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COOLERCHIPS™

Hyperefficient Data Centers for Deep Decarbonization of Large-scale Computing

Saeed Moghaddam, U. of Florida

COOLERCHIPS Annual Meeting
December 11 & 12, 2024

Total Project Cost:	$3M
Length	36 mo.

Brief COOLERCHIPS Project Overview

Team member	Location	Role in project, core competencies
University of Florida	Gainesville, FL	Lead, heat sink and system design and integration
Boyd Corporation	Laconia, NH	Manufacturing, liquid cooling and phase change
University of Maryland	College Park, MD	Reliability assessment
NREL	Golden, CO	Packaging and DC-level testing
TRINA	Ann Arbor, MI	Thermomechanical Analysis

Project Vision

- 126 kW rack with 1000 W chips operating @ 40 ℃ ambient, with ~70 ℃ exit primary loop temperature
  - Enabled by a unique water phase-change heat sink

- Reducing TCO while providing high quality waste heat for heating (space and water) and cooling (via operating heat-driven chillers)
  - Particularly attractive for EDGE computing

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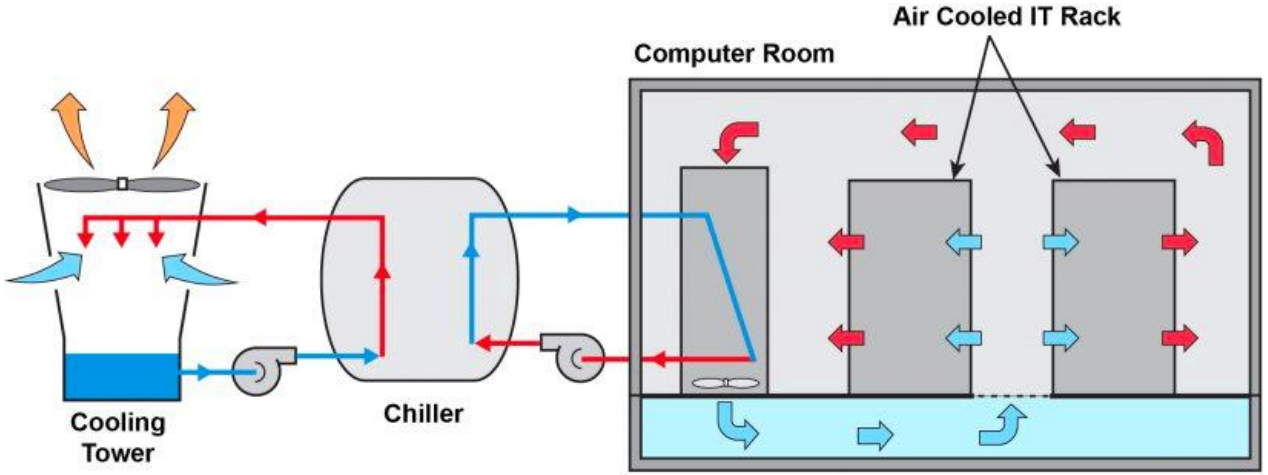
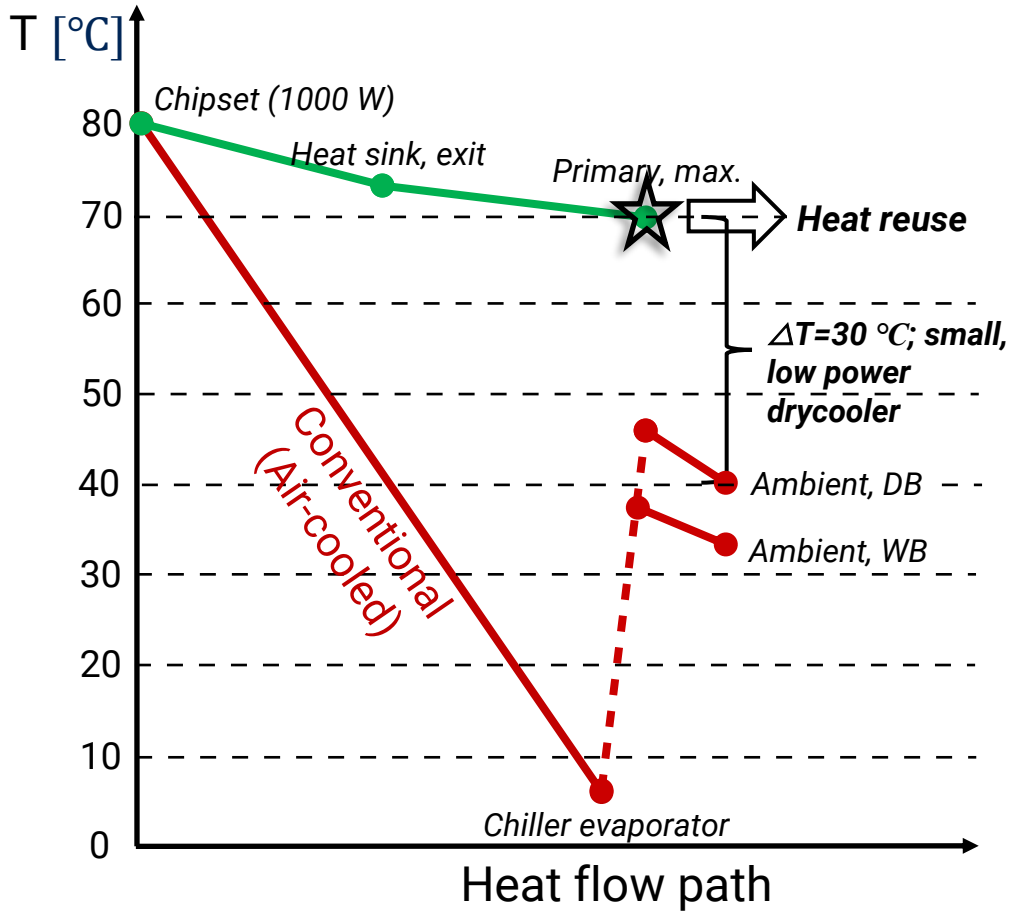
Objective



Conventional Air-cooled DC



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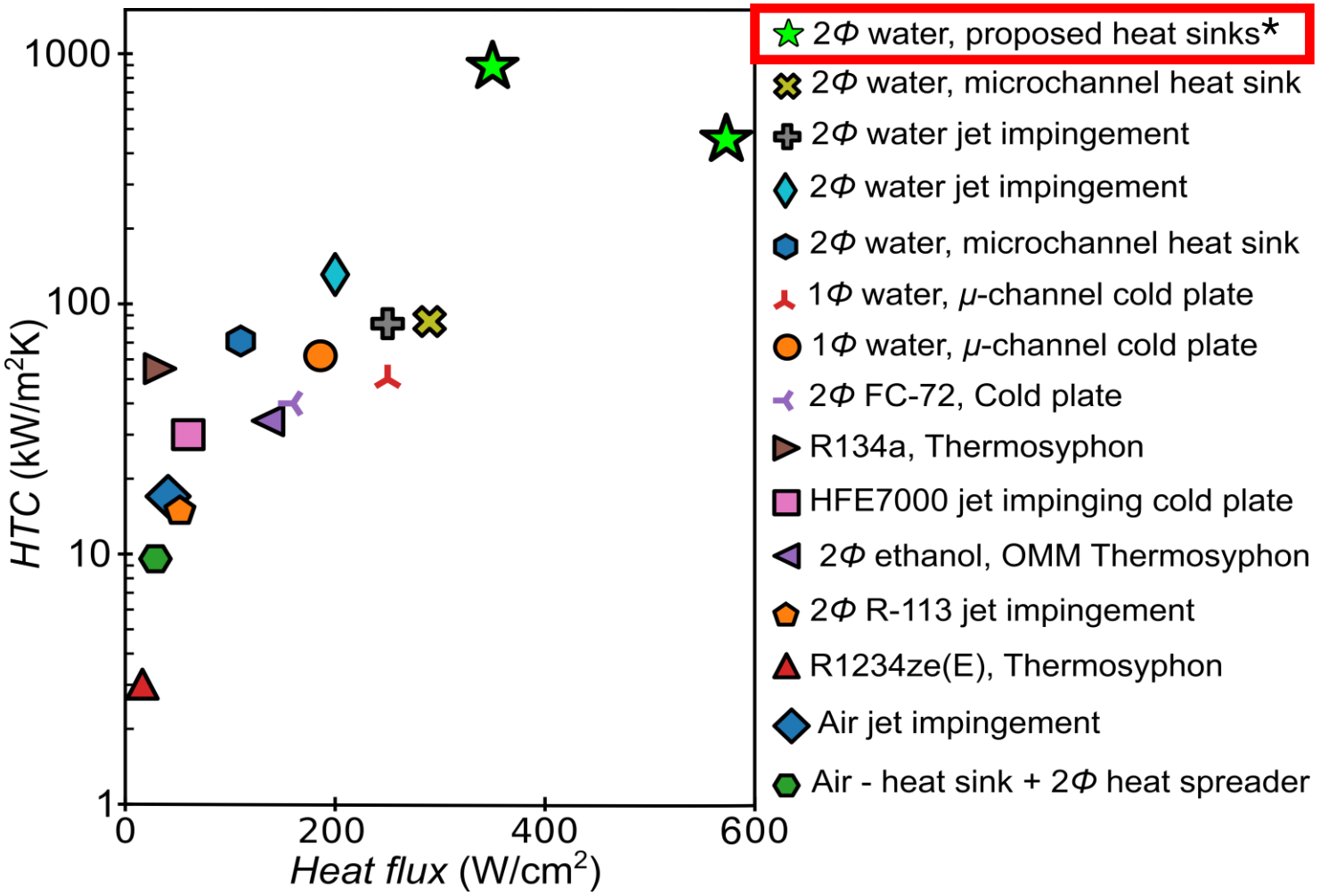
Innovation



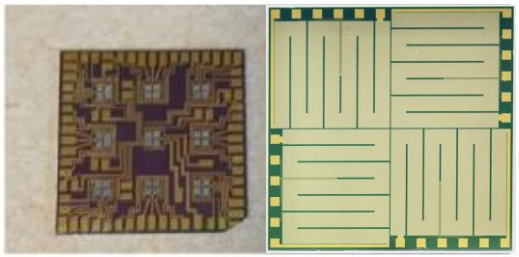
* Data collected at T_{sat}= 55 ℃ (increases to ~1800 W/cm^2 @ T_{sat}= 100 ℃)
- All 2ϕ heat sinks operating at T_{sat} < 60 ℃.

Tamvada and Moghaddam, ATE, 2023 & Moghaddam and Fazeli, US Patent #10,897,833, 2021

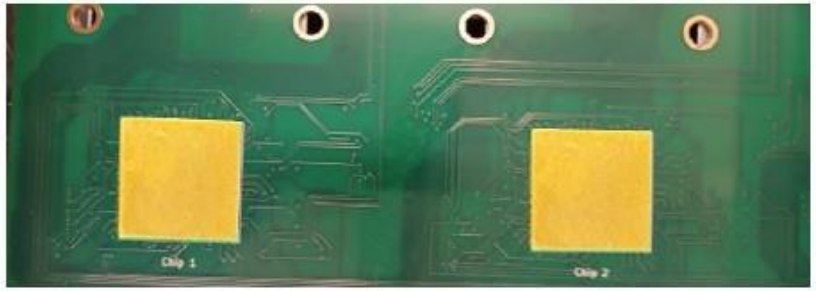
TTV Design and Manufacturing

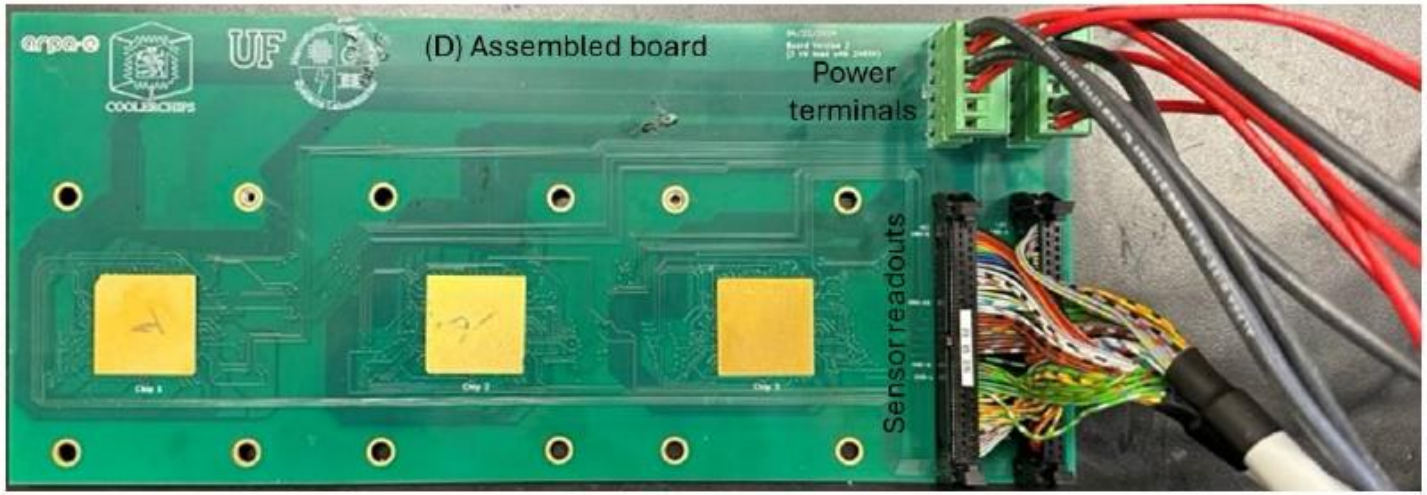
(A) TTV bond pads

(B) TTV underside



(C) Placing TTVs and reflowing in furnace





Suhas Tamvada
Postdoctoral Associate
Organization: UF

Chaitanya Bathina
Postdoctoral Associate
Organization: UF

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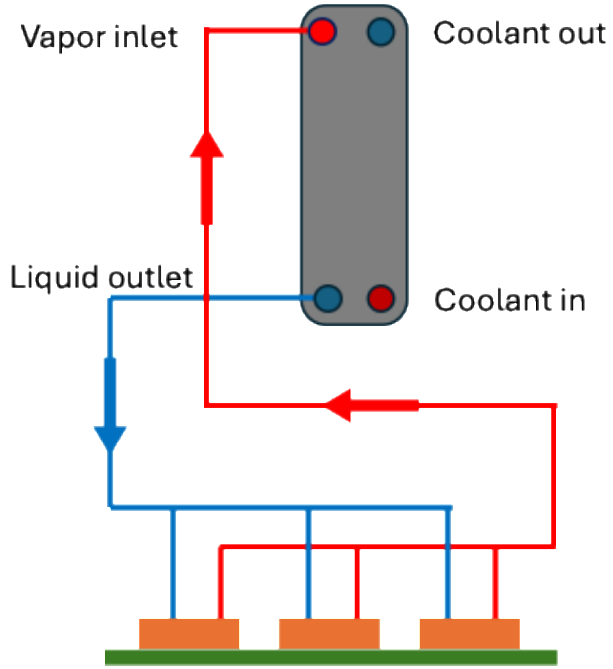
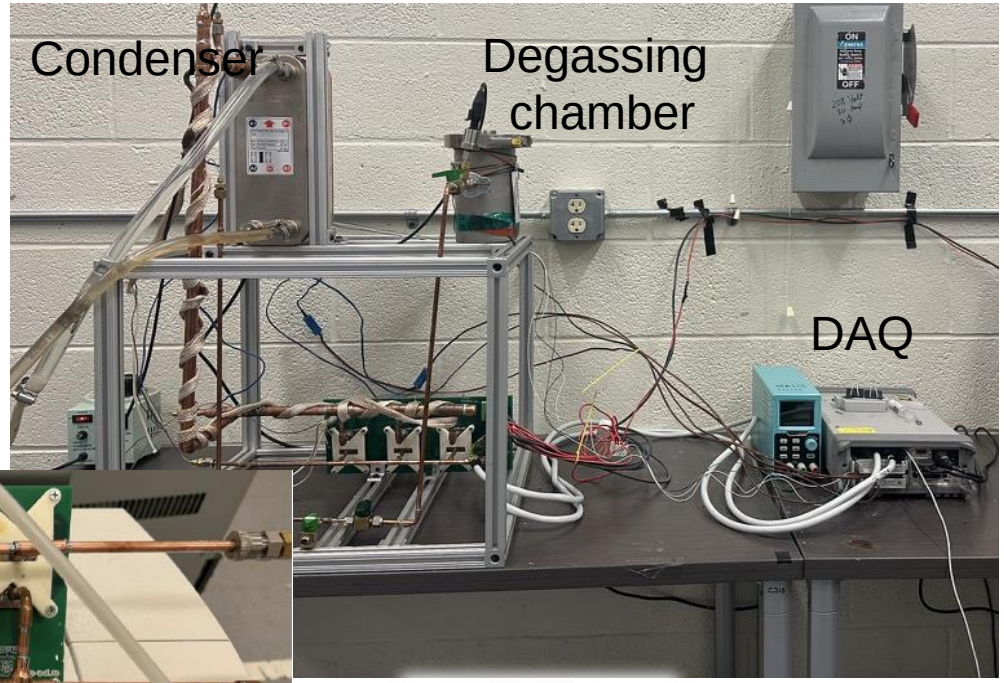
3 kW Experimental System

- Testing in thermosyphon configuration





Suhas Tamvada
Postdoctoral Associate
Organization: UF

Zihan Hu
Graduate Student
Organization: UF

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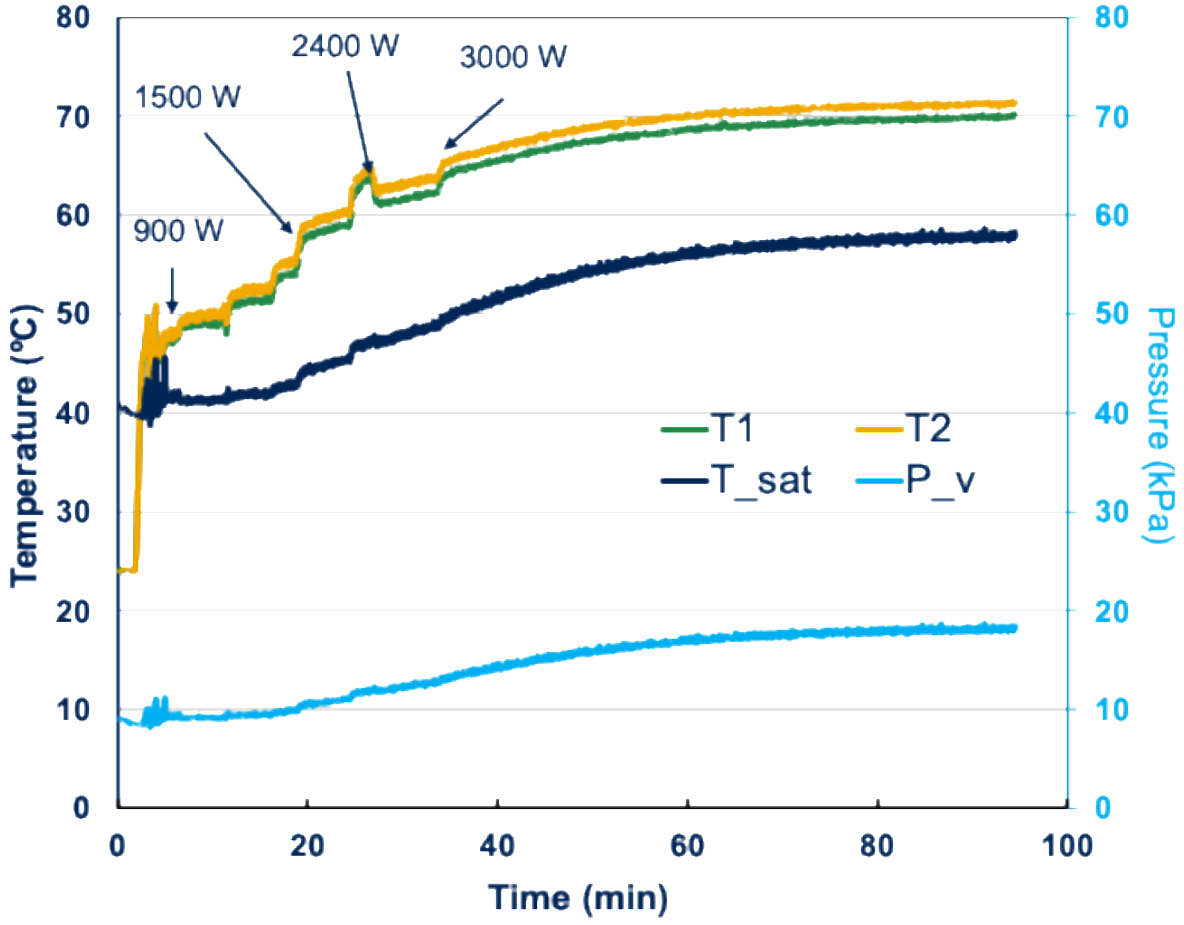
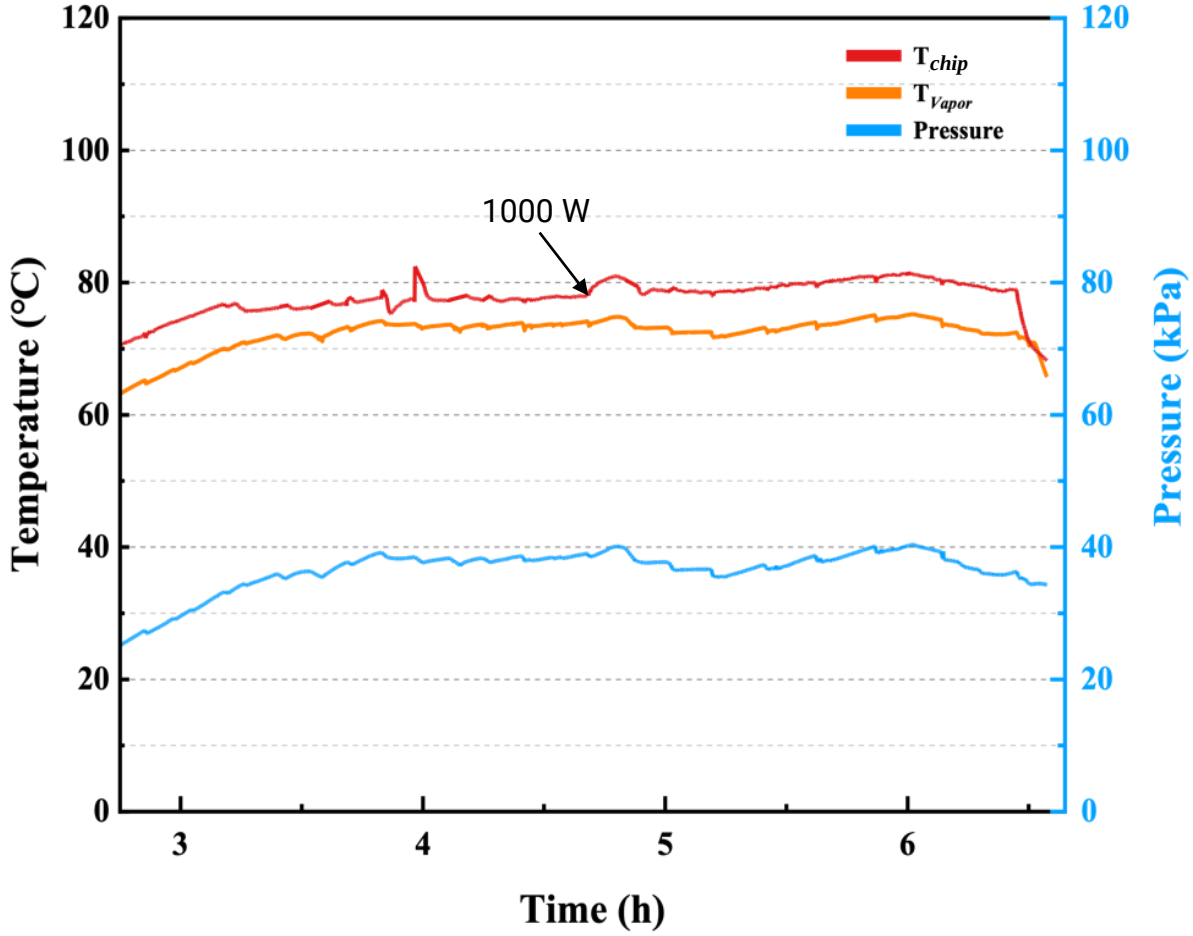
Heat Sink Performance

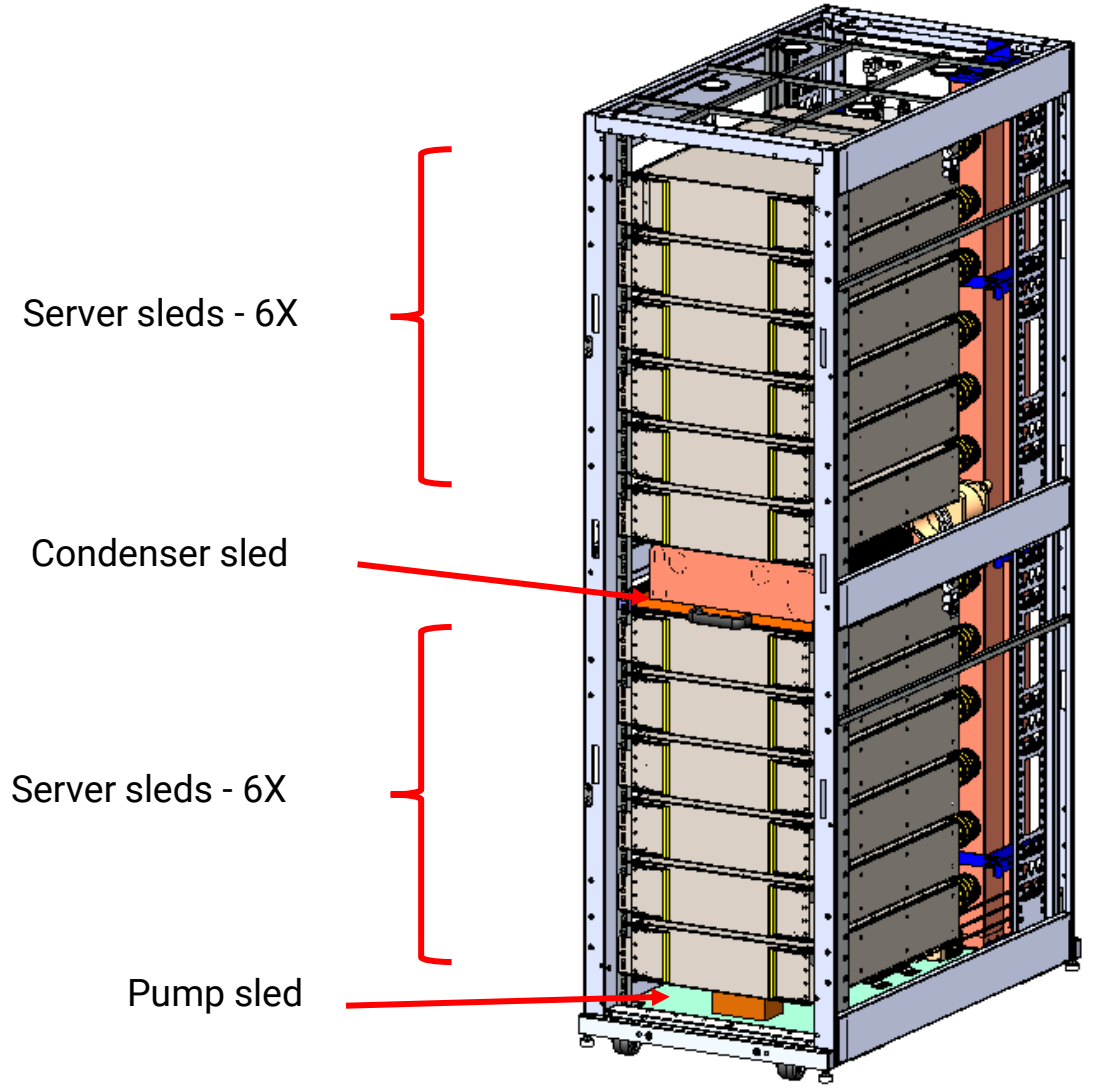


$T_{chip} - T_{fluid}$ = ~6 +/-0.35 °C @ 1000 W Chip



Integrated Server and Rack CDU Solution

- Completed two-phase rack level cooling solution using 50 – 55 C water from dry cooler
  - ✓ Tested manifold technology for coolant delivery to servers
  - ✓ Tested NCG management technology for reliable system operation at sub-ambient pressure
  - ✓ Tested in-rack condenser cooling capacity for >120 kW cooling



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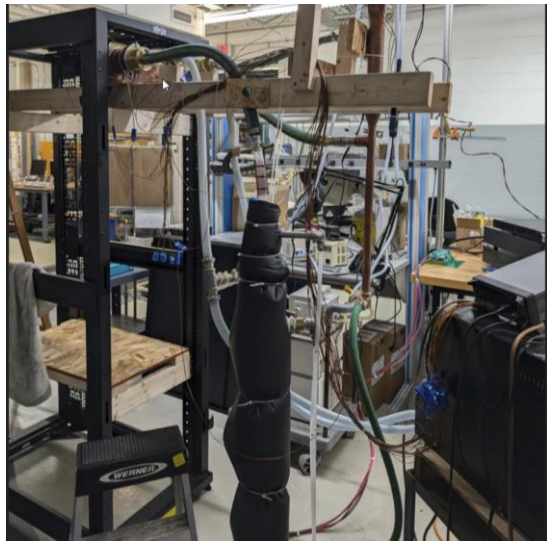
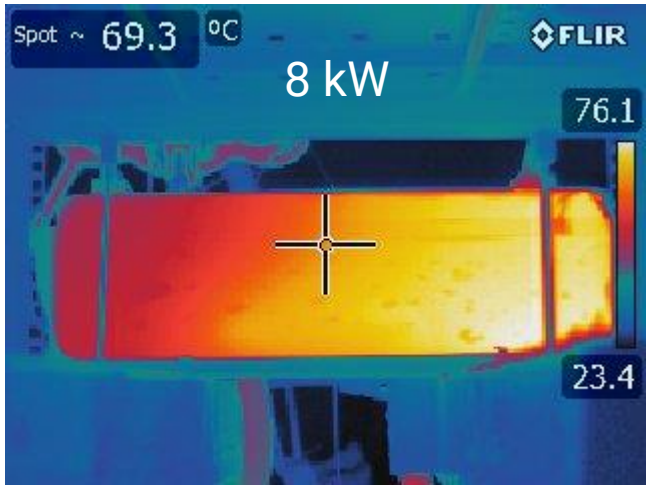
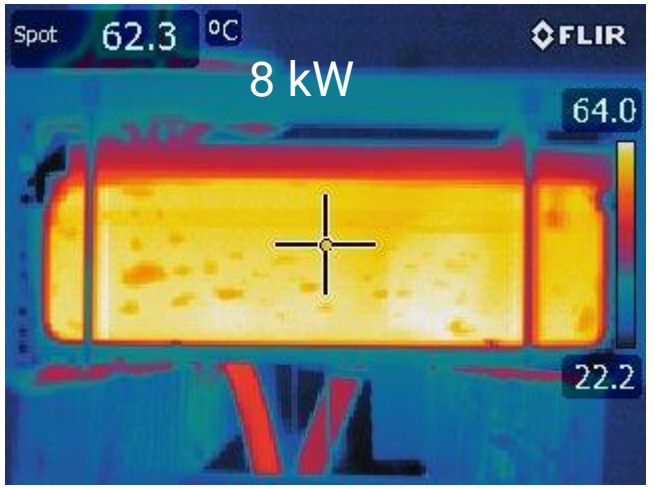
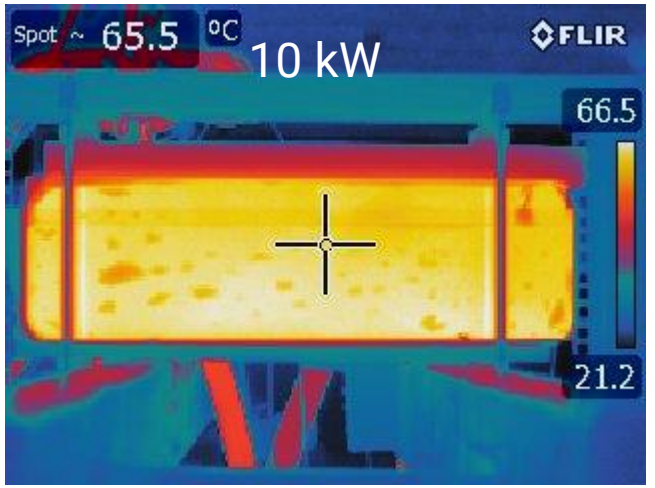
10kW Scale Condenser Testing

- The images on the left show substantial initial NCG in the system
- ✓ Images on the right demonstrate that NCG has been eliminated
- ✓ Measured cooling capacity meets performance target









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IR Images show the back side of the condenser exposed to the vapor

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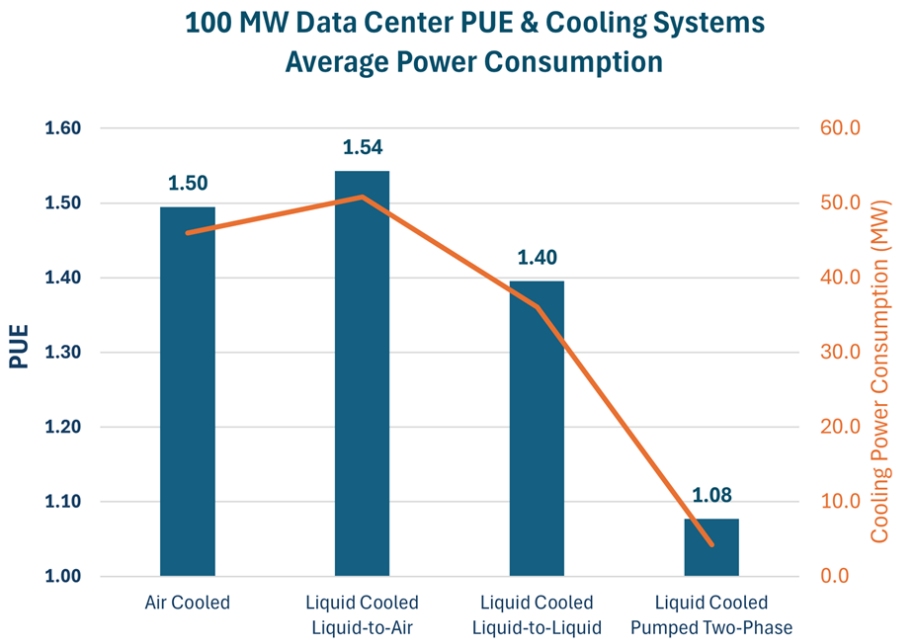
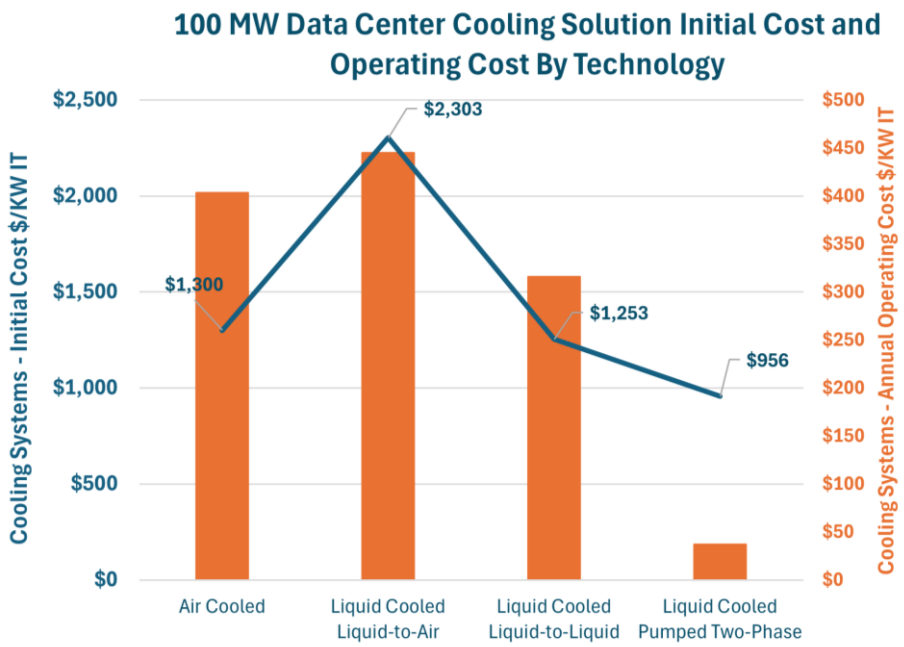
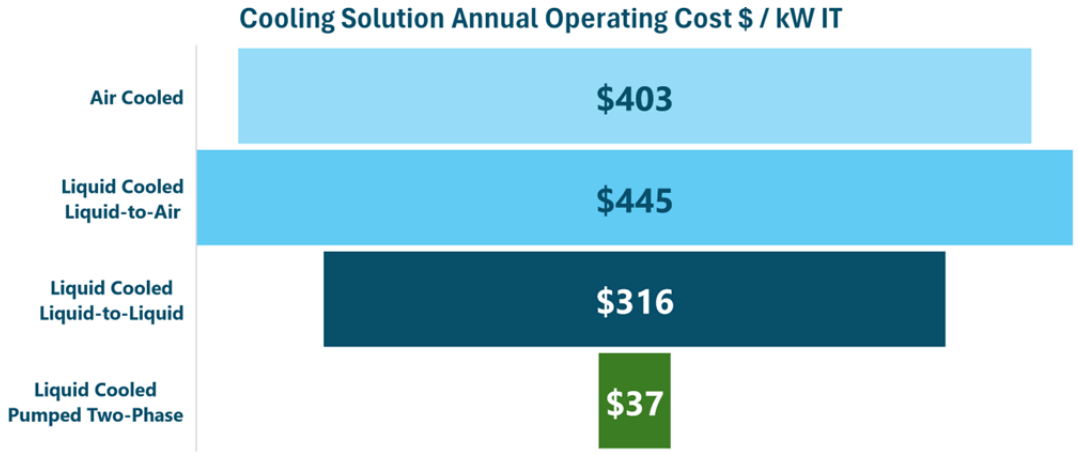
Technoeconomic Analysis







Jerome Toth
Sr. Vice President, Eng. & Tech.
Organization: Boyd

Sukhvinder Kang
Chief Technology Officer
Organization: Boyd

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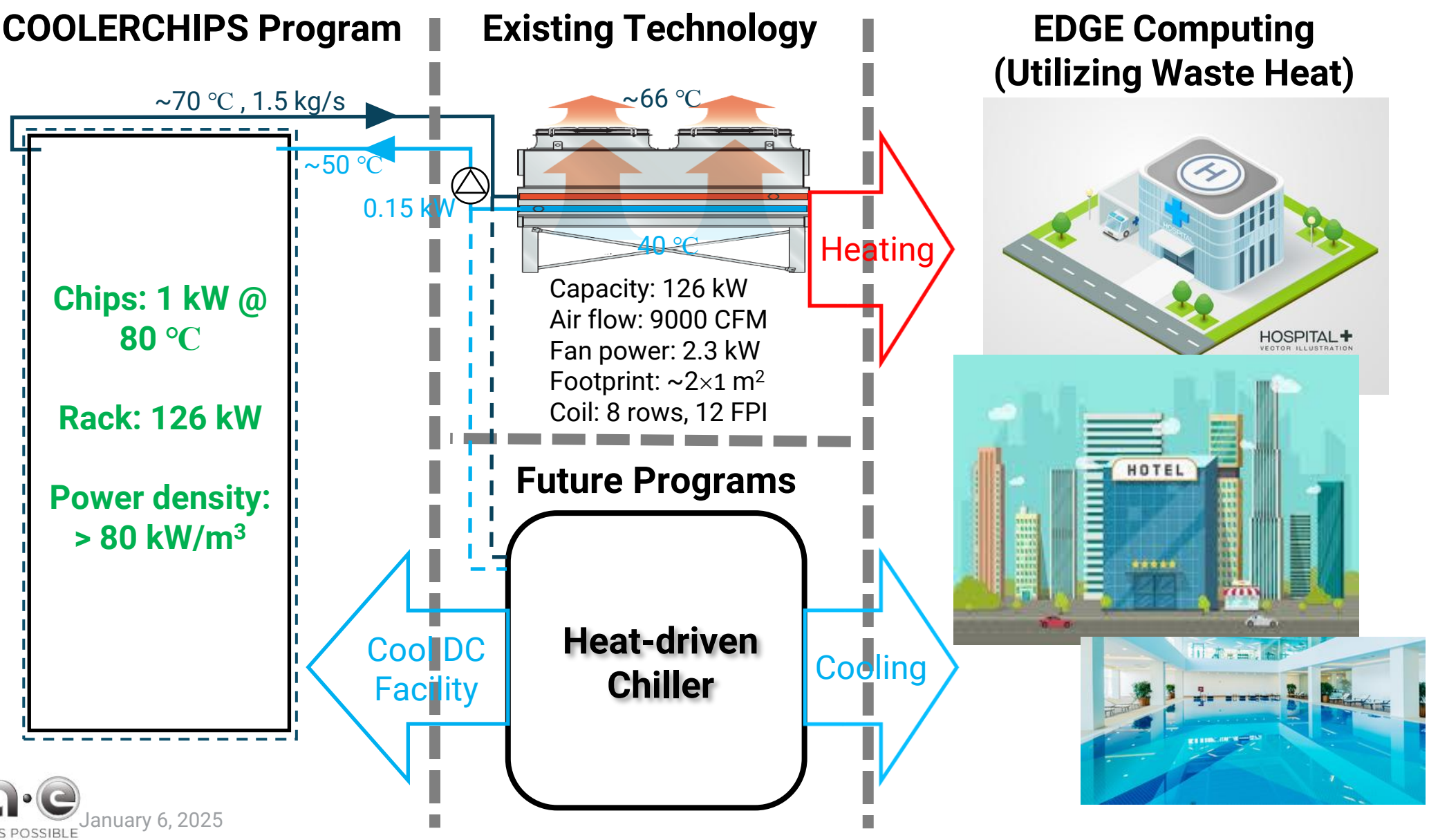
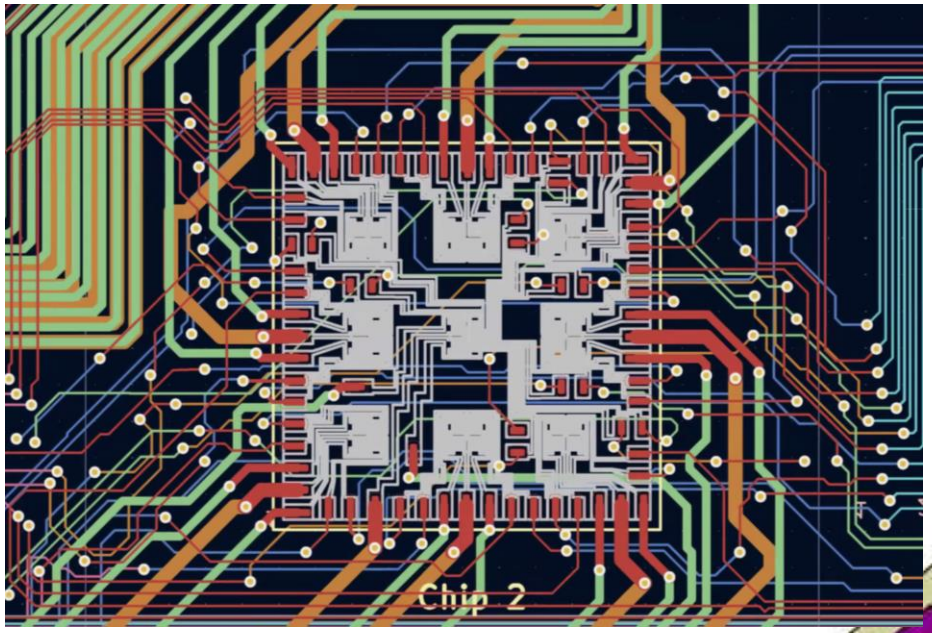
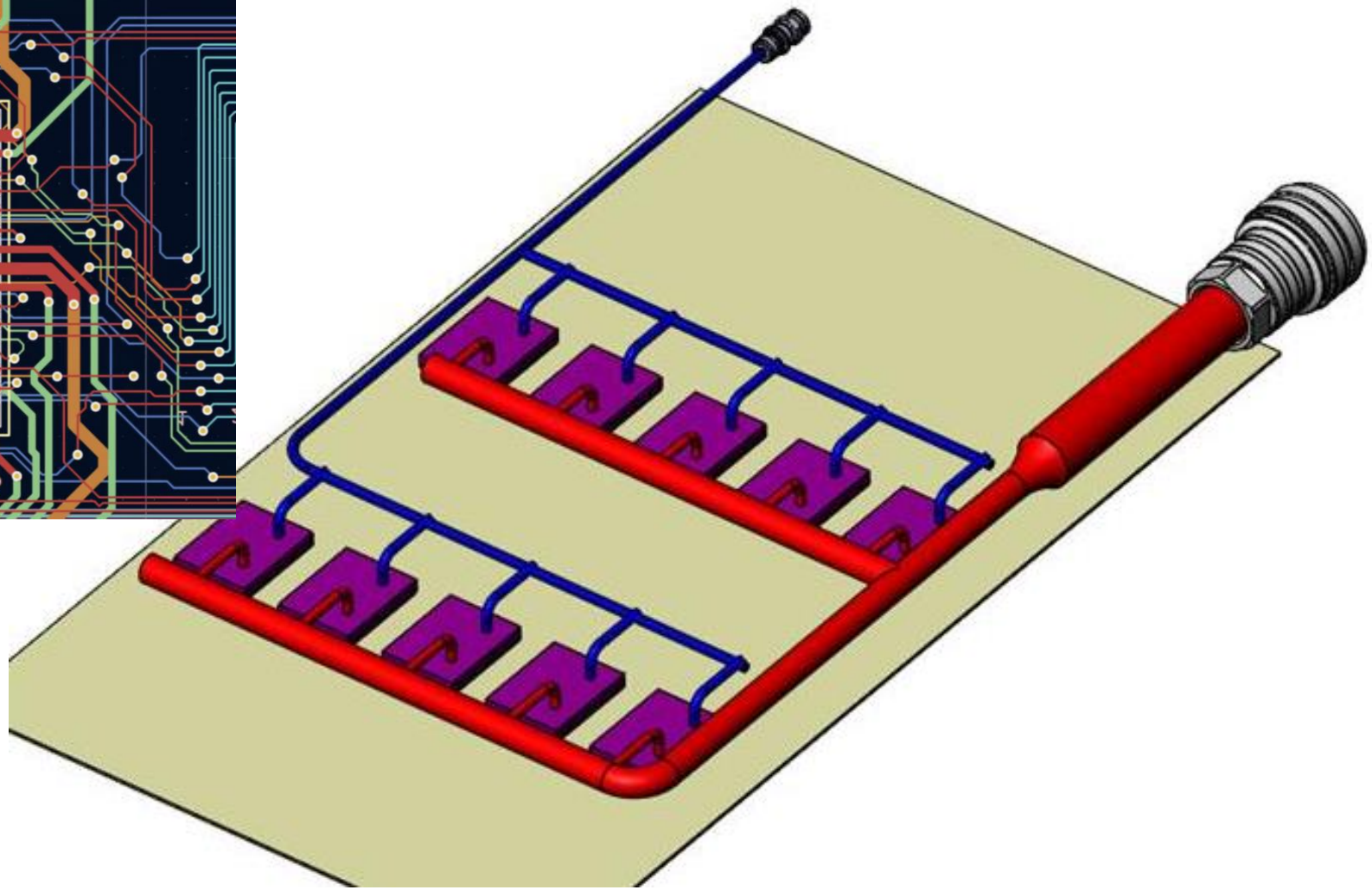
System Configuration

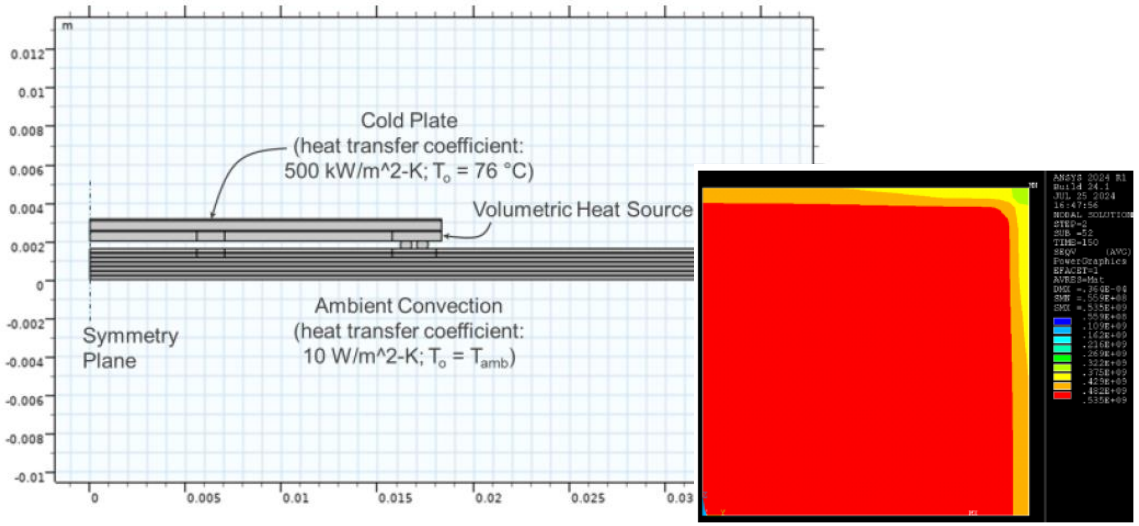


10 kW Server Design & Manufacturing





Mechanical Analysis & Reliability



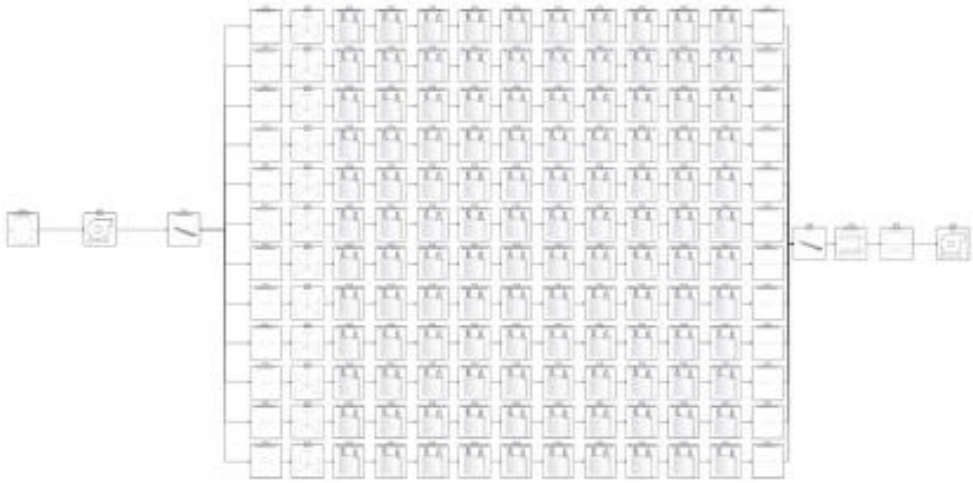


Fig. 11: System Availability Model

Eric Dede
Title: Director, ERD
Organization: TRINA

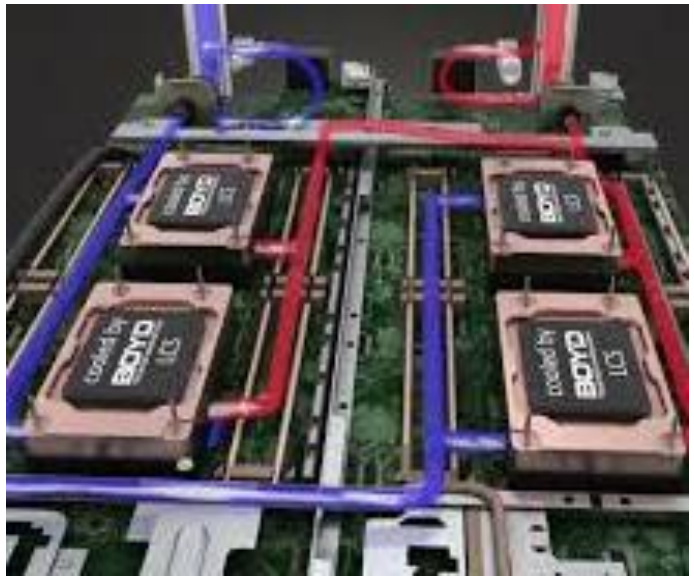
Paul Paret
Title: Sr. Res. Eng.
Organization: NREL

Gilbert Moreno
Sr. Res. Eng.
Organization: NREL

Patrick McCluskey
Professor
Organization: UMD

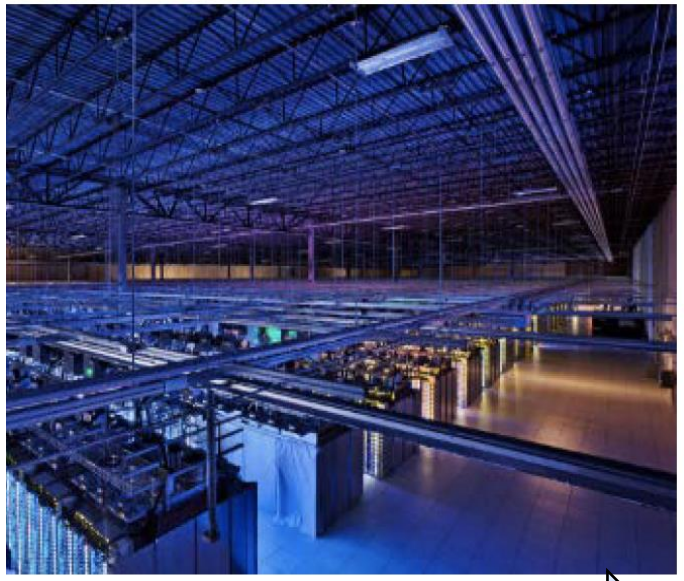
Schedule

Year 1 (chip/ server-level integration)



Year 2 (Rack-level integration/ validation)

Year 3 (Demonstration at data center)



Reliability assessment, enhancement, modeling, Digital Twin (DT)

Technoeconomic modeling

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Test Case: NVIDIA AI Technology Center at UF (NVAITC-UF)

- 3.2 MW, PUE ~ 1.6, serving Florida higher education institutions
- First in North America; a joint research center of NVIDIA and UF for advancing Artificial Intelligence (AI) education and research, as well as fostering partnership between higher education and industry.

Value Proposition:

- Eliminates the chiller plant and AHUs
  - Account for ~50% of facility footprint
- Higher server density per rack reduces white space by ~70%
  - Replace 40 (~40 KW) racks by 13 racks
- No water use in cooling towers
- Zero GWP coolant
- Silent operation
- > 70% of waste heat can be recovered and reused for district heating (when possible) or operating heat-driven chillers
  - Currently HPs are used to elevate temperature from ~30 ℃ to 60-80 ℃, depending on system requirements and climate.

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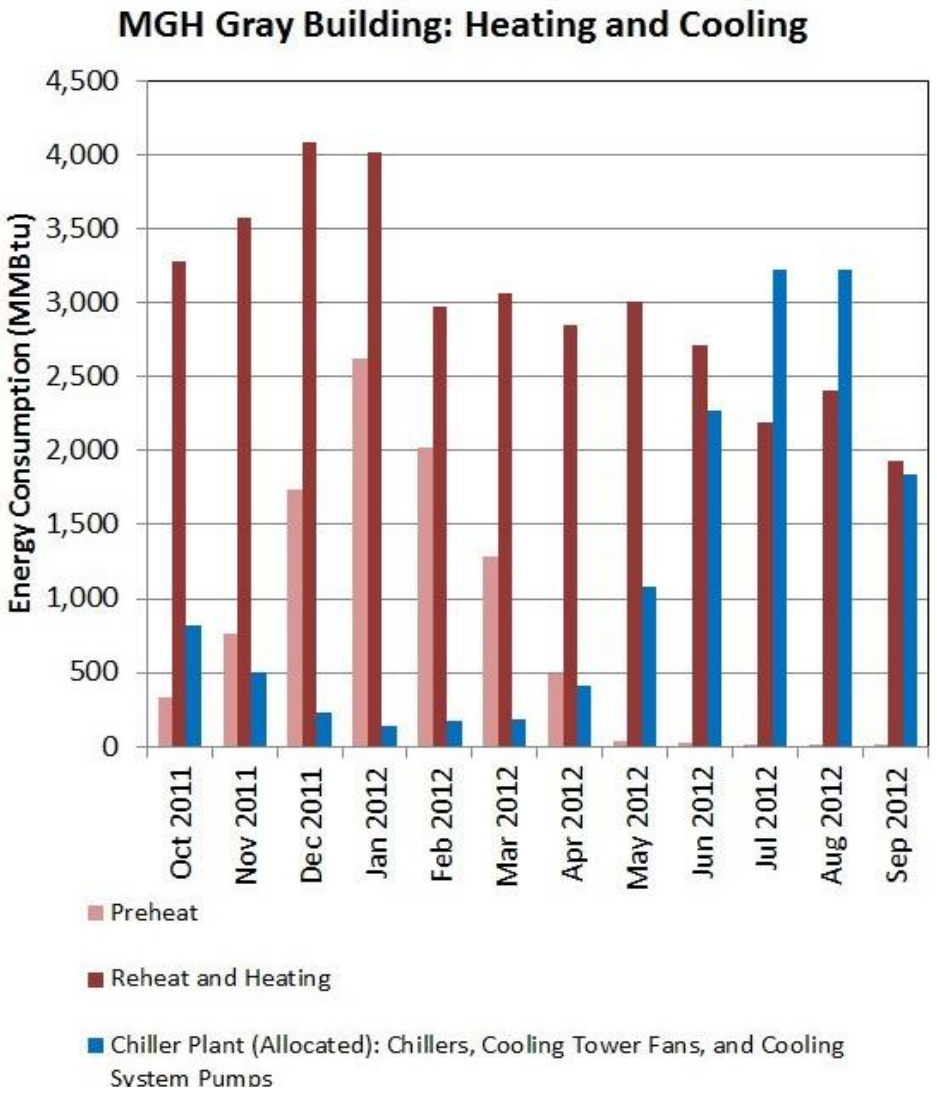
Q & A

saeedmog@ufl.edu

Market Opportunities (EDGE Computing – heat reuse)



Energy consumption associated with HVAC system in Massachusetts General Hospital (MGH) Gray building

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Technology to Market (T2M) Plan

- Finalize reliability and failure models, cost/ performance models, marketing collateral
  - Market demand survey, adoption challenge and opportunity analysis
- Business plan for Board approval
  - Technoeconomic analysis, value proposition, risk analysis
  - Required capital and ROI analysis
  - Materials and components Supply Chain analysis
  - Manufacturing ramp & scaling analysis
  - FIT models and insurance, warranty, and service cost analysis
- Regulatory
  - Safety compliance testing and certifications