Hybrid Energy Storage

Progress and Opportunities

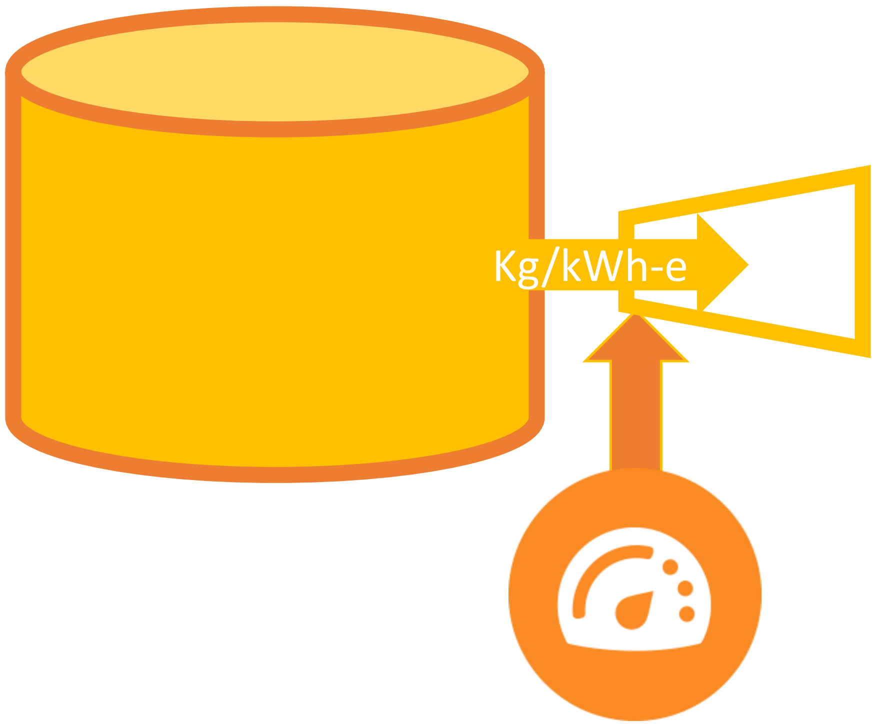
William M. Conlon, P.E., Ph.D.

2024 Thermal/Mechanical/Chemical Energy Storage Conference

1 August 2024

Efficiency must serve economy

Capital Cost driven by Storage Medium

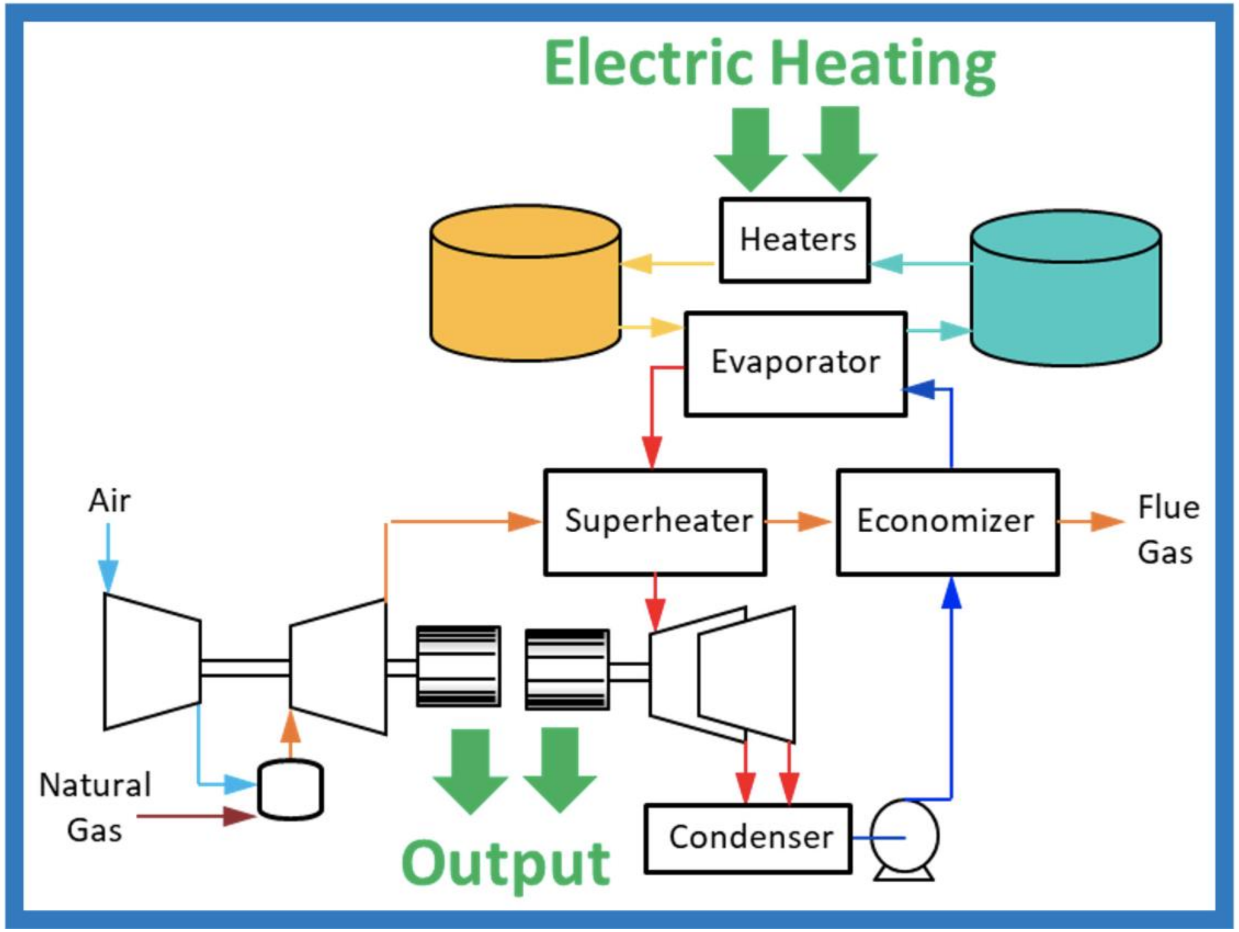


- Storage medium
  - Low cost ($/kg)
  - Low specific discharge flow rate (kg/kWh-e)
- Storage reservoir
  - High density medium (kg/m^3)
  - Material compatibility w/ medium
- Charge/discharge processes
  - Fluid: storage medium is transport medium
  - Decouple charge and discharge

Fuel reduces specific flow rate and specific CAPEX ($/kWh-e)

Liquid Salt Combined Cycle™ (LSCC)

Supported by DE-FE00320016



Source: Electric Power Research Institute. 2022. [Retiring Fossil Plants: Utilizing Thermal Energy Storage Technology for Longer Duration Energy Storage Deployment]()

EPRI System Readiness Assessment

- "The design of the LSCC follows a strategy of simplification and conservatism"
- "The system's readiness level is high, attributed to the inclusion of mature technologies."
- "A full-scale system is the imminent step."

Sources:

EPRI Program 217, Product 3002026290 System Readiness Assessment of Thermal Energy Storage for Gas Turbine-Based Power Plants: Status, Risks, and Potential Paths Forward. Dec 20, 2023

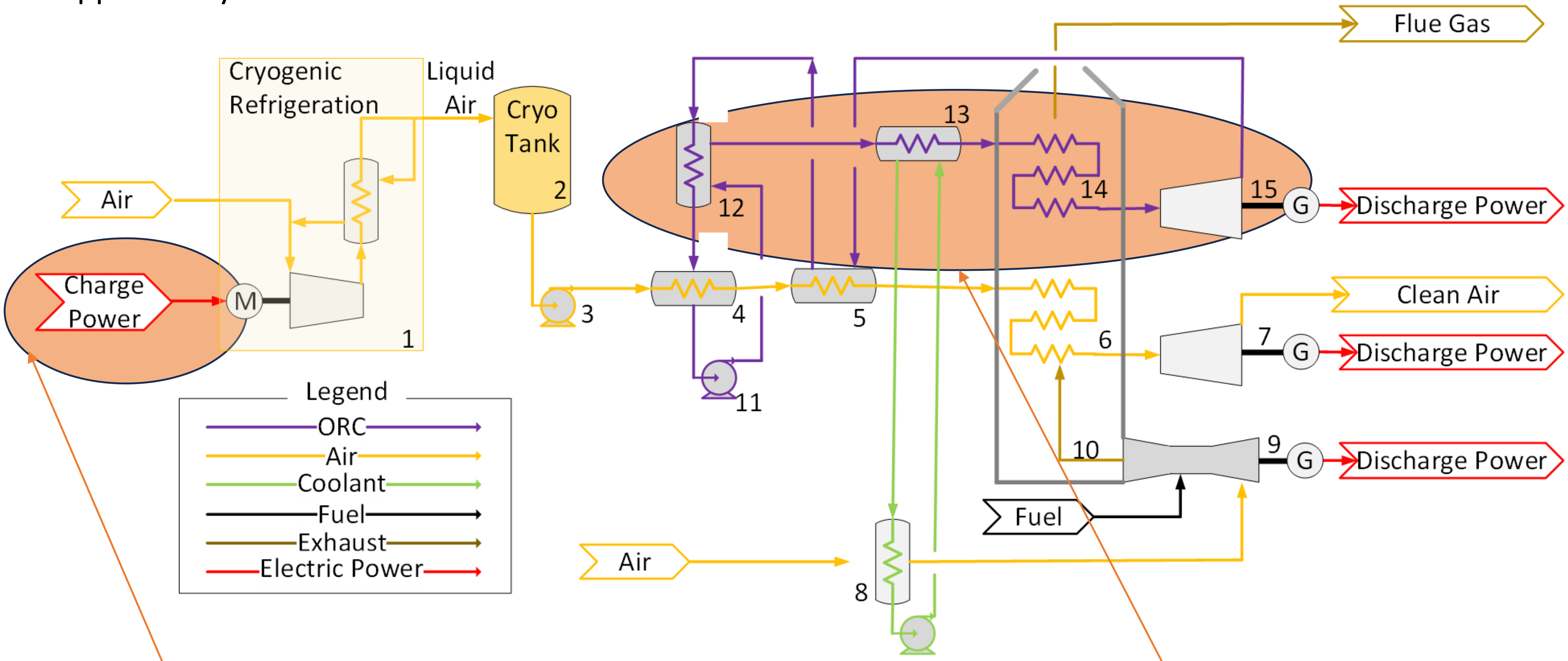
L. Angello et al., TECHNOLOGY READINESS ASSESSMENT OF THERMAL ENERGY STORAGE INTEGRATED WITH GAS TURBINE POWER PLANTS, ASME GT2024-126653

Liquid Air Energy Storage Opportunity

- Storage medium
  - Air is free
  - Air is non-toxic
  - Liquid air
    - Very high energy density
    - Atmospheric pressure storage
    - Low loss rate: <0.1%/day
- Scalable
  - Tank costs <$1/kWh-e at scale
  - Air consumption: ~2.5 l/kWh-e
  - Tank stores >75GWh-e
  - Low land use: up to 30 GWh-e/acre

Liquid Air Combined Cycle™ (LACC)

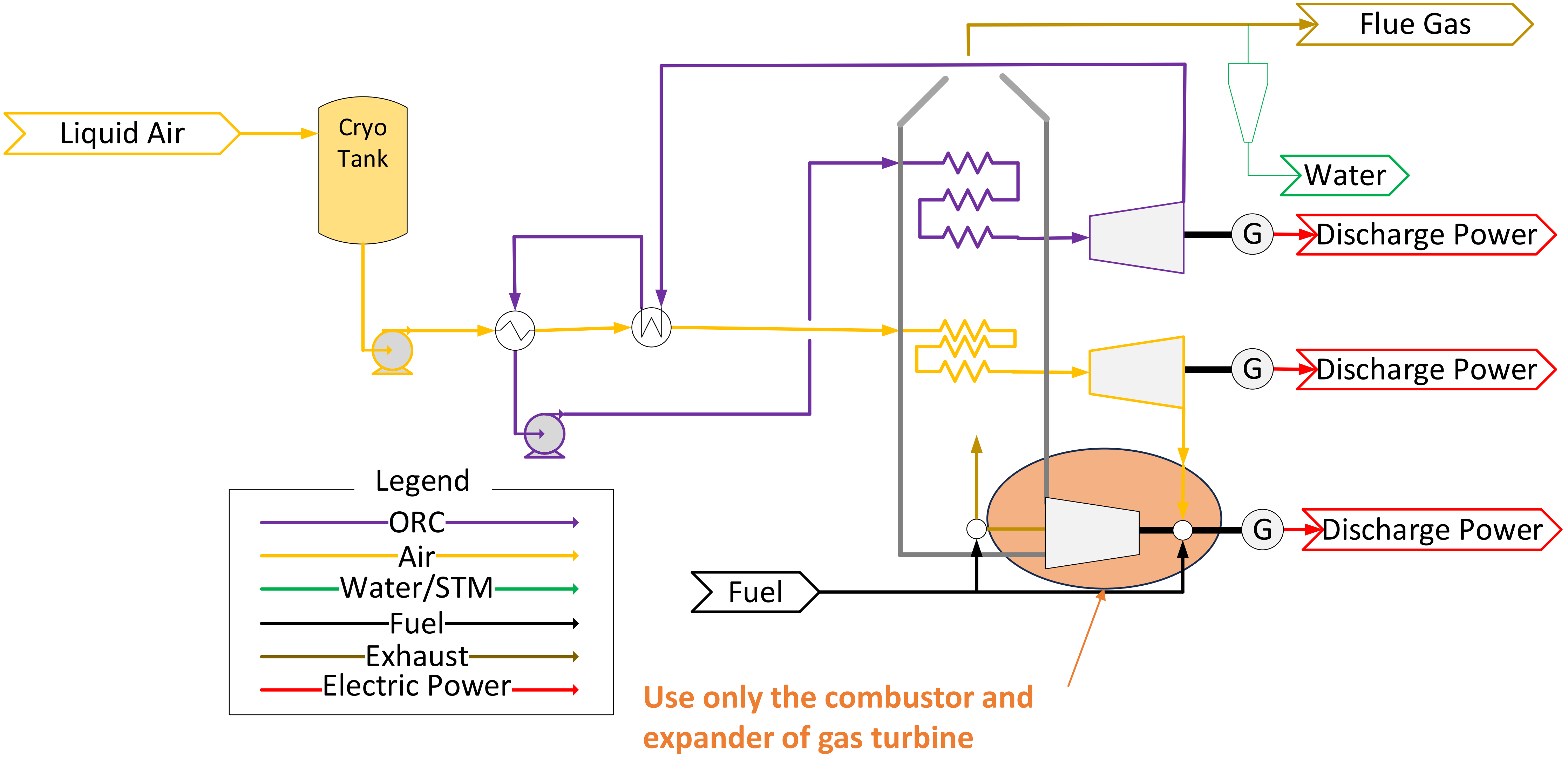
Supported by DE-FE0032002



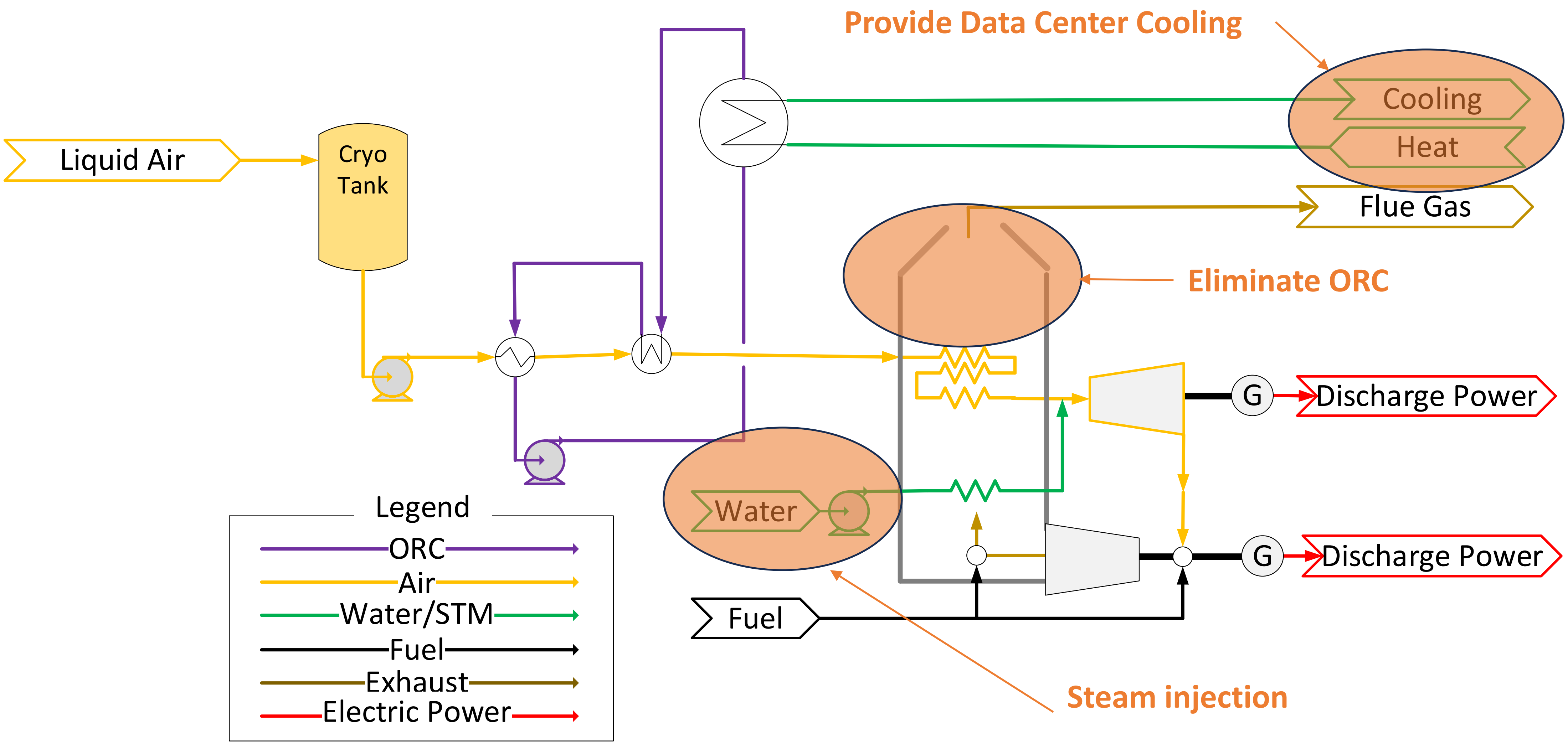
Charge energy reduced from 0.439 to 0.380 kWh/kg

Revised ORC to use COTS Generator Loaded Expanders

HPLAPS: High Pressure Liquid Air Power & Storage



HP-LAPS + Steam Injection



Hybrid Performance

Fuel reduces fuel heat rate and specific flow rate

System	Power (kW-e)	Fuel Heat Rate (Btu/kWh-e)	Primary Energy Rate (kWh-e/kWh-e)	Specific flow rate (kg/kWh-e)	Storage density (l/kWh-e)
LSCC	125,730	4141	0.99	10.35	5.85 x 2 tanks
LACC	117,320	4421	0.84	2.22	2.52
HP-LAPS	189,519	4215	0.97	2.56	2.92
HP-LAPS (Steam)	178,382	4925	0.85	2.23	2.54
HP-LAPS (H-class)	217,417	4108	0.85	2.24	2.54
CT-CAES[1]	400,000	3696	0.69	4.275	58.1
A-CAES[1]	72,200	0	1.34	7.48	94.8

Low fuel heat rate ideal for low-carbon fuels

[1] Shainker et al. New Utility Scale CAES Technology: Performance and Benefits (Including CO2 Benefits) https://www.sandia.gov/files/ess/EESAT/2007_papers/0010.pdf

Why Hybrid Storage + Generation? *SYNERGY*

- Reduced capital cost of storage
  - Less storage media
  - Higher density
- Reduced marginal cost of energy
  - Less fuel (and emissions)
  - Less stored electricity
- More economical on hydrogen
- Higher asset utilization
  - Increased capacity factor
  - Leverages proven equipment

Questions?

Bill.Conlon@PintailPower.com

http://www.PintailPower.com

@pintailpower

+1 650 327 2175