# Solid Oxide Fuel Cell – Gas Turbine Hybrid Power Plant

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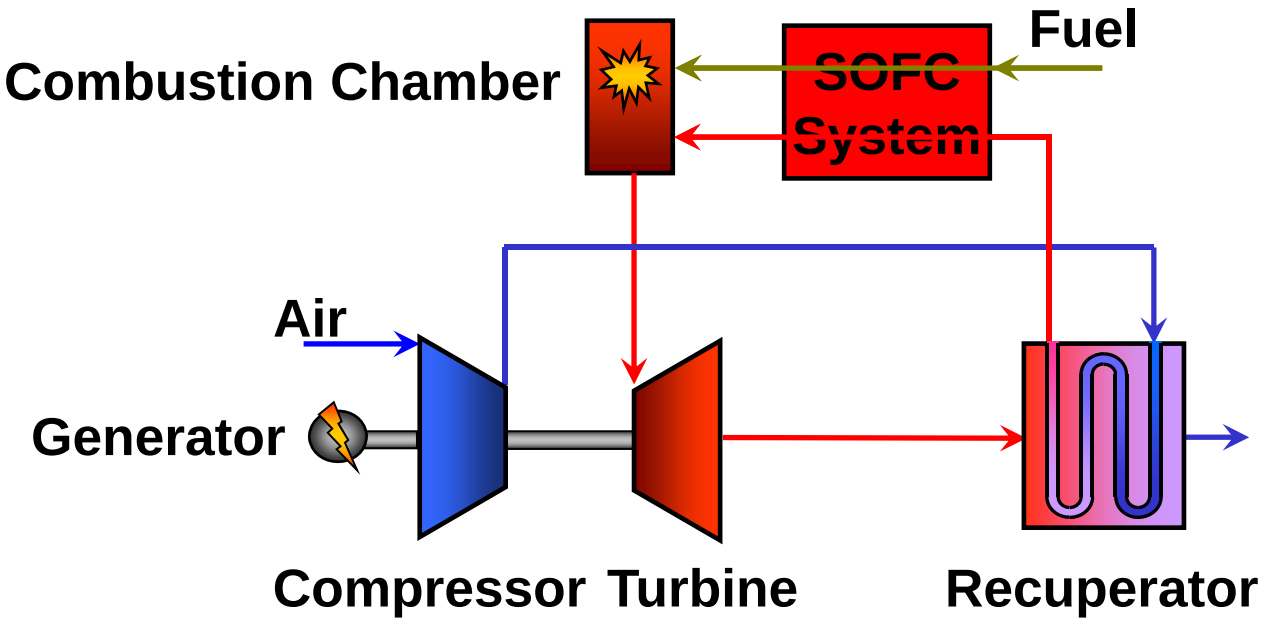
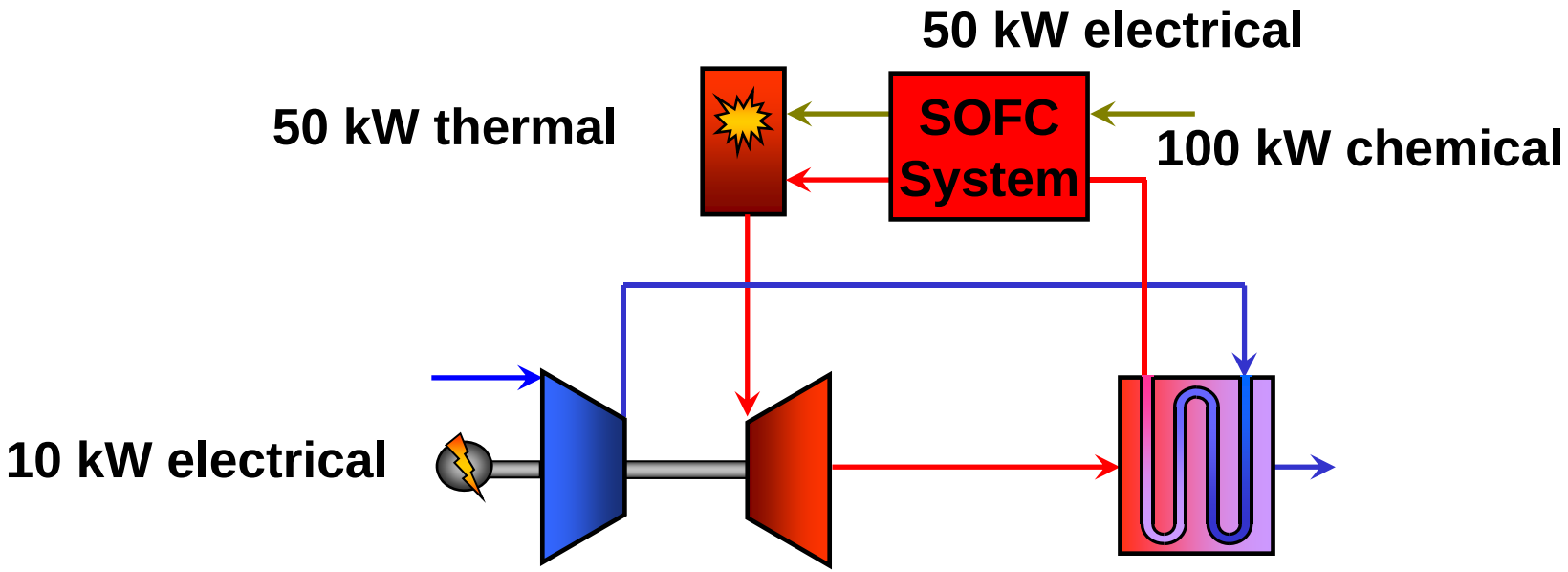
# Motivation: Hybrid Power Plant

- Combination of SOFC and gas turbine
- High electrical efficiency of 50-70 % (LHV)
- SOFC pressure determined by gas turbine
- Aim to build and operate a system with an electrical power output of about 30 kW




# Hybrid Power Plant: Efficiency

- SOFC $\eta_{el}$ = 50 kW / 100 kW = 50%
- Gas turbine $\eta_{el}$ = 10 kW / 50 kW = 20%
- Overall system $\eta_{el}$ = 60 kW / 100 kW = 60%



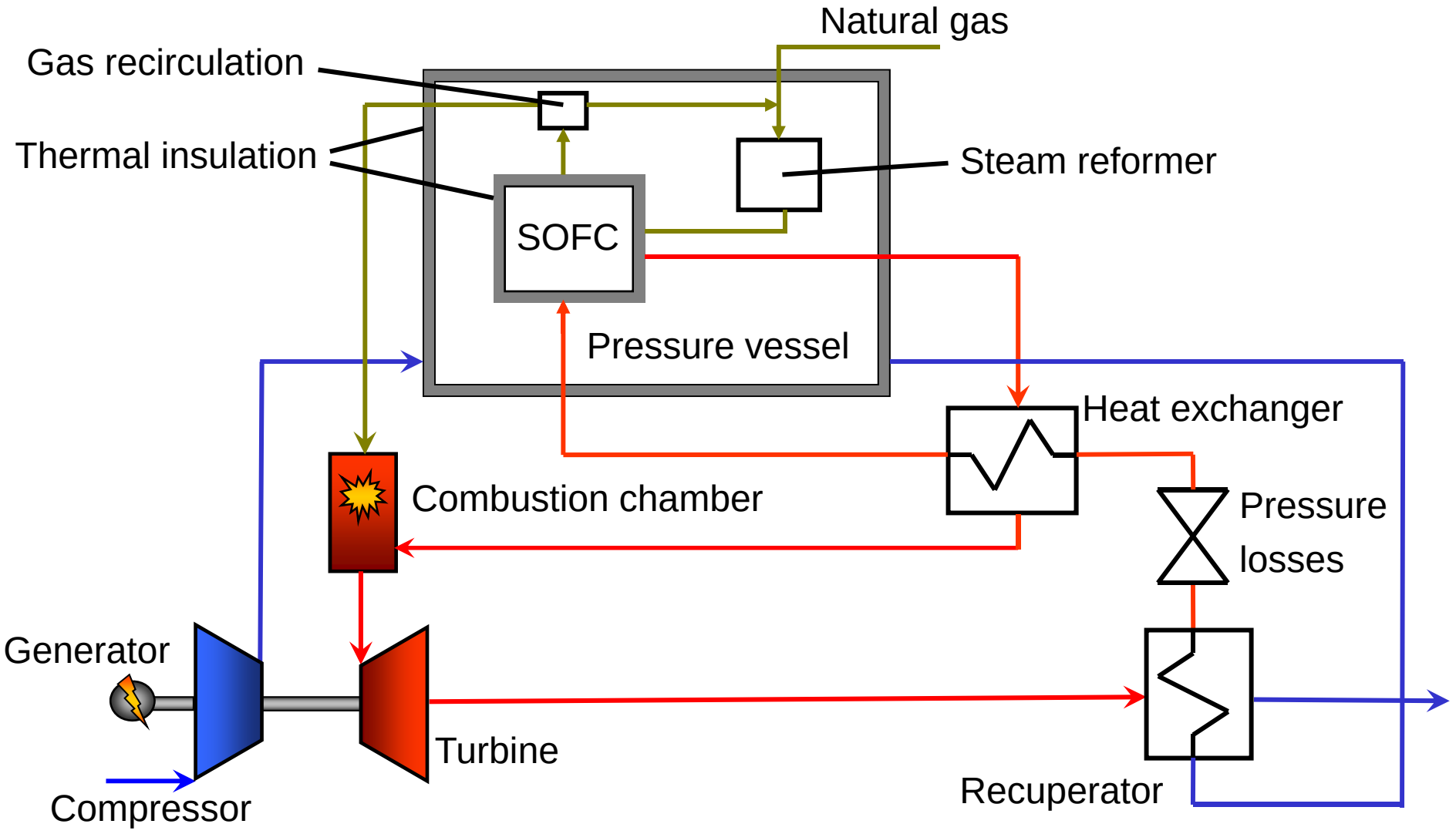
# Operating Strategy of Hybrid Power Plant

Aim:
- High electrical efficiency over wide power range
- Simple system layout

Operating Strategy:
- System control similar to gas turbine control
- Variable turbine speed
- Variable SOFC temperature and electrical power output

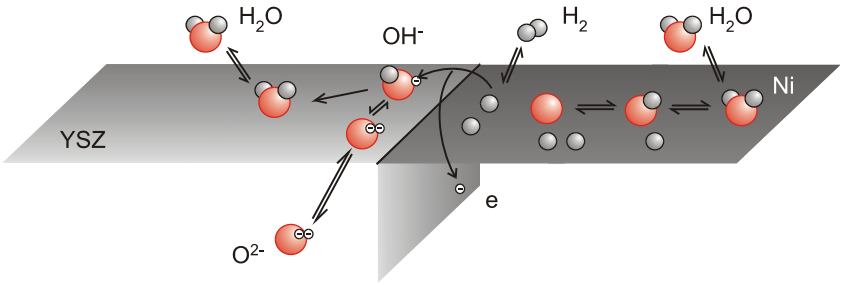
Scientific Approach:
- Matching of SOFC and gas turbine
- Sensitivity analysis
- Performance analysis

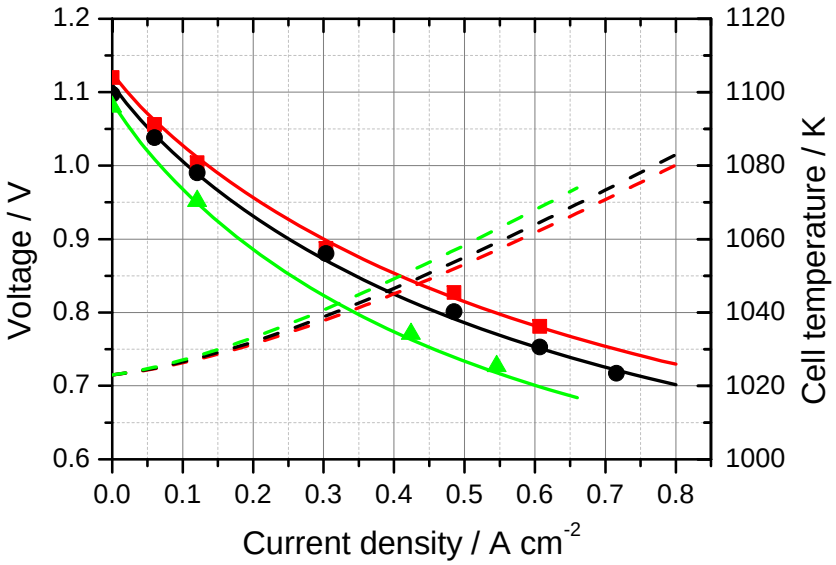
# Schematic of Hybrid Power Plant Model




DLR

# SOFC Model Validation




Experimental validation of detailed stack model
- Electrochemistry
- Temperature distribution

Pressure variation:
- 8 bar
- 4 bar
- 1.35 bar

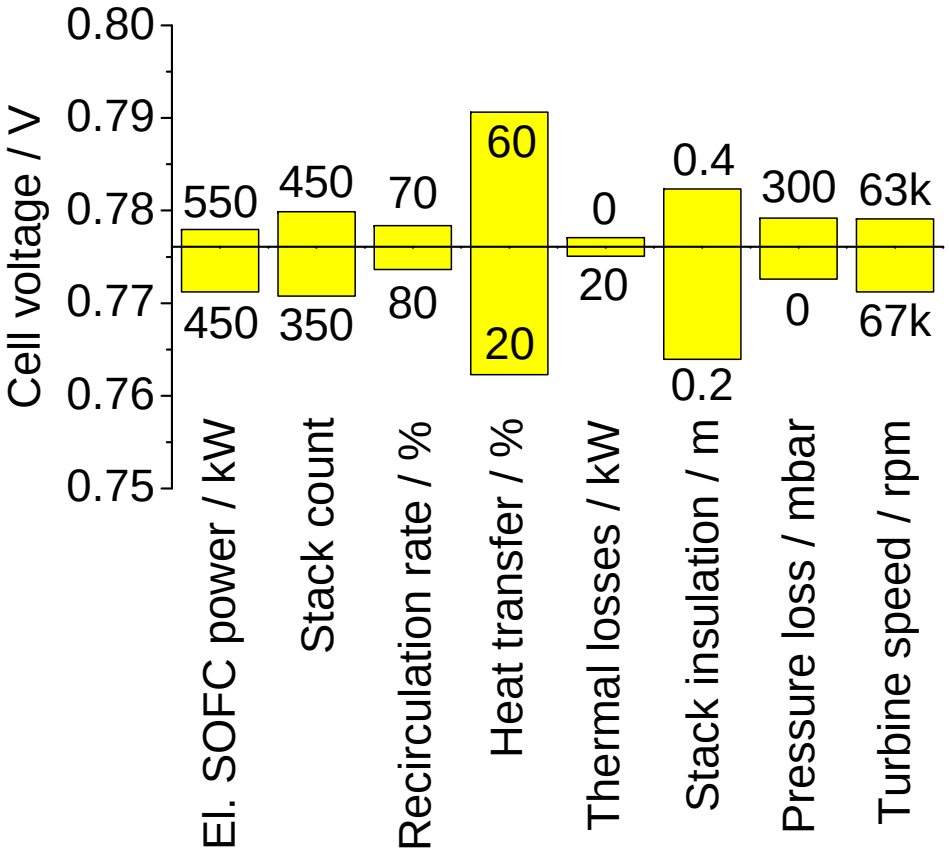
# Sensitivity Analysis

Reference conditions:
- 400 stacks with 60 cells each
- 500 kW electrical SOFC power (DC)
- 75% anode gas recirculation
- 40% efficiency of cathode heat exchanger
- 10 kW losses of thermal energy from pressure vessel
- 150 mbar pressure loss of SOFC system
- 65000 rpm turbine speed
- 0.3 m stack insulation thickness

Separate variation of each parameter within realistic limits

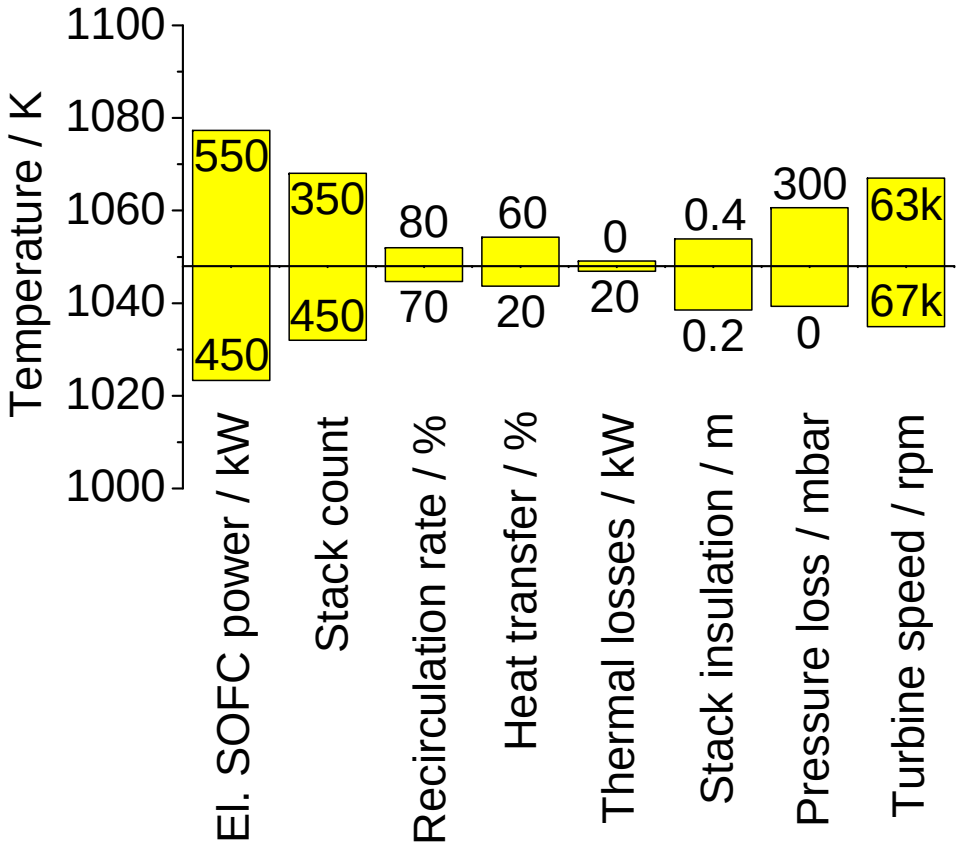
Analyzed data:
- SOFC voltage
- SOFC temperature
- Electrical efficiency

# Cell Voltage



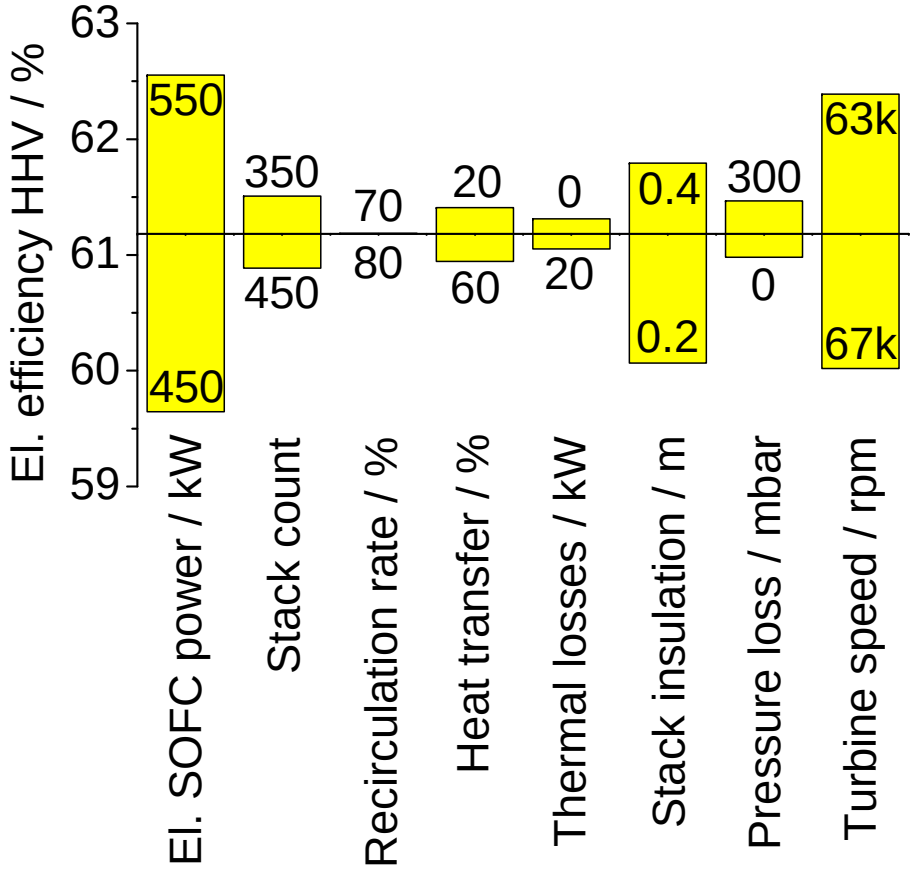

- Cell voltage is important parameter concerning degradation (> 0.7 V)
- Strongest influence of heat transfer and stack insulation (temperature effect)
- Only very small overall changes

# Cell Temperature



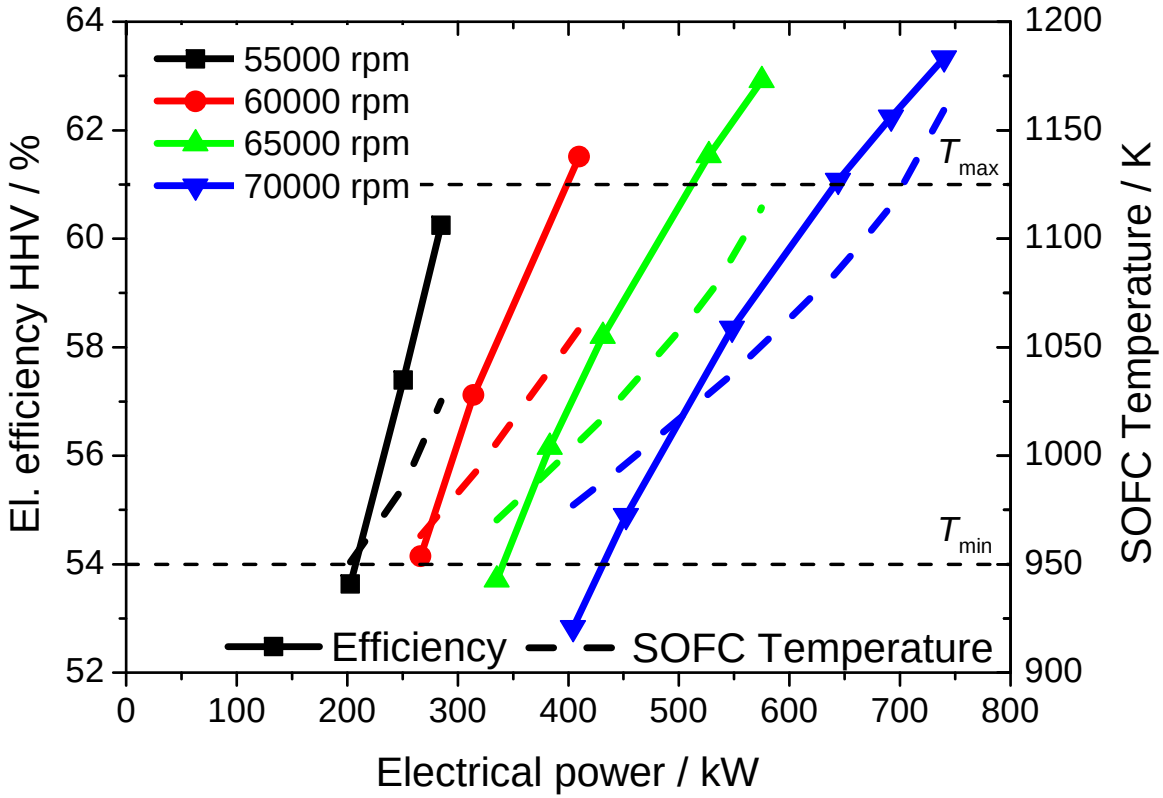

- Desired temperature of 950-1100 K
- Electrical SOFC power influences thermal power output
- Temperature limits SOFC power
- Increased losses of thermal energy with increasing stack number due to increased surface
- Turbine speed influences cooling via air mass flow

# System Efficiency




- Power ratio SOFC:GT is key parameter for high efficiency
- Non-linear influence of stack insulation
- Thermal losses of pressure vessel can be compensated

# Power Range of Hybrid Power Plant




- Fixed system components
- Variable turbine speed
- Variable SOFC electrical power

- Large power range from 200 kW to 700 kW
- Very high electrical efficiency of 60% from 300 kW to 700 kW

# Conclusions

- Operating strategy offers high electrical efficiency over large power range
- Power ratio of SOFC:GT is crucial parameter for high efficiency
- Optimized thermal insulation can improve efficiency
- SOFC temperature limits operating range of power plant

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