Supercritical $CO_2$ Power Cycles Symposium

# Technoeconomic Analysis of Low Temperature Reservoir Technologies for $sCO_2$ based Pumped Thermal Energy Storage Systems


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# Overview

- PTES Background
- Low temperature reservoir technologies:
  - Ice-on-Coil (IOC): Echogen Power Systems
  - Icephobic heat exchanger ($I^2HEX$): Active Energy Systems
  - Supercooler heat exchanger (SCHE): SPF Institute of Solar Technology
- Results and discussion

Acknowledgements:

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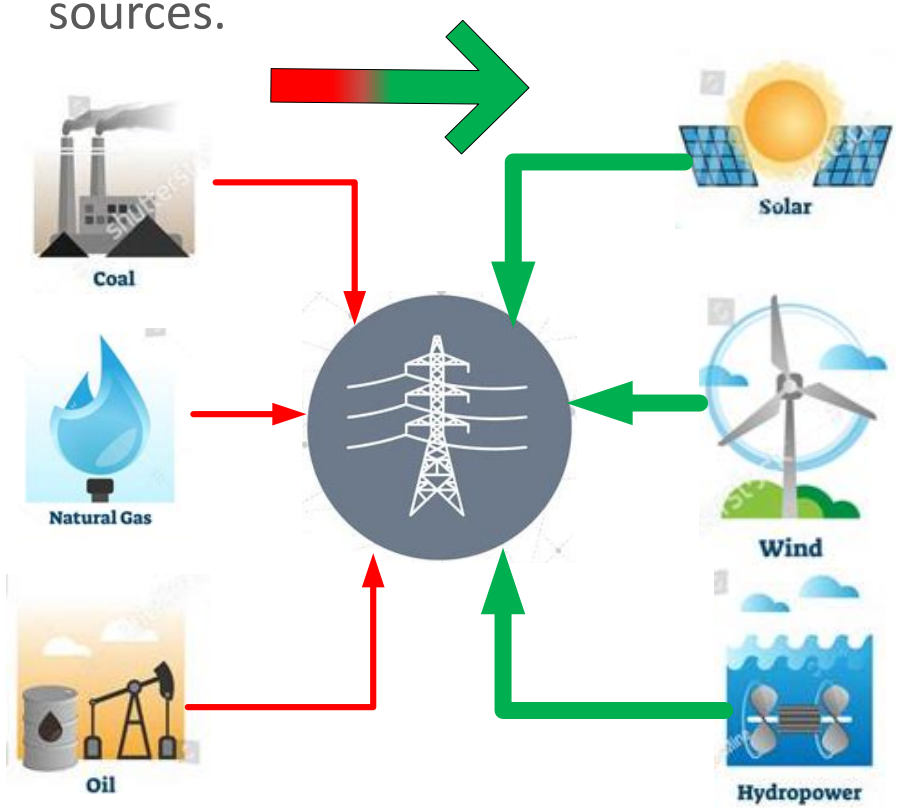
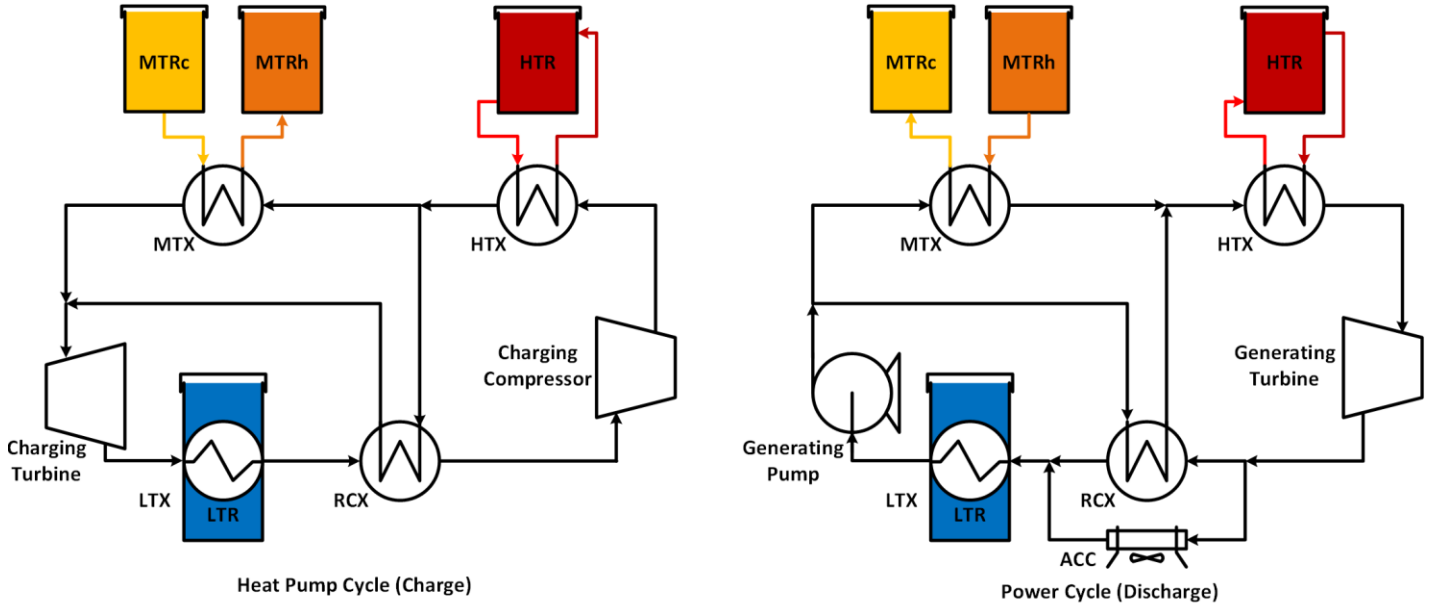
# $sCO_2$ based Pumped Thermal Energy Storage System

- Electrical Grid reliability at risk as we move away from traditional energy sources and increase dependence on renewable energy sources.




- Echogen's $sCO_2$ based PTES technology



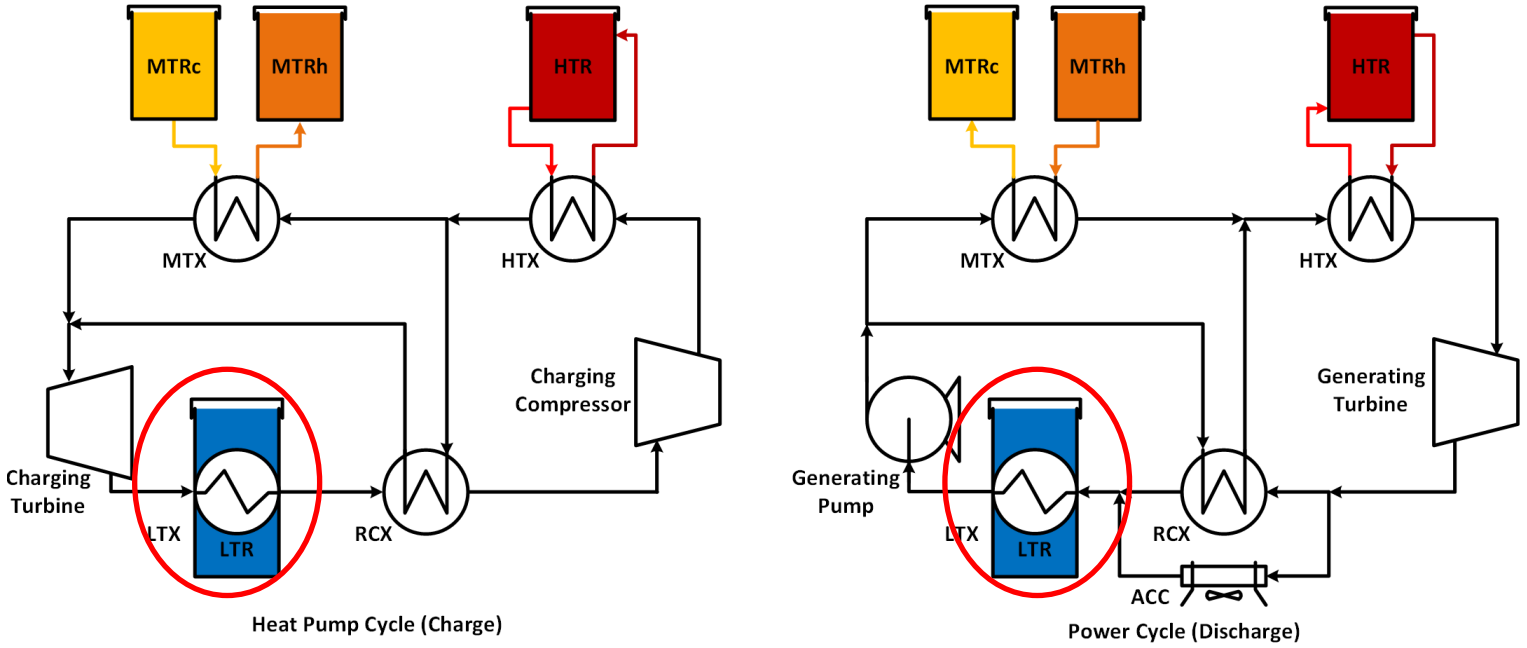

**Legend**

| | | |
|---|---|---|
| LT – Low Temperature | MT – Medium Temperature | HT – High Temperature |
| RC – Recuperative | __X – Heat Exchanger | __R – Reservoir |
| ACC – Air-cooled Condenser | __h – "hot" | __c – "cold" |

# $sCO_2$ based Pumped Thermal Energy Storage System

**Focus of present study: LTR technologies**

1. Ice-on-Coil (IOC)
2. Icephobic heat exchange ($I^2HEX$)
3. Supercooler heat exchange (SCHE)

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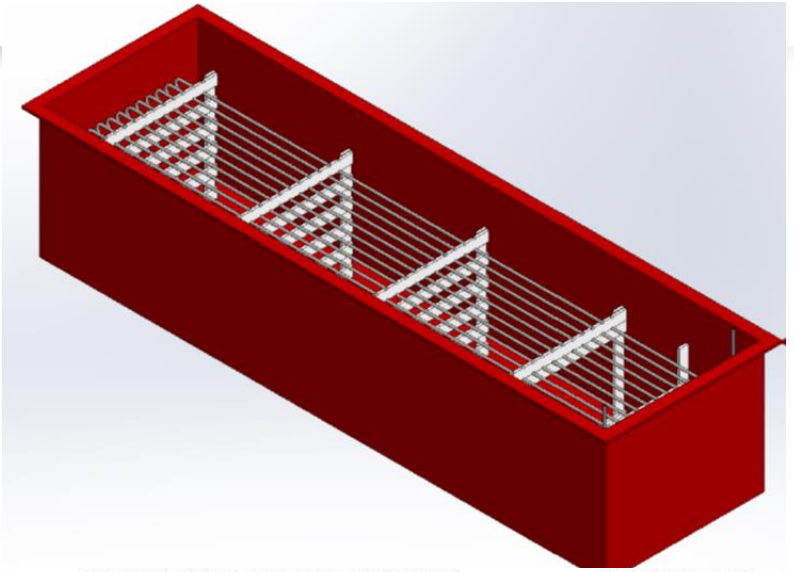
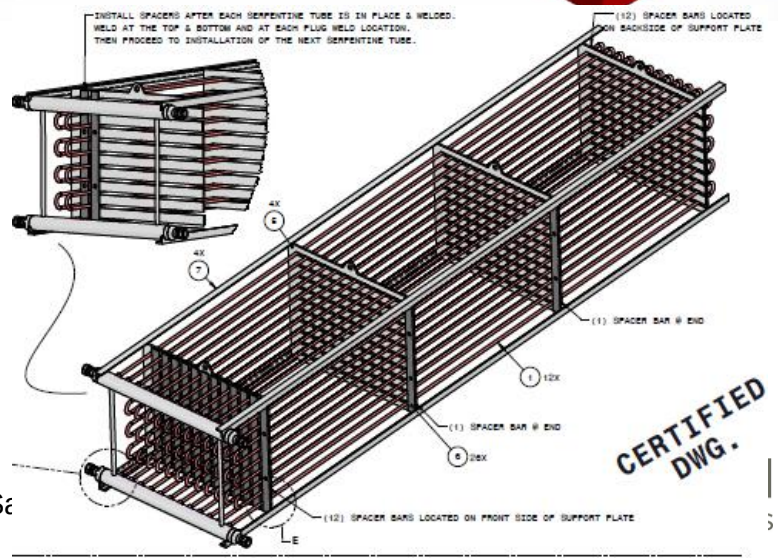
ECHOGEN power systems

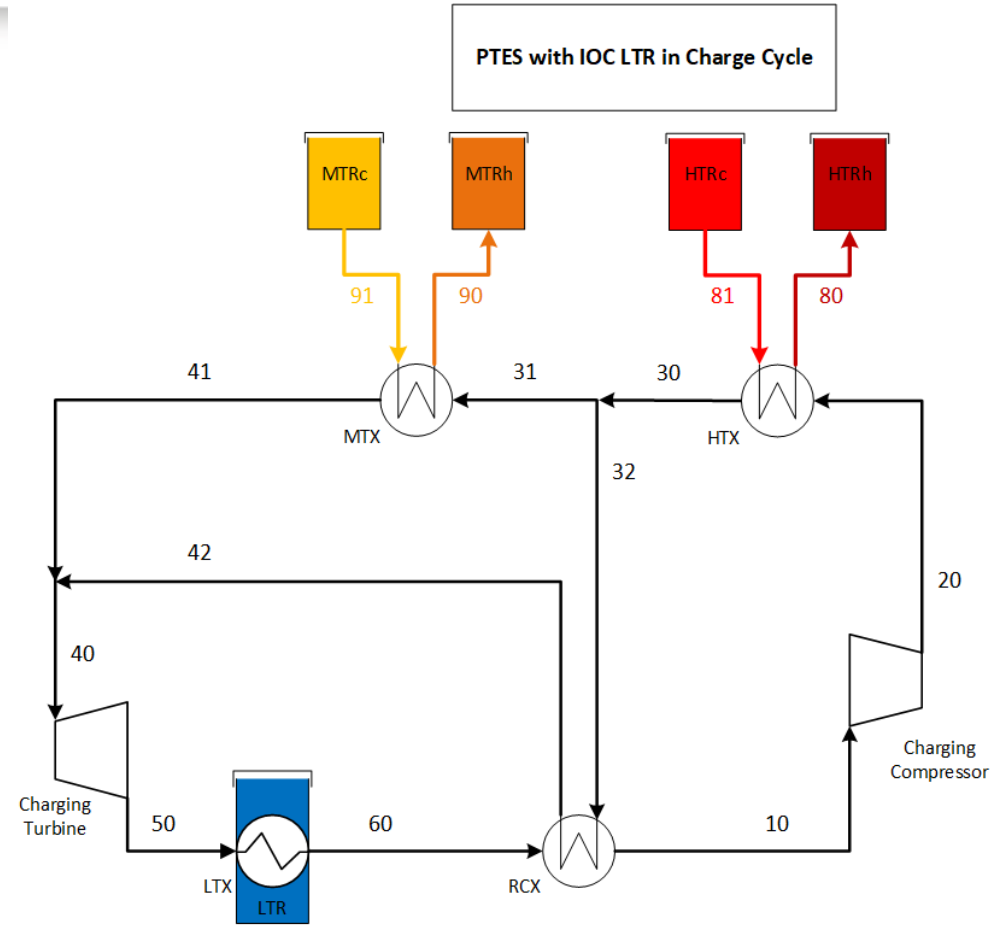
# 1. Ice-On-Coil

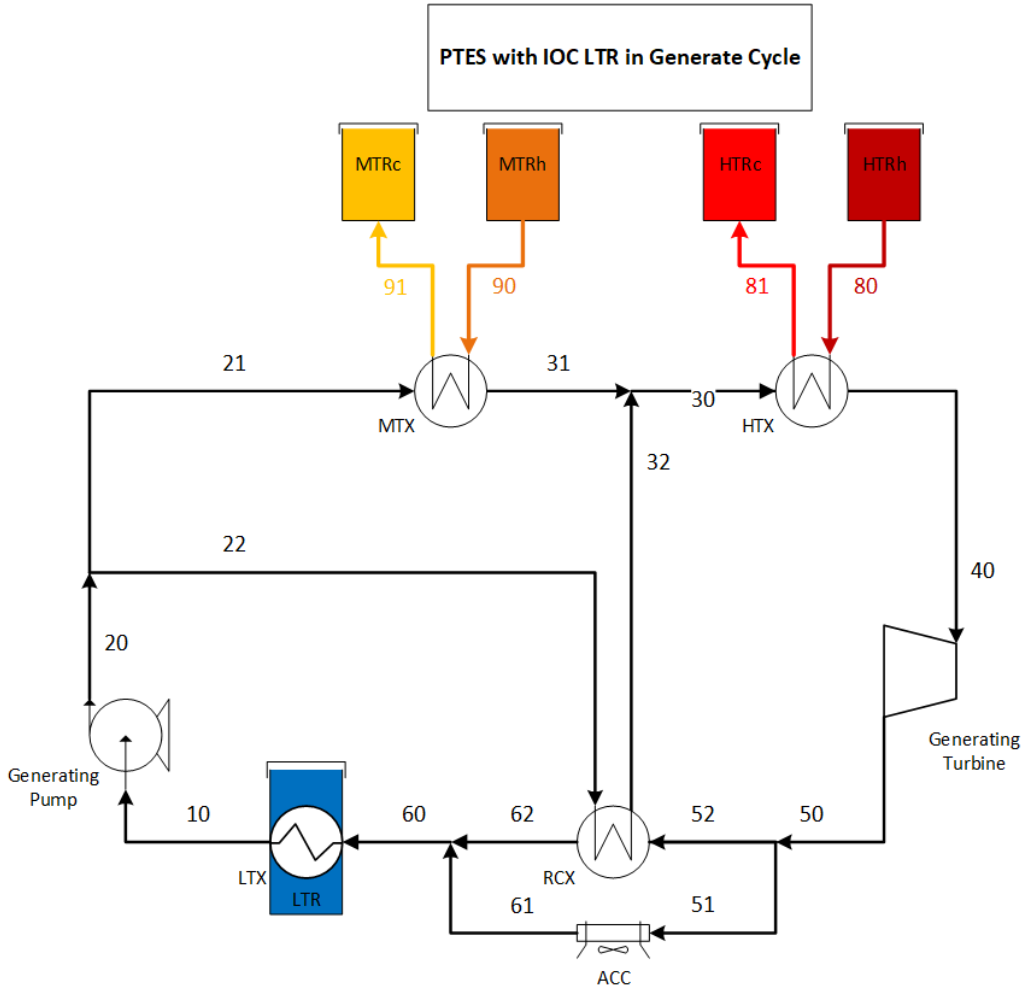
- IOC mainly consists of embedded tube banks in static bath of water.
- Charging: Saturated $CO_2$, at about −3°C to −5°C, flows through the embedded tubes causing the water to freeze on the outer surface of the tube transiently while vaporizing the $CO_2$.
- Generating: Relatively warm $CO_2$ (about 20°C) flows through the tubes causing the ice on the outer surface of the tube to melt while the $CO_2$ is cooled to saturated liquid conditions.
- Example: For 100 MWe: 220,580 tubes – 100ft/tube, ½”-0.035WT – about 8.6MM gal tank.





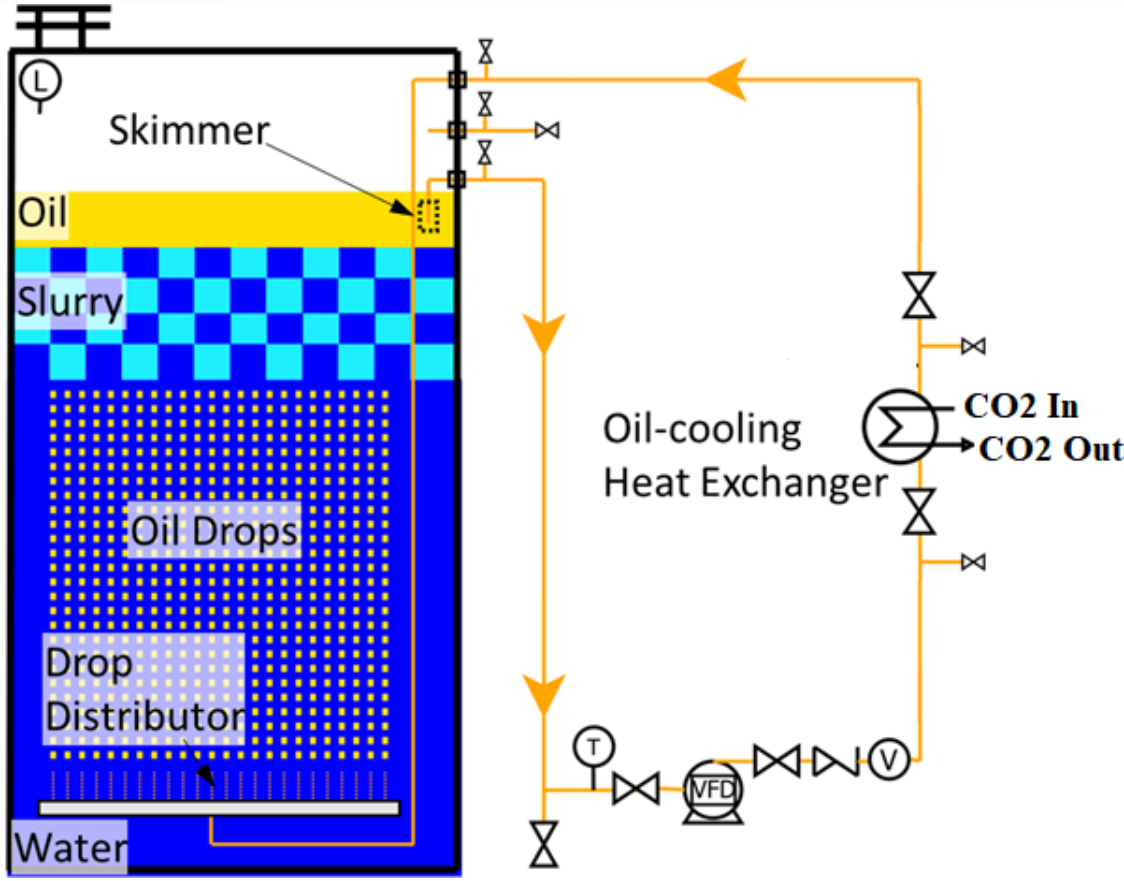
# 1. Integration of Ice-on-Coil into PTES System



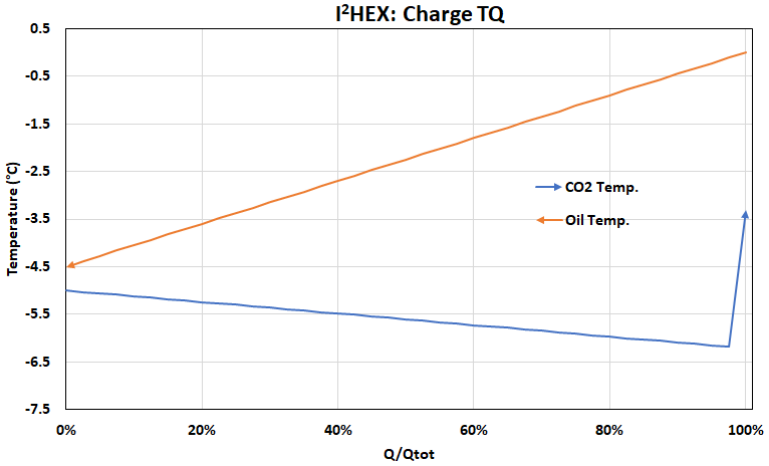



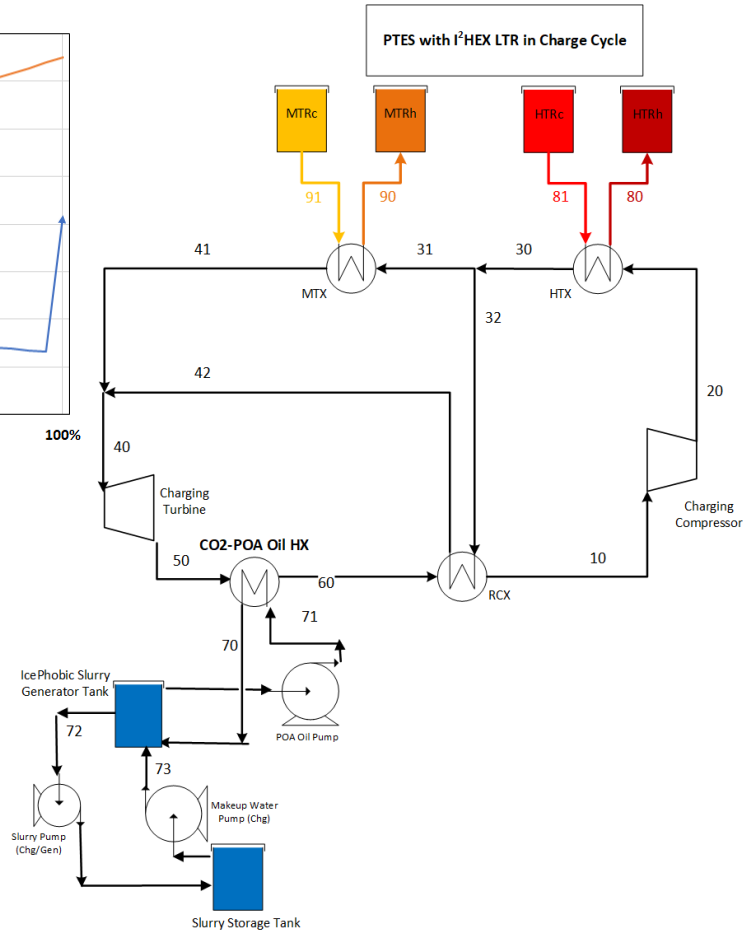
# 2. Icephobic heat exchange ($I^2HEX$)

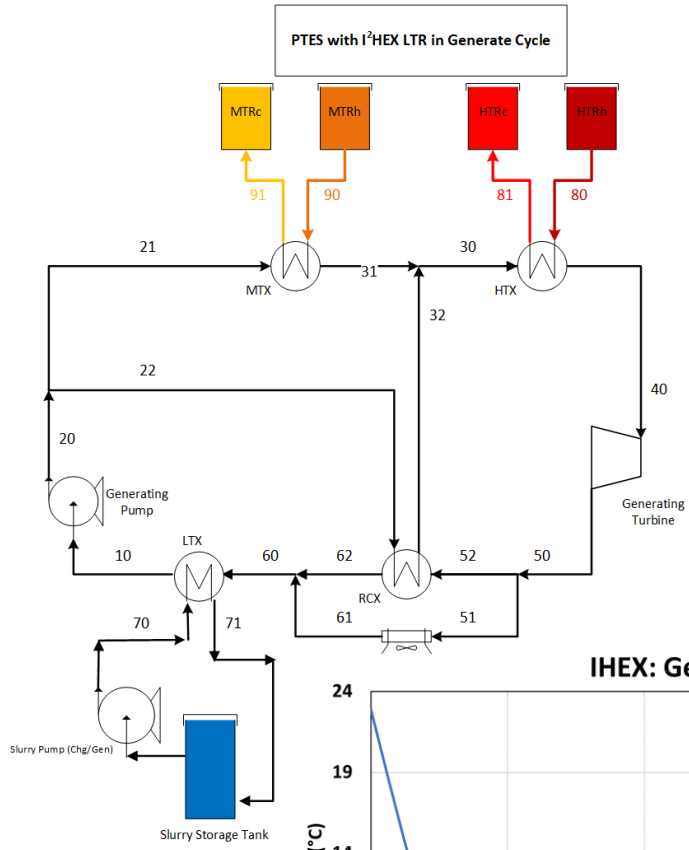
- $I^2HEX$ developed by Active Energy Systems, Oakridge, Tennessee.
- $I^2HEX$ is ice-slurry generator technology.

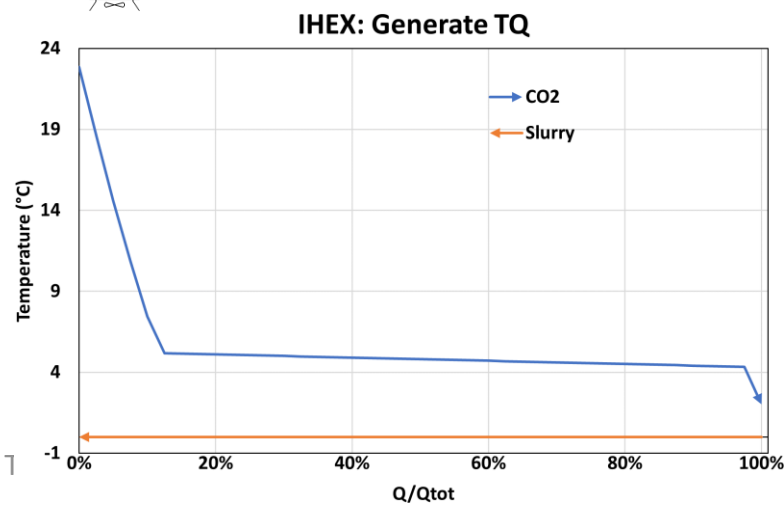


# 2. Integration of I²HEX into PTES System



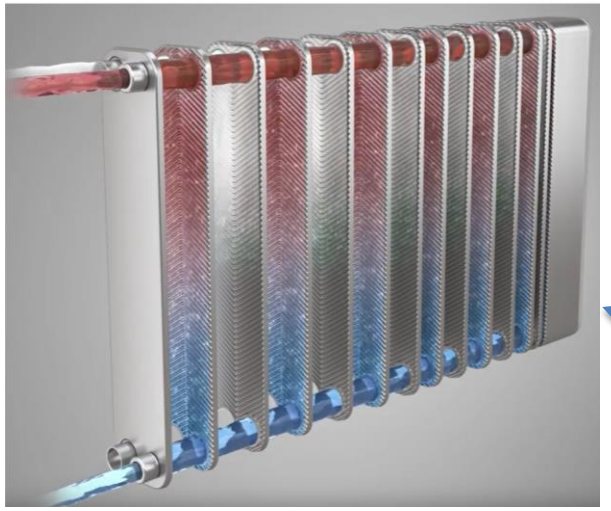



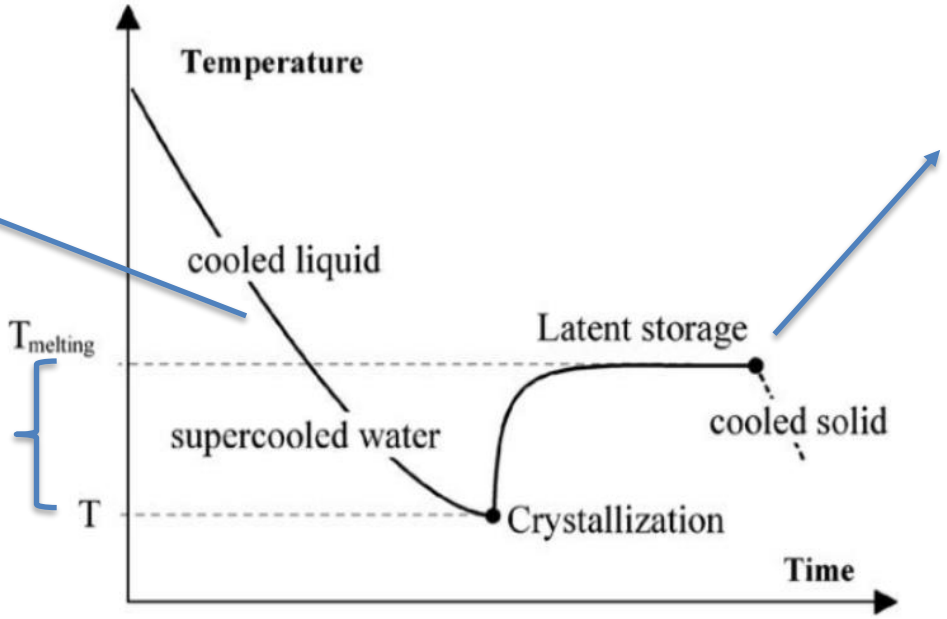



# 3. Supercooler Heat Exchanger (SCHE)

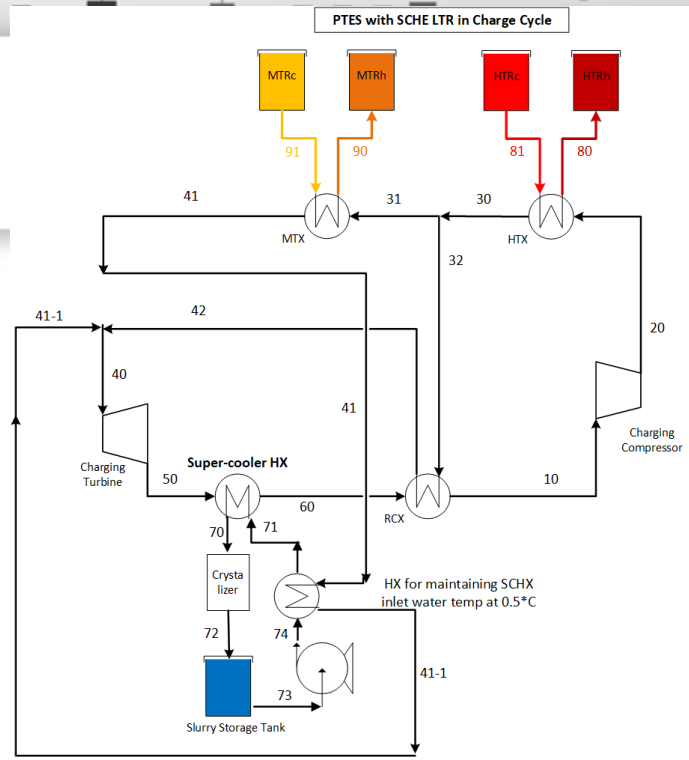
- SCHE is ice-slurry generator technology.
- Developed by SPF Institute of Solar Technology based in Rapperswil, Switzerland

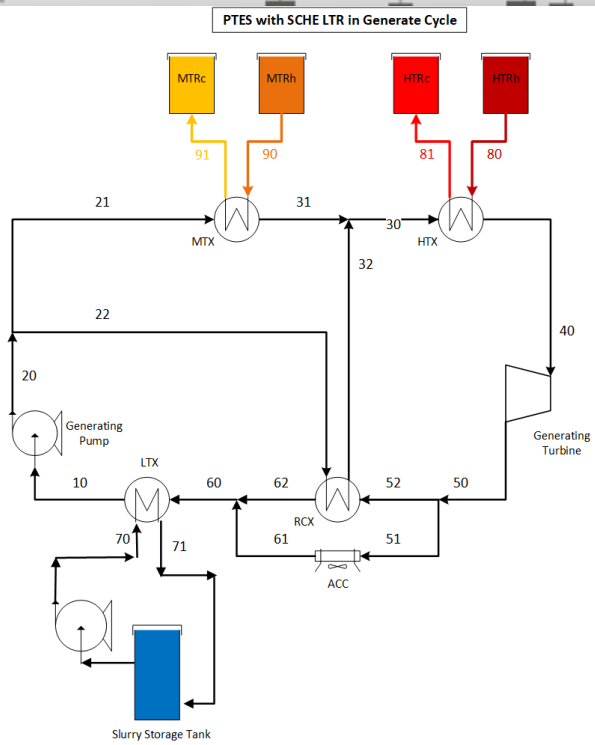


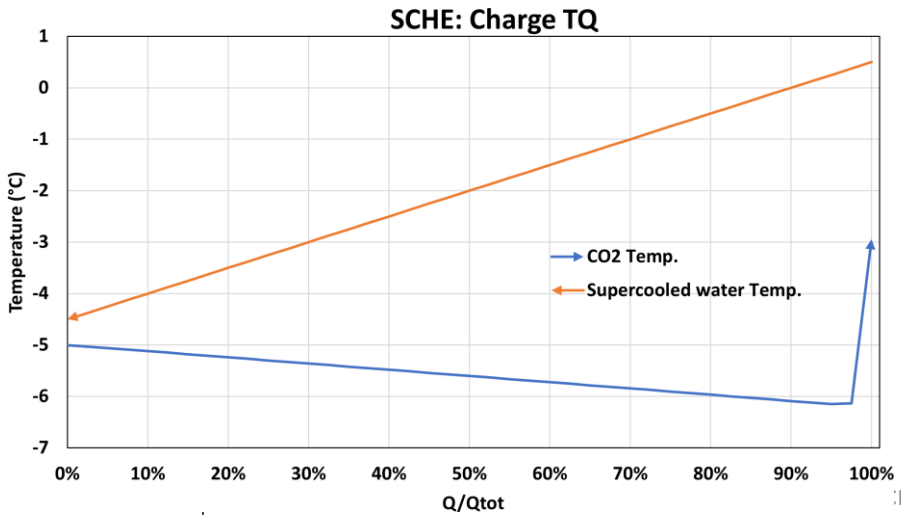


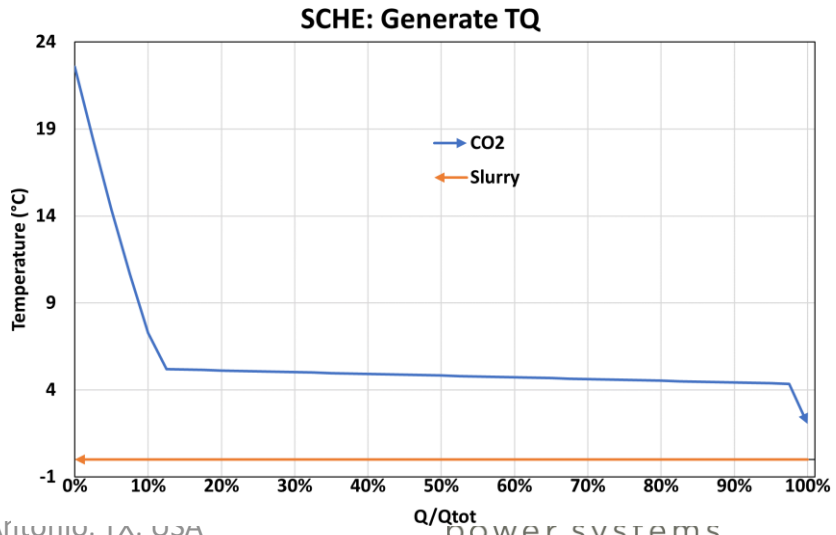

Supercooling degree (SD>0)

# 3. Integration of SCHE into PTES System



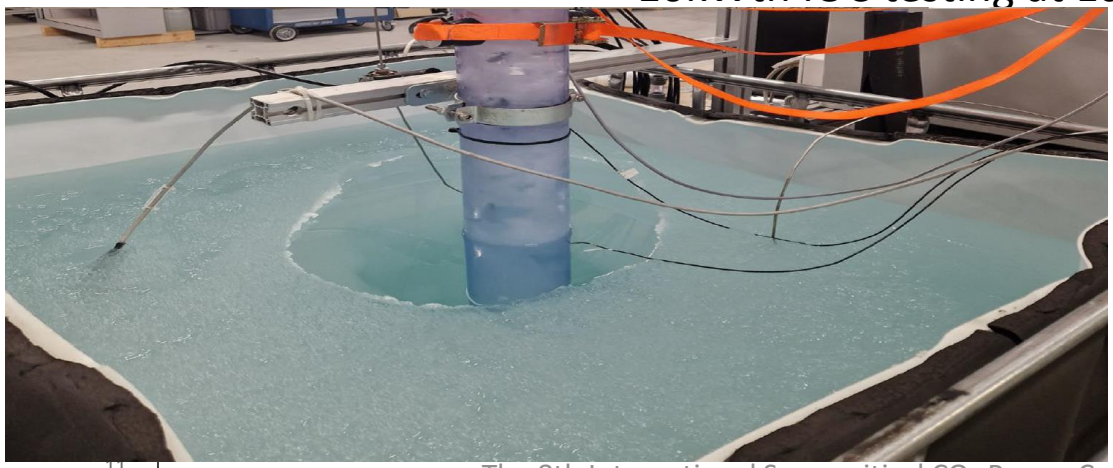



# LTR Technologies Demonstrated at Lab Scale Capacities

10kWth IOC testing at Echogen (2023)

25kWth $I^2$HEX testing at AES facility:
(2023-2024 at AES; 2024 at Echogen)



10kWth SCHE testing at SPF Lab
(2024 at SPF; 2025 at Echogen)

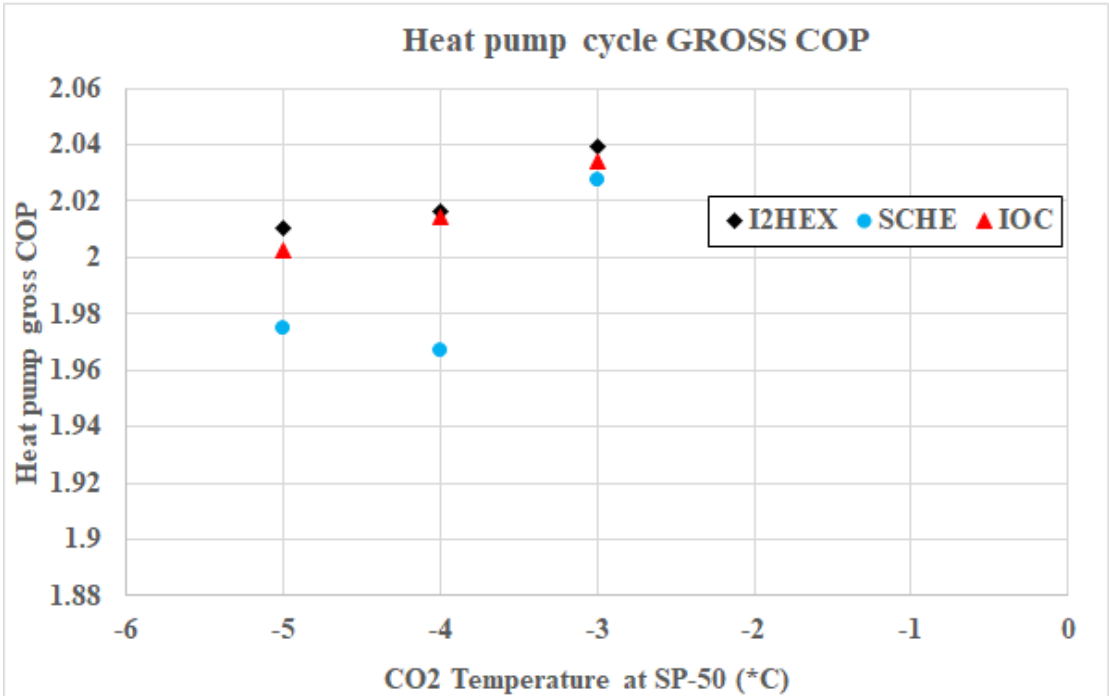
# LTR Technologies Technoeconomic Analysis

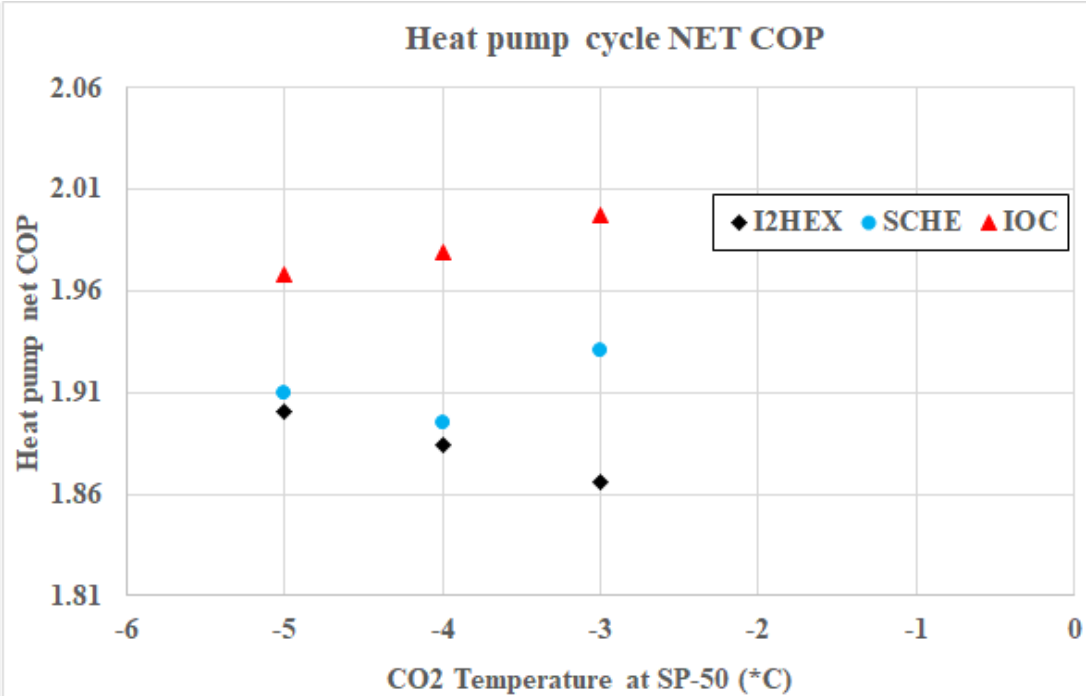
**Baseline Cycle:** 100MWe 10hr-Charge and 10hr-Generate PTES system selected as base case for TEA on all three LTR technologies.

**Optimization Tool:**

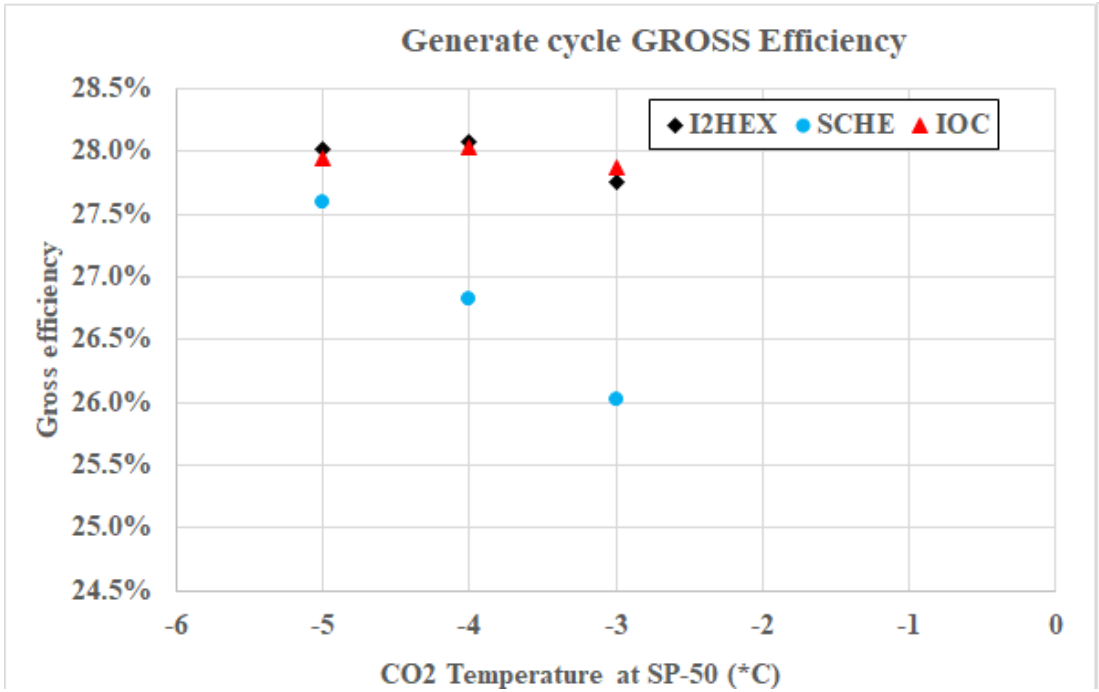
- Echogen developed an Optimization tool for PTES system which can be used for combined optimization of Charge and Generate cycle.
- Optimization Parameters: (i)maximize net round trip efficiency (RTE) (OR) (ii) minimize cost to hit a target net RTE.
- Optimization tool finds a solution by varying list of Variable values within specified range of min-max values and checks for list of Constraint limits min-max values.

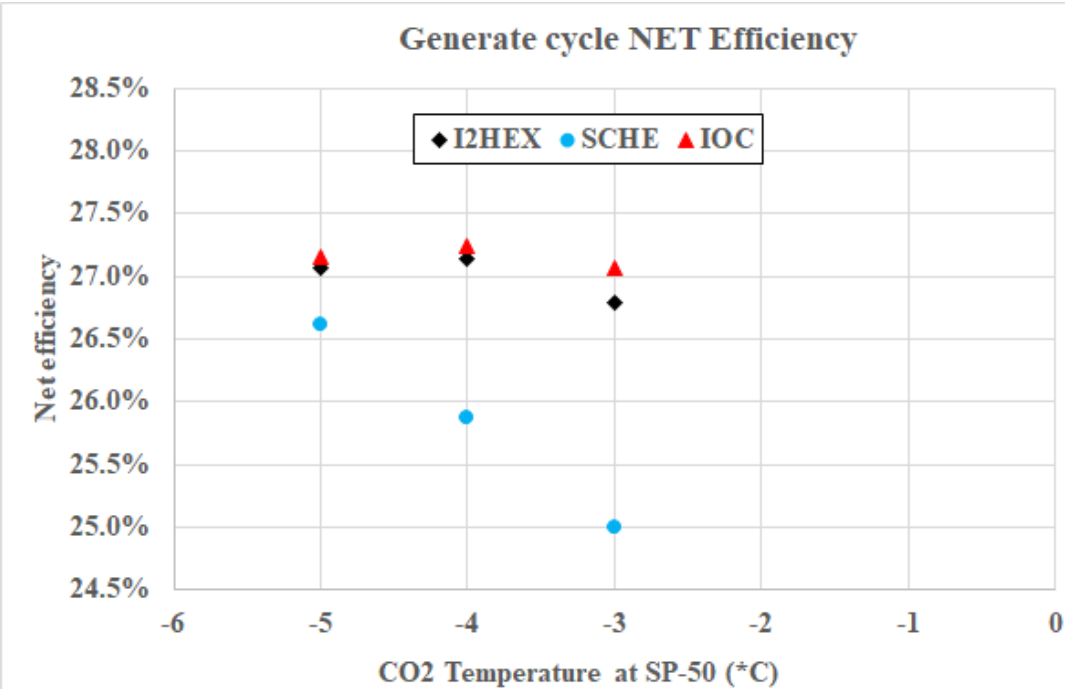
# LTR Technologies Technical Analysis: Charge COP



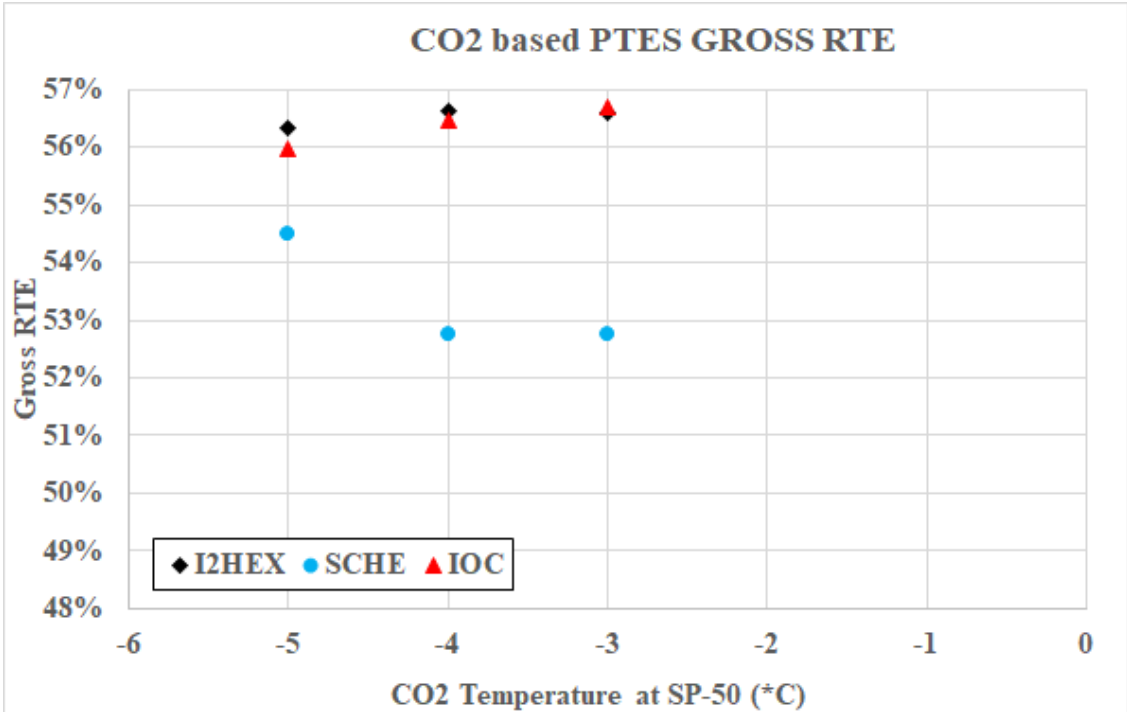



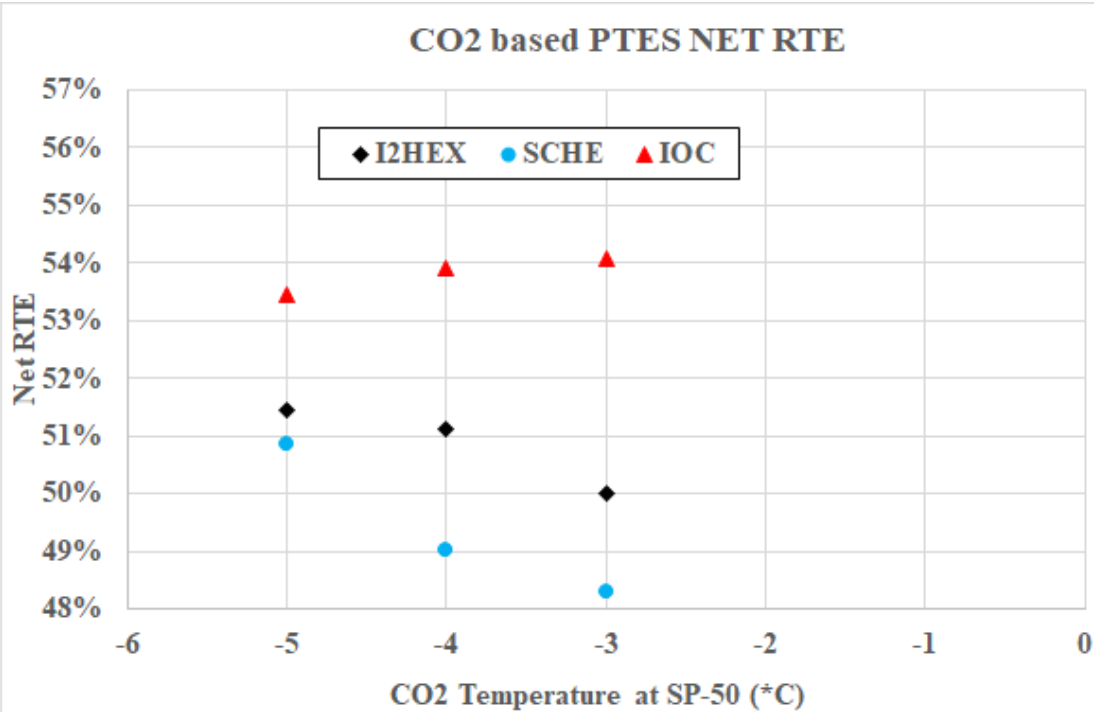
# LTR Technologies Technical Analysis: Generate efficiency



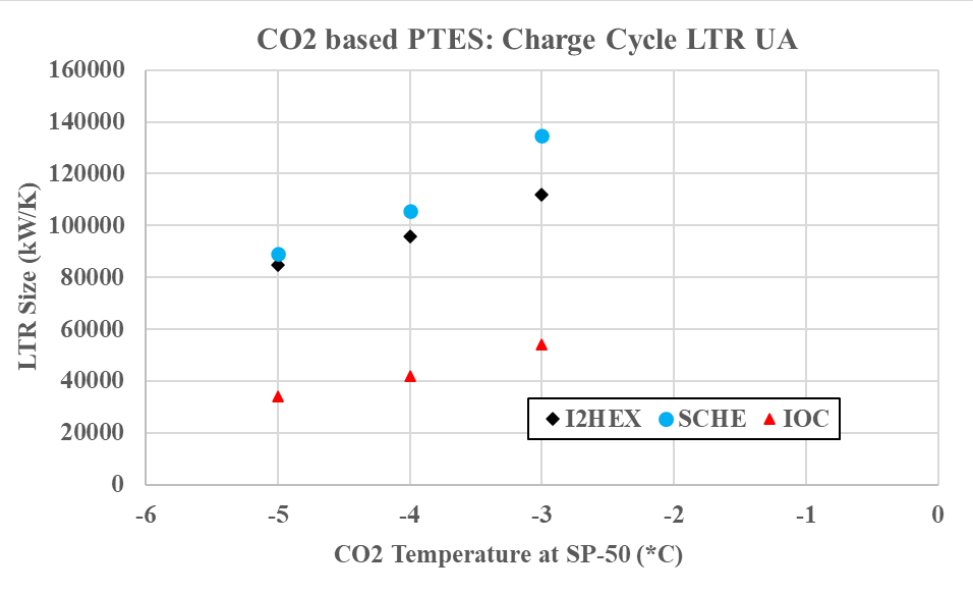



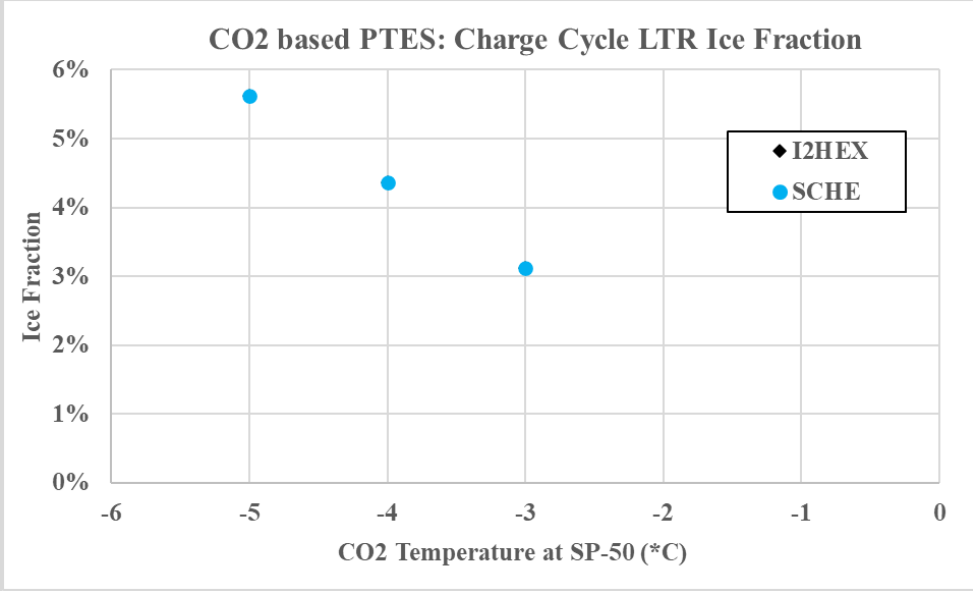
# LTR Technologies Technical Analysis: Net RET

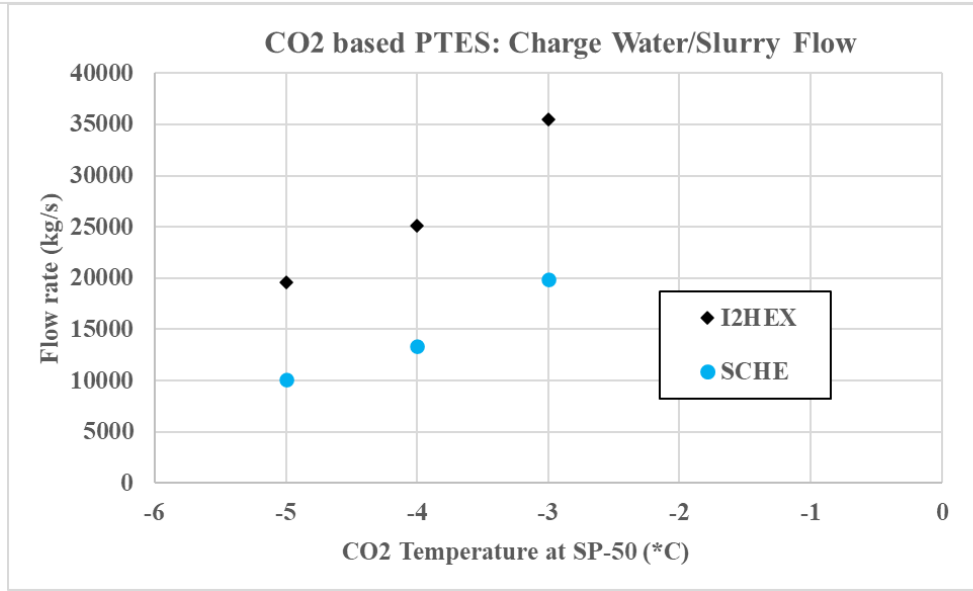


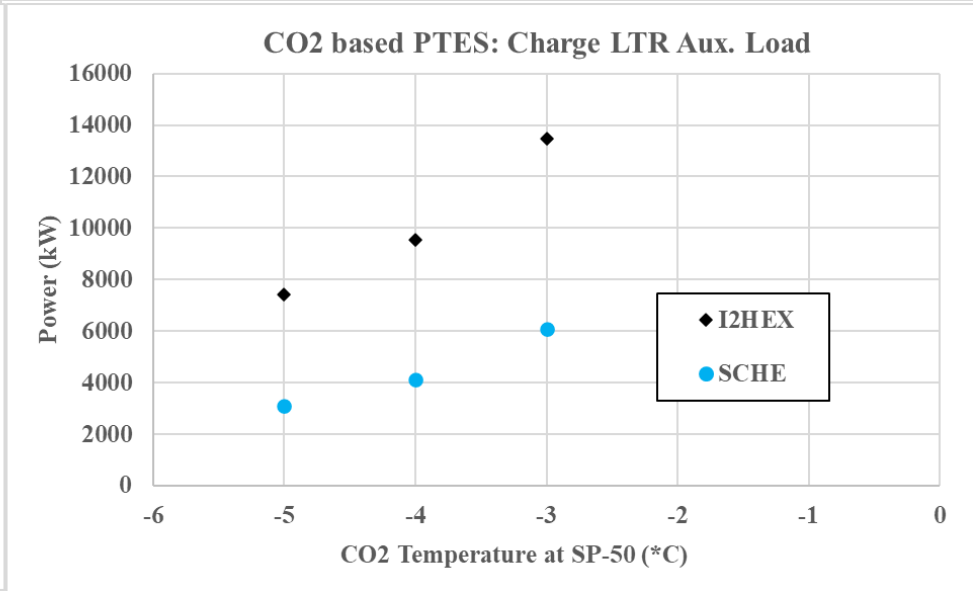



# LTR Technologies Analysis: HX Size and Aux. Loads

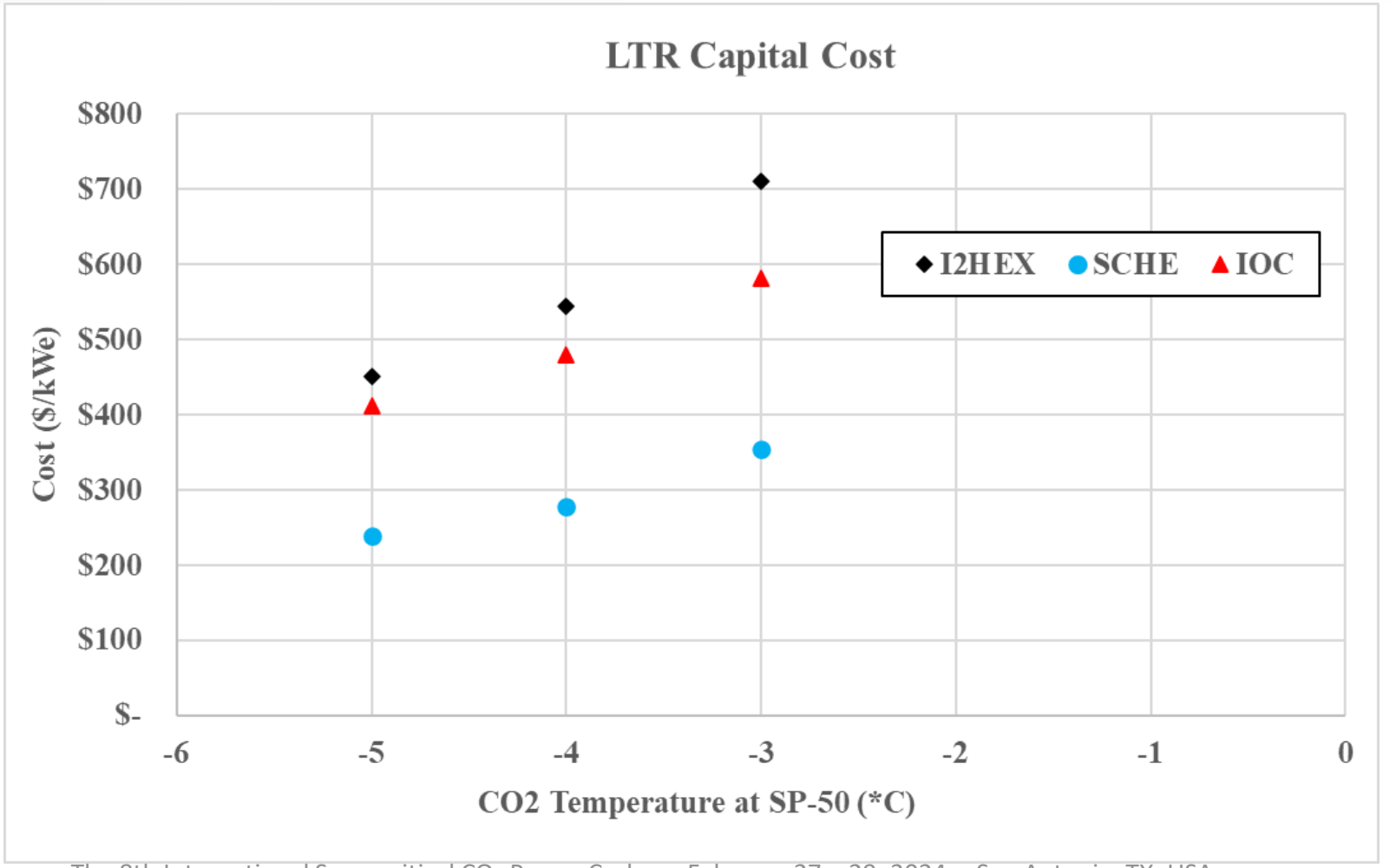


# LTR Technologies Capital Cost Analysis



# LTR Technologies Summary

- Three LTR technologies conceptualized, studied and analyzed for 100MWe PTES system (10h Charge – 10h generate).
- Proof of concept at lab scale capacities (10kWth to 25kWth) demonstrated.
- Based on the performance optimization, 50% round-trip efficiency is achievable using all three LTR technologies.
- On a capital cost basis, SCHE has a lower cost compared to IOC and $I^2$HEX technologies.
- Next steps: Include more detailed cost models and O&M costs for each of the LTR technology.

**Thank you!**

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**Paper # 64**

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## Disclaimer: