Clean Energy Systems Integration Lab

Washington State University

System Characterization of a De-Coupled Hybrid Fuel Cell – Gas Turbine

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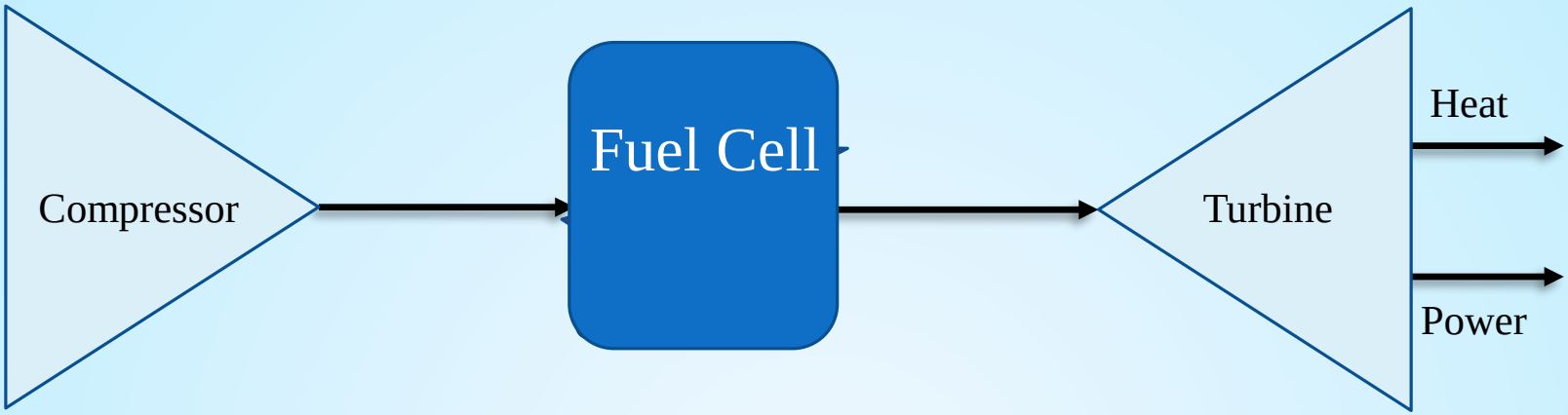
What is a FC-GT?



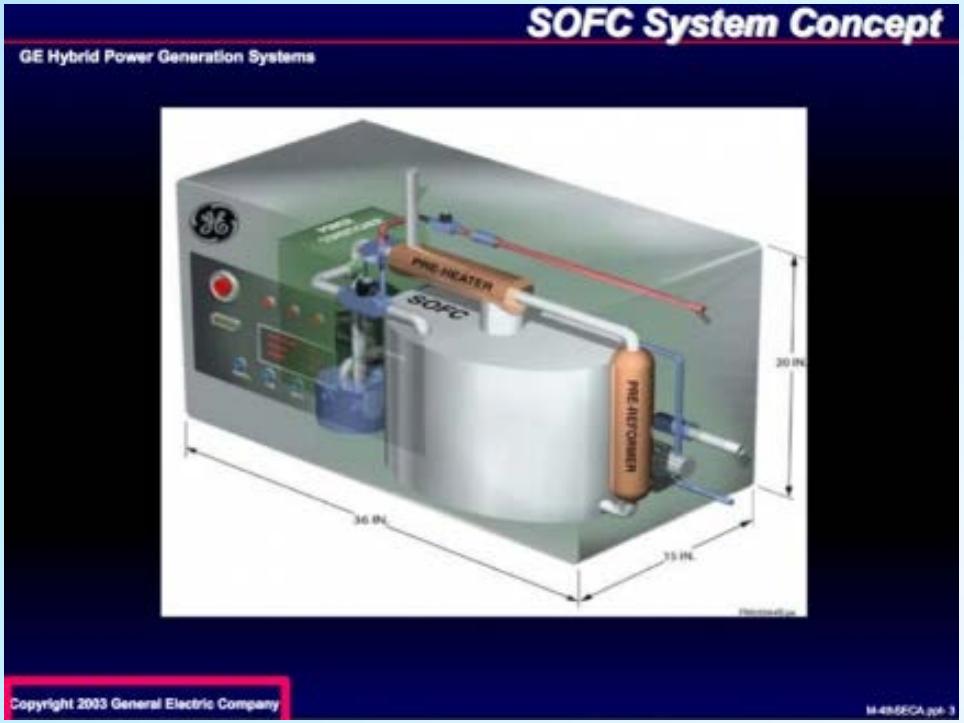
Hybrid System:

- Waste heat recovery
- Fuel Cell pressurization
- Air Preheating
- Minimal impact to GT and FC systems

Fuel Cell's cannot utilize all of their chemical energy for power

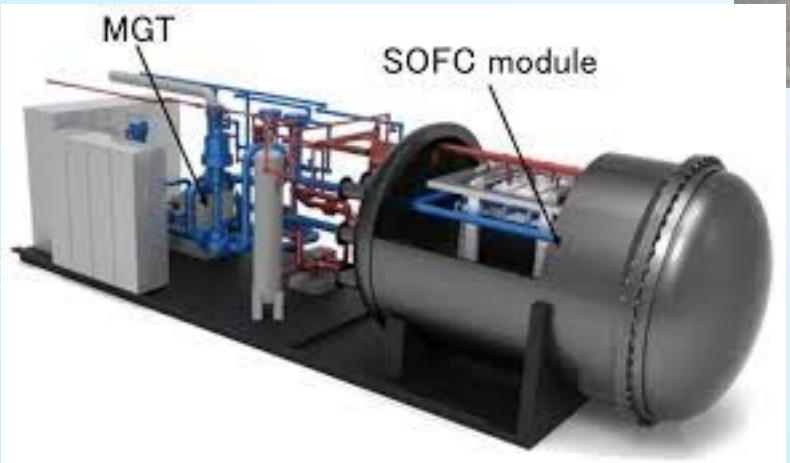
Gas turbines utilize waste chemical energy for air movement and power

Real World Examples



GE 2003

UC Irvine



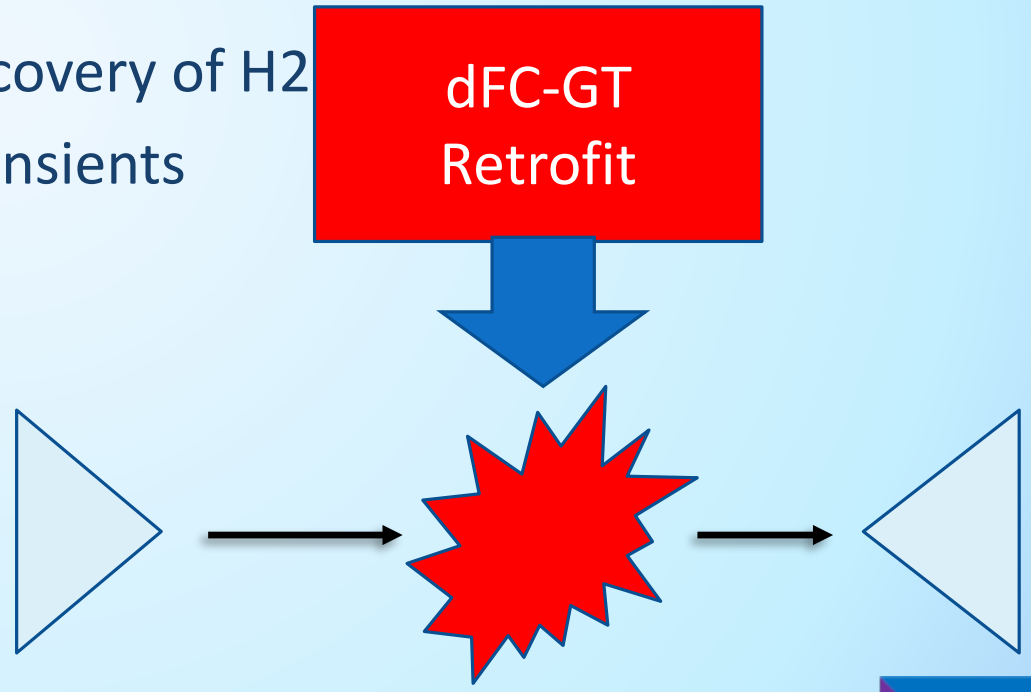
Mitsubishi

Motivation

- Gas Turbines operate with nearly constant flow rates but changing temperature.
- Fuel Cells operate at near constant temperature with changing flow rates
- Controls are necessary to modulate the air flow through the Fuel Cell at different power outputs

What is the dFC-GT?

- **FC-GT design concept**:
- Able to achieve 70% FTE
  - Thermodynamically same
- OTM pulls O2 from working fluid
- Energy transfer from FC to GT in chemical form
- Possibility for Co-Production/Recovery of H2
- Avoid surge/stall and slow FC transients
- GT behavior minimally affected
  - Retro-fit capable
- Scalable fuel cell capacity



Oxygen Transport Membrane

» **OTM:**

- Ceramic Perovskite
- Separates Oxygen Ions from air

» Benefits:

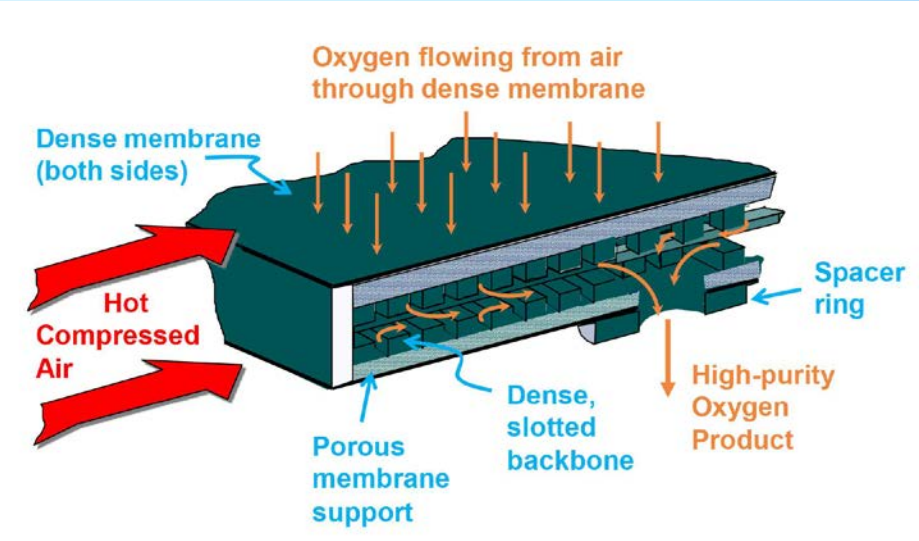
> Smaller volume – Less Pressure Drop

> Operates on Pressure Gradient

> Theoretical Recovery Limit

» Drawbacks:

> Lose Pressurization → Need to include parasitic compressor



Air Products Proposal

$$R_T = \frac{1-(1-X_{feed})*P_{Permeate}}{X_{Feed}(P_{Feed}-P_{Permeate})}$$

Oxy-FC

» **Oxy-FC:**

- Pure Oxygen Cathode FC
- Lower Heat Produced

» Benefits: Higher Voltage

> Pure Oxygen fed cathode

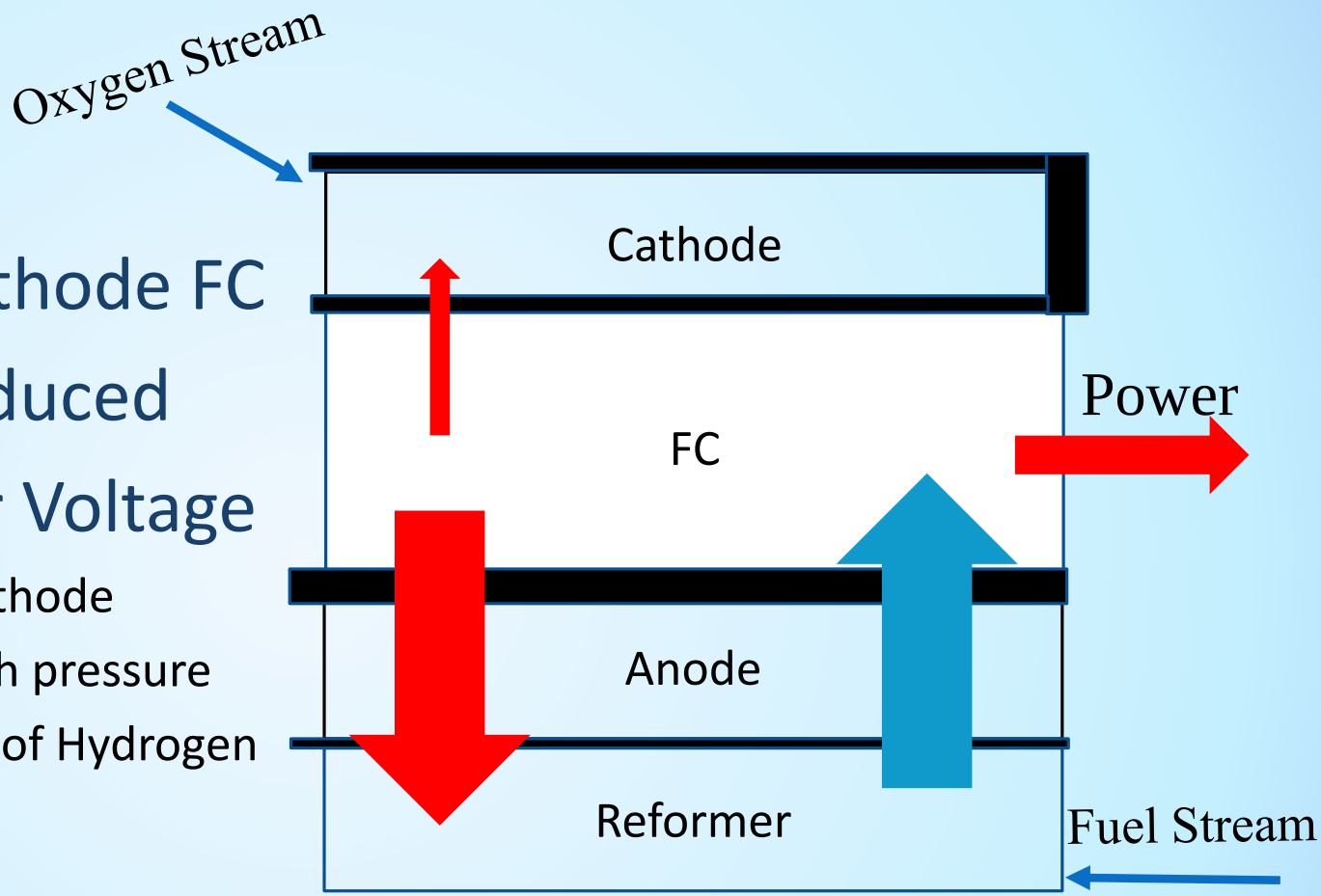
> Operates under high pressure

> High concentration of Hydrogen at anode

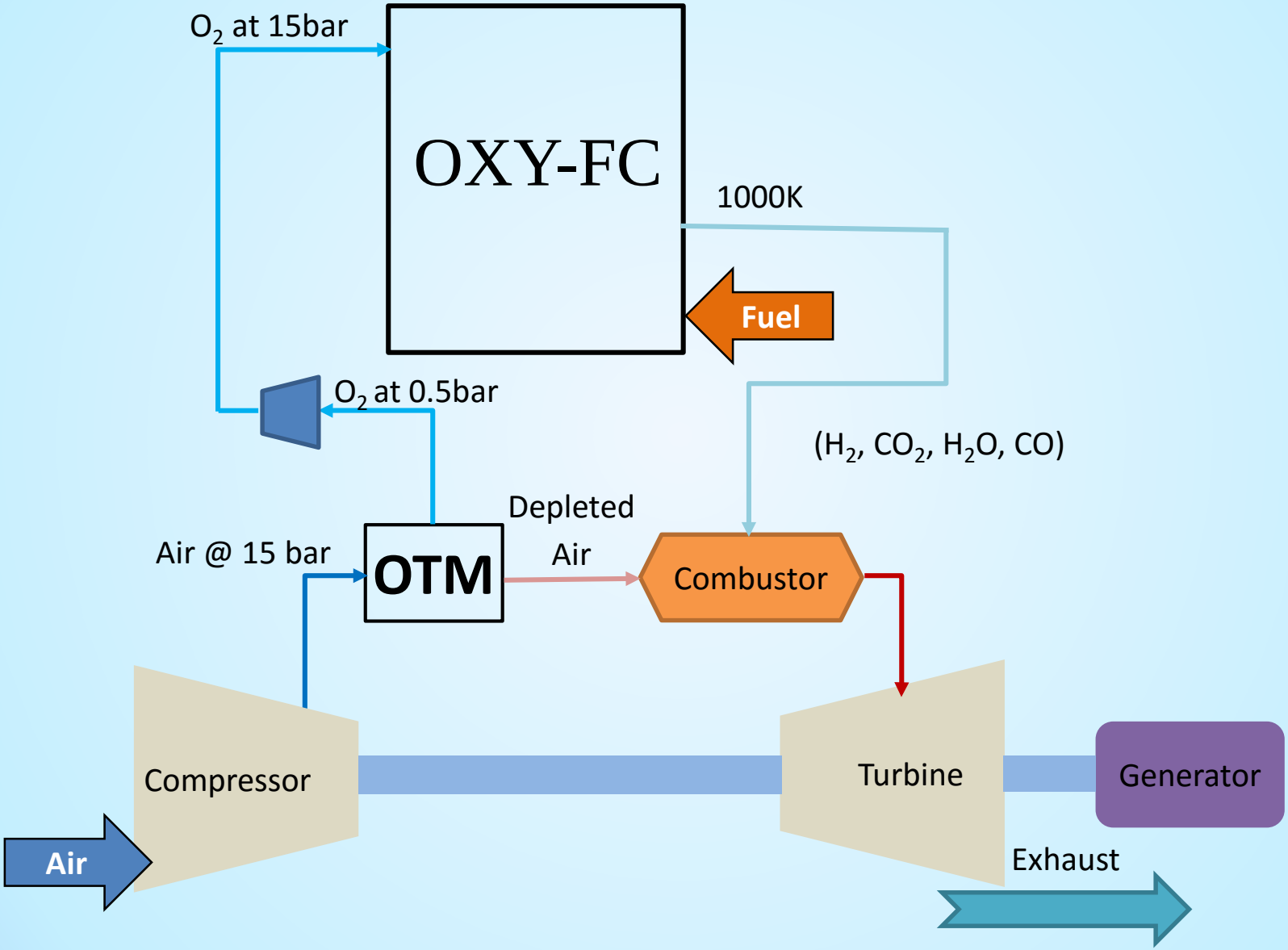
» Drawbacks:

> Lose degree of freedom managing temperature and power independently

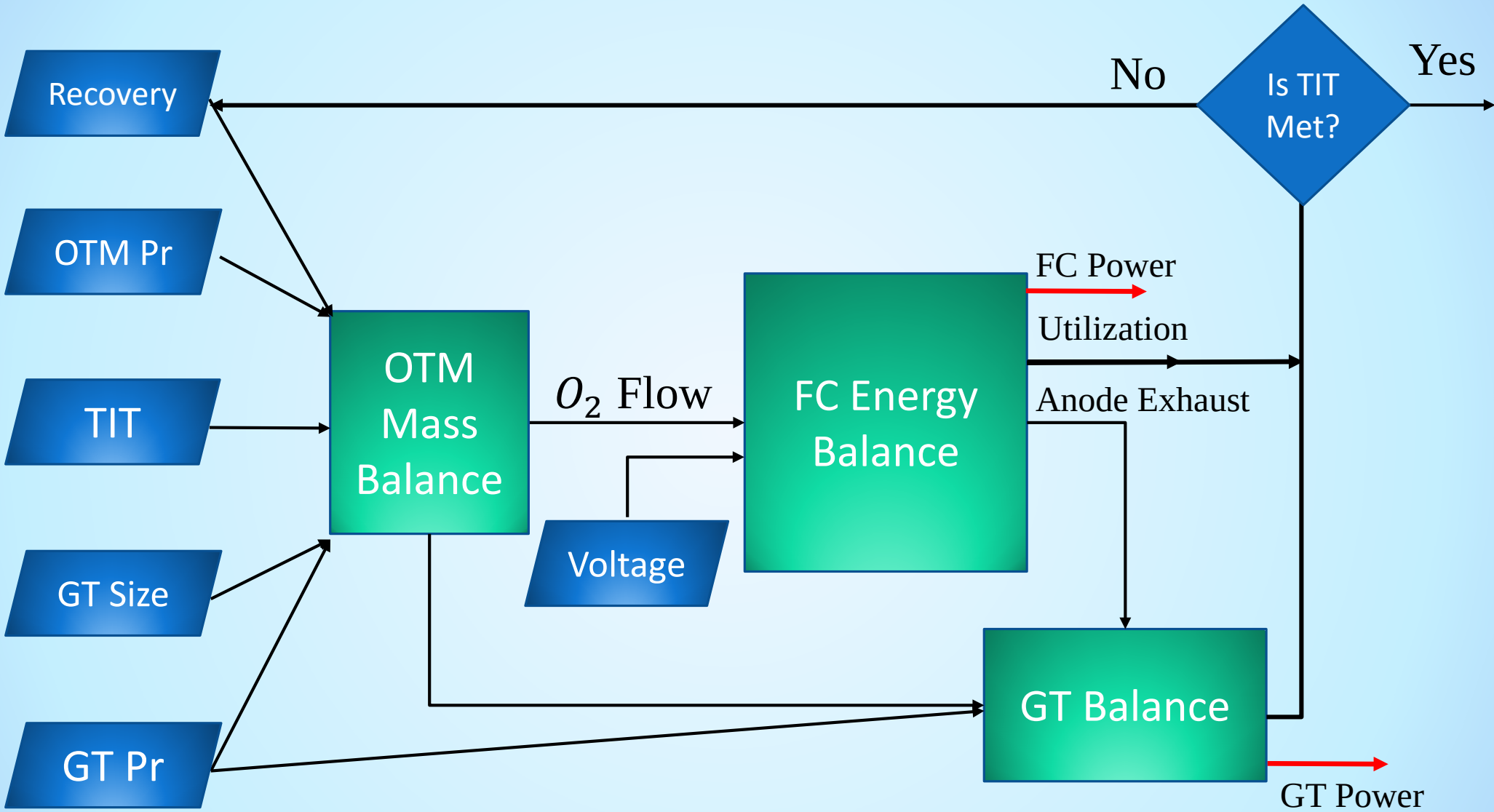
> Tall task



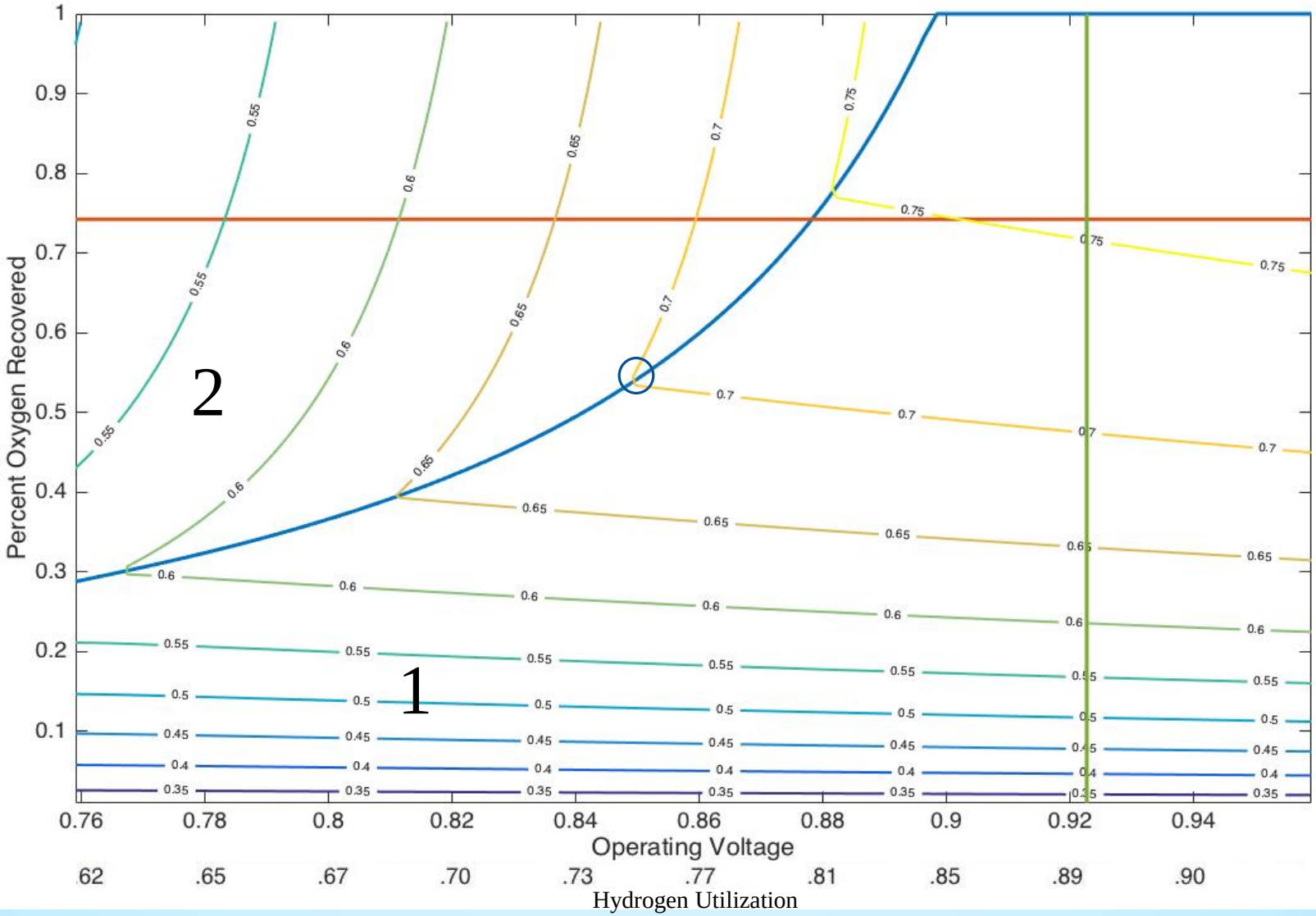
De-Coupled FC-GT



Model Development



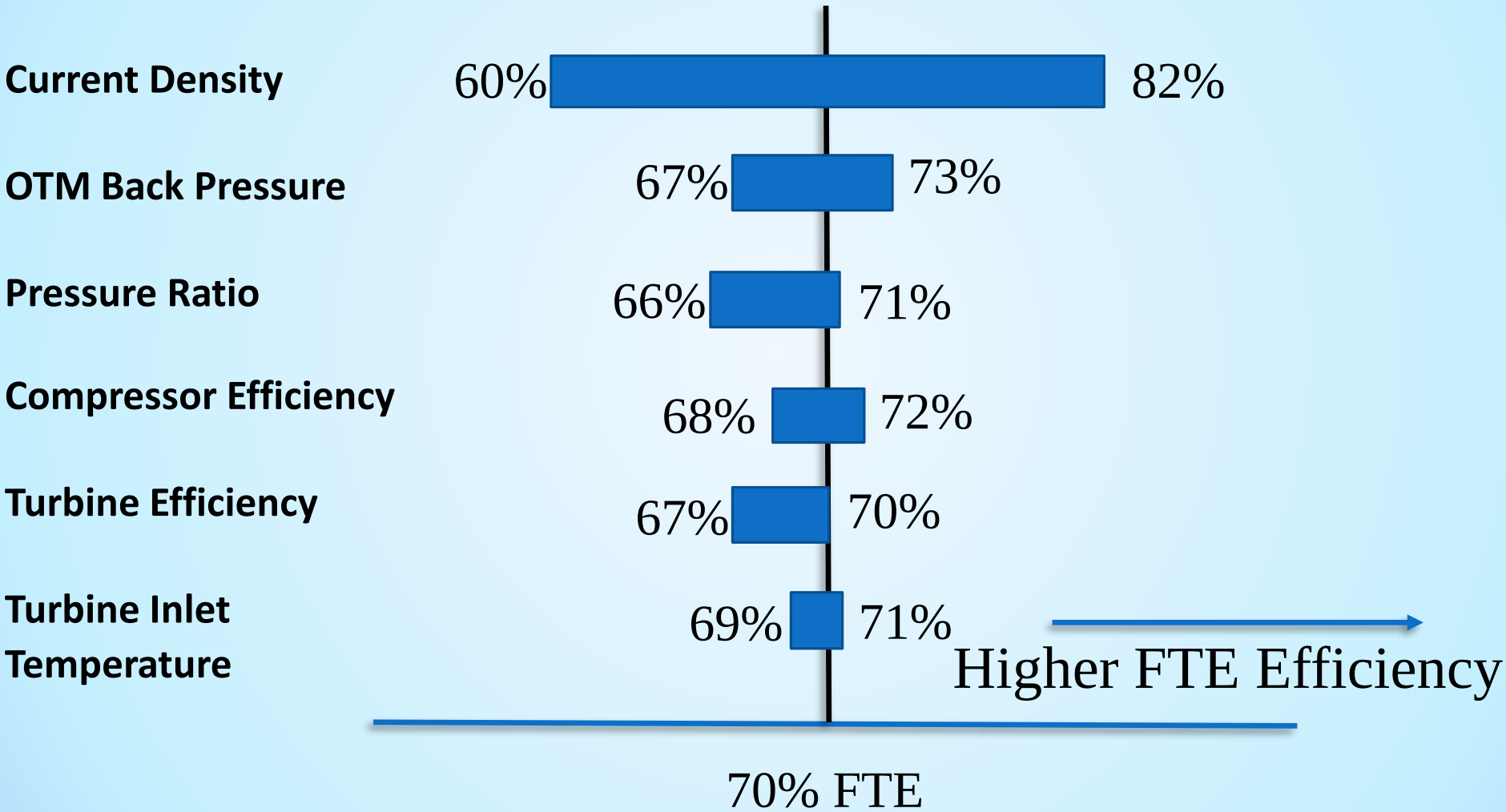
Design Space



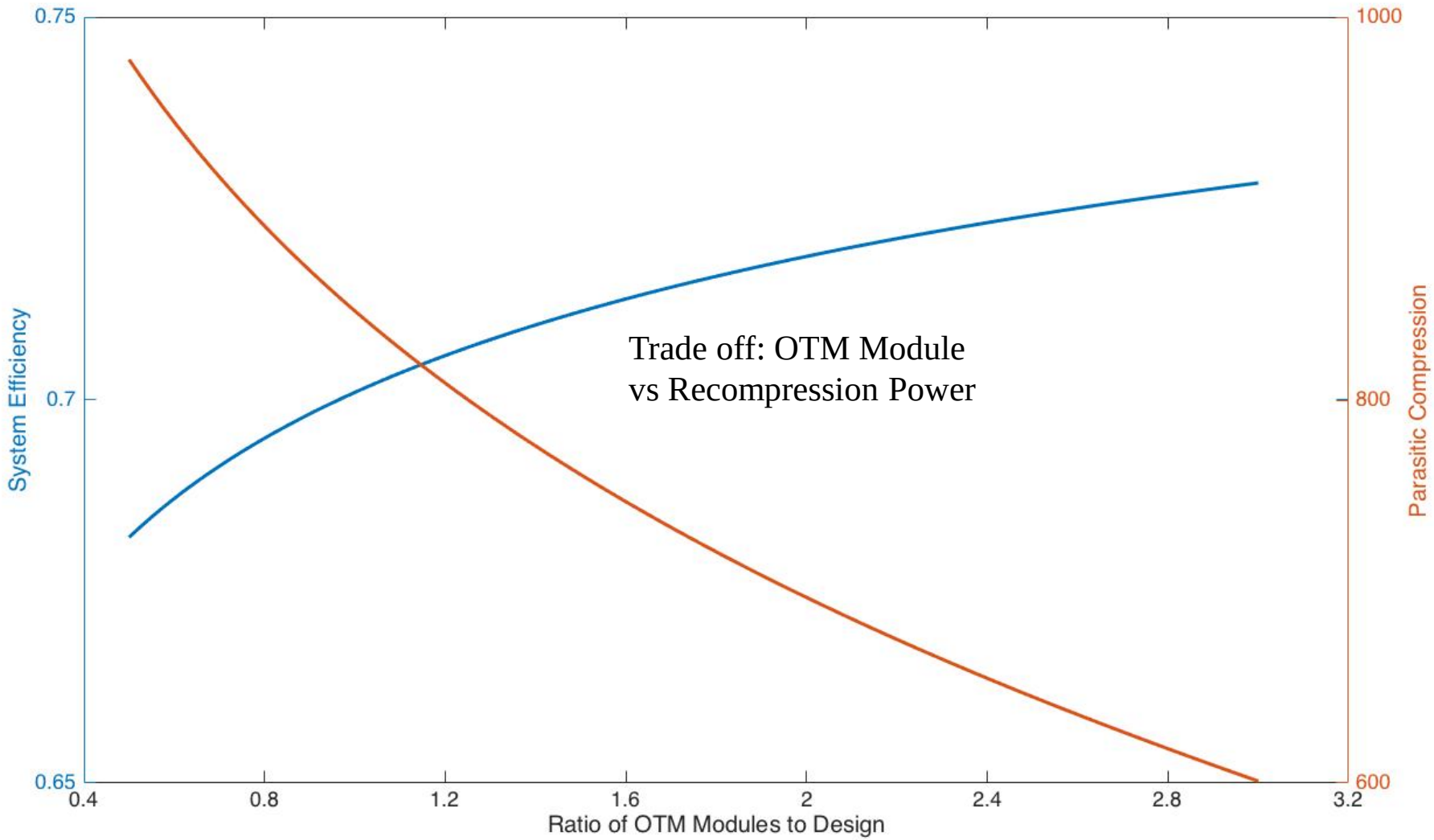
Results

Parameter	Value	Unit
Pressure Ratio	15	-
Back Pressure	50	kPa
Voltage (FC)	0.85	V
Recovery (OTM)	0.51	%
GT Efficiency	0.36	%
FC Efficiency	0.62	%
Hybrid Efficiency	**0.70**	%

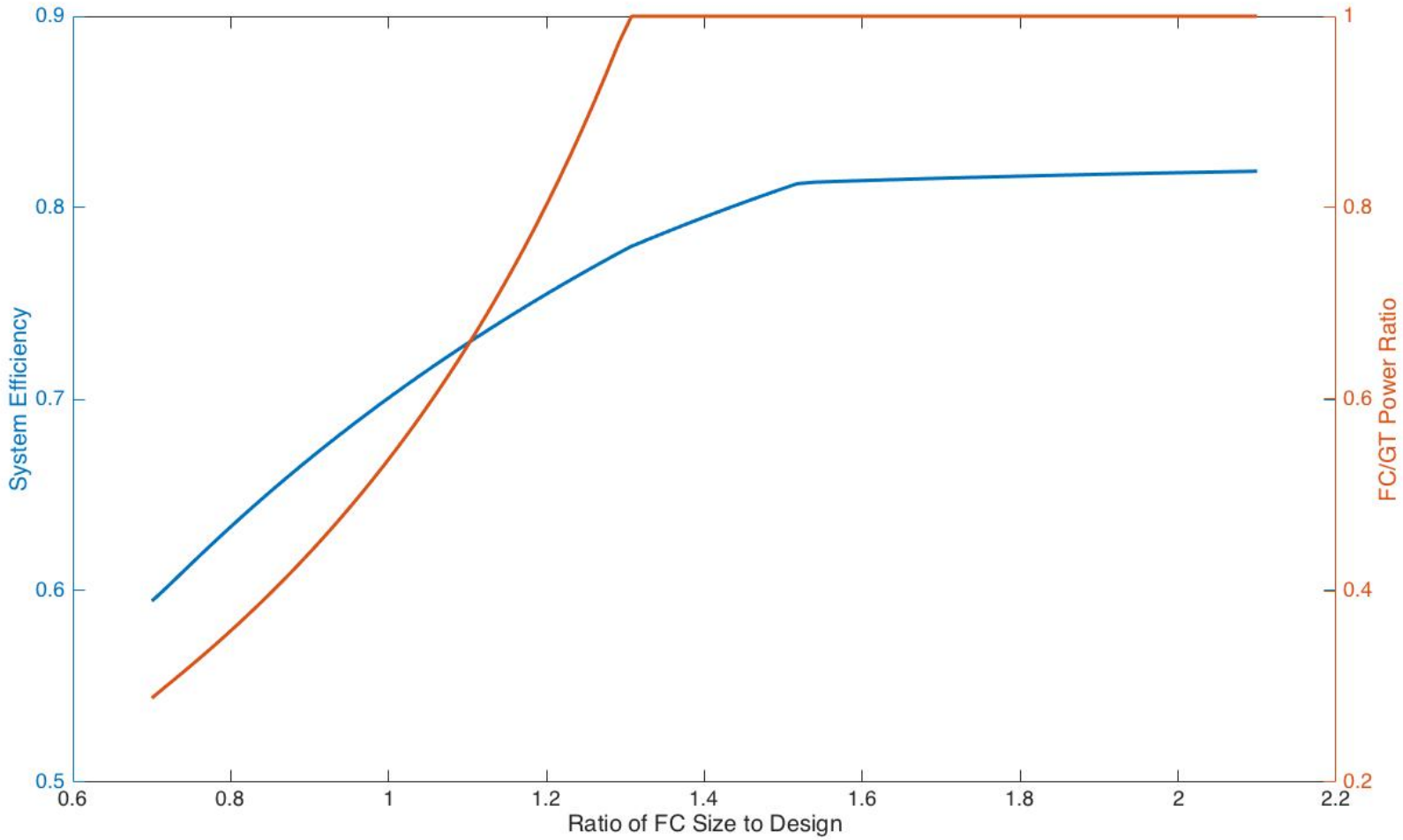
Sensitivity Analysis



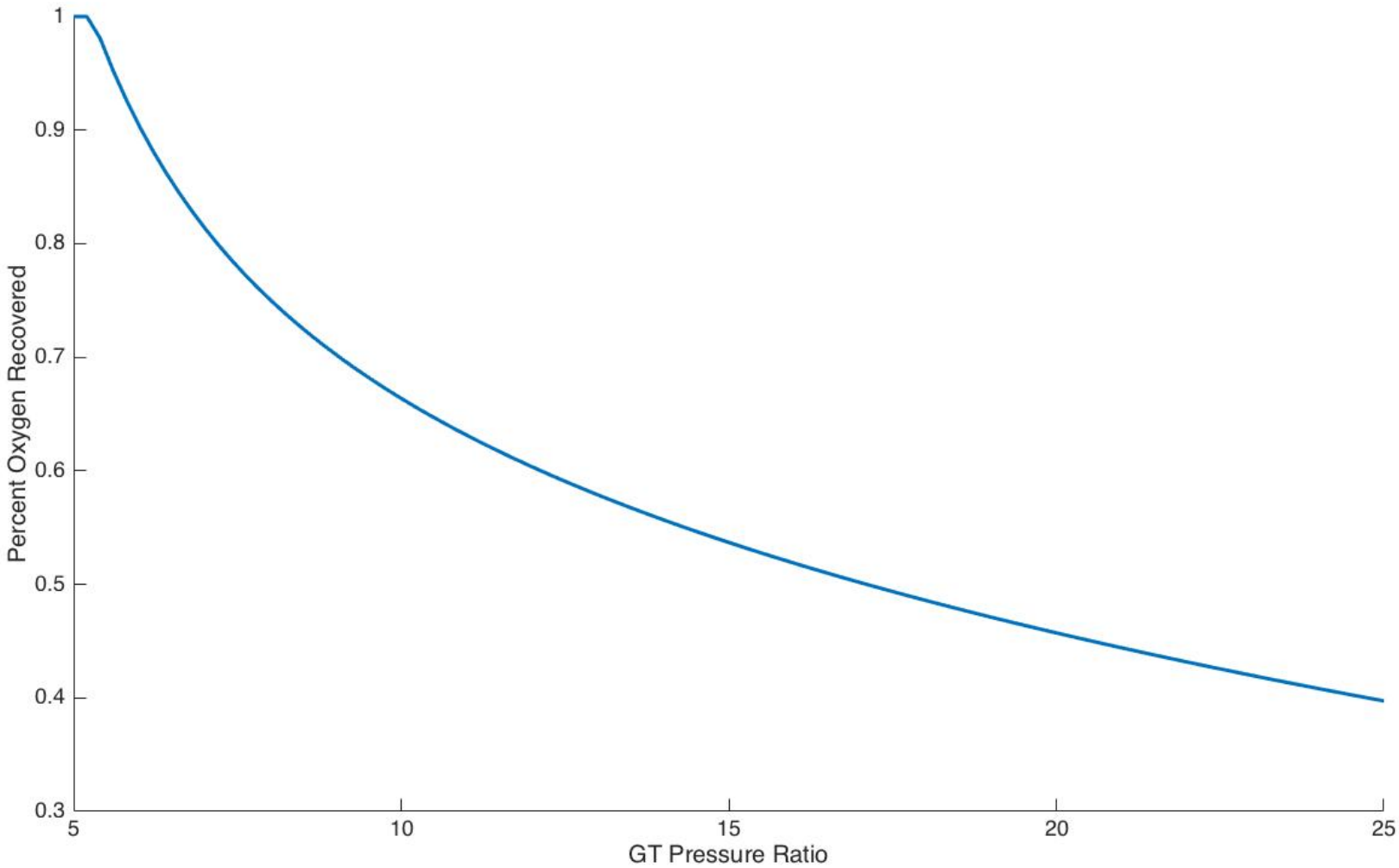
Varying Back Pressure



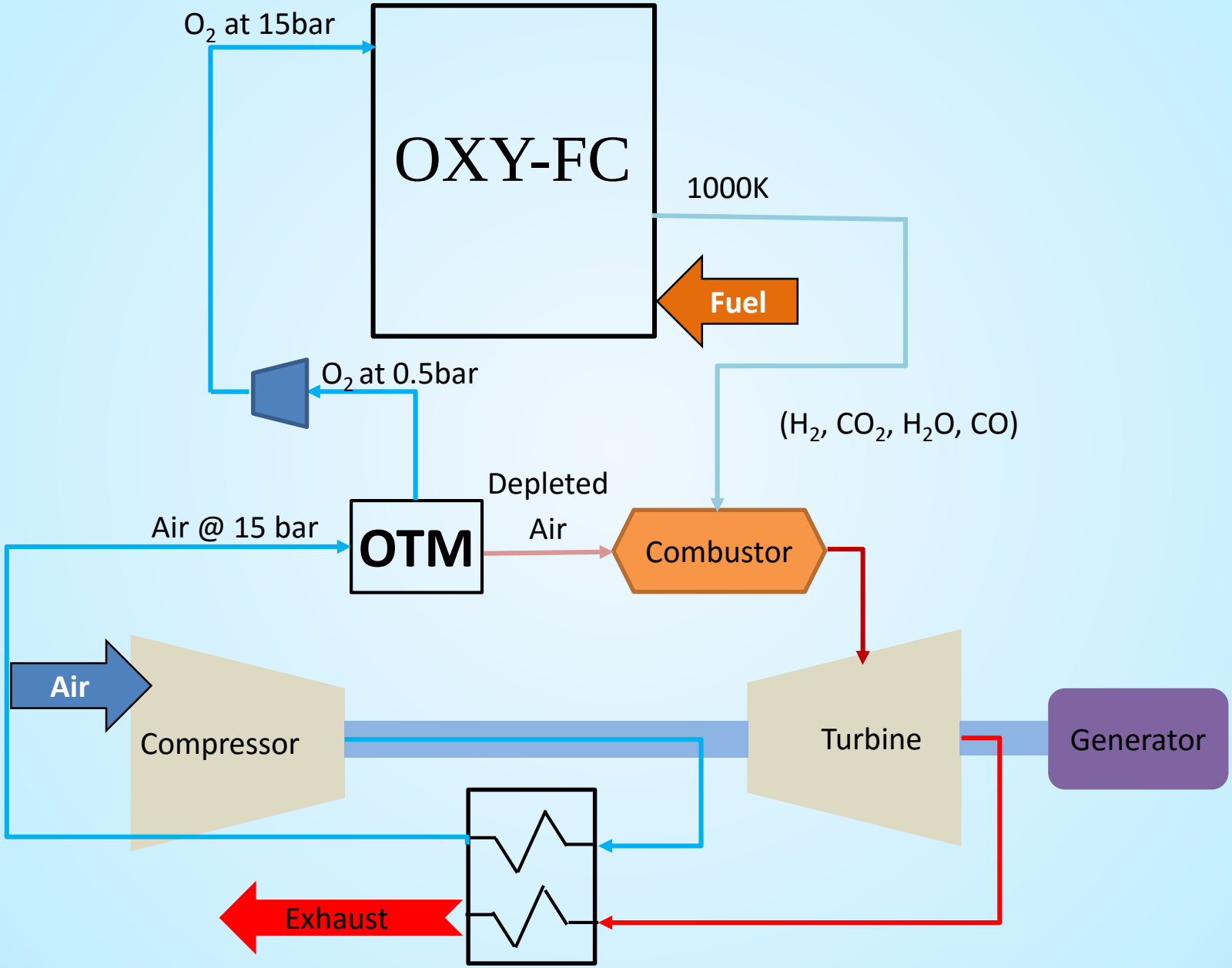
Varying Current Density



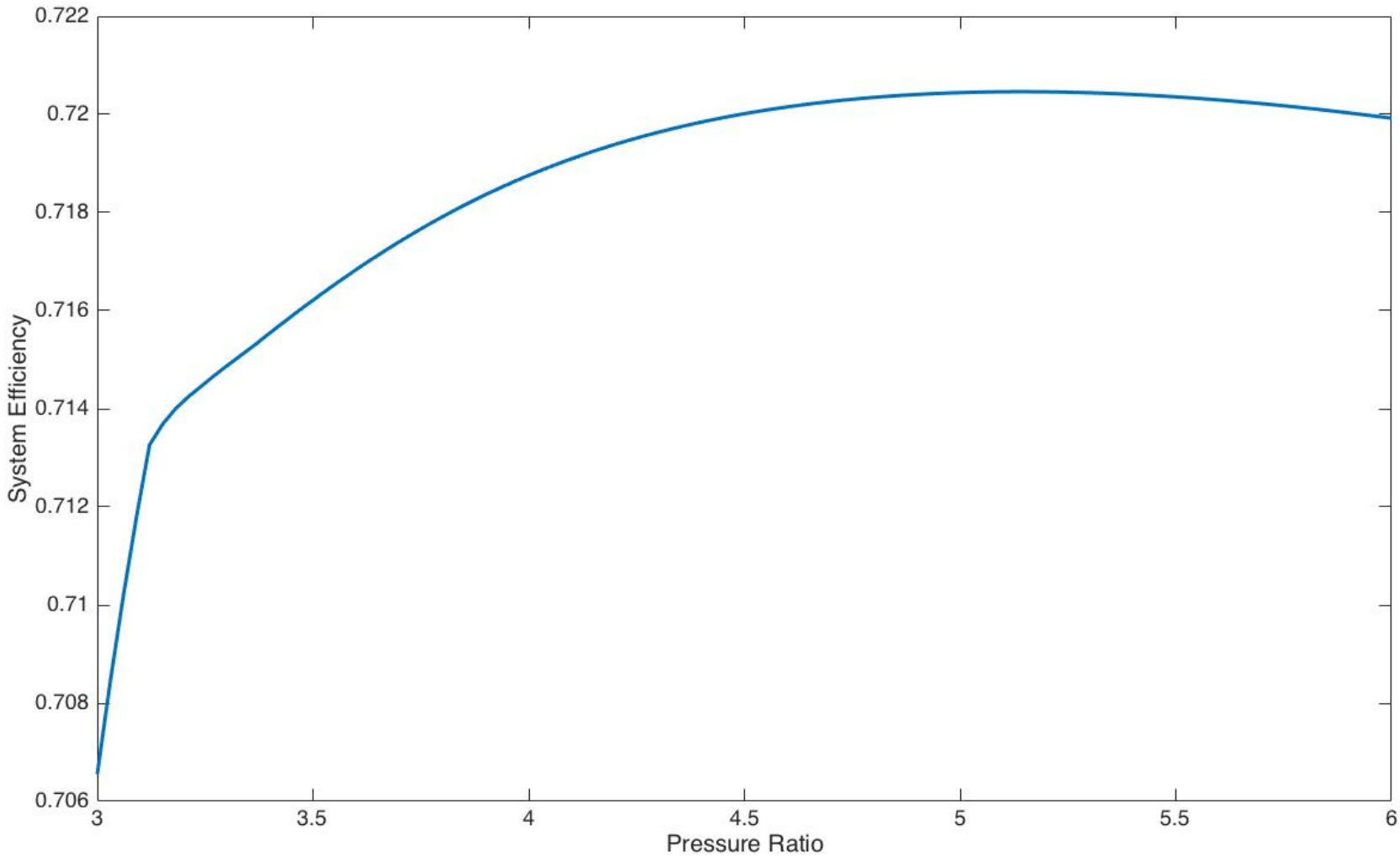
Varying Pressure Ratio



Heat Recuperation



Micro-Turbines

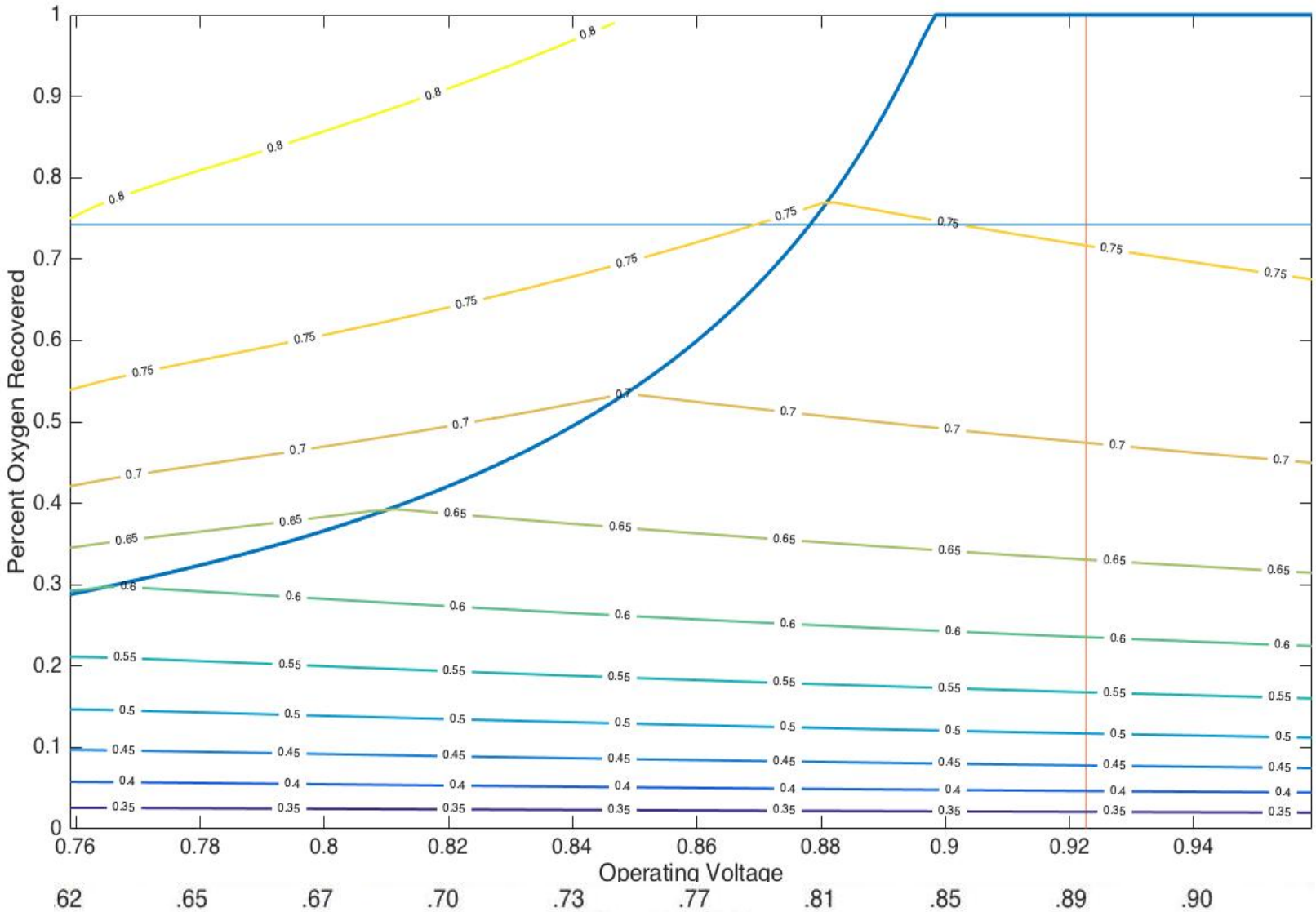


Potential Hydrogen Recovery

- » Excess Hydrogen buildup at the anode
  - > Presents opportunity to harness
- » Same Design Conditions
  - > .85 Volts
  - > 51% Recovery
- » Transportation grade fuel
- » Increase Net Efficiency

Toyota Mirai

Hydrogen Recovery



Conclusions

- » Design analysis shows potential for dFC-GT system configuration
  - > Addresses known challenges to FC-GT's
- » Verification of Oxy-FC
  - > Pressurization and supply of pure oxygen
- » Oxygen Transport Membrane
  - > Part-load operation
- » Retro-fit capability analysis
- » **QUESTIONS?**