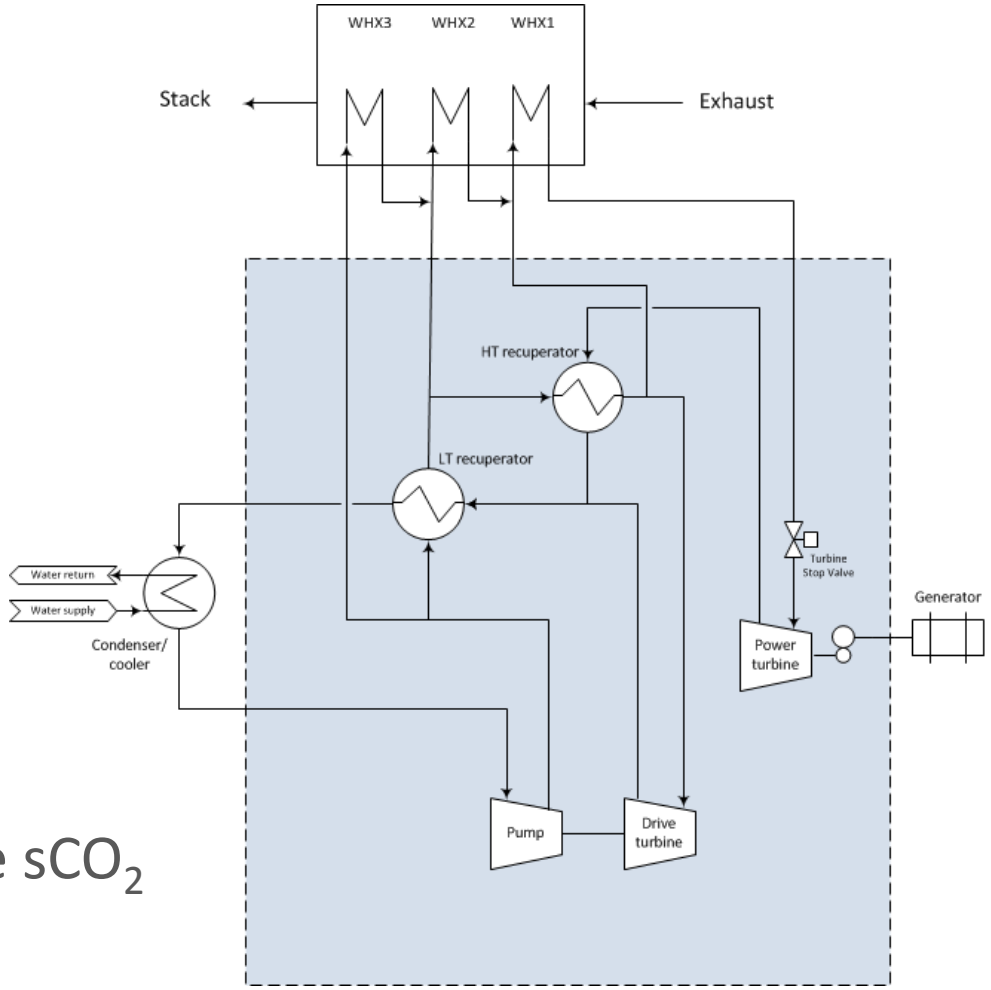
sCO_2 for WHR

Barriers to Entry and Help Needed

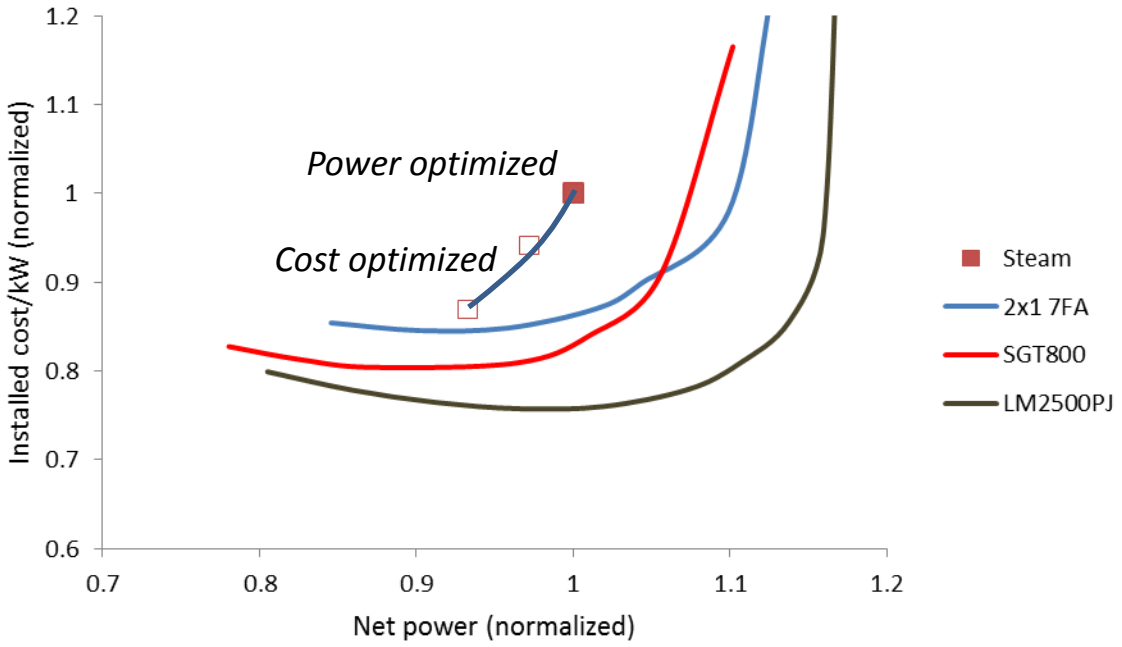
EPS100 & Dual rail WHR cycle

WHR cycle



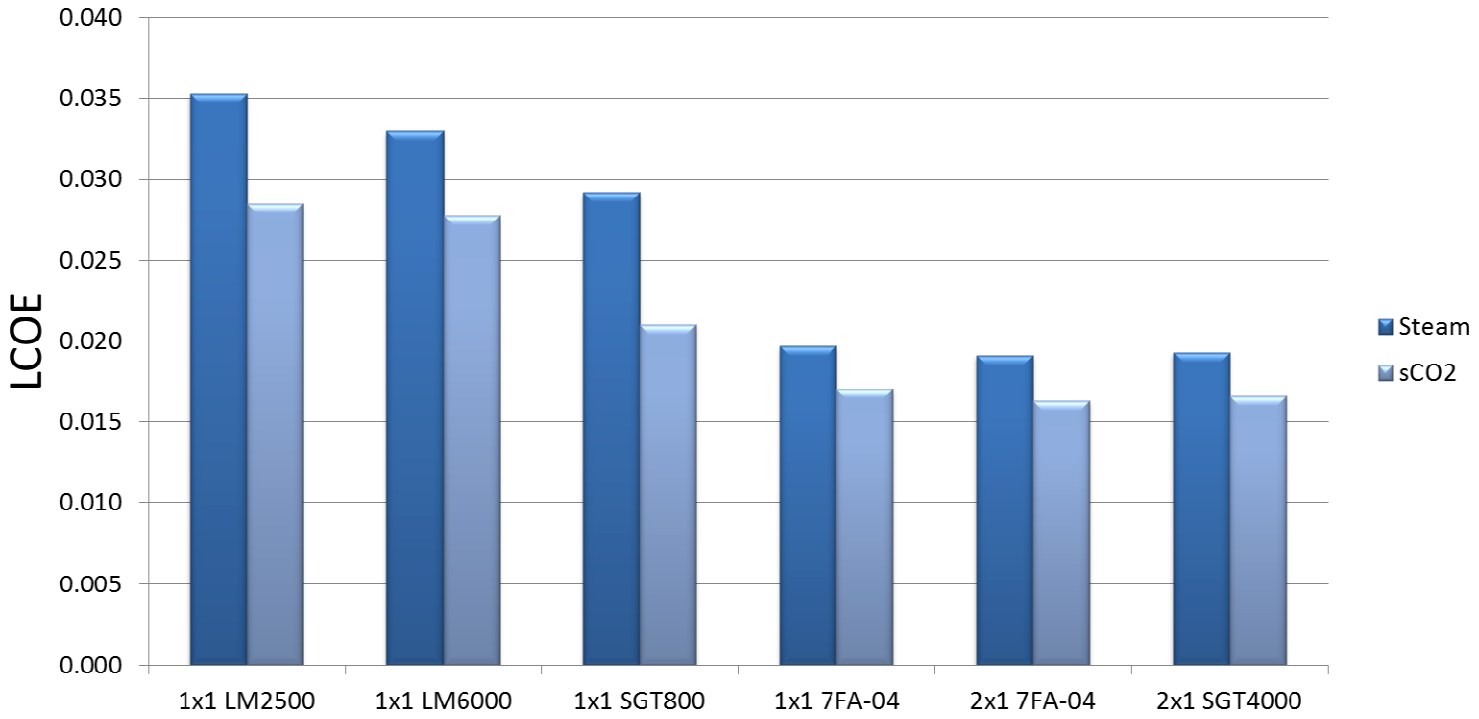
- EPS100 first commercial-scale sCO_2 engine
- Advanced cycle architecture to deliver high efficiency heat recovery

sCO_2 vs steam



- Normalized to steam power & cost from GT-Pro, “power-optimized” solutions (“cost-optimized” point shown for reference)
- Same exhaust and boundary conditions used for sCO_2
- 10-20% lower cost for same power
- 7-14% higher power for same cost

LCOE comparisons



- Case studies covering 30-800+MW
- Plant LCOE consistently lower with sCO_2

Barriers to entry

- Technical risk
- Market driven economics

A simple LCOE analysis

- 2 cases
  - Simple (open) cycle gas turbine (SC)
  - Combined cycle gas turbine, with generic bottoming cycle (BC)
- Calculate an LCOE for SC by itself, and incremental LCOE for BC

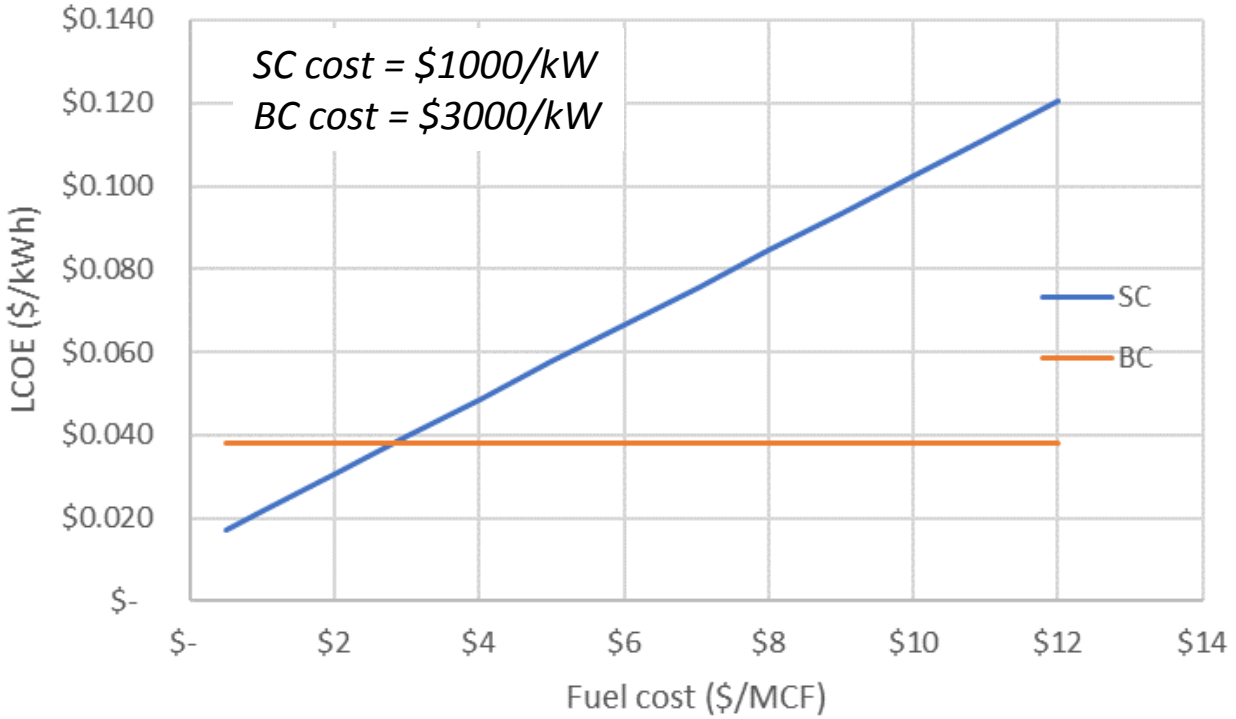
LCOE inputs

$$COE = (\beta \cdot C)/(P \cdot H) + f/\eta + OM/H + \mu \cdot OM(v,b)$$

where
β = Levelized carrying charge factor or cost of money
C = Total plant cost ($)
H = Annual operating hours
P = Net rated output (kW)
f = Levelized fuel cost ($/kWh)
η = Net rated efficiency of the combined-cycle plant (LHV)
OM = Fixed O&M costs ($/kW-yr)
$OM(v,b)$ = Variable O&M costs for baseload operation ($/kWh)
μ = Maintenance cost escalation factor (1.0 for baseload operation)

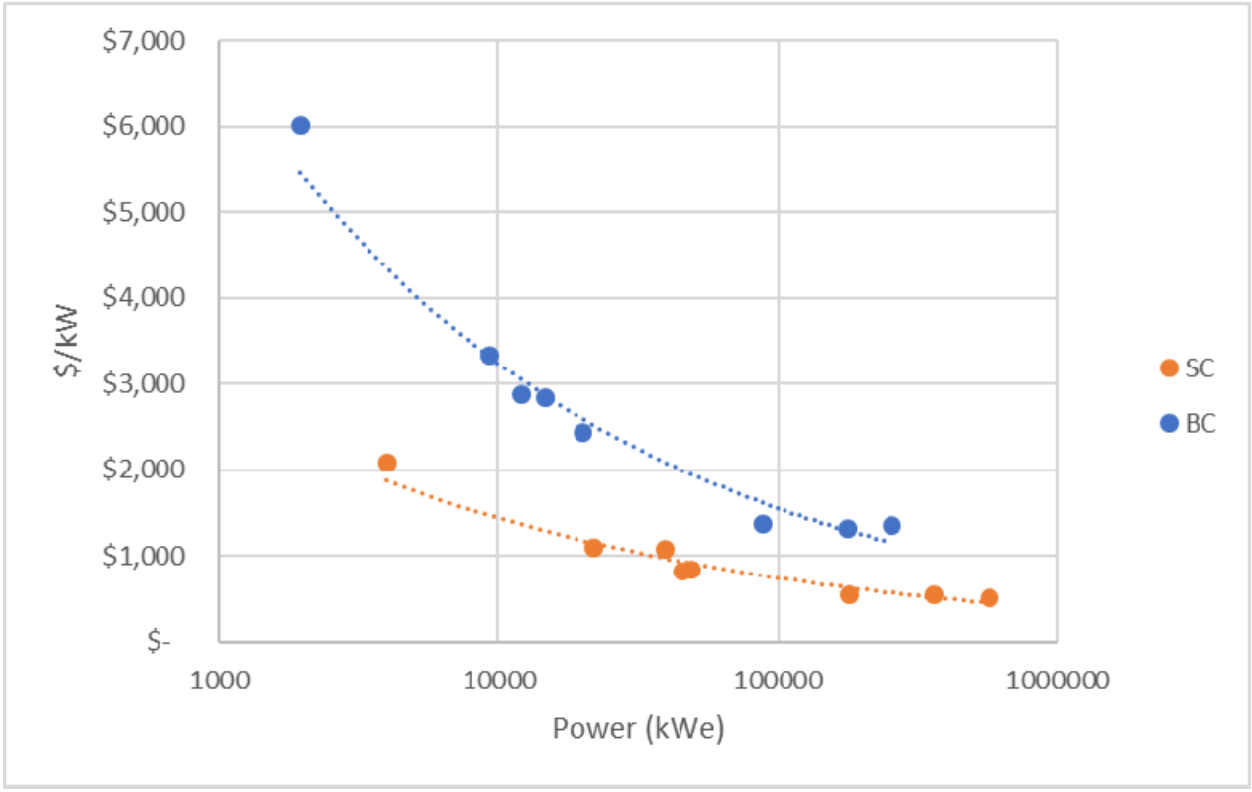
- Assumptions:
  - Ignore O&M costs for now
  - SC efficiency of 38% (range is 36-41%)
  - 80% utilization

Breakeven LCOE



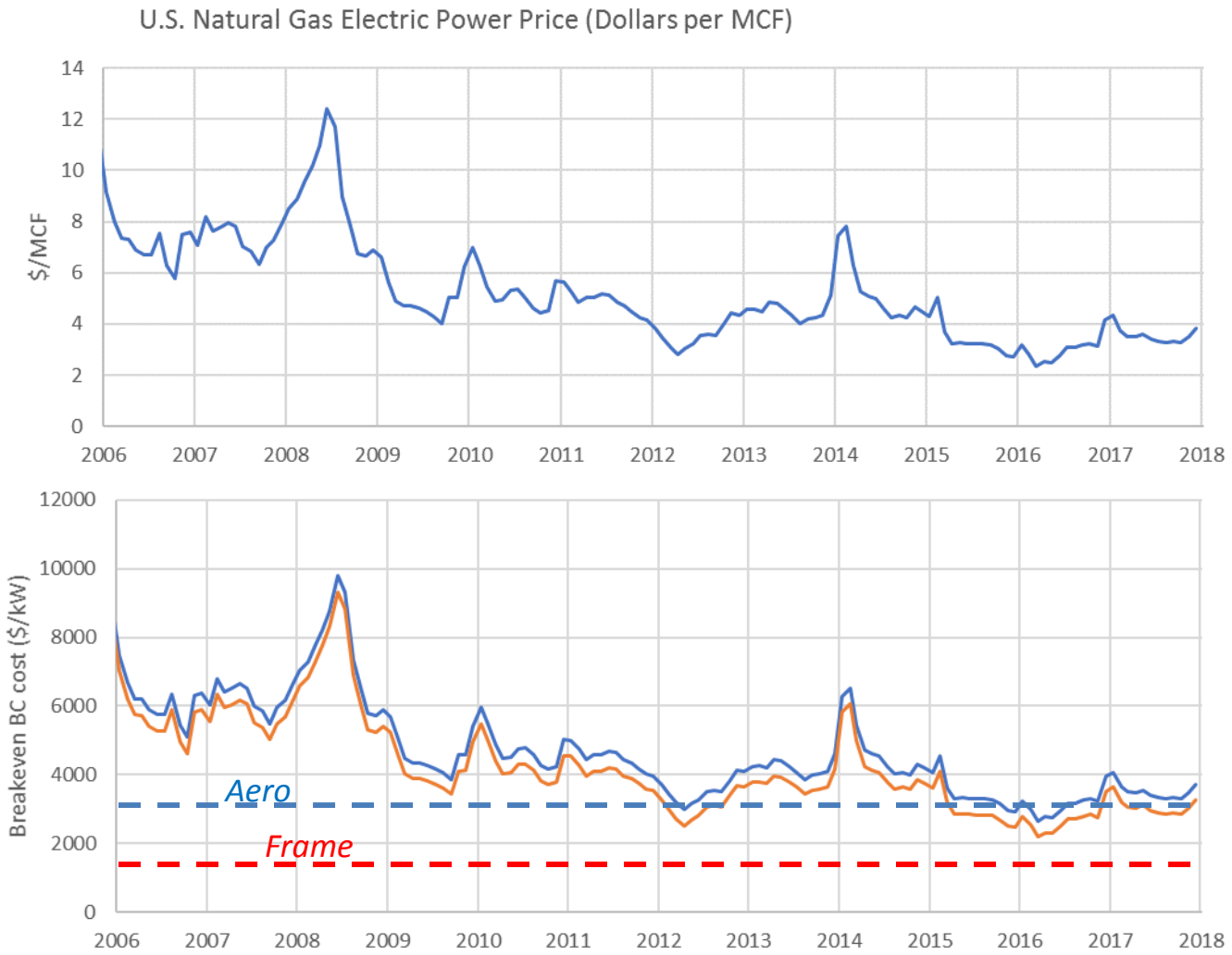
- SC LCOE has both capex and fuel costs
- BC LCOE has capex contribution only
- Below “breakeven” fuel cost, SC plant produces power at lower LCOE than CC plant

Current SC and BC costs



- From GTW Handbook & GT-Pro analysis
- 20-50MW class GTs (aeroderivatives)=$1000/$3000 per kW
- 100+MW class GTs (frames) = $550/$1300 per kW

Fuel price history (US)



Low natural gas prices, and 20-50MW GT scales make for a difficult value proposition

“Help needed”

- Higher natural gas prices would help… but not much control
- Need to make the jump to larger GT sizes
  - Financial risk mitigation needs reasonable (2-3 years) operation
  - 20-50MW commercial operation will require financial assistance (carbon credits, favorable PPA) to make economic-only value proposition work
  - Emphasize water-free operation, low O&M potential
  - Expand to target markets with either higher gas prices or applications with fundamentally different economics