Cost effective hybrid cycles and supporting turbomachinery

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Overview

PART 1 — **G Agnew**

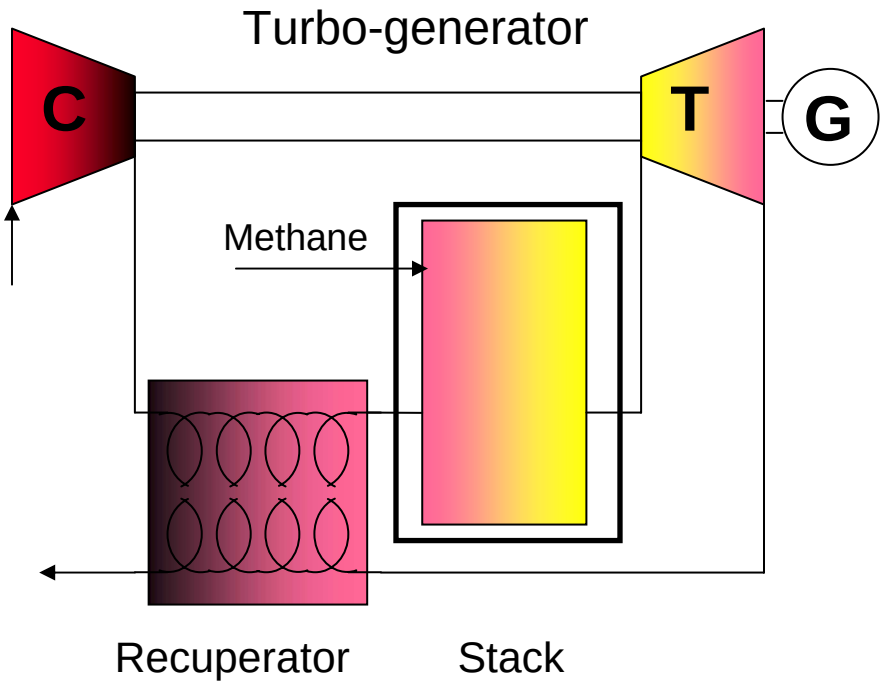
- Recuperated cycles
  - Efficiency optimisation
  - Cost optimisation
- Novel cycles
  - Reducing heat exchanger requirements
  - Potential to eliminate heat exchangers
  - Special-purpose turbomachinery required

PART 2 — **S Berenyi**

- Turbomachinery
  - Unique capability at Indianapolis

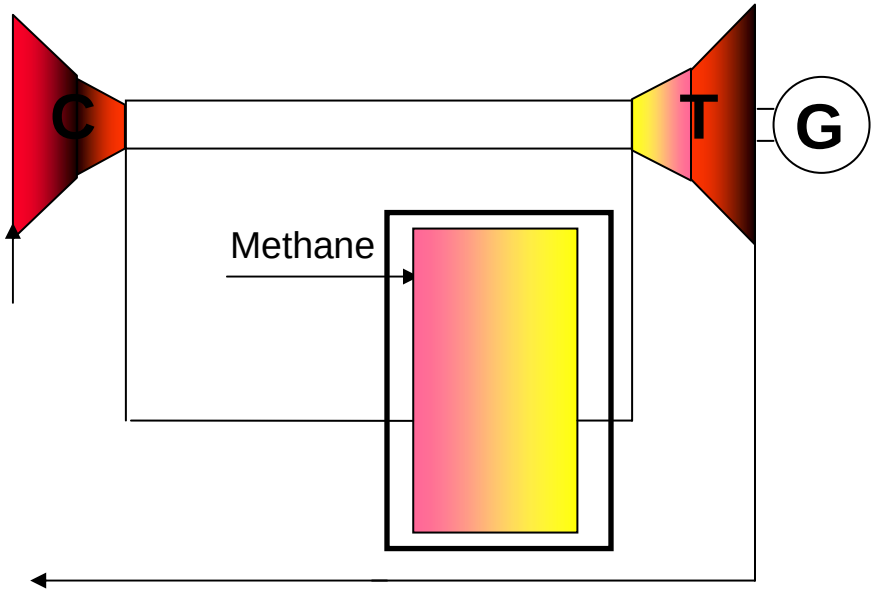
Conventional families of hybrid cycels

LP hybrid PR~4



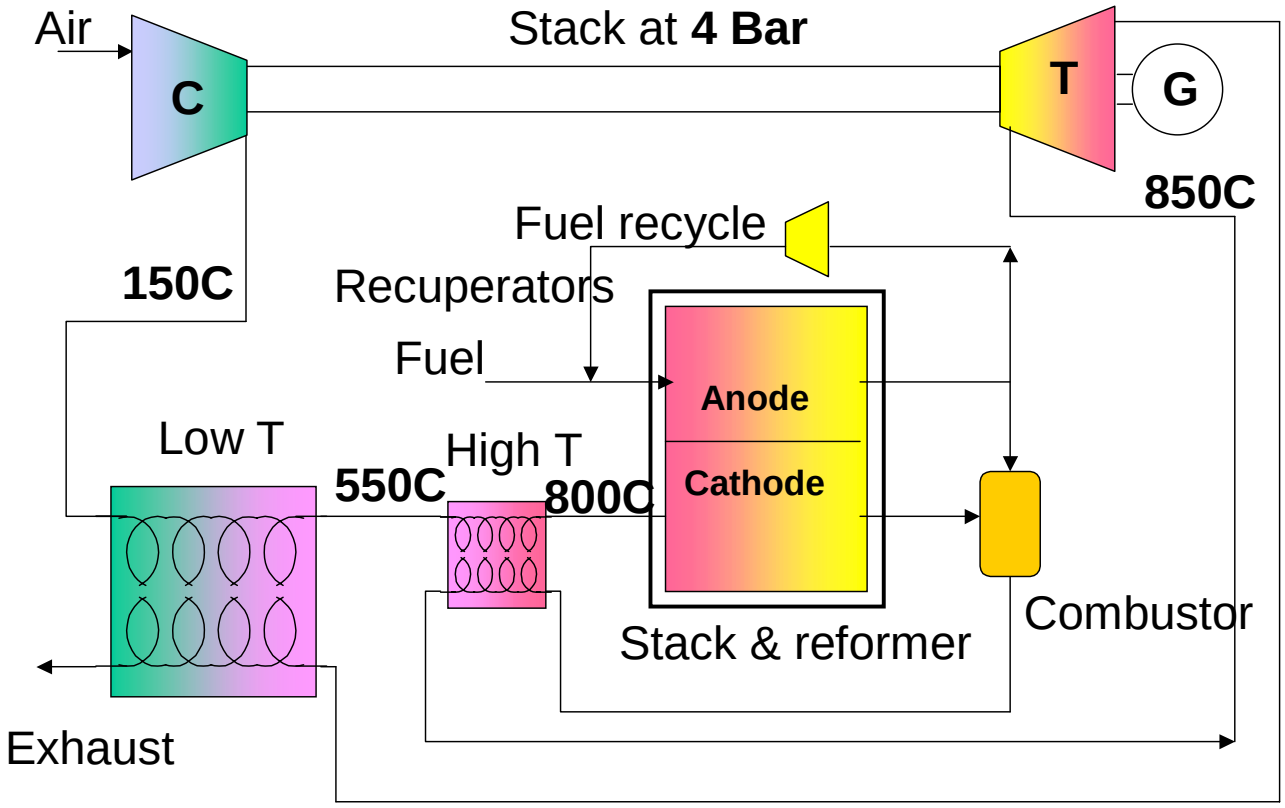
Compressor does little heating
Recuperator required .. COST
PR limited - need hot turbine exhaust

HP hybrid PR~20

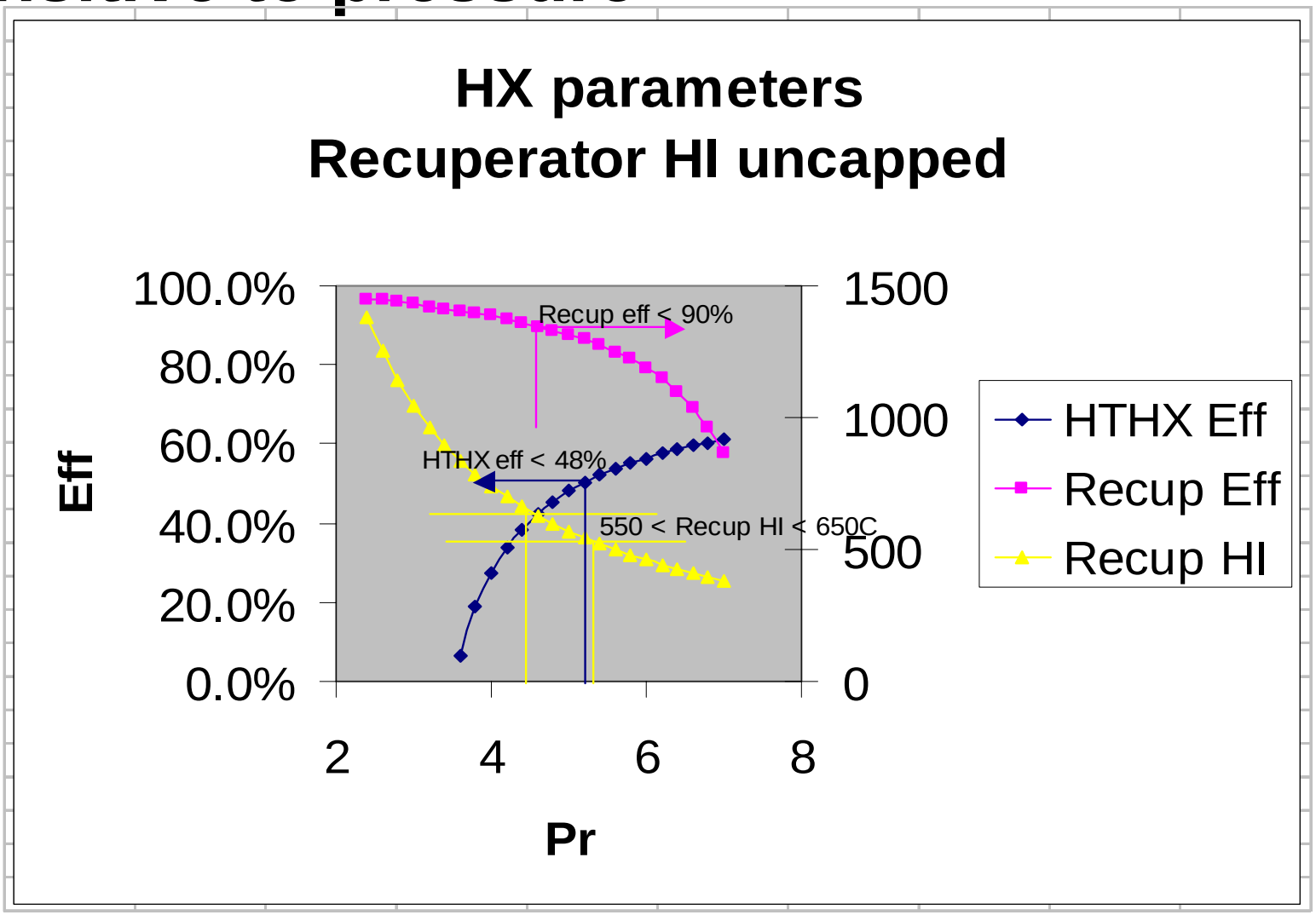


Compressor completes heating
PR makes integrated reforming difficult

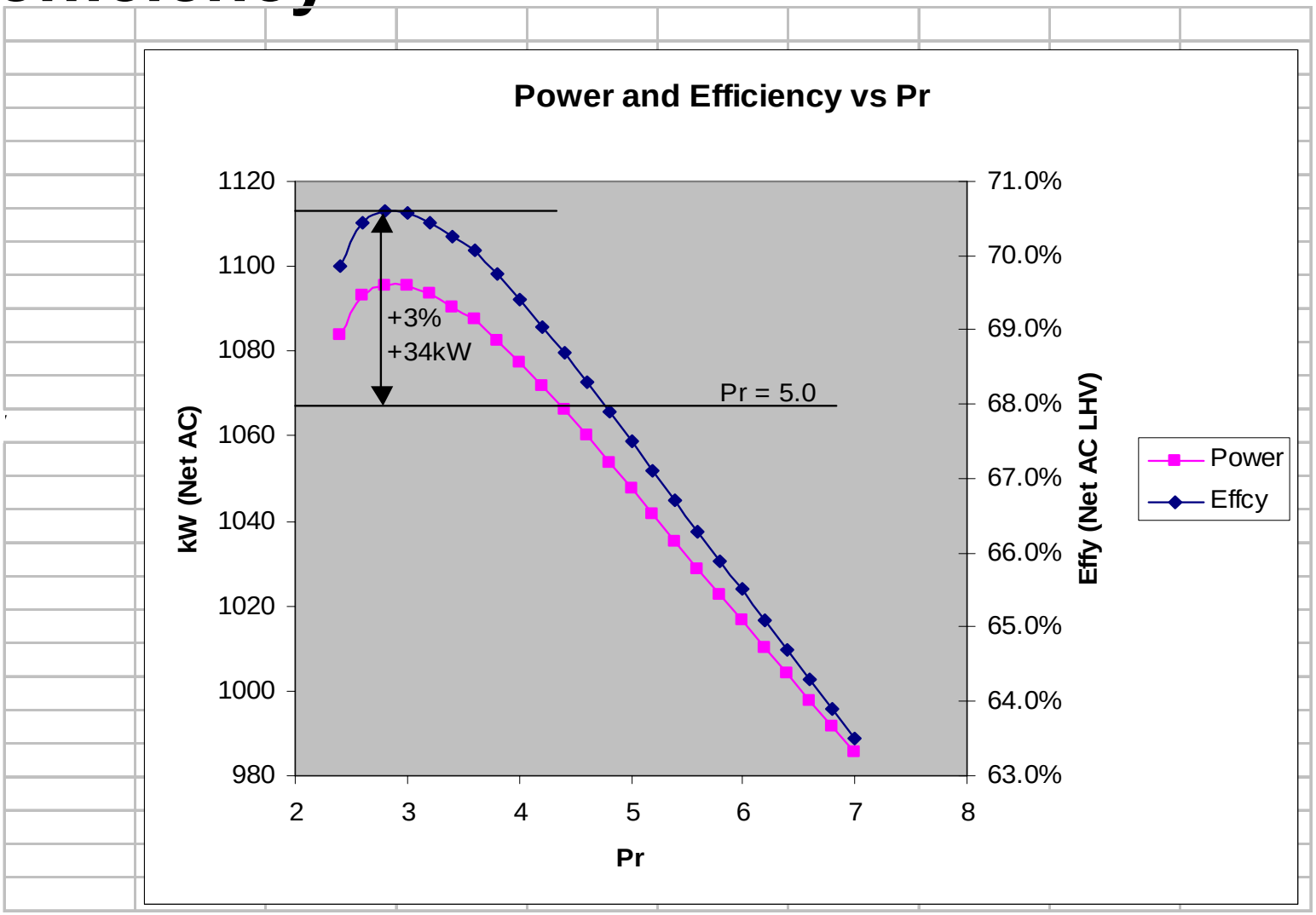
Two stage recuperated hybrid



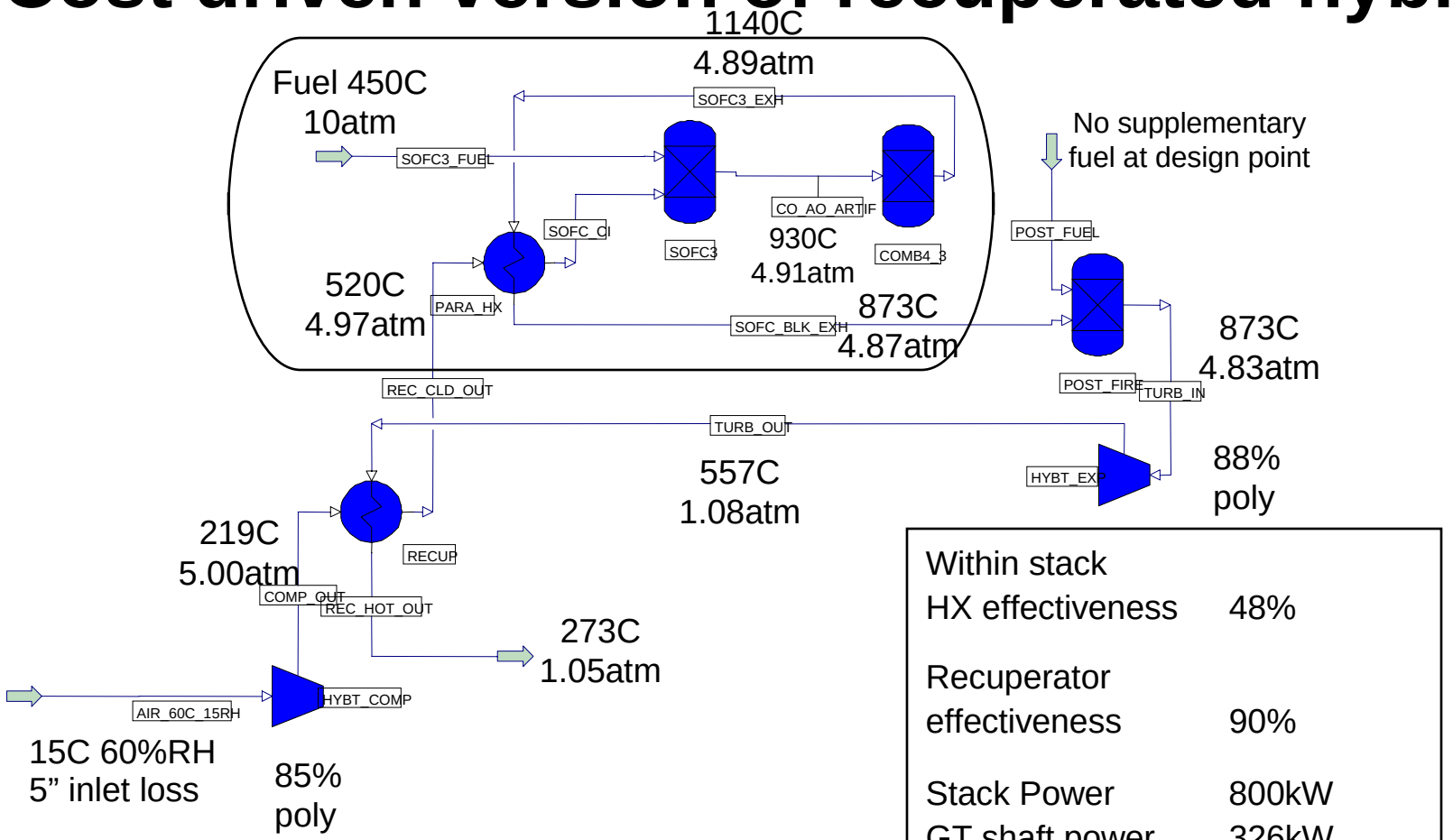
Cost effectiveness of recuperated cycle sensitive to pressure



Improving cost comes at small penalty in efficiency

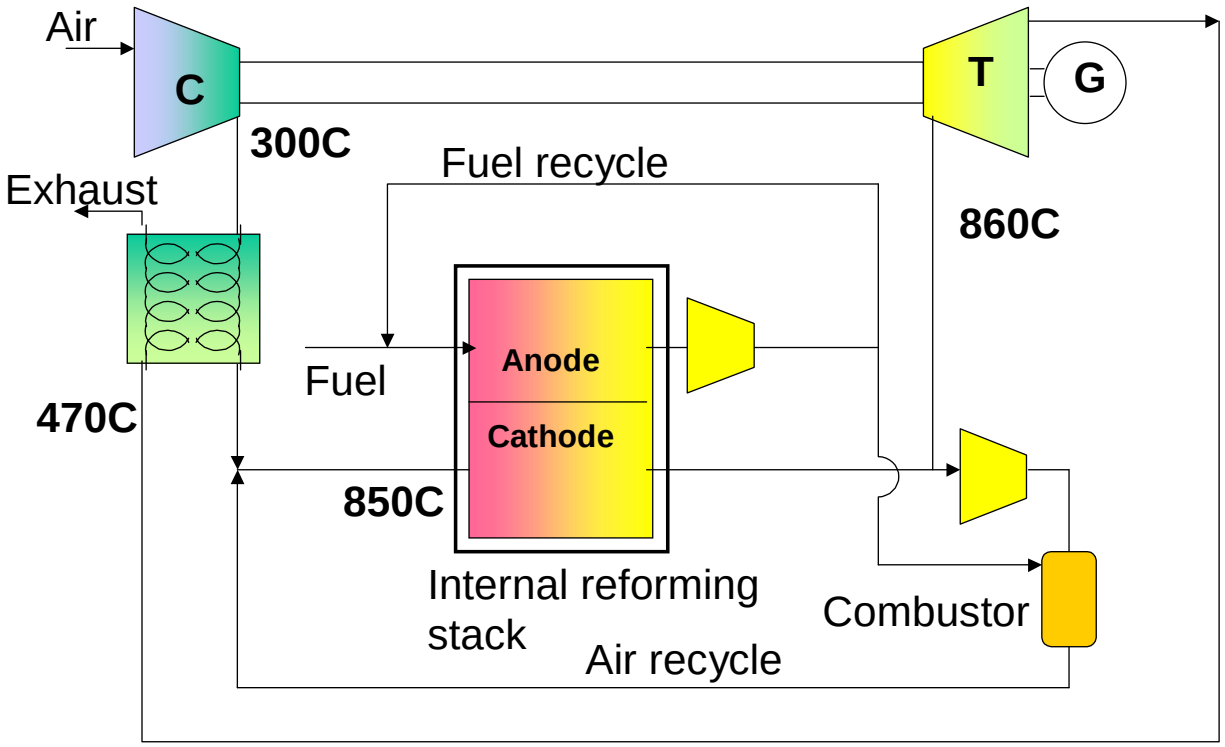


~Cost driven version of recuperated hybrid



Within stack HX effectiveness	48%
Recuperator effectiveness	90%
Stack Power	800kW
GT shaft power	326kW
Parasitics	50kW AC
Net AC	1.021MW
Efficy (LHV to AC)	65.1%

New advanced cycles eliminate heat exchangers



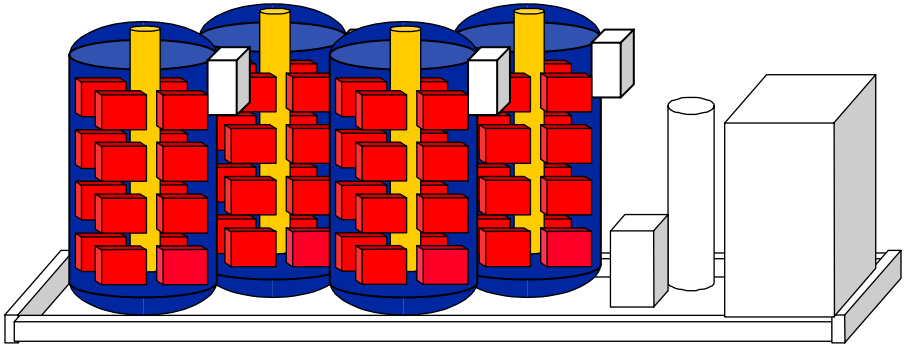
- Efficiency 65-68% at 1MW scale
- No high temperature heat exchangers
- Supports current day stack technology without need to lower temperatures
- 950C peak stack temperature with heat exchanger hot inlet only 470C

The simplicity trade-off can be taken further

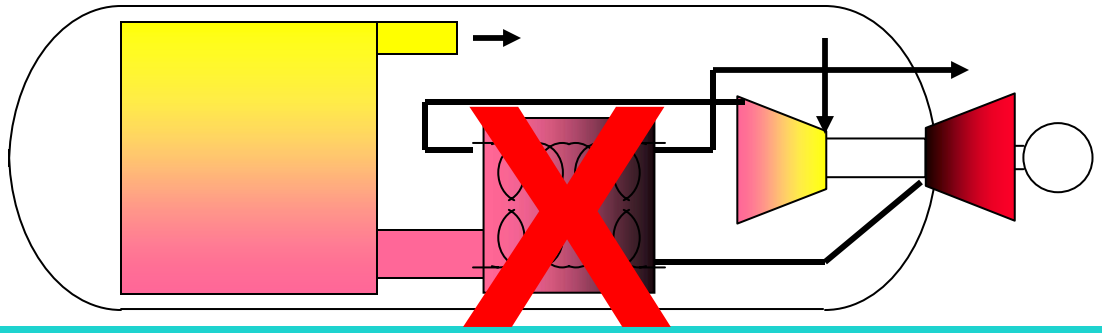
- Trade-off between efficiency and simplicity can be pushed further toward simplicity
- Smaller scale hybrids can have more temperature swing in the turbomachinery (ASME June)
- Completely heat-exchanger less cycles can be implemented with cathode re-cycle hybrids
- For low fuel inventory stack technologies, hybrids can be implemented in thin wall pressure vessels
- Initial efficiencies are below 60% but system is simpler and cheaper than open cycle fuel cell
- Part load efficiencies remain very high
- Small scale hybrids can use 1/3 or even ¼ fuel of alternative prime movers at part load

3rd generation system uses integration to reduce complexity and cost

- Integrated design
  - Thin ducts rather than thick pipes
  - Complexity gathered in small number of components, designed for manufacture
  - Avoids mechanical constraint and high temperature bellows
  - Avoids OTS scattergun components



Integrated
Few high ΔP joints
Careful thermal zoning



Novel turbomachinery required to support new hybrids

- Cycles differ significantly from conventional GT cycles
- Pressures, temperatures and matching not close to any existing machines
- Shaft power in relation to size differs even from previously projected fuel cell turbines
- Required machines are of limited value in other applications
- Two shaft machine requires advanced physical configuration due to small size
- Bearings, shaft dynamics, alternator and couplings all challenging
- Needs to integrate with bleed valves in cost effective manner
- Ideal area for targeting R&D funding
  - Initial configurations
  - Oil-free versions

Summary for first part of talk (cycles)

- Small departures away from maximising efficiency can result in dramatic cost savings and system simplification
- Novel SOFC/GT hybrid cycles give system designs that are simpler and cheaper than open cycle fuel cell systems
  - New hybrid configurations become economically viable through their cost rather than just their efficiency
- Novel turbomachinery is required to implement these next generation hybrids