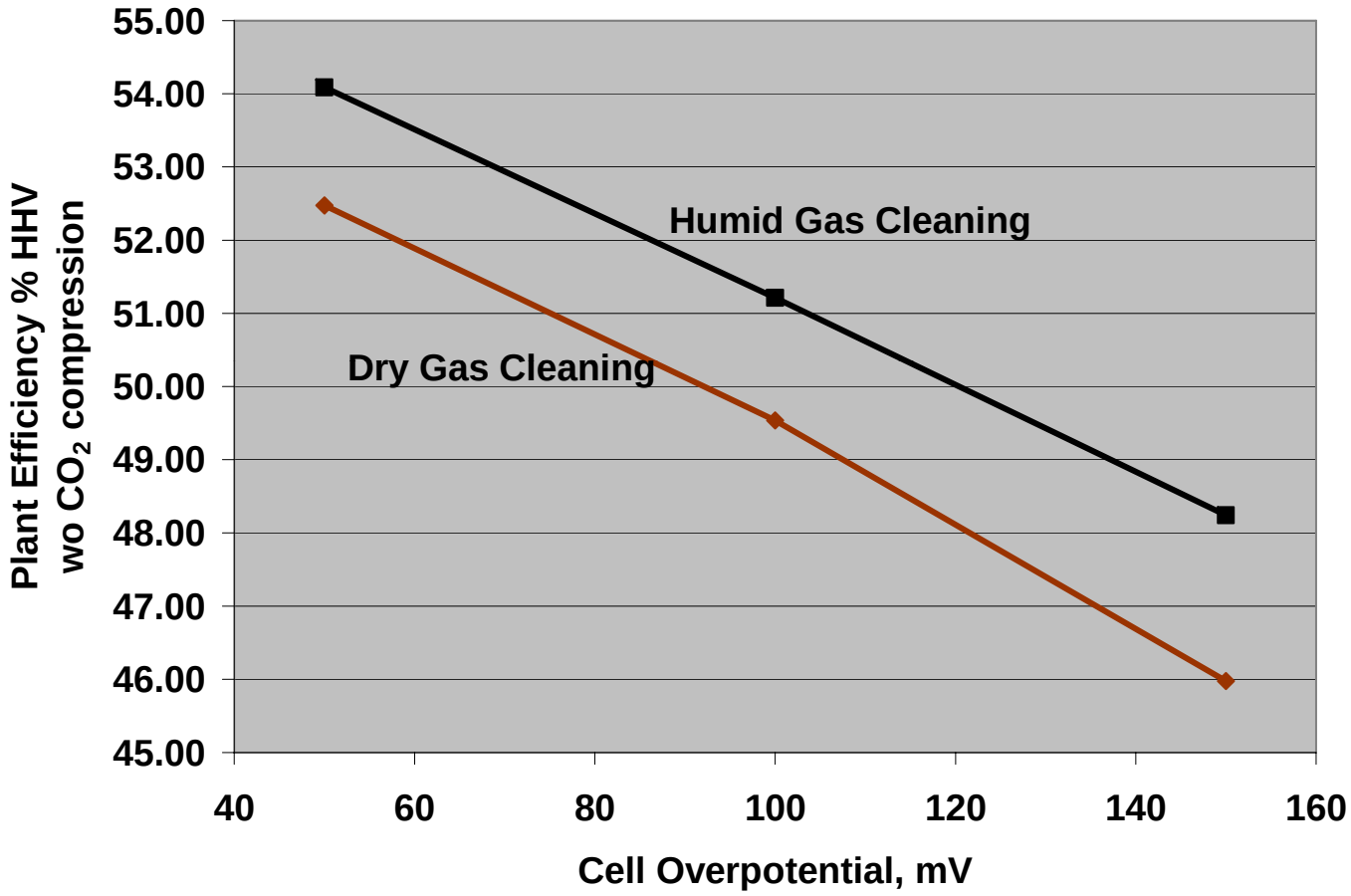
Integrated Gasification Fuel Cell System Choices



Gas Cleaning Considerations

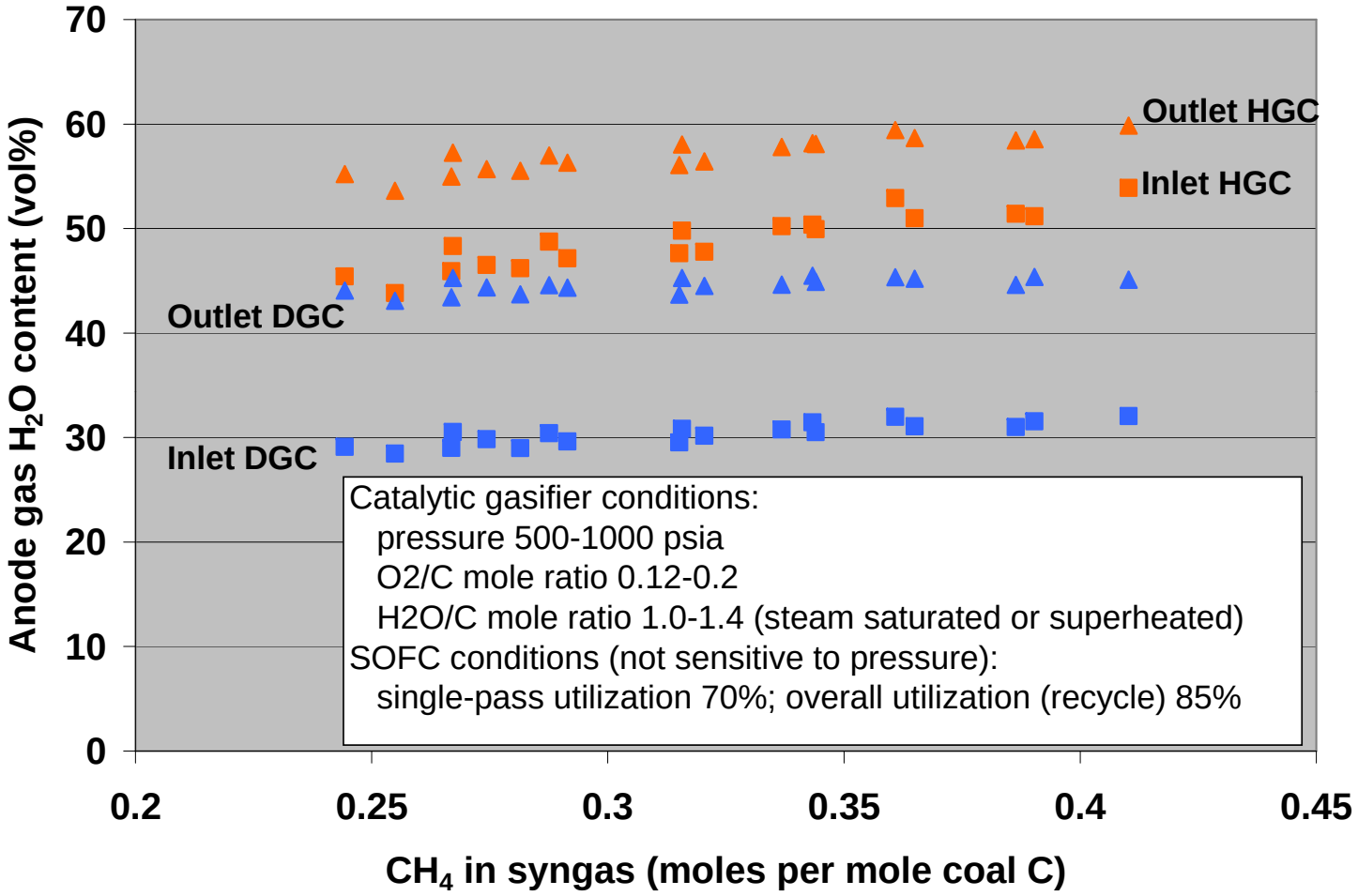
- Dry or humid gas cleaning: HGC minimizes thermal loss; retains H_2O to prevent C deposition; gas-liquid vs gas-solid processes
- More stringent requirements for some contaminants compared with IGCC (e.g. S, halides, phosphorus, etc.)
- No requirements for other species (e.g. ammonia)

Illustration of Gas Cleaning Choice and SOFC Performance



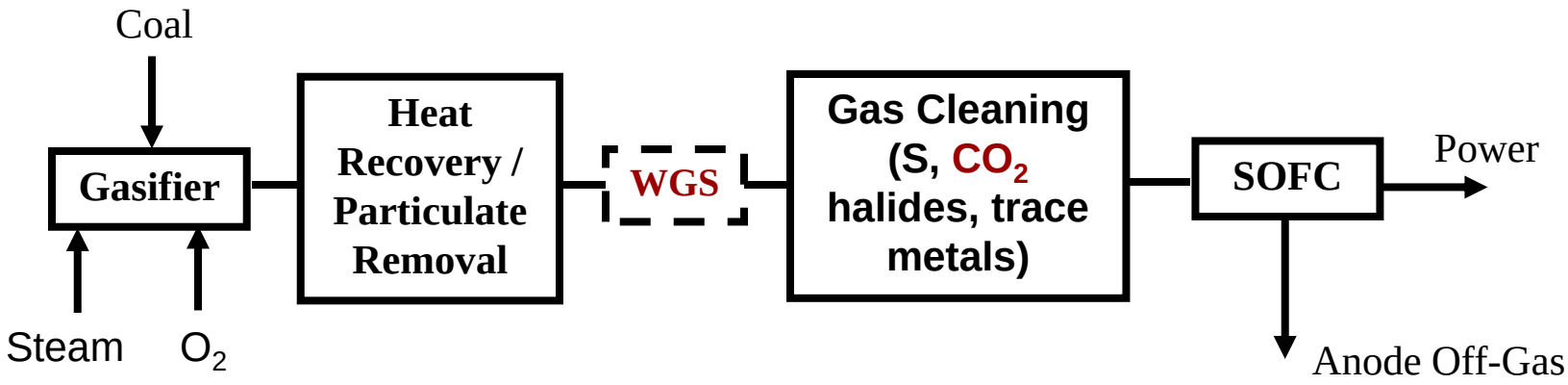
System Design: Catalytic Gasifier; Atm pressure SOFC; Temperature: 650/800ºC; Anode gas recycle; 85% fuel utilization; CO_2 compression is 3.5 % points

Design to Meet SOFC Operating Constraints



DGC = dry gas cleaning; HGC = humid gas cleaning

Integrated Gasification Fuel Cell System Choices



CO_2 Capture

- Integrate with gas cleaning: efficiency penalty; retains WGS; use with combined cathode / anode off-gas SOFC designs
- Utilize SOFC to convert CO to CO_2: SOFC capital cost
- Utilize oxygen combustion of anode off-gas to maximize carbon capture
- Recycle anode gas with oxy-combustion of off-gas: increased efficiency
- Recycle anode gas with recycle gas CO_2 capture (lower efficiency)

IGFC System Integration Assessment

- IGFC systems have high performance capability
  - Efficiency: 40 to 60% with carbon capture
  - CO2 emissions up to 99% removal
  - S, NOx, particulate, trace emissions << NSPS
  - Fresh water makeup < 300 gal/MWh
- There are many component design choices – requires integrated system analysis to understand trade-offs for system efficiency, capital and operating cost, reliability