New Braunfels Regional Rehabilitation Hospital

New Braunfels, TX

Adam Bernardo

Mechanical Option

Images courtesy of Dekker/Perich/Sabatini Architects

PROJECT INTRODUCTION

DEPTH STUDIES

BREADTH STUDY

OVERALL EVALUATION

CONCLUSION / QUESTIONS

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PROJECT INTRODUCTION

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- MECHANICAL DEPTH STUDIES
- STRUCTURAL BREADTH
- OVERALL EVALUATION
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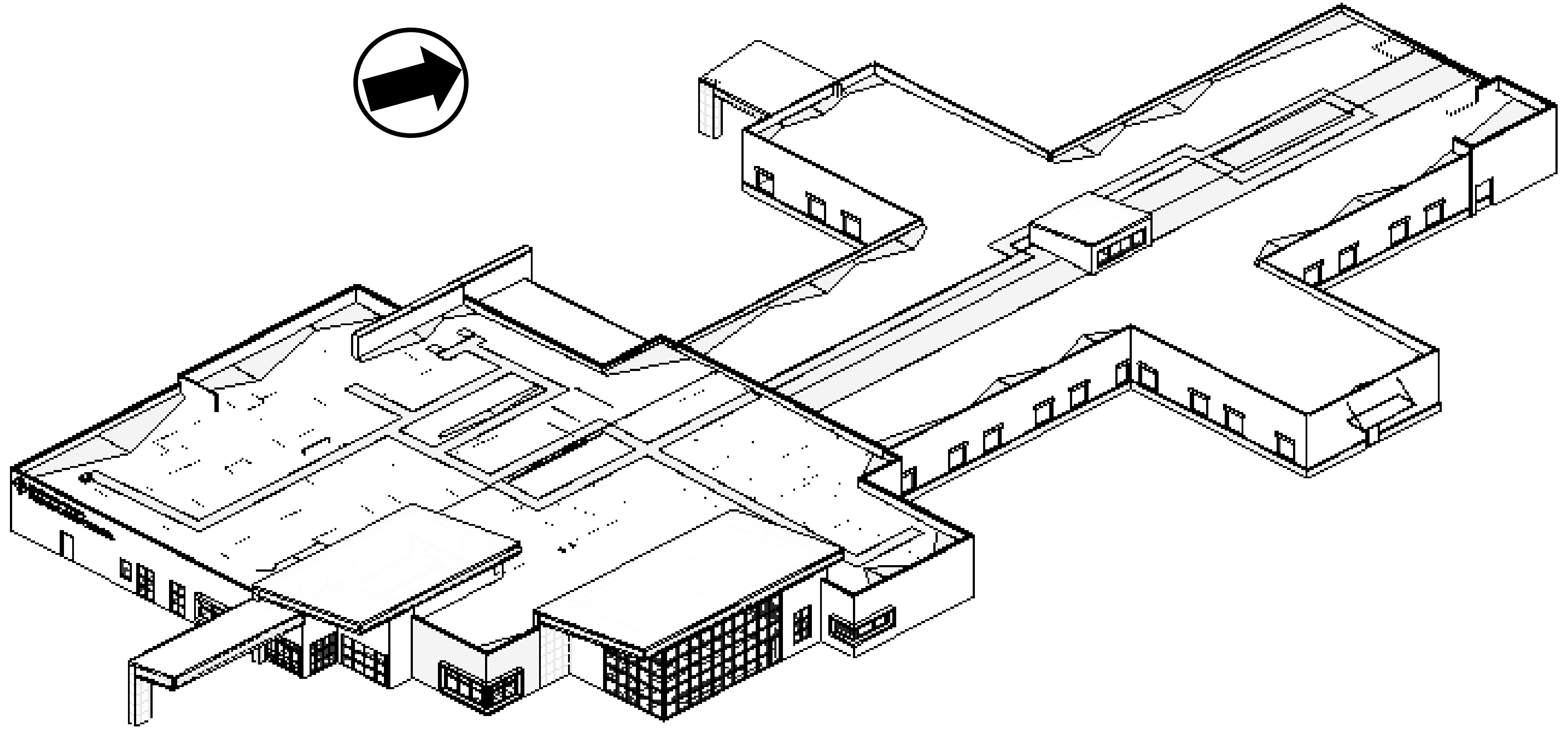
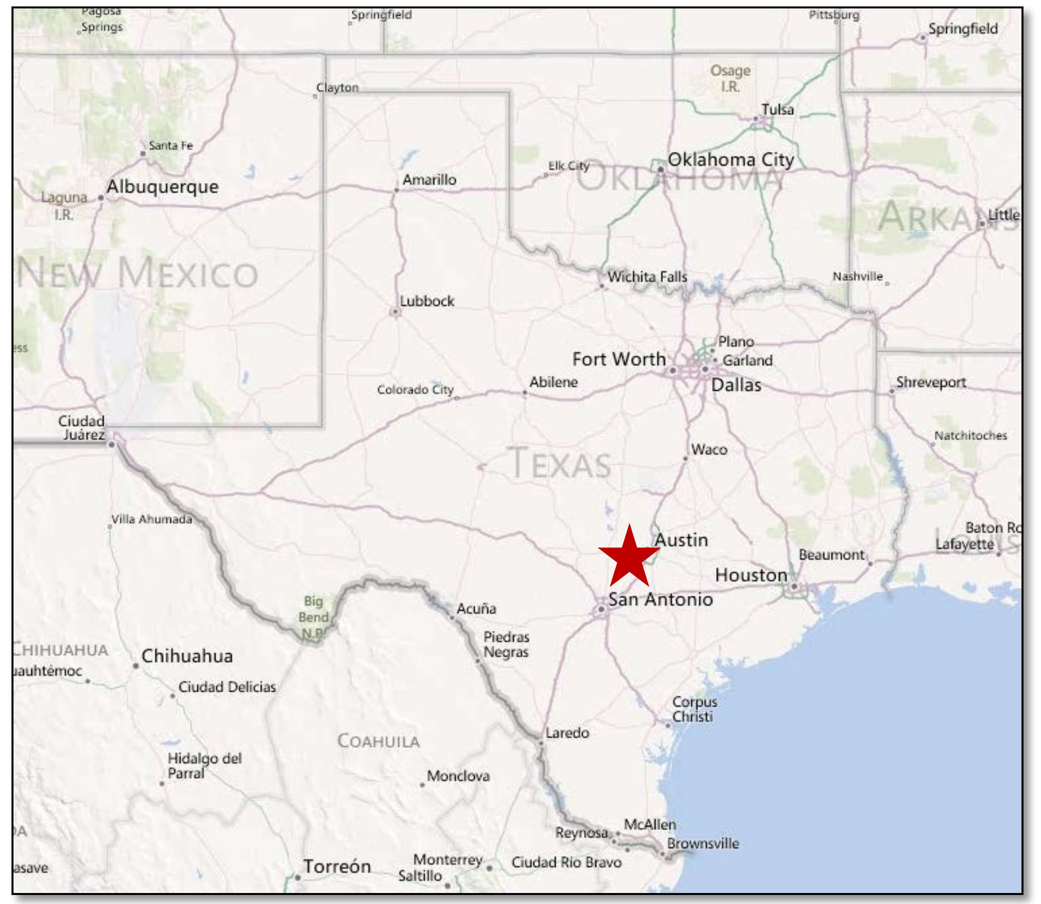
FACILITY DESCRIPTION



Function: acute-care rehabilitation hospital

Location: New Braunfels, TX

~30 miles NE of San Antonio



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AGENDA

FACILITY DESCRIPTION

PROJECT INTRODUCTION

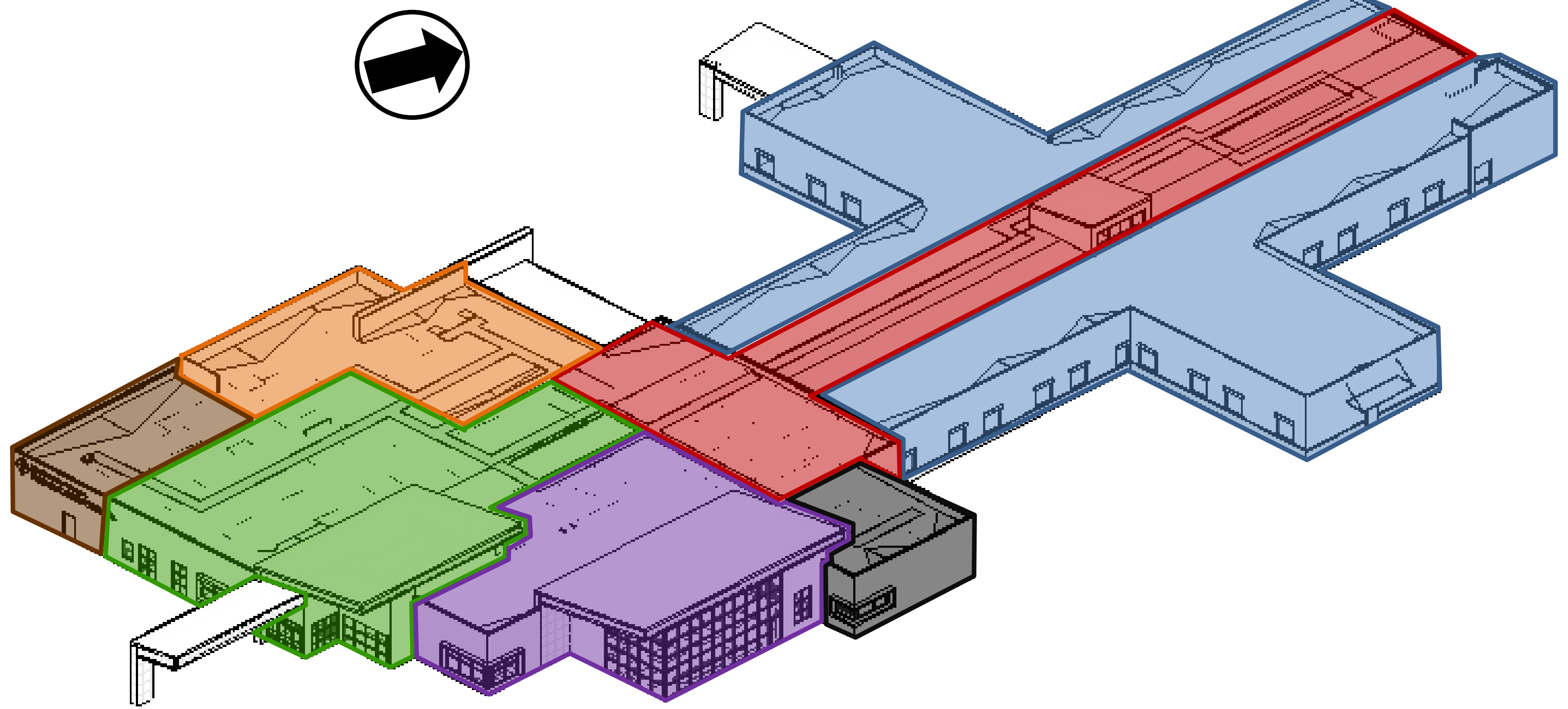
- FACILITY DESCRIPTION
- MECHANICAL SYSTEM OVERVIEW
- THESIS GOALS

MECHANICAL DEPTH STUDIES

STRUCTURAL BREADTH

OVERALL EVALUATION

CONCLUSION / QUESTIONS



Function: acute-care rehabilitation hospital

Location: New Braunfels, TX

~30 miles NE of San Antonio

Spaces:

- 40 Patient Rooms
- Exam and Light Procedure Rooms
- Physical Therapy Gym
- Therapy Pool
- Kitchen and Dining
- Office and Administration
- Service Rooms

MECHANICAL SYSTEM OVERVIEW

Three rooftop air-handling units

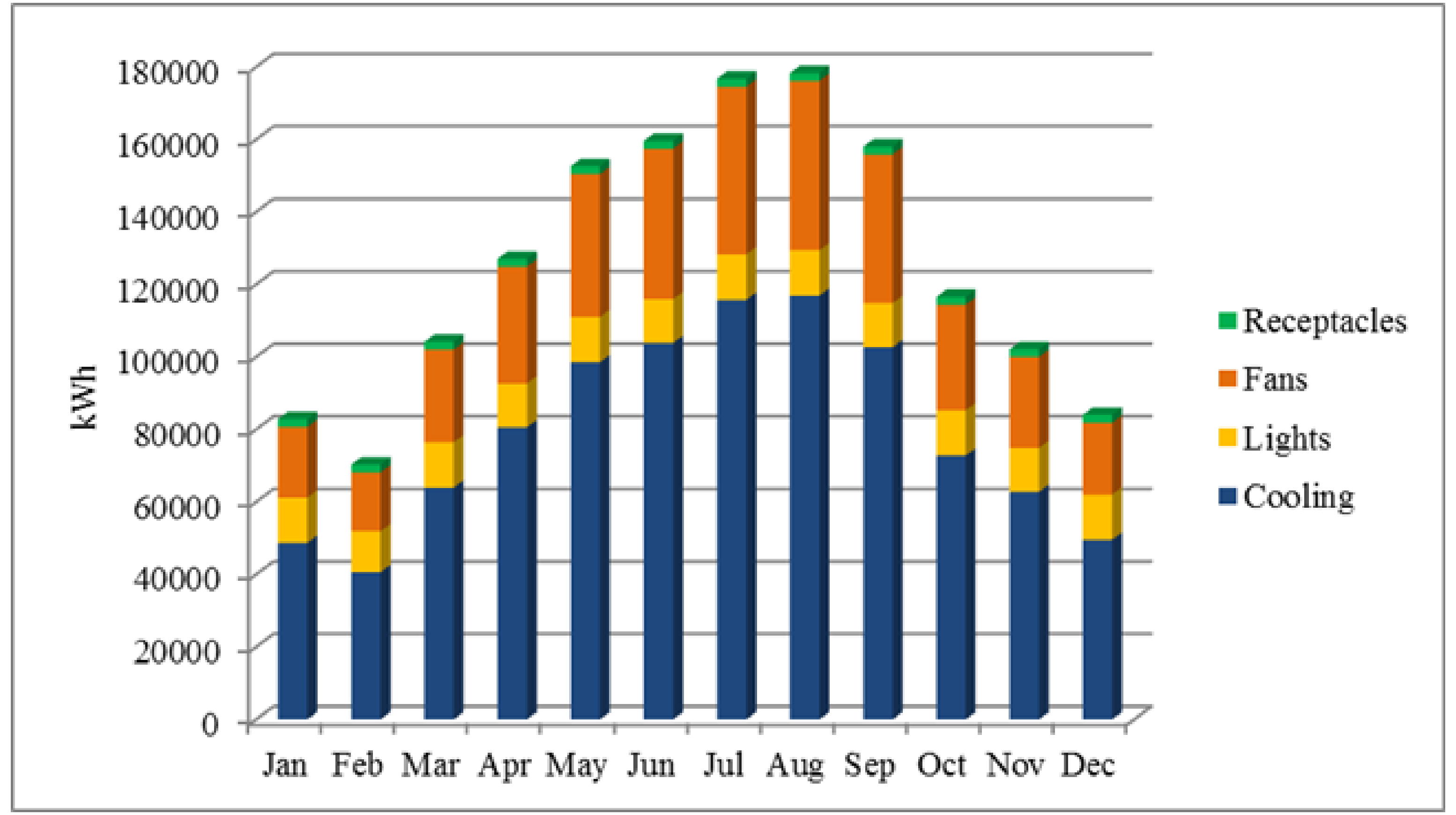
- Air-cooled, DX cooling
- Gas-fired pre-heat
- 55,500 CFM Total

VAV terminal units with reheat

- Zone-level reheat coils
  - Heating hot water supplied by gas-fired boilers
- Fully ducted return system

MAU and PAC Unit

- 100% OA makeup air unit serves kitchen and dining
- PAC Unit controls therapy pool temperature/humidity



Monthly Electrical Energy Consumption

AGENDA

PROJECT INTRODUCTION

FACILITY DESCRIPTION

MECHANICAL SYSTEM OVERVIEW

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MECHANICAL DEPTH STUDIES

STRUCTURAL BREADTH

OVERALL EVALUATION

CONCLUSION / QUESTIONS

THESIS GOALS

Investigate systems that could:

- Reduce energy use and operating costs
- Improve occupant temperature control
- Pay back in ~5 years
- Have academic benefit

MECHANICAL DEPTH STUDIES

PROJECT INTRODUCTION

MECHANICAL DEPTH STUDIES

- CENTRAL PLANT INVESTIGATION
- VRF SYSTEM
- SOLAR THERMAL SYSTEM

STRUCTURAL BREADTH

OVERALL EVALUATION

CONCLUSION / QUESTIONS

Depth Study 1: Central Plant Investigation

- High Efficiency Condensing Boilers
- Chilled Water Plant: Air-Cooled vs. Water-Cooled
- Hypothesis: Will not be cost-effective

Depth Study 2: Variable Refrigerant Flow System

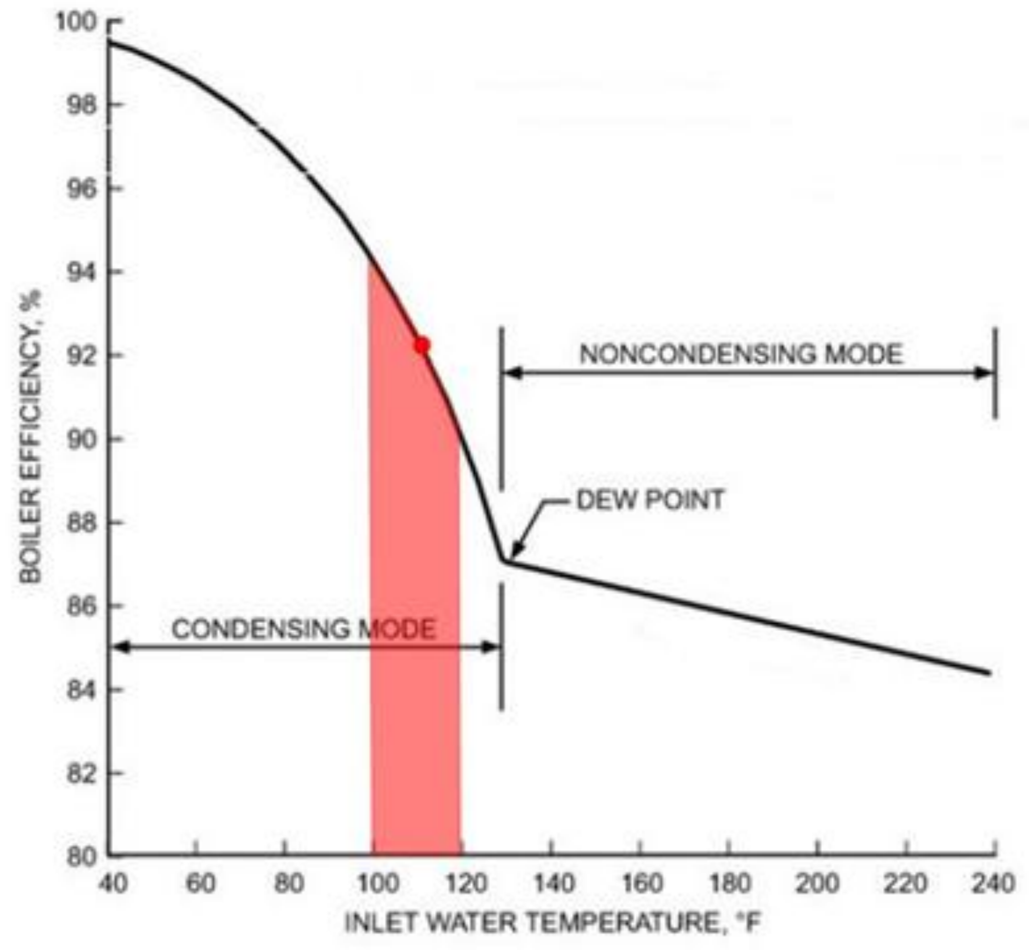
- Heat recovery operation: Reduce annual energy use
- Improve zone-level temperature control
- Academic benefit: Learn the principles of system operation

Depth Study 3: Solar Thermal System

- Reduce domestic hot water and space heating load
- Utilize the hot Texas climate
- Take advantage of fairly constant domestic hot water demand
- Academic benefit: Learn the principles of system operation

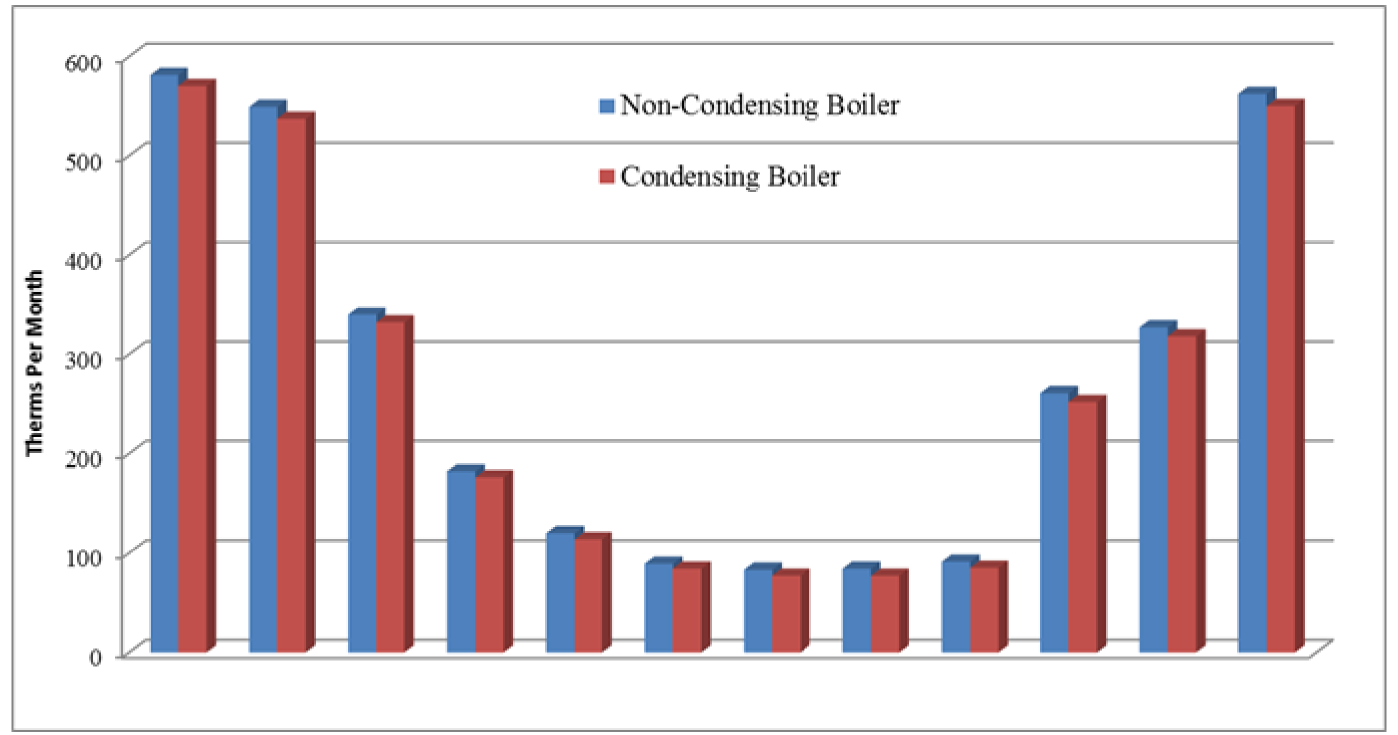
Condensing Boilers:

- Condense the water vapor produced by combustion to recover latent heat
- Increase overall boiler efficiency
- Ideal with low return water temperatures
  - Varies with load – average range used for model



Condensing Boilers:

- Condense the water vapor produced by combustion to recover latent heat
- Increase overall boiler efficiency
- Ideal with low return water temperatures
  - Varies with load – average range used for model
- Decrease in natural gas consumption not significant
- 97-year simple payback



Monthly Natural Gas Consumption

DEPTH STUDY 1: CENTRAL PLANT INVESTIGATION

Chilled Water System Design:

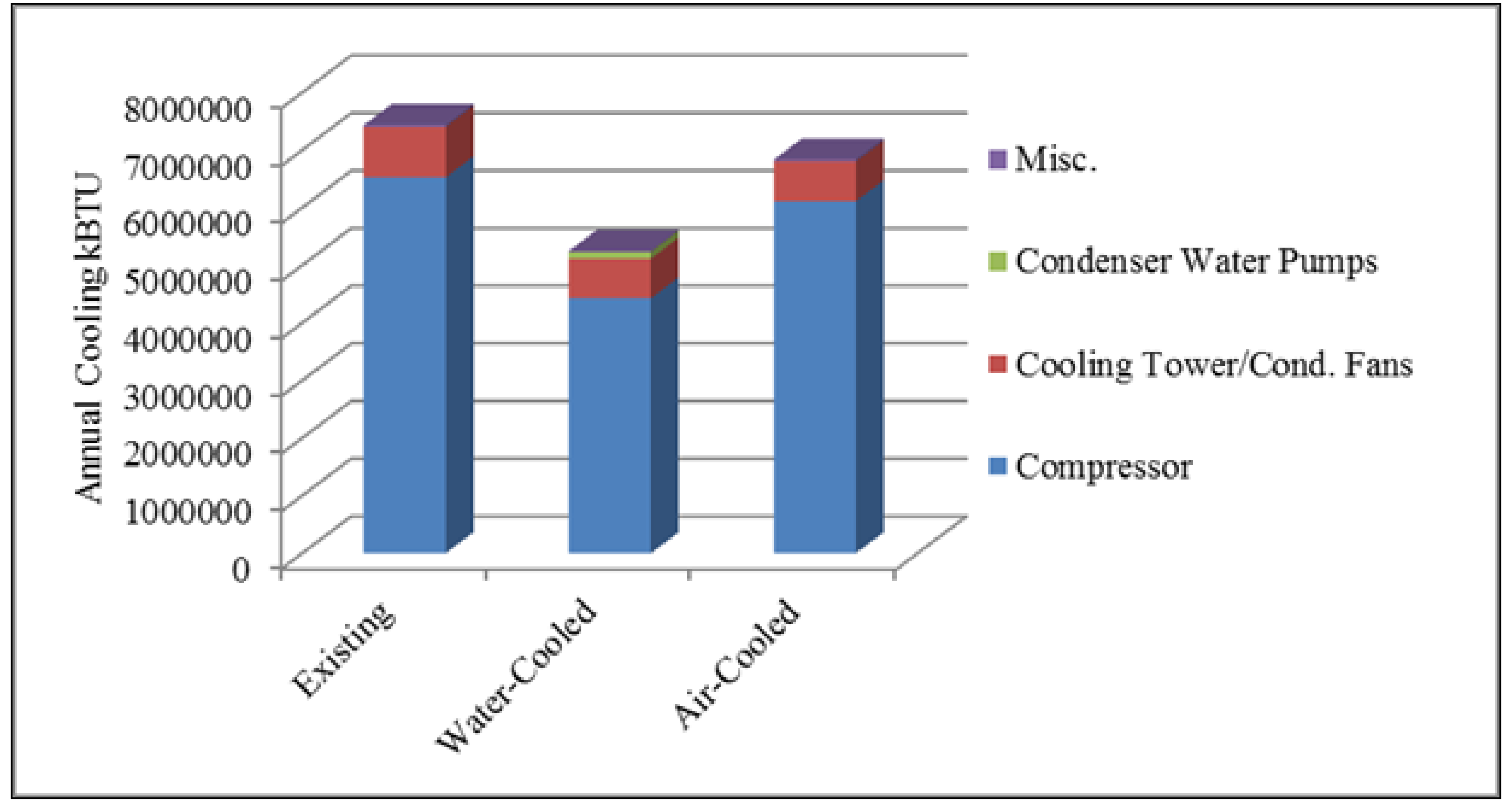
- Two 90-ton chillers arranged in parallel
- Primary-secondary chilled water pumping configuration

Air-Cooled:

- Chillers placed outside – no mechanical room space requirement
- Less significant first cost increase and energy savings

Water-Cooled:

- 200-ton cooling tower with associated condenser water loop
- Increased equipment cost, increased energy savings

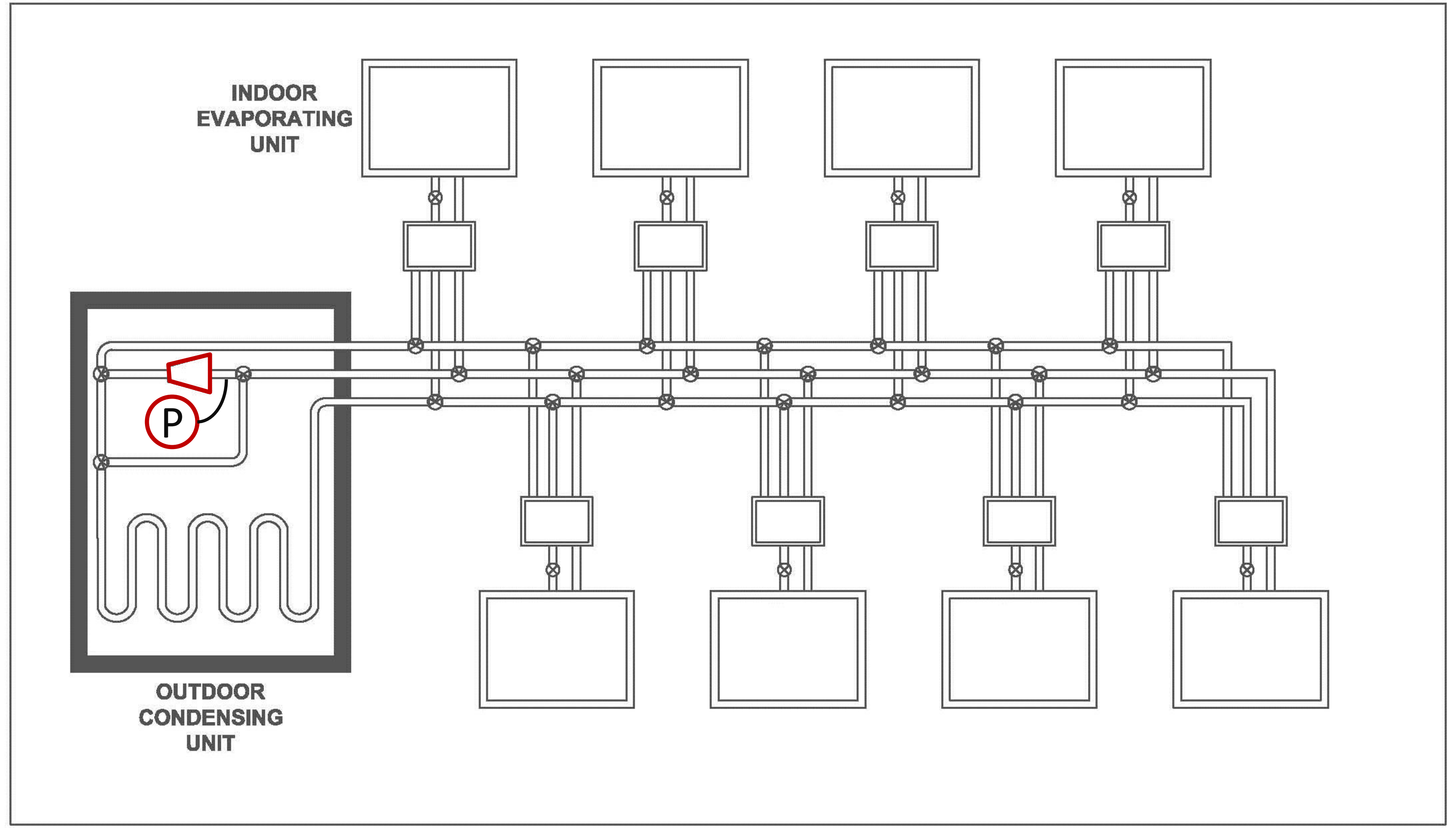


Equipment Energy Use

DEPTH STUDY 2: VRF SYSTEM

System Operation:

- Several indoor evaporating units connected to one outdoor condensing unit
- Refrigerant flow modulated by inverter-driven scroll compressor
  - Flow rate controlled by low pressure sensor at suction side of compressor
  - Goal: control evaporation temperature to match load on each evaporator



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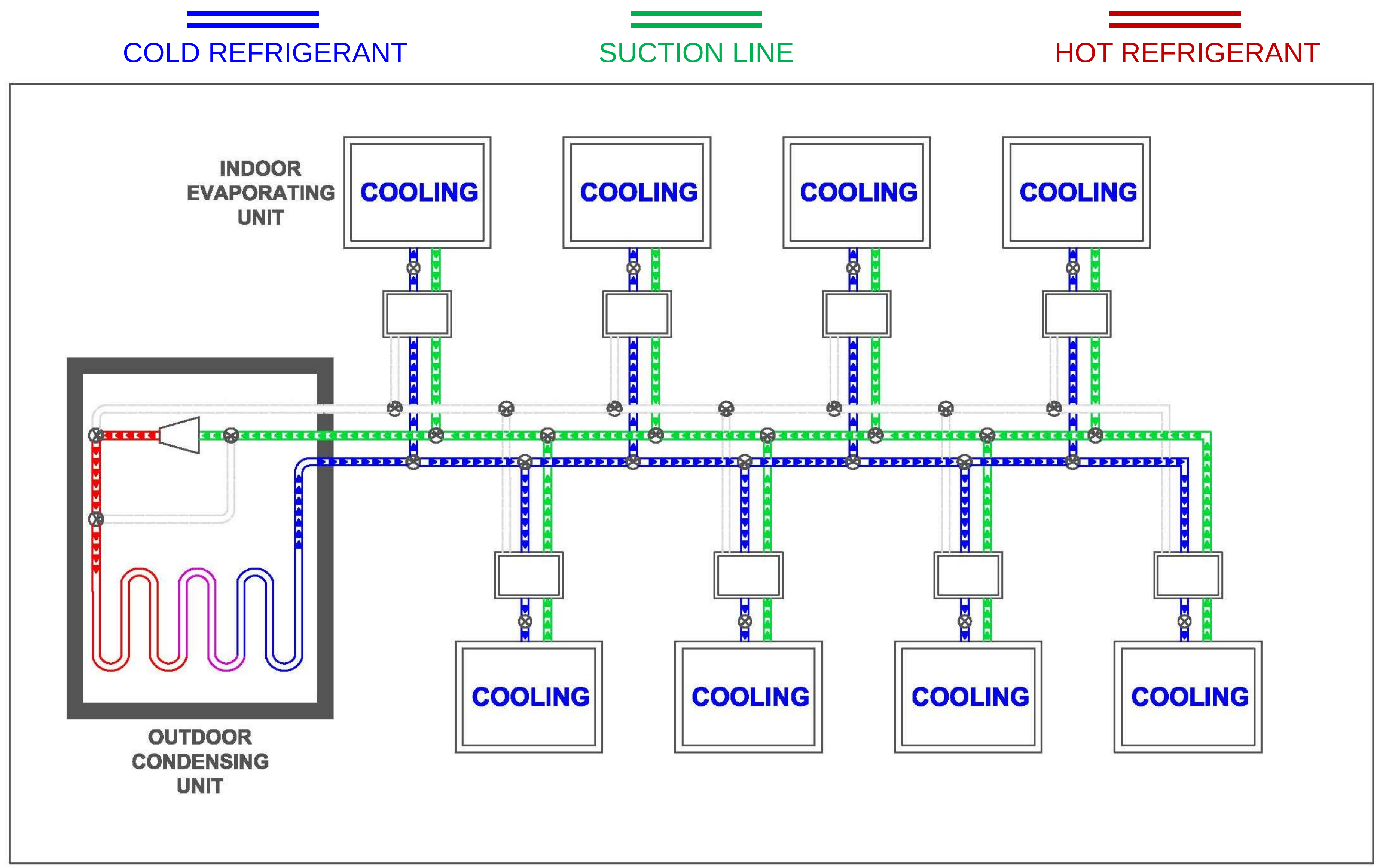
  - 3-pipe system for simultaneous heating and cooling



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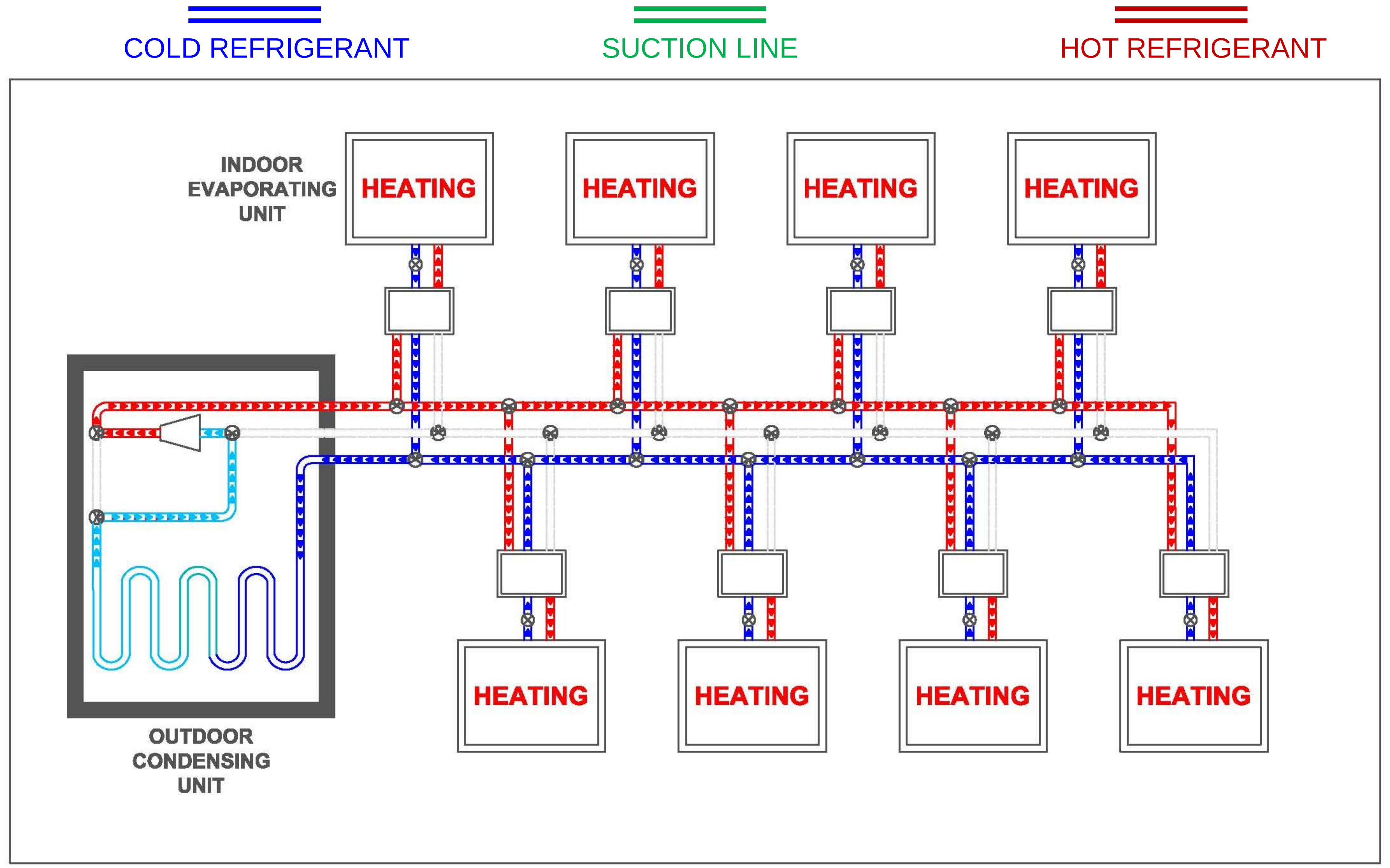

AGENDA

- PROJECT INTRODUCTION
- MECHANICAL DEPTH STUDIES
  - CENTRAL PLANT INVESTIGATION
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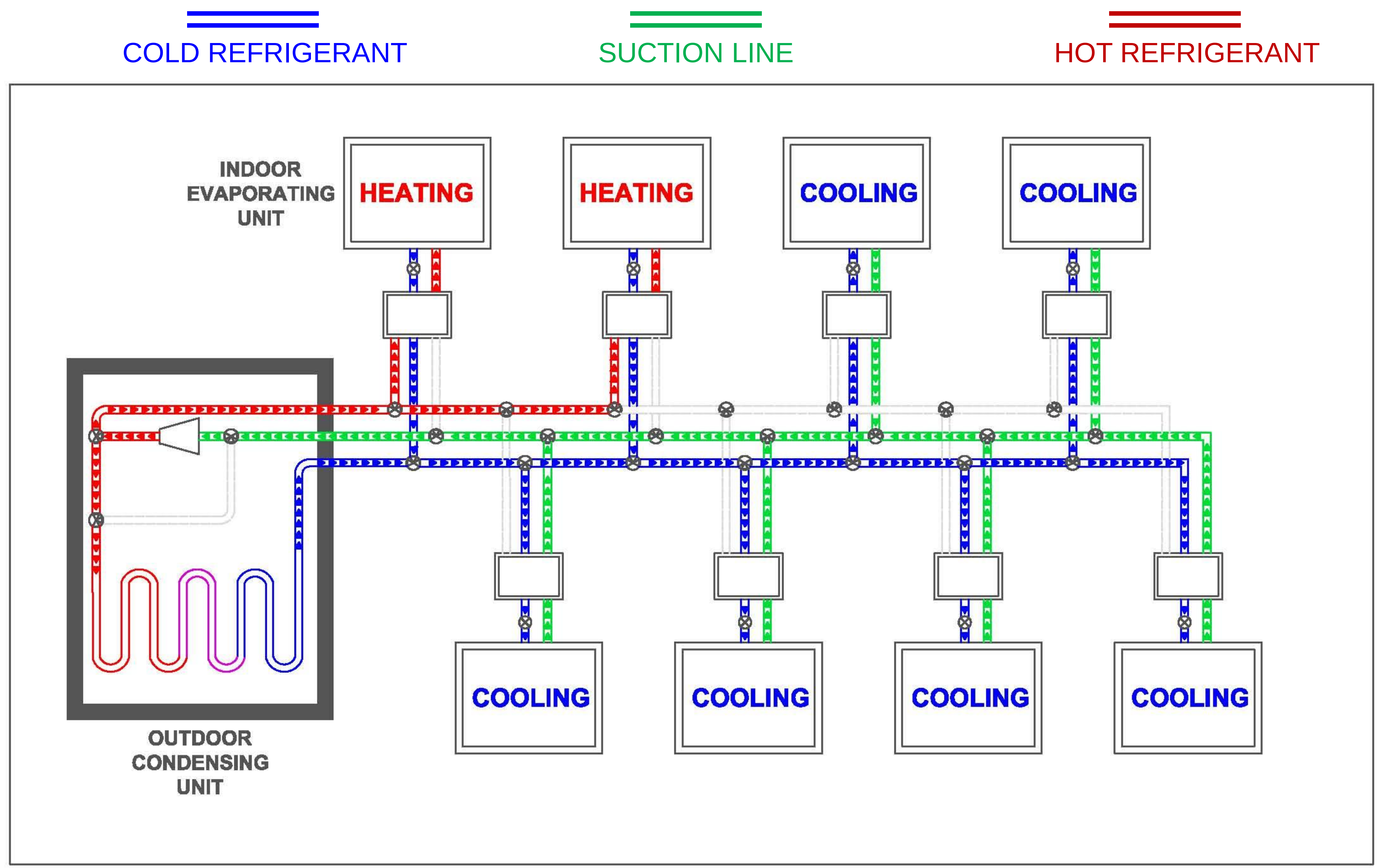

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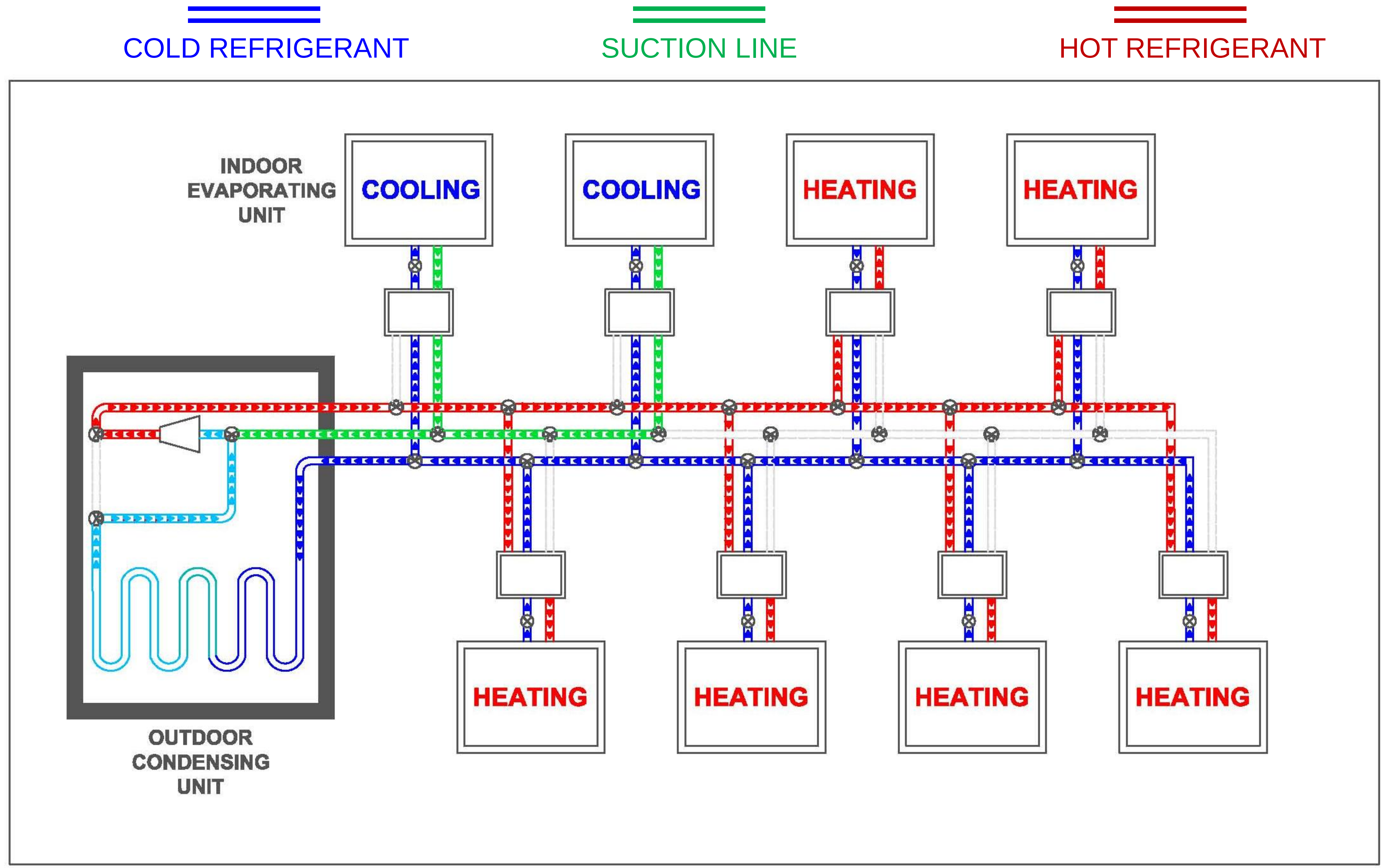
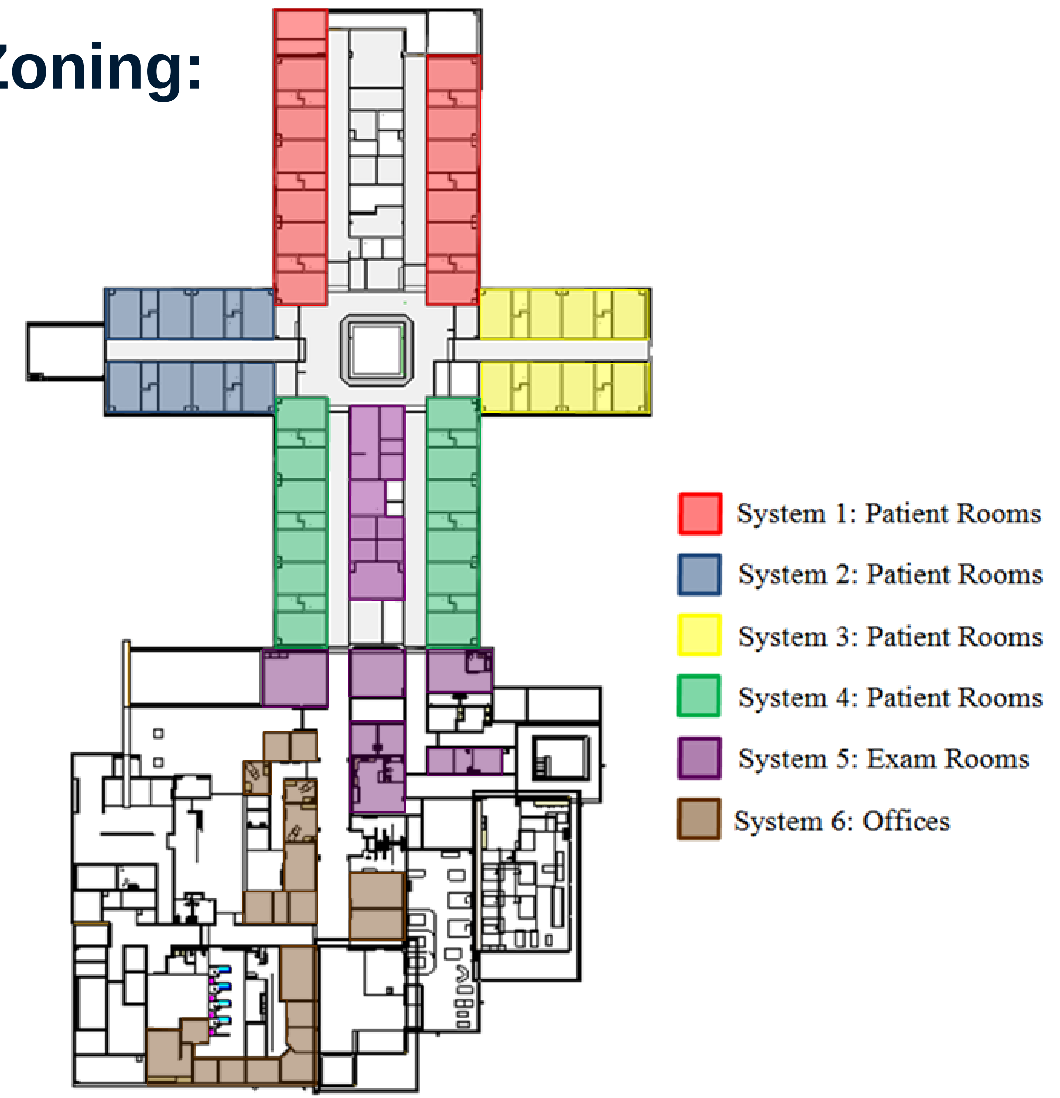


DEPTH STUDY 2: VRF SYSTEM

System Zoning:



- **System Designed: six condensing units:**

System	Existing System Zone		VRF System	
	Cooling (Ton)	Heating (MBh)	Cooling (Ton)	Heating (MBh)
VRF-1	11.6	28.6	10.8	54.0
VRF-2	7.1	17.1	6.7	35.1
VRF-3	7.2	17.1	6.8	35.1
VRF-4	11.0	27.3	10.3	51.1
VRF-5	8.1	13.5	7.5	33.0
VRF-6	8.4	20.9	7.9	30.0

- **All indoor units ducted – connected to a 100% outside air unit for ventilation**
- **RTU-1 can be removed, remaining zones served by existing RTUs 2 & 3**

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- PROJECT INTRODUCTION
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  - VRF SYSTEM
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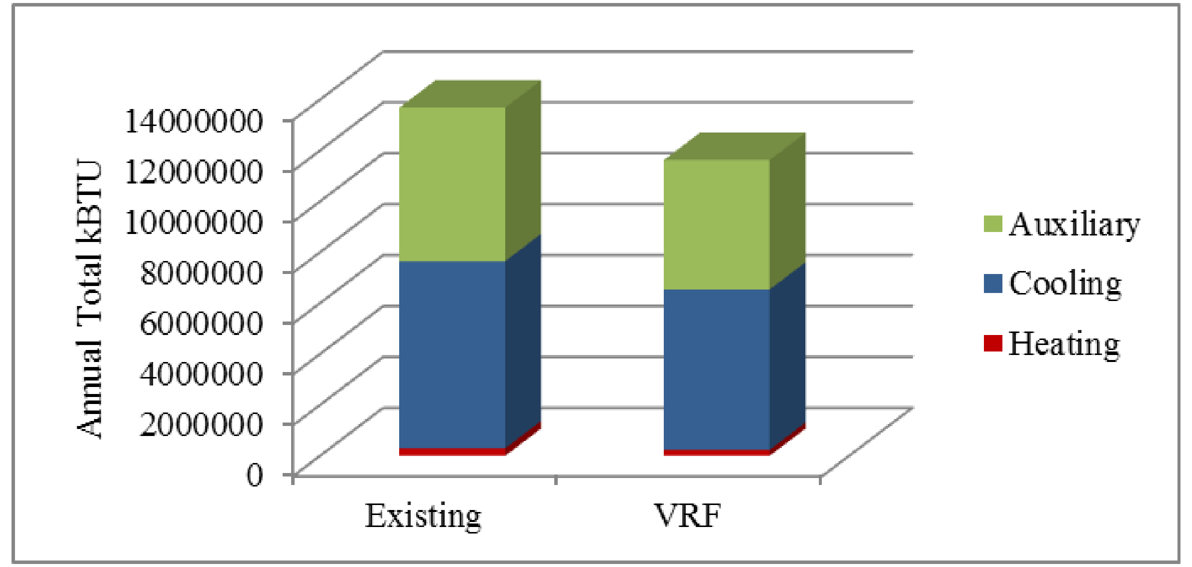

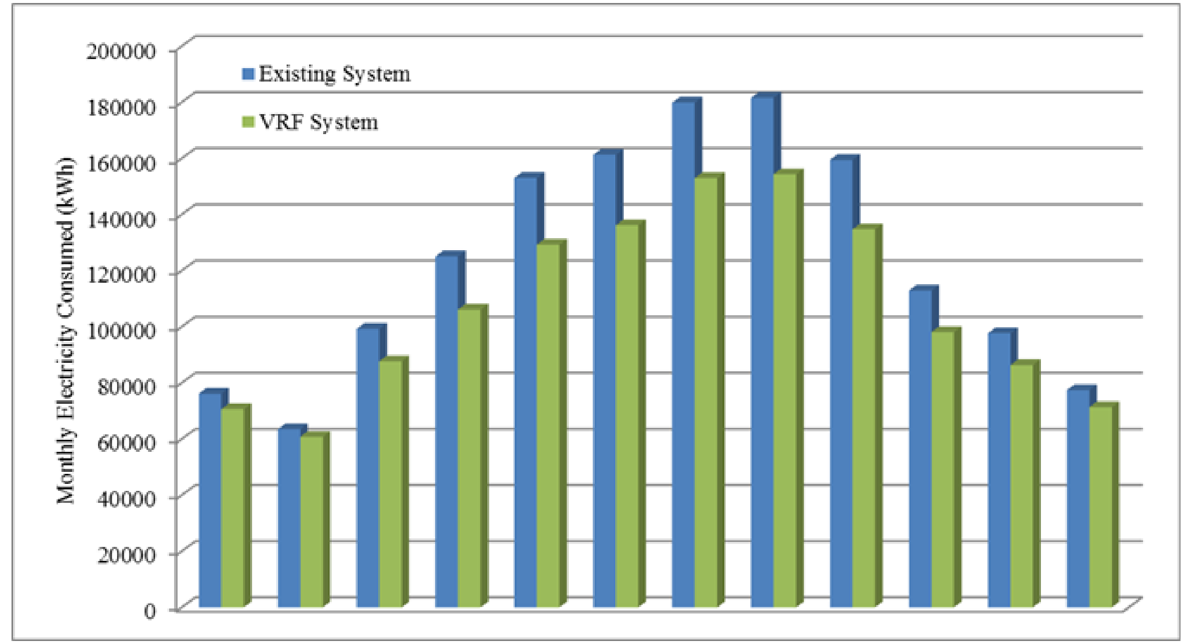

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- All indoor units ducted – connected to a 100% outside air unit for ventilation
- RTU-1 can be removed, remaining zones served by existing RTUs 2 & 3
- Significant energy savings from cooling and fan energy reduction
- System most efficient in summer months – not attributed to heat recovery

AGENDA

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PROJECT INTRODUCTION

MECHANICAL DEPTH STUDIES

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STRUCTURAL BREADTH

OVERALL EVALUATION

CONCLUSION / QUESTIONS

- <u>**System Added First Cost: $57,442**</u>
  - **+ Indoor & Outdoor Units ($53,680)**
  - **+ VRF Piping & Distribution ($76,580)**
  - **+ Outdoor Air Unit ($23,725)**
  - **+ Refrigerant & Controls ($6,600)**
  - **- RTU-1 Eliminated (-$86,502)**
    - **- Roof Framing Cost (-$2,900)**
- **Yearly Savings: $9,906**
- **Simple Payback Period: 5.8 years**
- **20-year life-cycle cost: $1,104,911**

  (existing system: $1,171,718)*

  ***Does Not Include Domestic Hot Water Energy Use**

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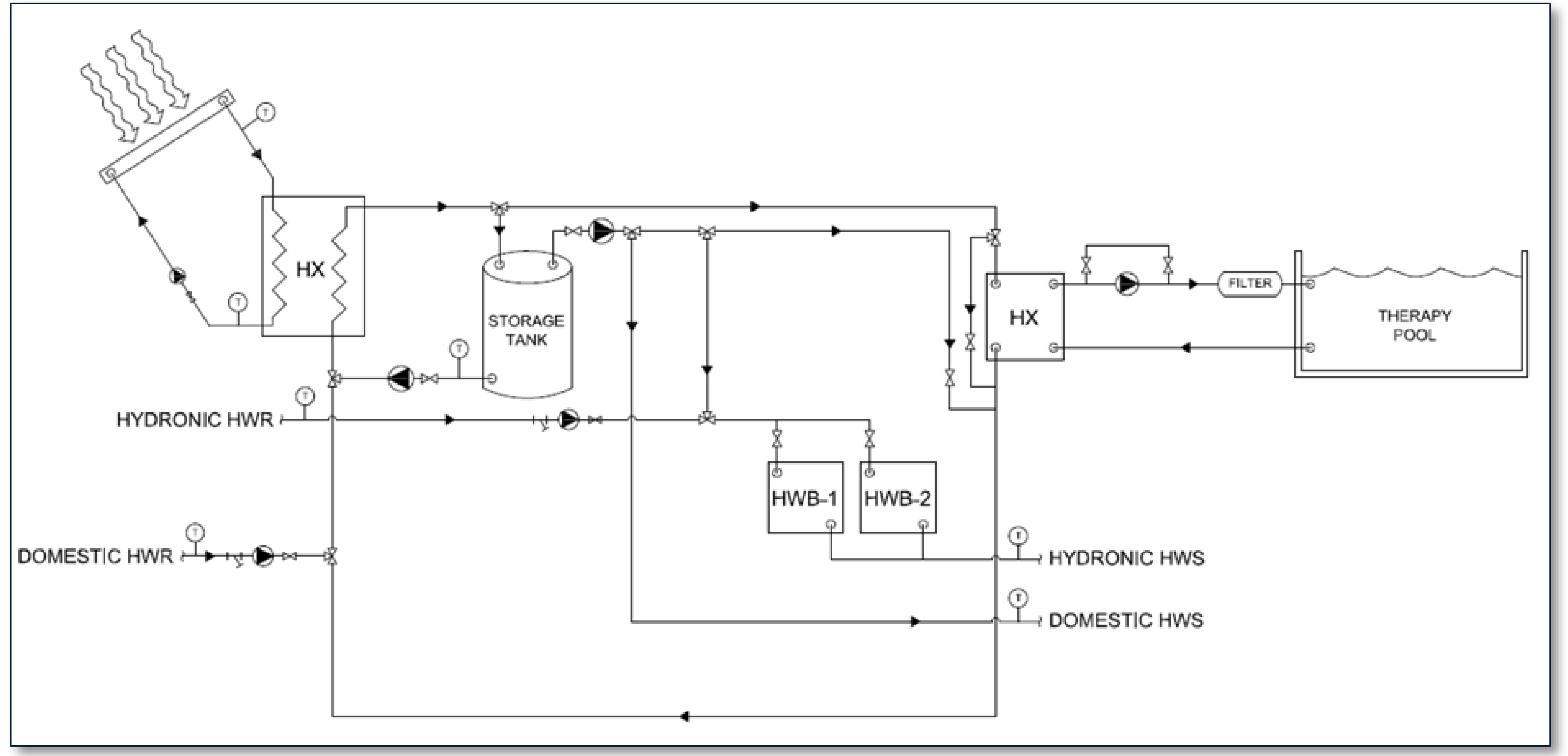
- **Significant energy savings from cooling and fan energy reduction**
- **System most efficient in summer months – not attributed to heat recovery**

DEPTH STUDY 3: SOLAR THERMAL SYSTEM

System Operation:

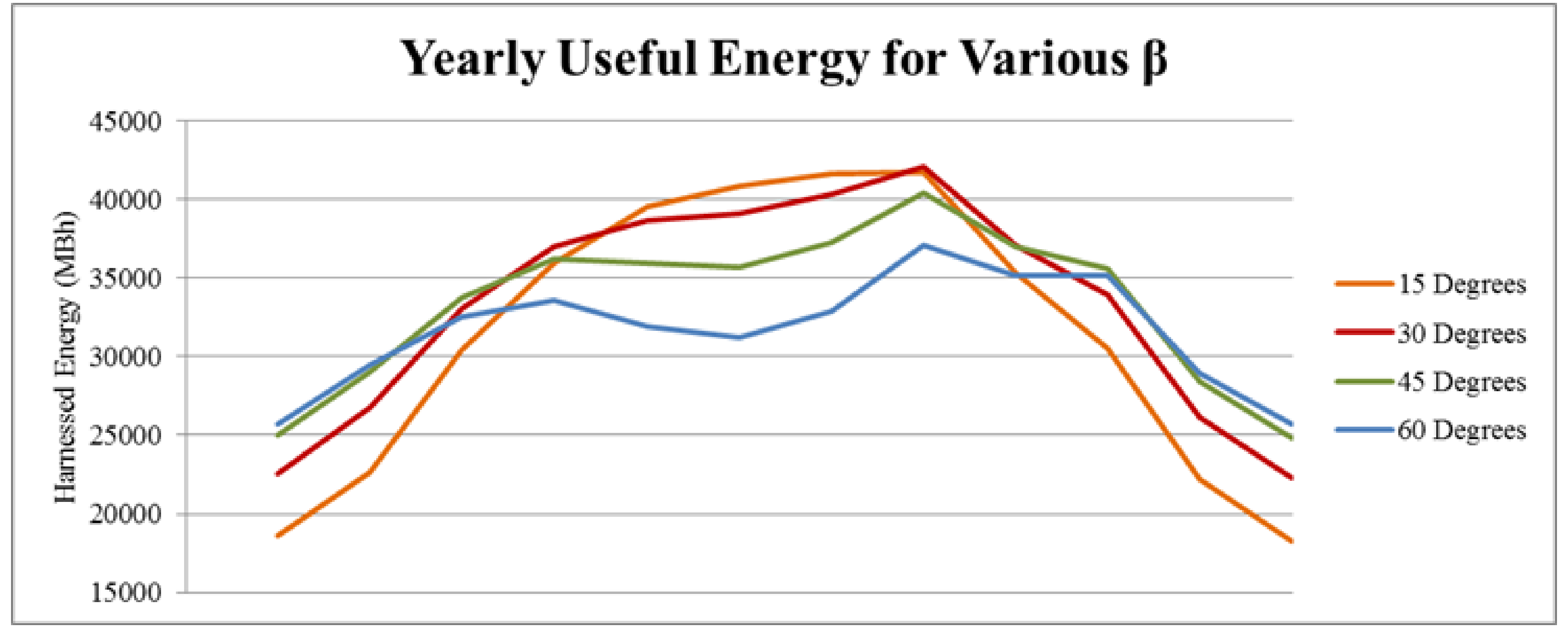
- Flat-plate, forced circulation solar collection system
  - Glycol-water mixture used in collection loop for freeze protection
- Thermal storage in hot water storage tank
  - Has indirect heater: replaces existing hot water heaters
- Primary Functions: Heat domestic hot water & Therapy pool heating
  - Loads calculated through methods in ASHRAE Handbooks
- Secondary Function: Space heating
  - Loads from Trace Energy Model



Solar Gain Calculation

Based on:

- Latitude ($\Phi = 29.69°N$)
- Zenith Angle (θ_z) — Hourly dependent
- Hour Angle (ω)
- Solar Declination(δ) – Date dependent
- Collector Tilt (β) - optimized at $\beta = 37.2°$ → 40° was used
- Surface Azimuth (Υ) - optimized at $\beta = 37.5°W$ → 33°W was used
- Collector Characteristics
- System Operation Characteristics



DEPTH STUDY 3: SOLAR THERMAL SYSTEM

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Image courtesy of Bing maps

AGENDA

PROJECT INTRODUCTION

MECHANICAL DEPTH STUDIES

- CENTRAL PLANT INVESTIGATION
- VRF SYSTEM
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STRUCTURAL BREADTH

OVERALL EVALUATION

CONCLUSION / QUESTIONS

DEPTH STUDY 3: SOLAR THERMAL SYSTEM

Collector Arrangement

- Area: (3) 130 ft^2 collectors → 390 ft^2 total

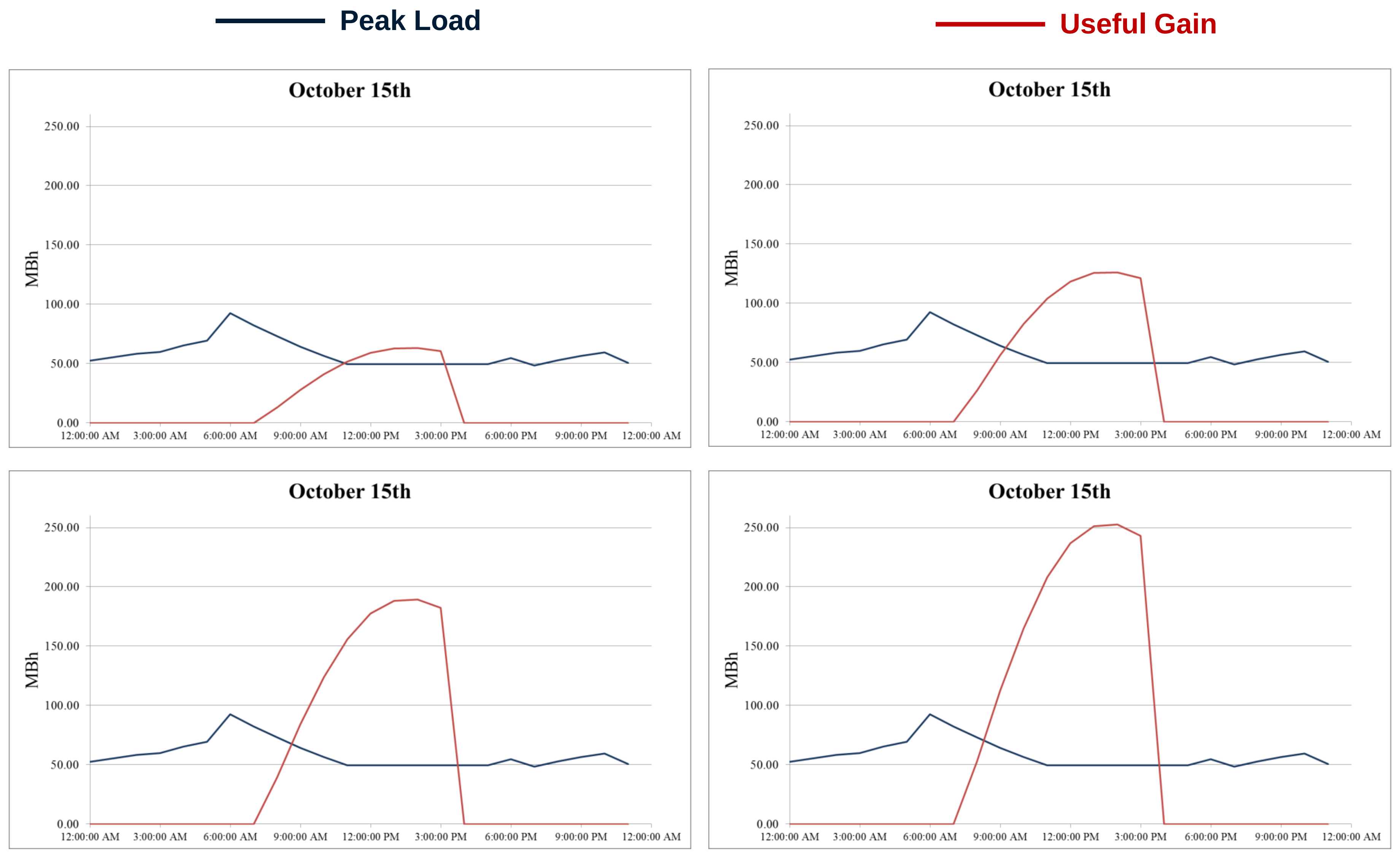
Goal: maximize total solar fraction:

$$\frac{\textit{Load met by solar system}}{\textit{Total load}}$$

without overheating or throwing away energy

⬇

Thermal Storage



DEPTH STUDY 3: SOLAR THERMAL SYSTEM

PROJECT INTRODUCTION

MECHANICAL DEPTH STUDIES

CENTRAL PLANT INVESTIGATION

VRF SYSTEM

SOLAR THERMAL SYSTEM

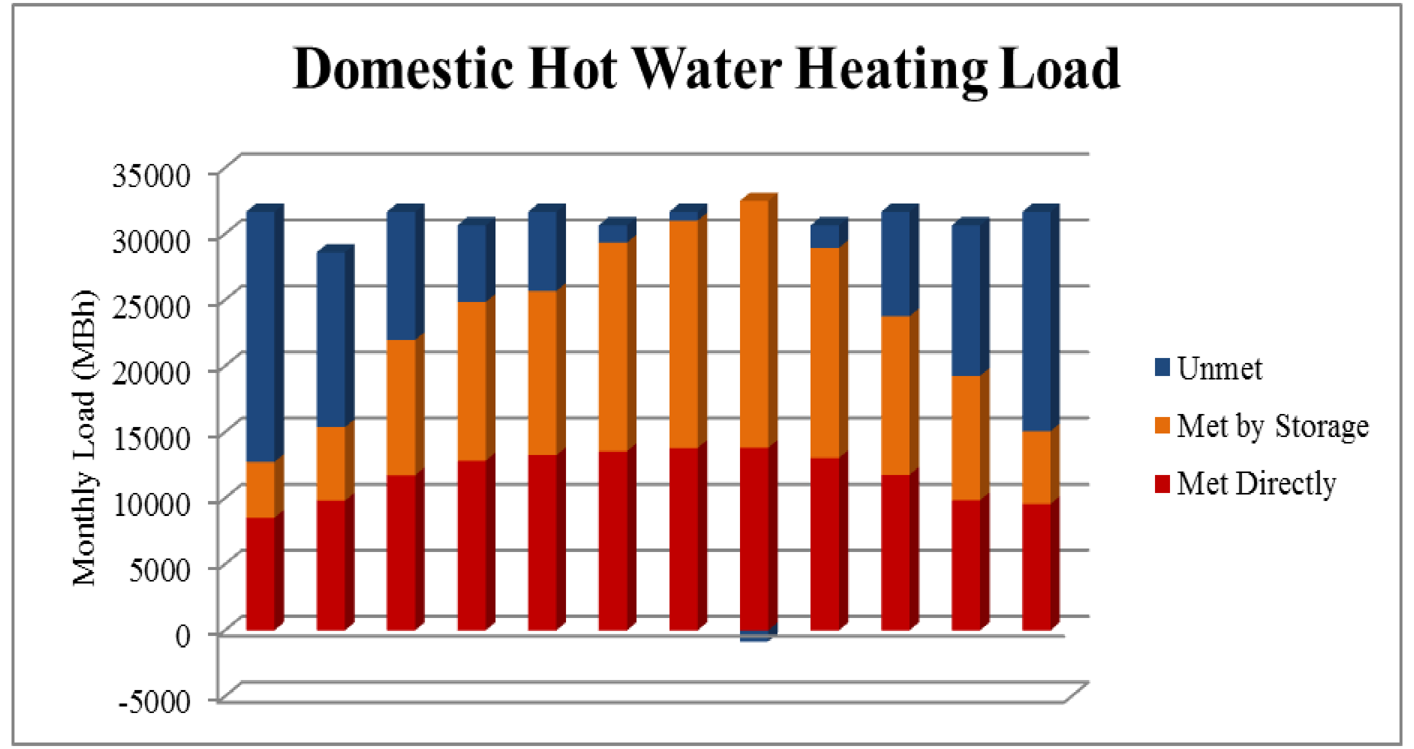
STRUCTURAL BREADTH

OVERALL EVALUATION

CONCLUSION / QUESTIONS

Load Met Directly:

- **38%** of annual domestic hot water heating load met directly
- **8%** of space heating load met directly



Thermal storage in a 400 gallon stratified hot water tank:

- **38%** of DHW load through storage

76% total

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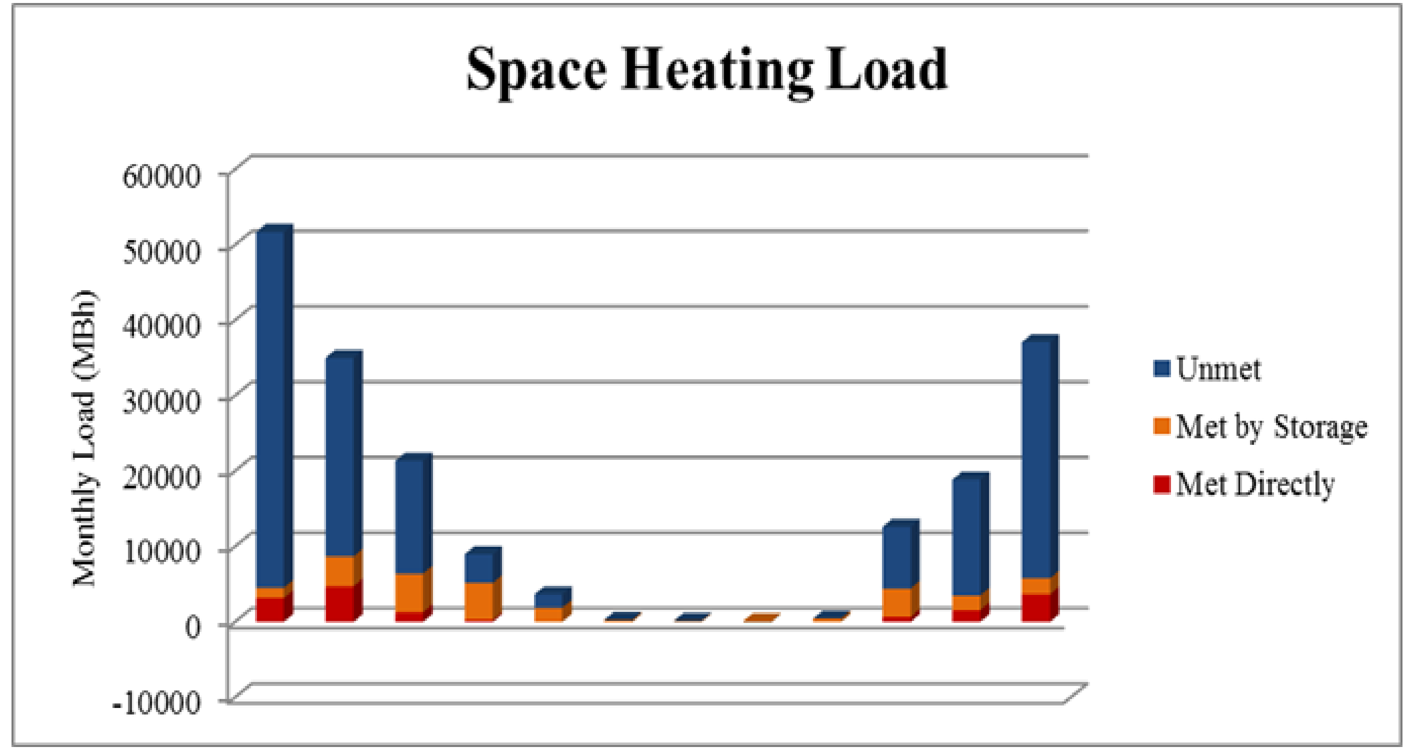


Thermal storage in a 400 gallon stratified hot water tank:

- **38%** of DHW load through storage

  76% total

- **14%** of space heating through storage

  22% total

DEPTH STUDY 3: SOLAR THERMAL SYSTEM

- **System Added First Cost: $61,906**
  - + Collectors ($26,758)
  - + Storage Tank ($4,670)
  - + Heat Exchangers ($8,403)
  - + Piping & Distribution Equipment ($1,555)
  - + Controls ($10,520)

- **Yearly Savings: $30,814**
- **Simple Payback Period: 2.06 years**
- **20-year life-cycle cost: $1,742,889**

  (existing system: $2,070,197)*

  *Includes Domestic Hot Water Energy Use

BREADTH STUDY: STRUCTURAL

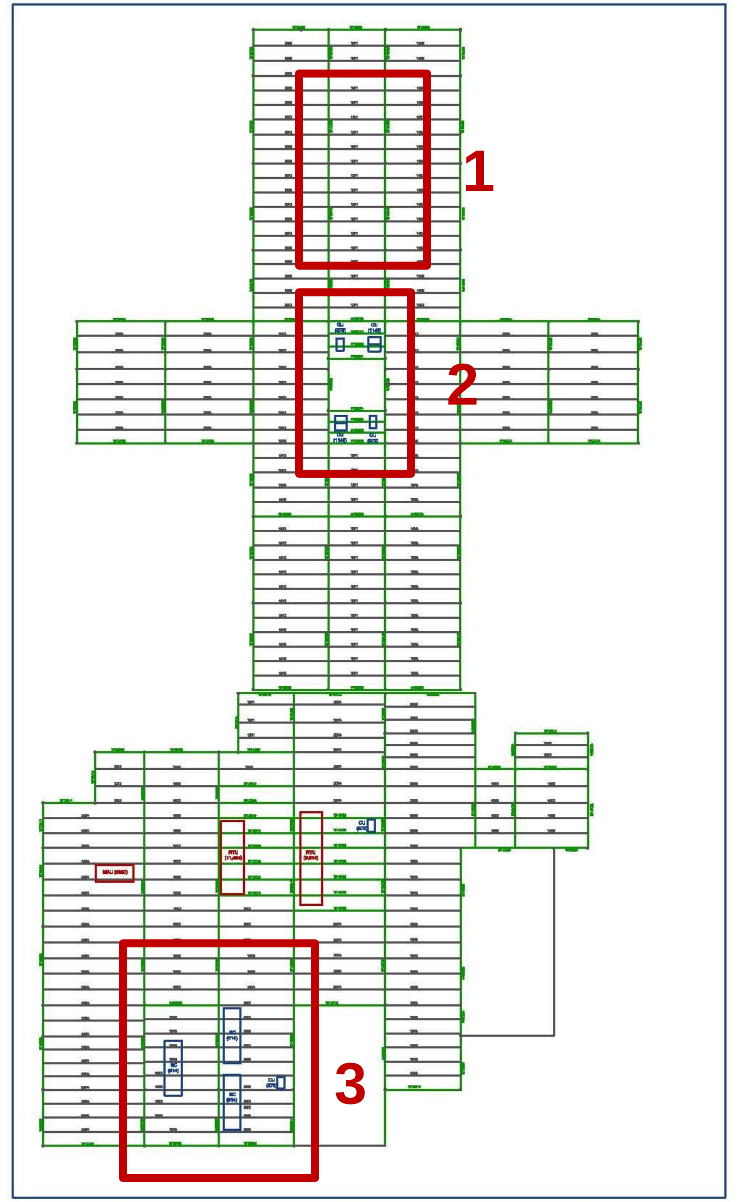
PROJECT INTRODUCTION

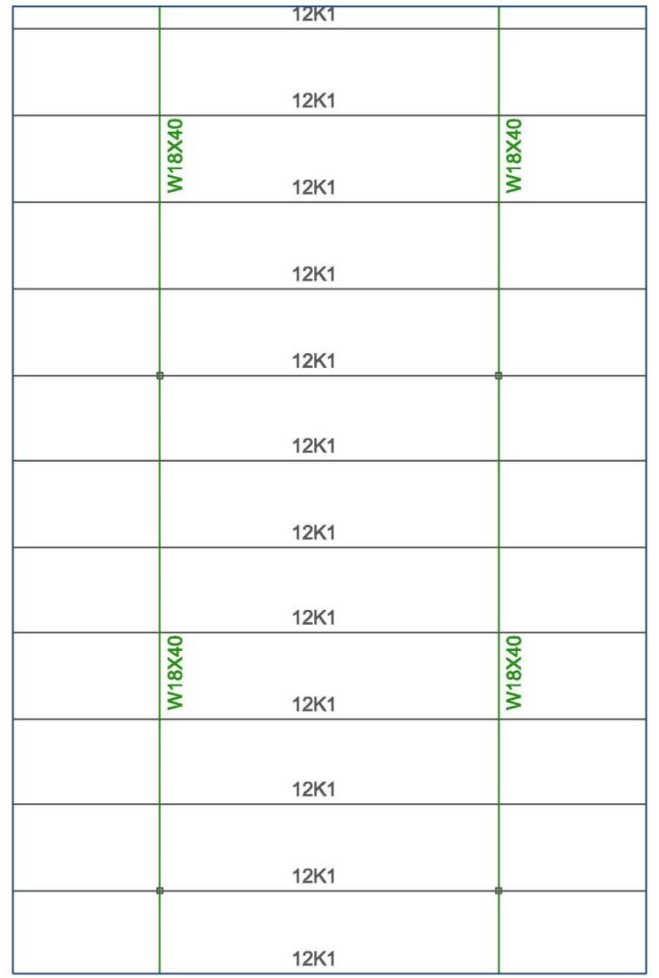
MECHANICAL DEPTH STUDIES

STRUCTURAL BREADTH

OVERALL EVALUATION

CONCLUSION / QUESTIONS





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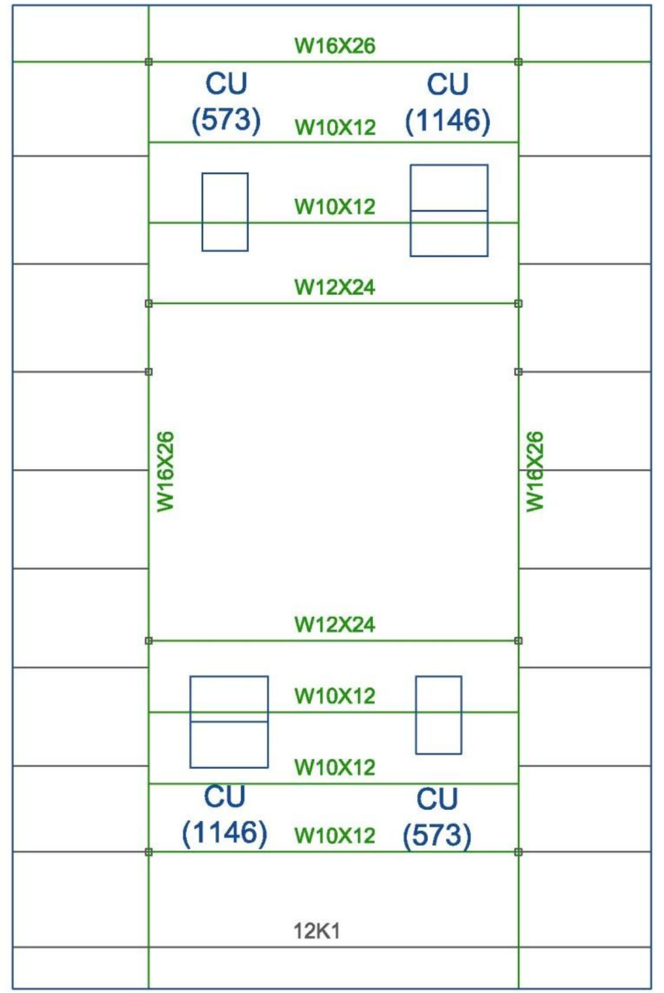

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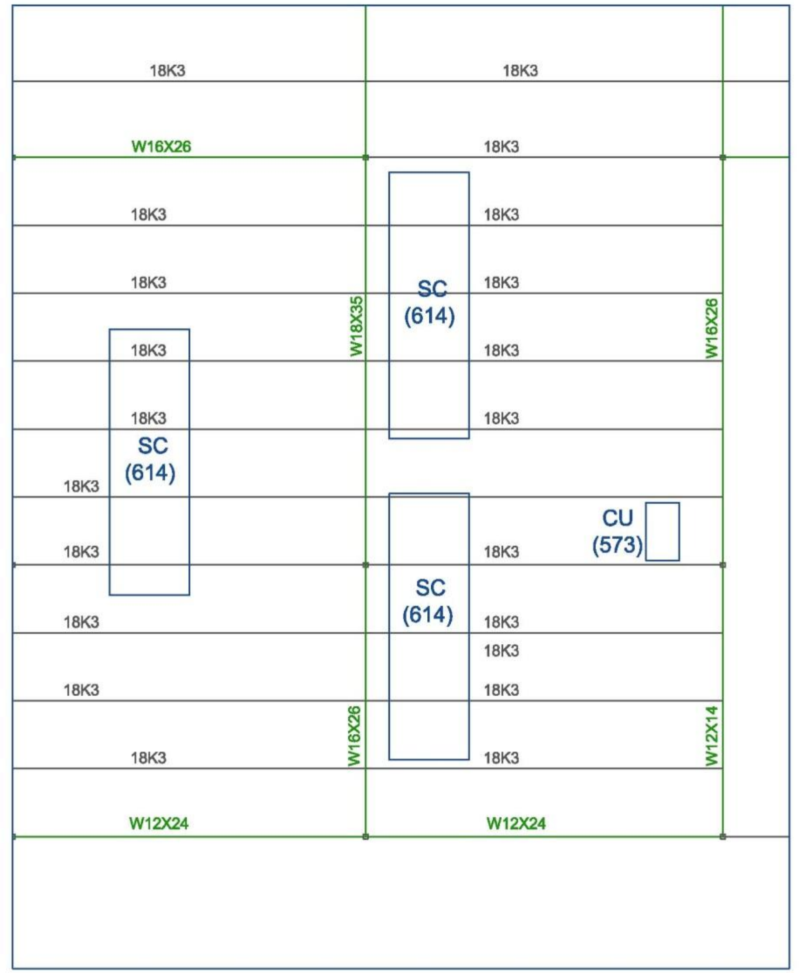

3

AGENDA

PROJECT INTRODUCTION
MECHANICAL DEPTH STUDIES
STRUCTURAL BREADTH
OVERALL EVALUATION
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OVERALL EVALUATION

Chilled Water System Not Recommended ✘

- Facility not large enough
- Energy requirement not high enough
- No life-cycle cost benefit

VRF System Recommended ✓

- Contingent on CFD analysis
- Humidity Control Necessary
- Dependent on owner’s payback threshold

Solar Thermal System Recommended ✓

- Quick payback
- Great climatic conditions
- Free energy!

PROJECT INTRODUCTION

MECHANICAL DEPTH STUDIES

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Special Thanks:

- Ernest Health, Inc.
- JBA Consulting Engineers
  - Jason Witterman
  - Kris Kalkowski
  - Stephen Haines
- Dekker/Perich/Sabatini Architects
  - Bobby George
- Faculty Advisor: Dr. William Bahnfleth
- Faculty Member: Dr. Stephen Treado
- Fellow AE Students

QUESTIONS?