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NATIONAL ENERGY TECHNOLOGY LABORATORY

Performance Comparison of Internal and External Reforming for Hybrid SOFC/GT Applications using 1D Real-time Fuel Cell Model

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Introduction: INTERNAL REFORMING

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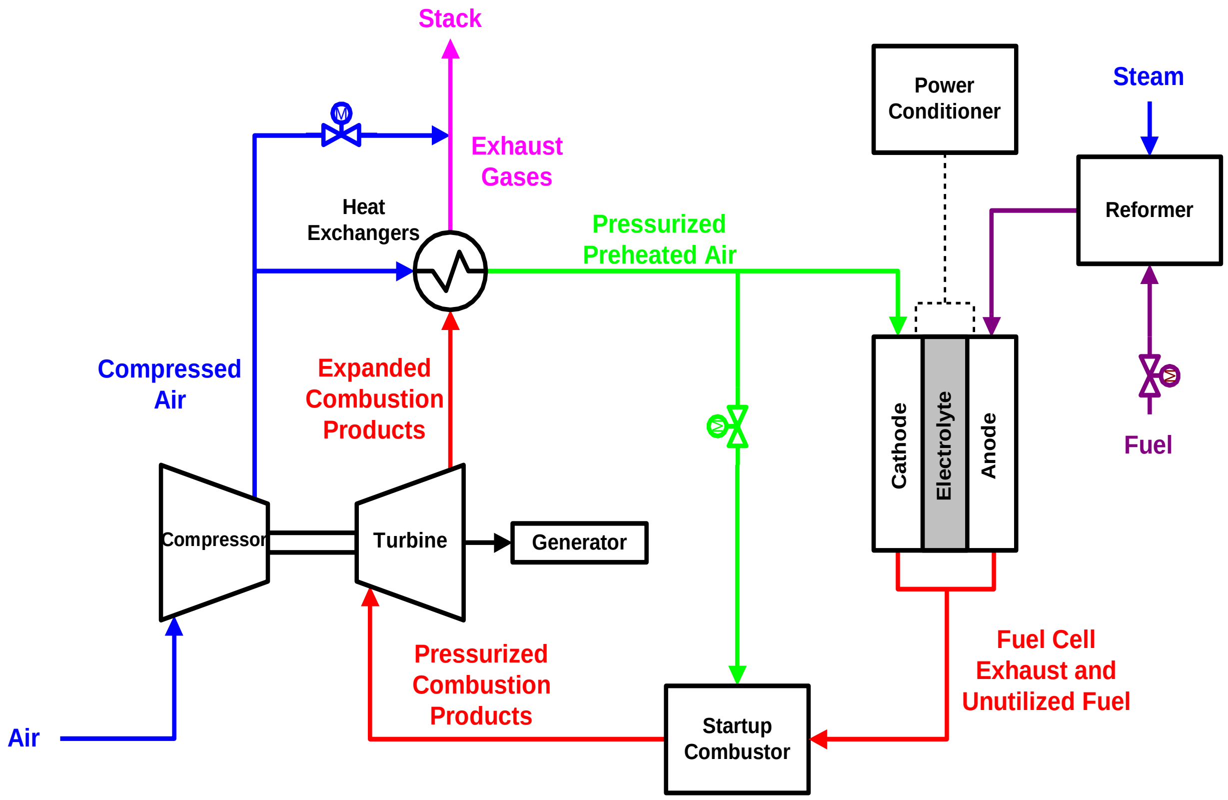
Pros

- Low capital cost – no external reformer is required
- Low parasitic loss due to less air requirement
- Less heat loss
- High H_2 yield in the SOFC stack

Cons

- Catalyst for SMR is required at the anode
- Risk for carbon deposition if high CH_4 is fed
- Risk for high temperature gradient
- Risk for inlet cooling
- Waste the inlet section for SMR



Research HIGHLIGHTS

Objective:

- To develop **real-time reformer model** for cyber-physical applications
- To identify **the most efficient SOFC configuration with reformer;** internal reforming (low reforming temperature) vs external reforming (high reforming temperature)

1. Varying SOFC fuel utilization
2. Varying reforming temperature
3. Design points (Different SOFC size, GT size, etc.)

Scope:

1. Total hybrid power: 100 kW
2. Total current: 220 A
   (Average current density: 550 mA/cm^2)
3. SOFC average temperature: 835°C
4. ΔT solid ($T_{out} - T_{in}$): 120°C
5. Hybrid cycle pressure: 4 bar

Scopes: OPERATIONAL CONSTRAINTS

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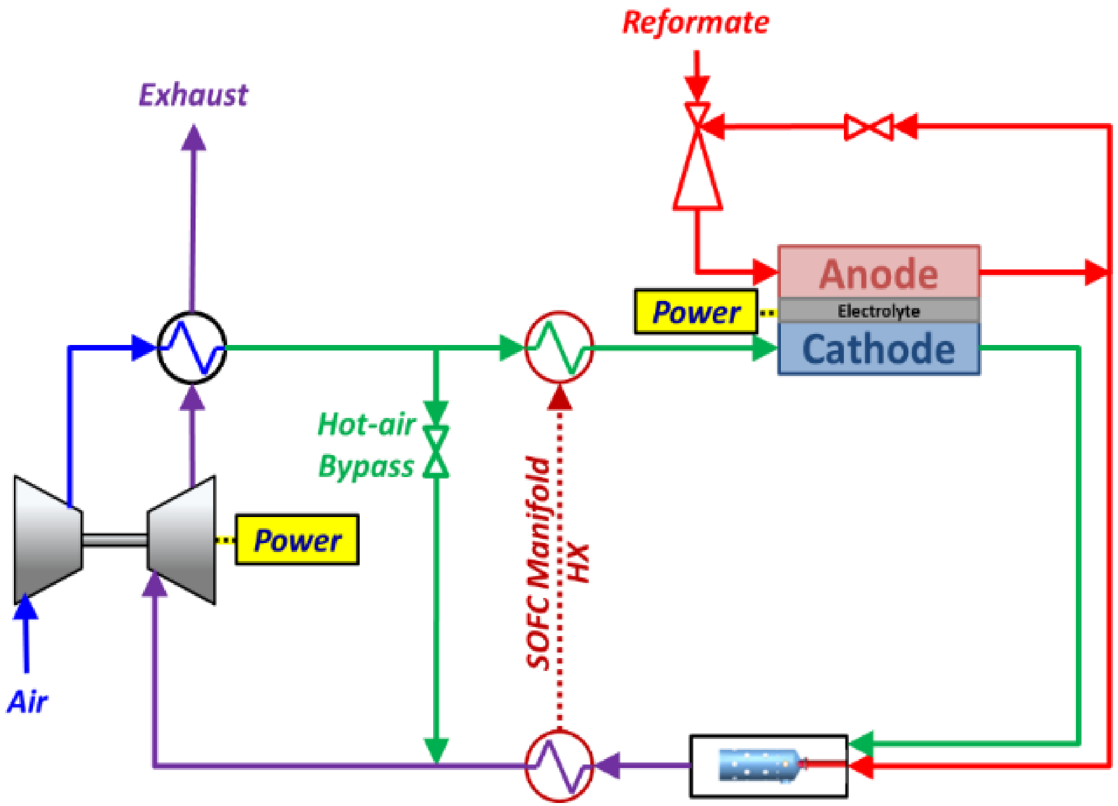
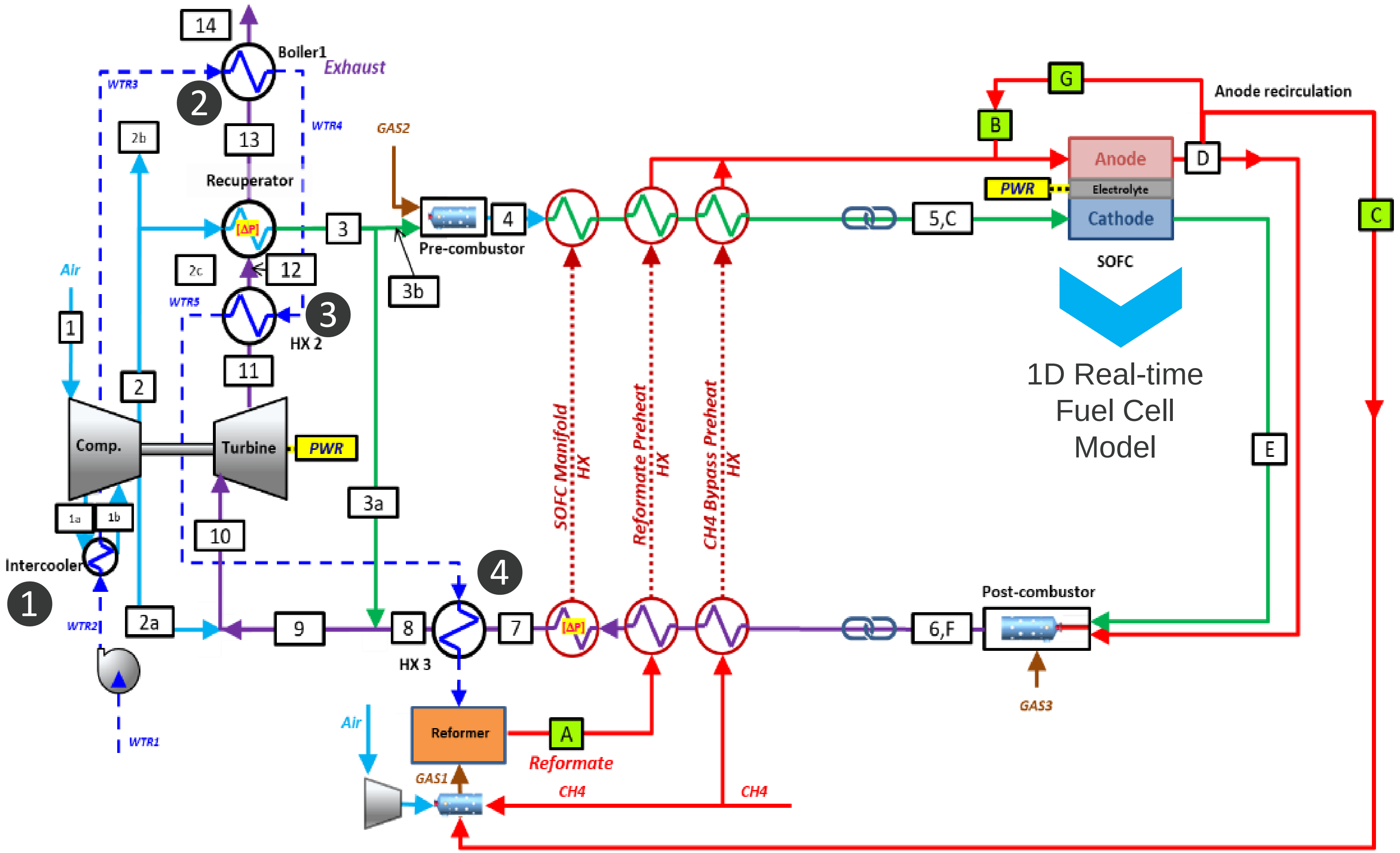
Thermal constraints	Range
SOFC Solid Temperature Gradient	10°C/cm (localized), 6°C/cm (overall)
Reforming Temperature	600 - 1000 K • on-anode reforming (600K) • complete external reforming (1000K)
Turbine Inlet Temperature	1200 ˚C - 1300˚C
Recuperator Operating Temperature	800˚C (900˚C requires exotic materials)
Air and Fuel Manifolds	• ceramic heat exchanger • effectiveness of 2% (insulated) - 30% (max)



Cycle Analysis: NG SOFC/GT CYCLE



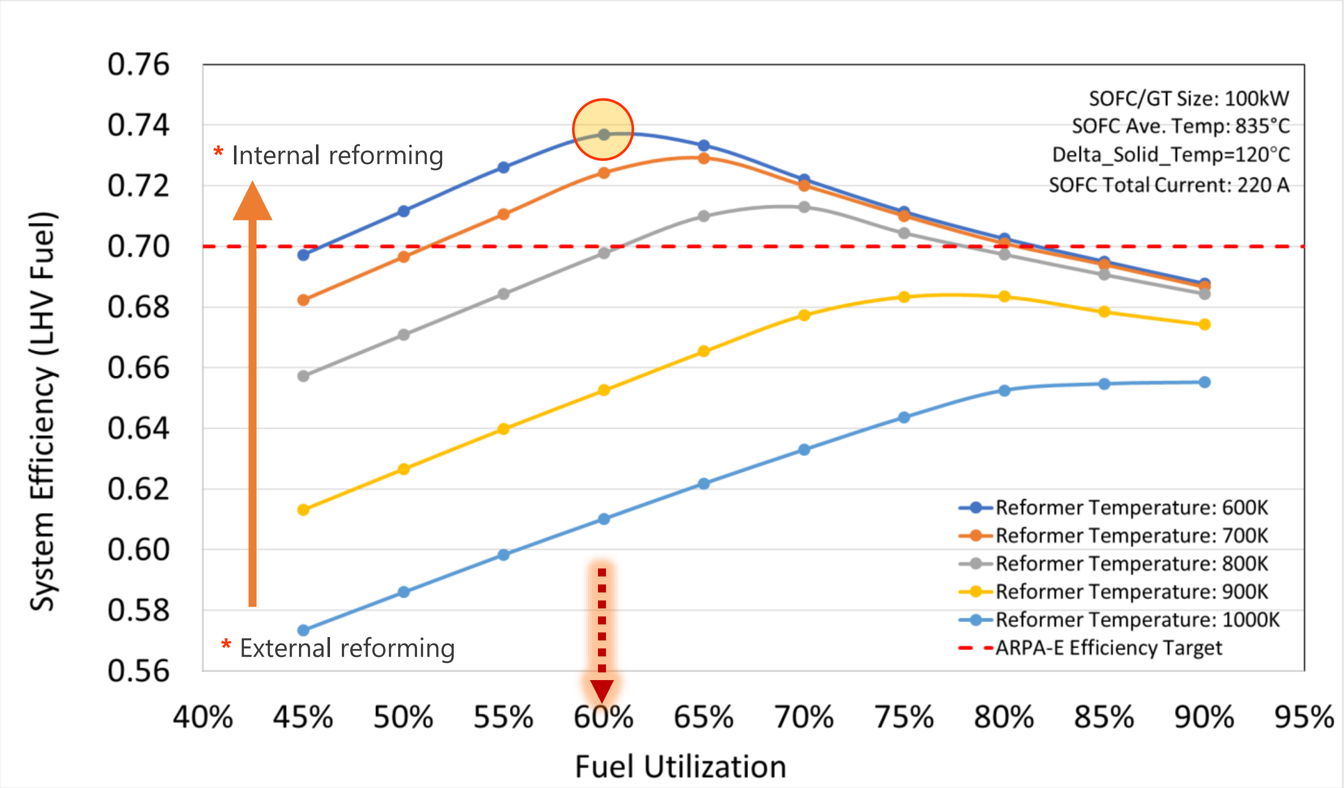
Using a Gibbs minimization routine.

Reformer heat management:

1. compressor intercooler
2. recuperator exhaust
3. turbine exhaust
4. post combustor through superheat steam;

Results:

Reformer temperature (autothermal): A baseline for the SOFC-GT cycle without thermal integration of the reformer or anode recycle.



Hybrid system efficiency as a function of SOFC fuel utilization and reformer operating temperature

Results: NG SOFC/GT CYCLE

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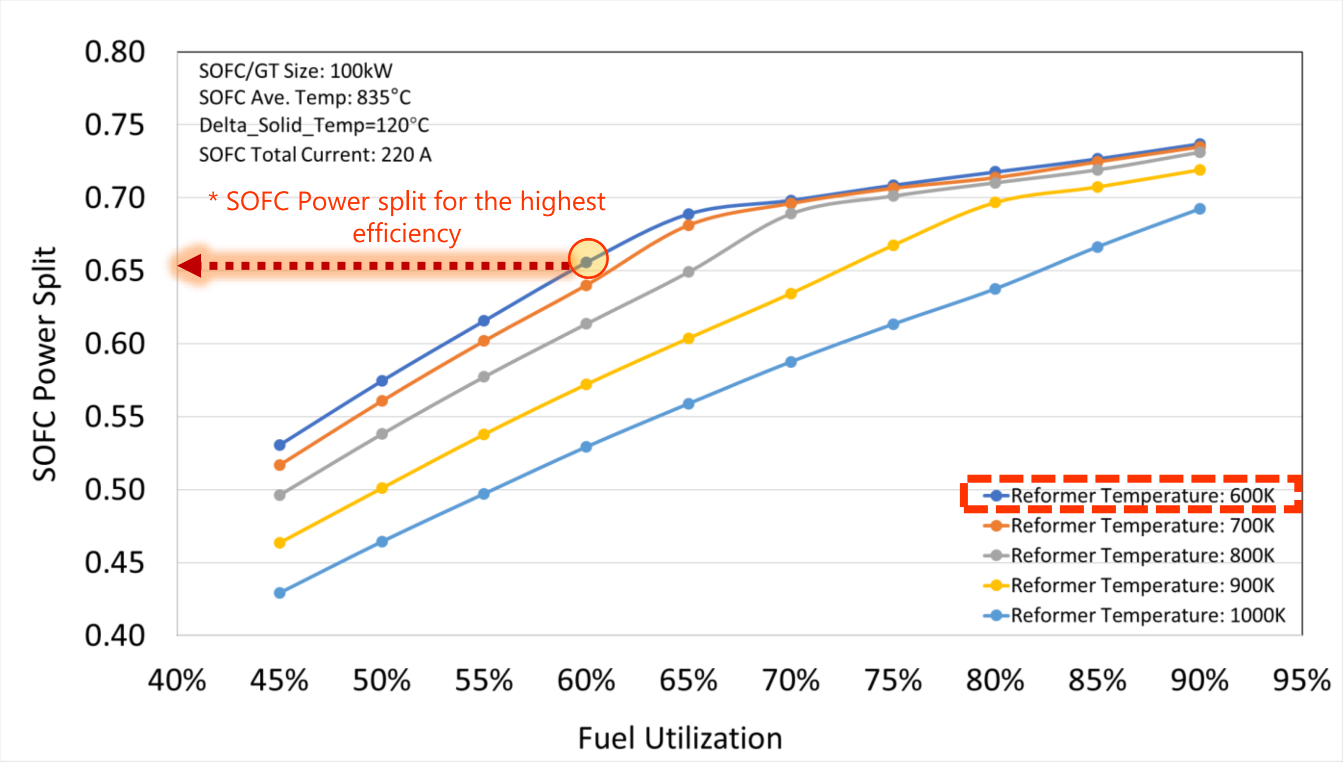
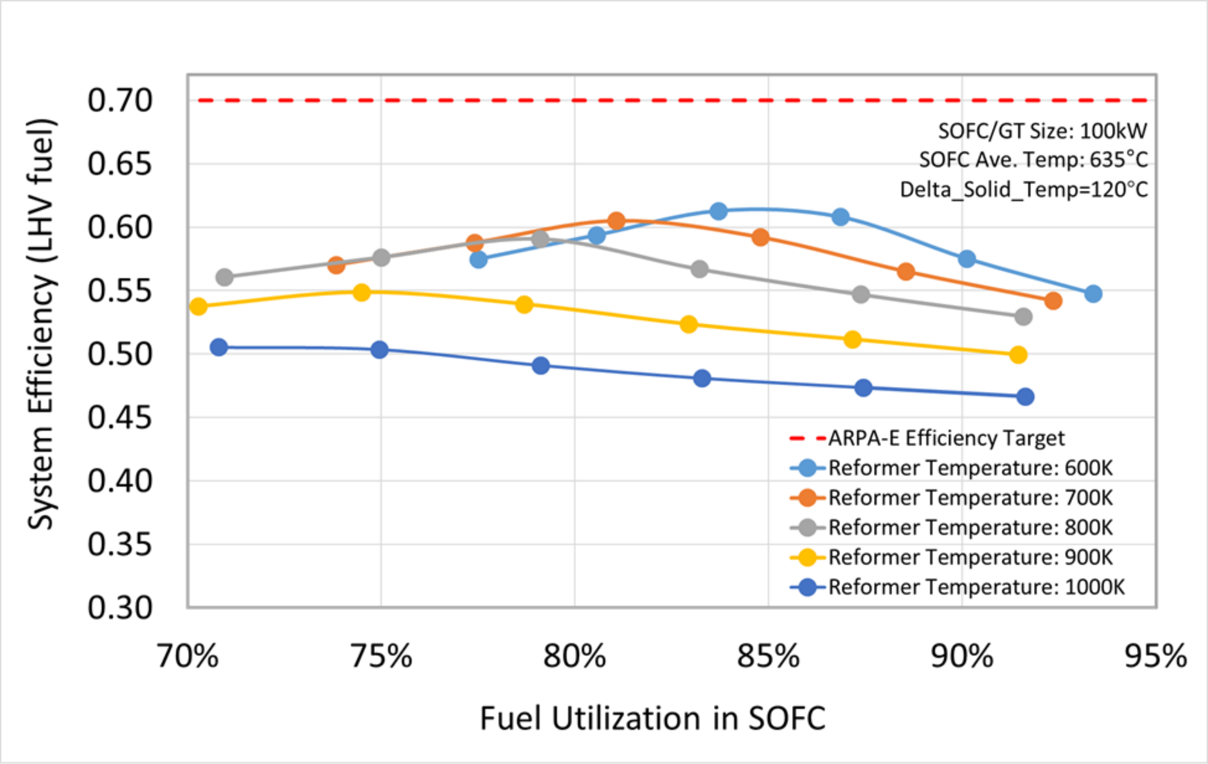
Reformer temperature (autothermal): A baseline for the SOFC-GT cycle without thermal integration of the reformer or anode recycle.

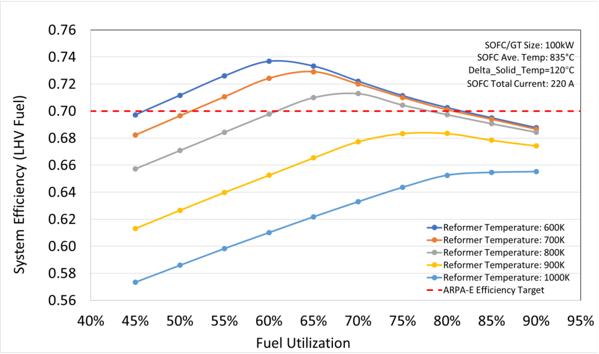


Hybrid system efficiency as a function of SOFC fuel utilization and reformer operating temperature

Results: NG SOFC/GT CYCLE

Performance at SOFC average temperature of 635˚C

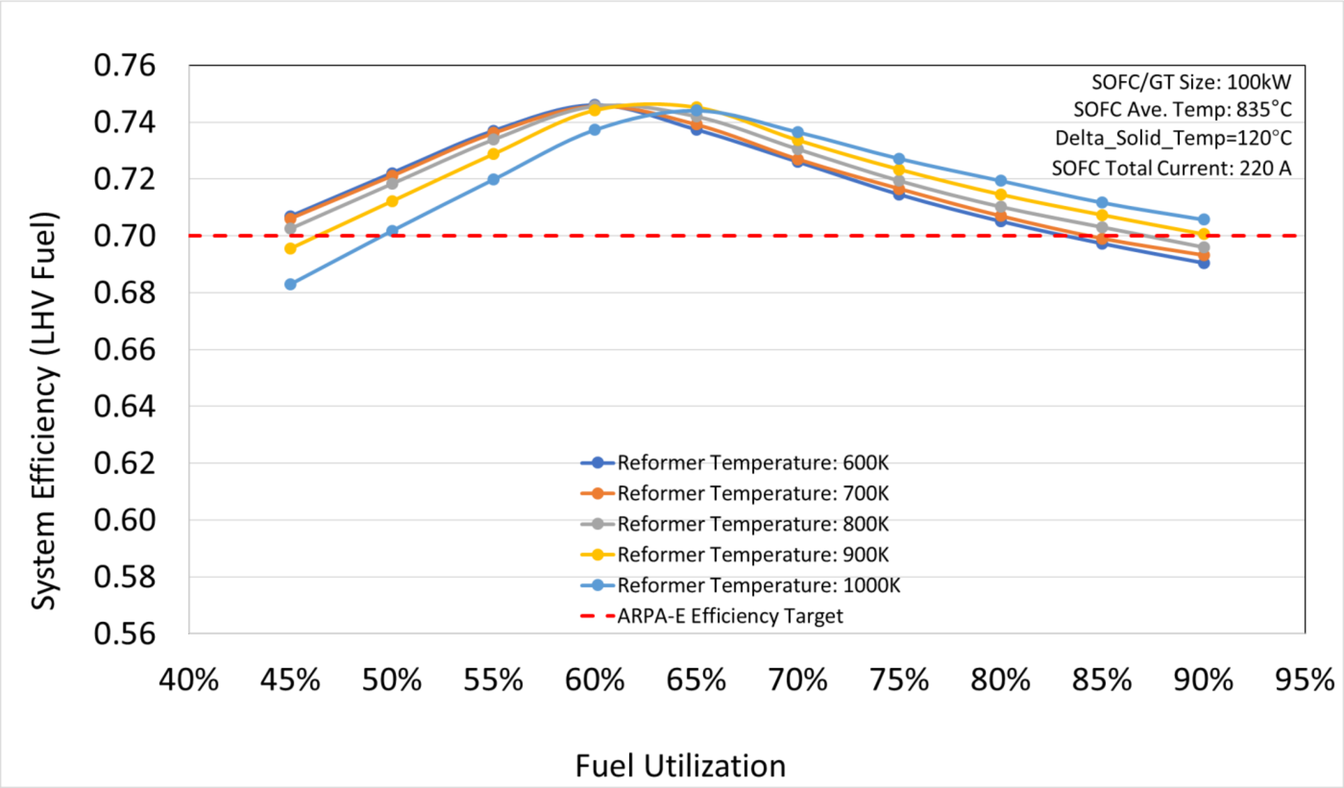




Hybrid system efficiency as a function of SOFC fuel utilization and reformer operating temperature for a fuel cell operating temperature of 635˚C

Results: NG SOFC/GT CYCLE

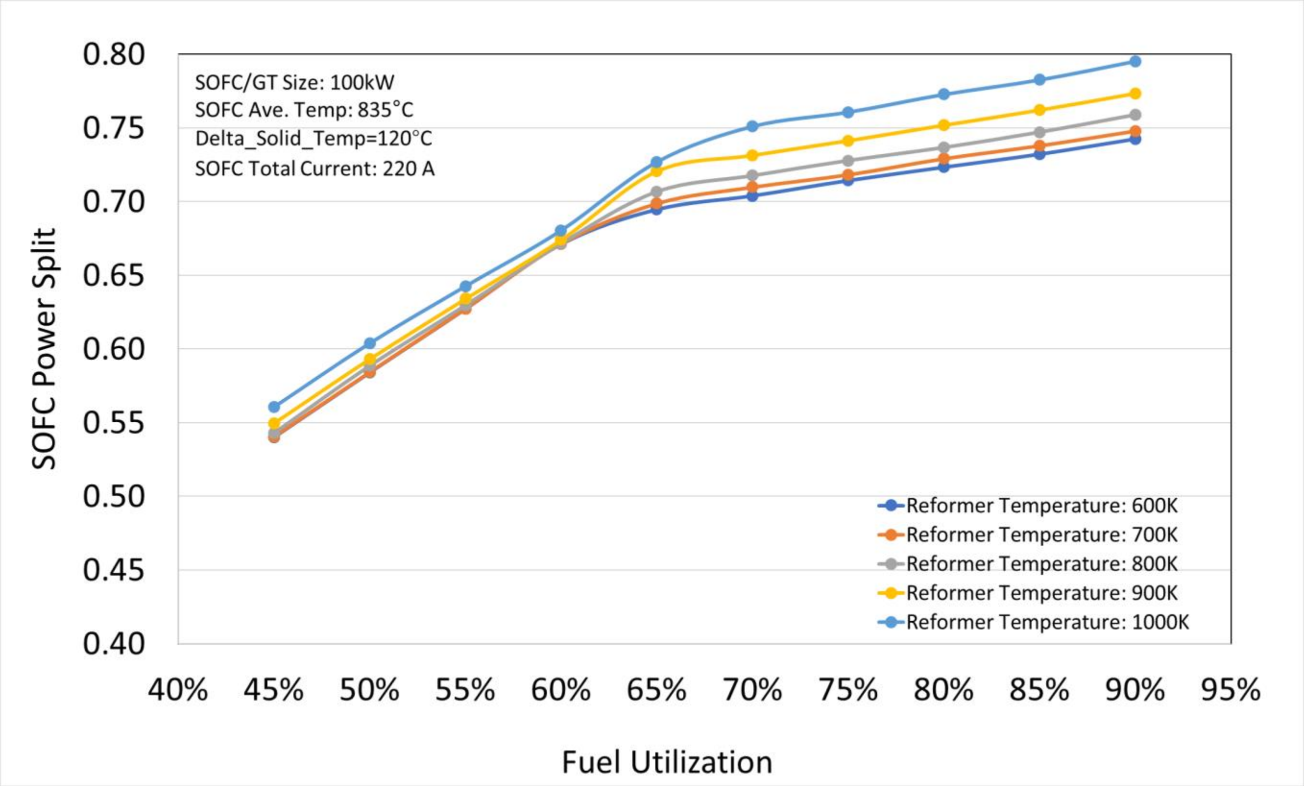
Physical reformer location at the turbine inlet



Hybrid System Efficiency as a Function of SOCF Fuel Utilization and Reformer Operating Temperature when the Reformer is Located at the Turbine Inlet

Results: NG SOFC/GT CYCLE

Reformer at the Turbine Inlet



Hybrid System Efficiency as a Function of SOCF Fuel Utilization and Reformer Operating Temperature when the Reformer is Located at the Turbine Inlet

Conclusions:

Common reformer/SOFC/GT configuration:

- The highest efficiency is given by internal reforming: 74% at 60% SOFC fuel utilization
- The optimum power split: 65% SOFC power: 35% GT power
- Peak efficiency for internal reforming is at a low fuel utilization (55% - 65%)
- Peak efficiency for external reforming is at a high fuel utilization (80% - 90%)
- Reducing SOFC average temperature decreases the overall hybrid performance to a maximum of 60%

SOFC/GT with physical reformer location at the turbine inlet:

- By using turbine inlet heat for reformer, overall hybrid performance increases to a maximum of 75%
- By using turbine inlet heat for reformer, performance of internal reforming (low temperature) and external reforming (high temperature) are almost identical.
- Using turbine inlet heat for reformer help increase external reforming efficiency (65% to 74% - peak efficiency)

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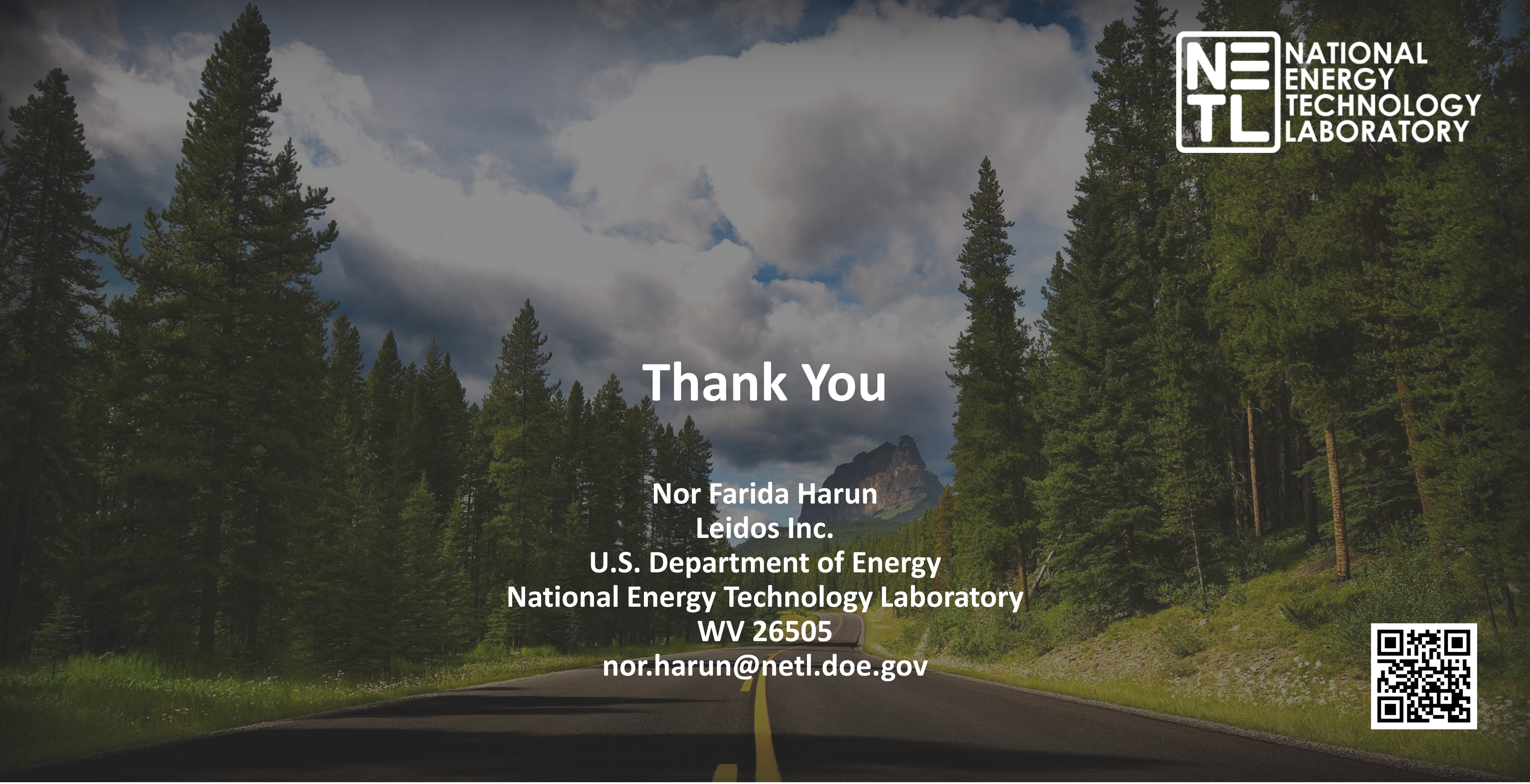
Disclaimer:



Thank You

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