CHASING 2030:
MECHANICAL STRATEGIES FOR HOSPITALS AND LABORATORIES

B|W|B|R

MEP ASSOCIATES, LLC

DUNHAM

CHASING 2030:
MECHANICAL STRATEGIES FOR ENERGY INTENSIVE FACILITIES

1. Develop a deeper understanding of what site energy, source energy and EUI represent
2. Explain the idea of “decoupling the mechanical distribution system” and illustrate strategies for accomplishing this principle.
3. Explain the efficiencies and flexibilities of having a water-based system for heating and cooling.
4. Demonstrate how a recently completed critical access hospital could improve its energy performance if more efficient mechanical strategies were in place, and additionally how it might achieve net-zero.
5. Review how a recently completed research facility improved its energy performance by changing mechanical strategies, and demonstrate how this building could share resources with neighboring buildings to create a more efficient district.
6. Discuss costs and paybacks for these more efficient mechanical strategies.

TODAY'S FOCUS

Necessity

Strategies

Savings

Timing

BACKGROUND AND CASE STUDIES

Necessity

WHY THIS TEAM CAME TOGETHER?

Paul Riemer, PE, LEED AP BD+C, ***Dunham Associates***

Lee Tapper, PE, LEED AP, ***MEP Associates***

Steve Busse, AIA, LEED AP, ***BWBR***

Chris Fischer, AIA, LEED AP BD+C, ***BWBR***

THANK YOU!

Schadegg, Egan, and Metro Mechanical

WHY HOSPITALS?

HEALTH CARE USES 5% OF TOTAL US ENERGY

Greenbuild Seminar : Targeting 100 : A National High Performance Hospital Model; Joel Loveland and Heather Burpee, Univ. of Washington, Duncan Griffin, NBBJ; 2012.

WHY HOSPITALS?

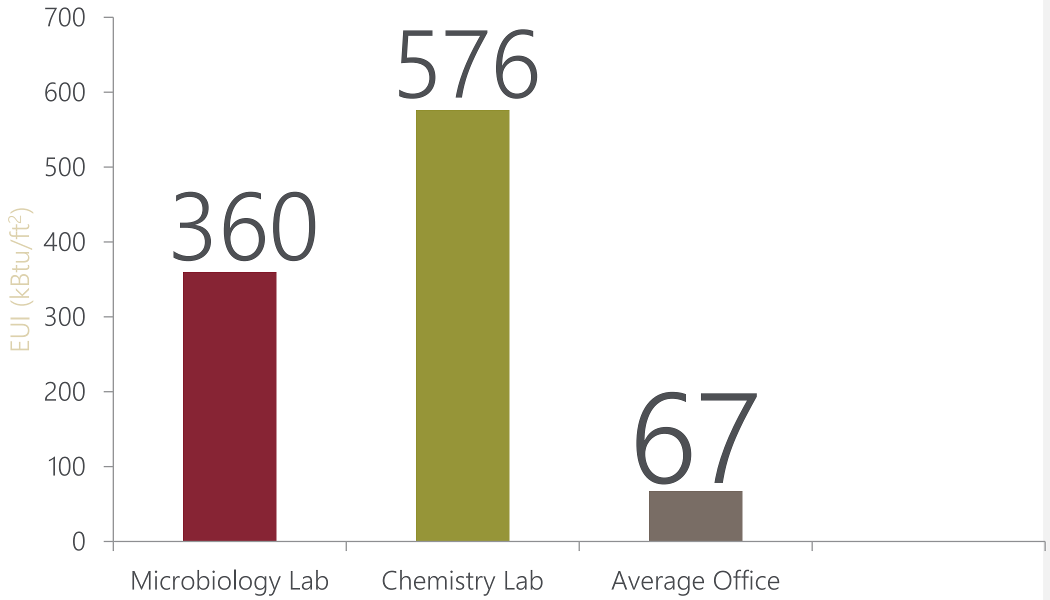
24/7 operations = higher yearly energy costs

Diverse program requires multiple HVAC strategies

Health care growth in the near future

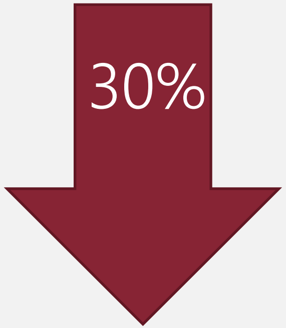
Detailed constraints on temperature and humidity

WHY LABORATORIES?



Laboratories use 5 to 10 times more Energy/SF than an office building of the same size.

Clean Rooms can use 100 times more Energy/SF than an office building of the same size.



2.6 Million

Reduction

Source: 1. Labs 21 "Laboratories for the 21st Century", EPA in partnership with the US Dept. of Energy. 2. Energy Star

WHY LABORATORIES?

Hazardous materials and contagions require 24/7 containment = higher yearly energy costs

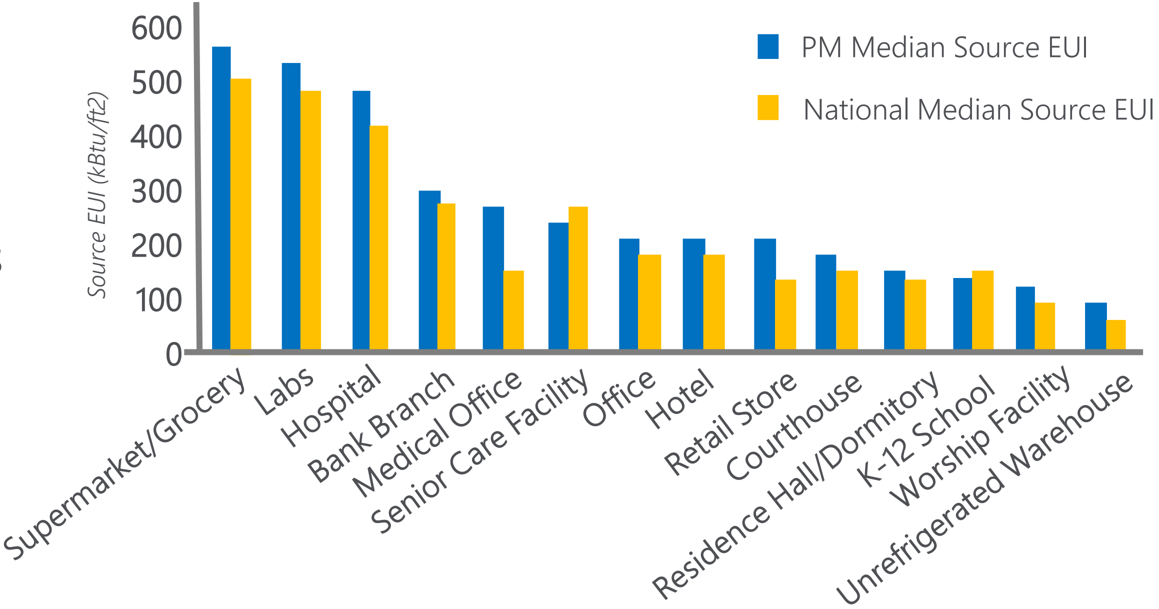
Diverse program requires multiple HVAC strategies

Multi disciplined – academic vs. research/commercial,   Research equipment, storage, vibration, BSL, vivarium, CTH, necropsy + basic office/ staff functions

Detailed constraints on temperature and humidity

WHY HOSPITALS AND LABORATORIES?

- We design both of these complex building types
- We feel it is our duty to be as diligent as possible with your resources



Some building types excluded due to inadequate date and/or EUI values beyond this range.

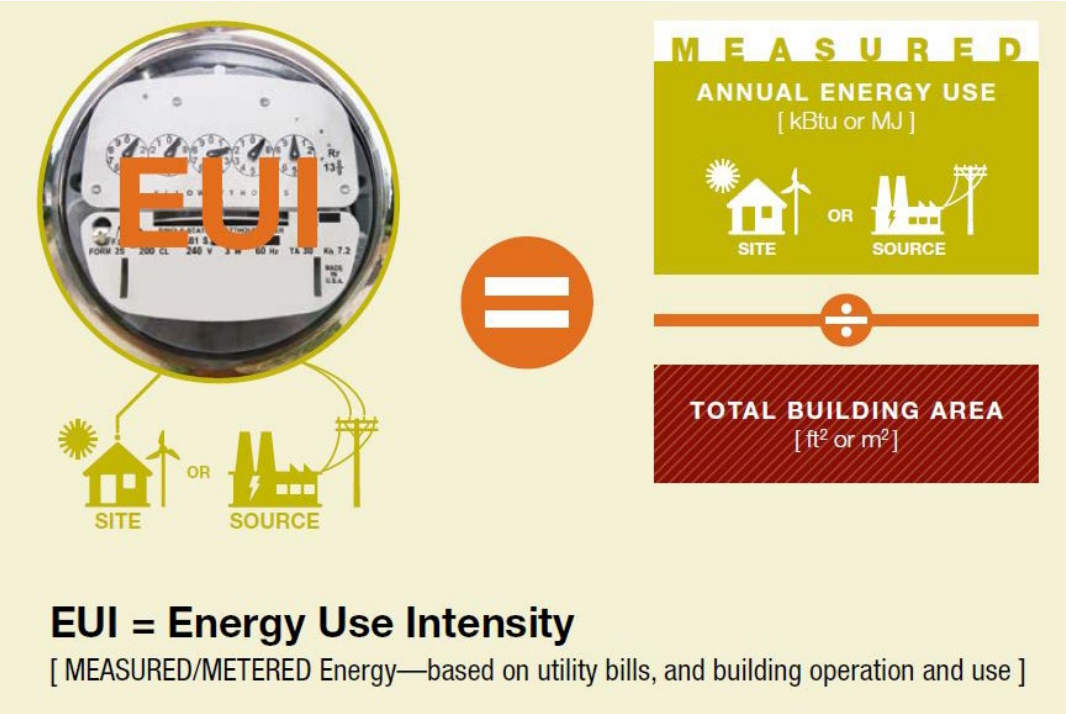
DataTrends: Energy Use Benchmarking; Energy Star Portfolio Manager, United State Environmental Protection Agency; October 2012.

This graph is based on research EPA conducted on more than 100,000 buildings benchmarking in Portfolio Manager to develop its Portfolio Manager DataTrends series. See the Portfolio DataTrends: Energy Use Benchmarking report for additional EUI comparisons.

ESTABLISHING A BASELINE

How do we measure a building's energy use?

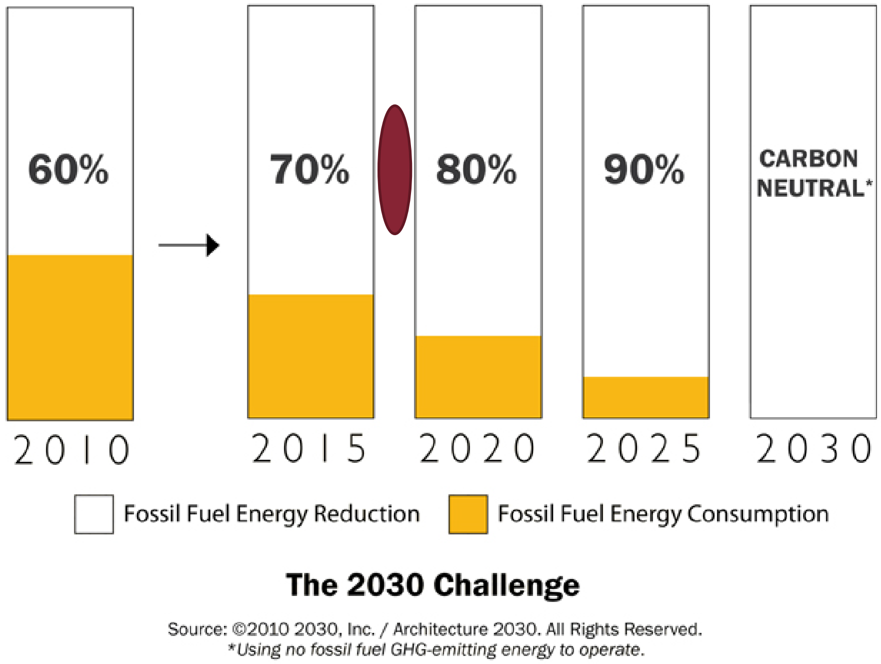
- **Energy Use Intensity (EUI)** – annual energy consumption of all streams(electric, gas, etc.) per square foot
- **Site Energy** – amount of energy consumed by a building (reflected in utility bills)
- **Source Energy** – more accurate measure of building's energy footprint, includes energy lost during production, transmission, and delivery



An Architect's Guide to Integrating Energy Modeling in the Design Process; The American Institute of Architects; 2012.

ESTABLISHING A BASELINE

2030 ⁰Challenge - Our Guideline

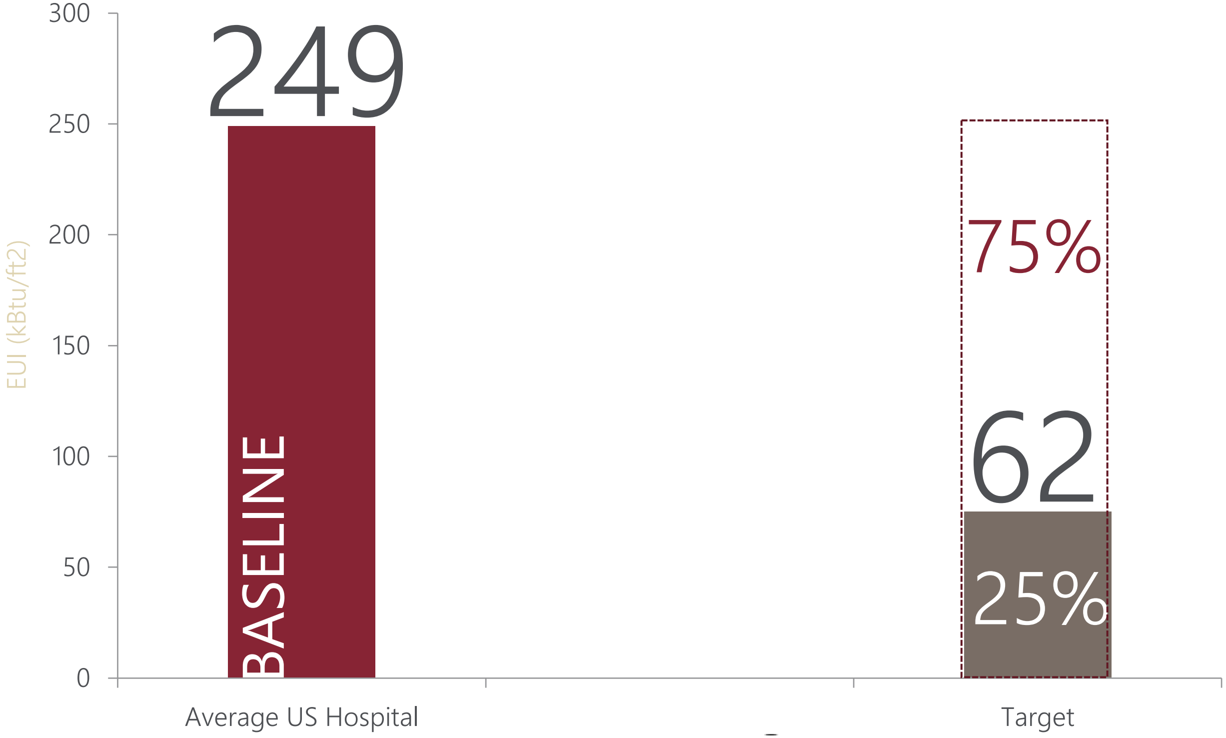


Based on ASHRAE 90.1 - 1989

Current Minnesota Energy Code Baseline is IECC 2012/ ASHRAE 90.1 -2010:

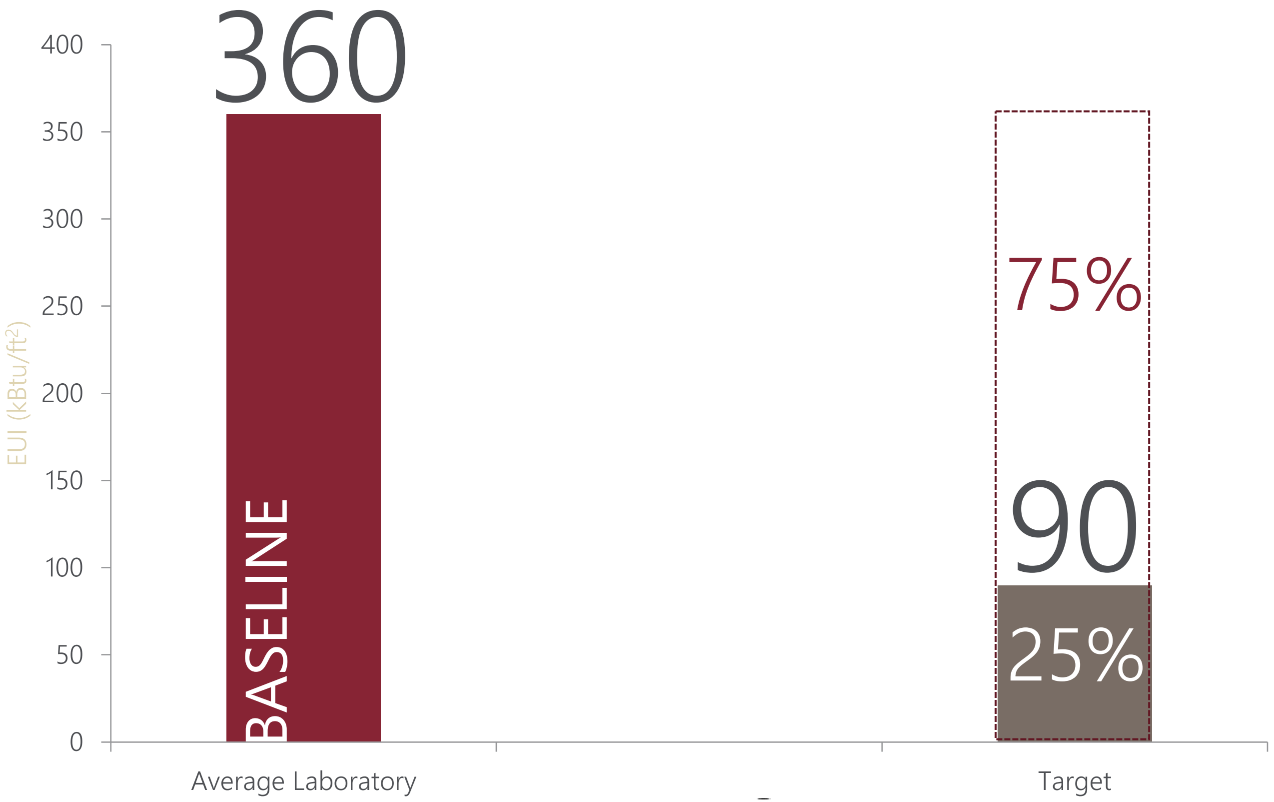
This Baseline impacts:
LEED
EDA – Xcel

HOSPITALS: THE GOAL FOR 2018



*Using no fossil fuel GHG-emitting energy to operate.

LABORATORIES: THE GOAL FOR 2018



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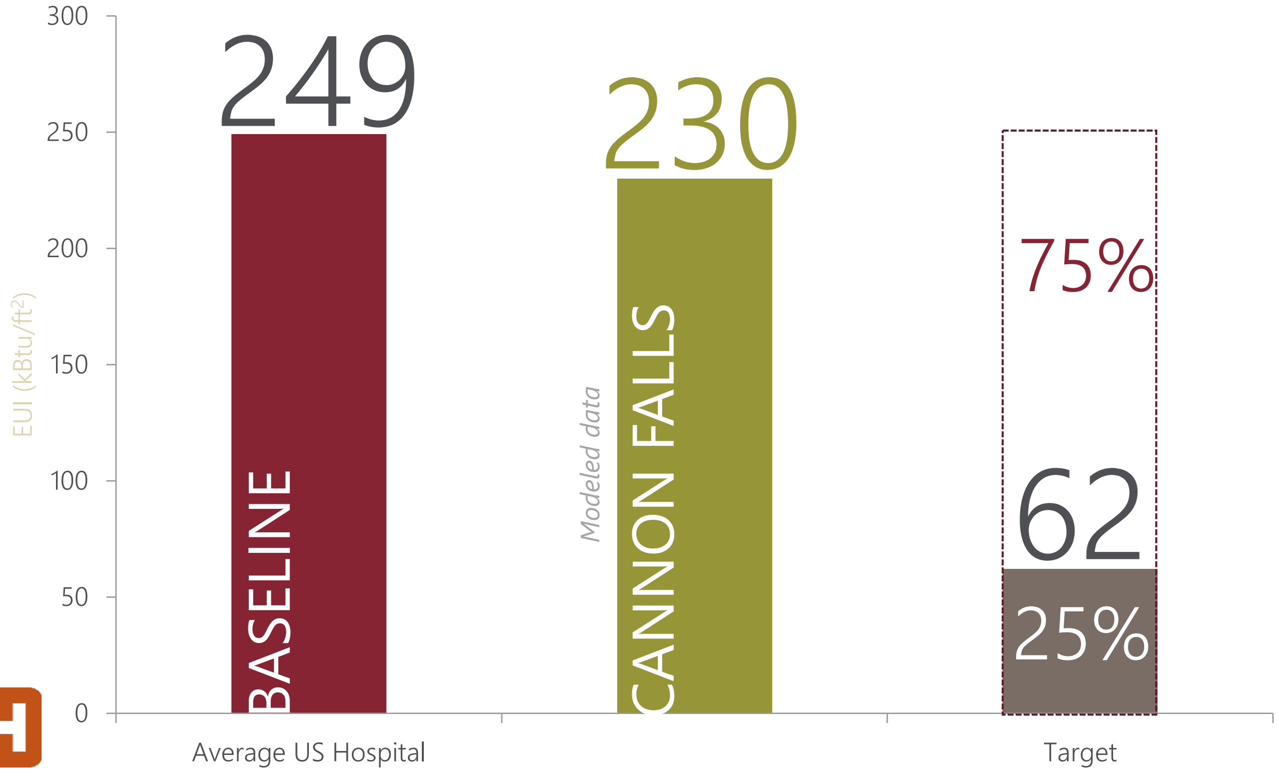
CASE STUDY
MAYO CLINIC HEALTH SYSTEM CANNON FALLS

Cannon Falls, MN
89,252 SF | 15-bed Critical Access Hospital
Designed 2012, construction complete July 2014

STRATEGIES

- Air cooled chiller
- Condensing boilers
- Conventional VAV boxes
- Airflow varied down to 40-50% flow
- Hot water reheat
- Perimeter radiation for envelope heating loads

CASE STUDY
MAYO CLINIC HEALTH SYSTEM - CANNON FALLS



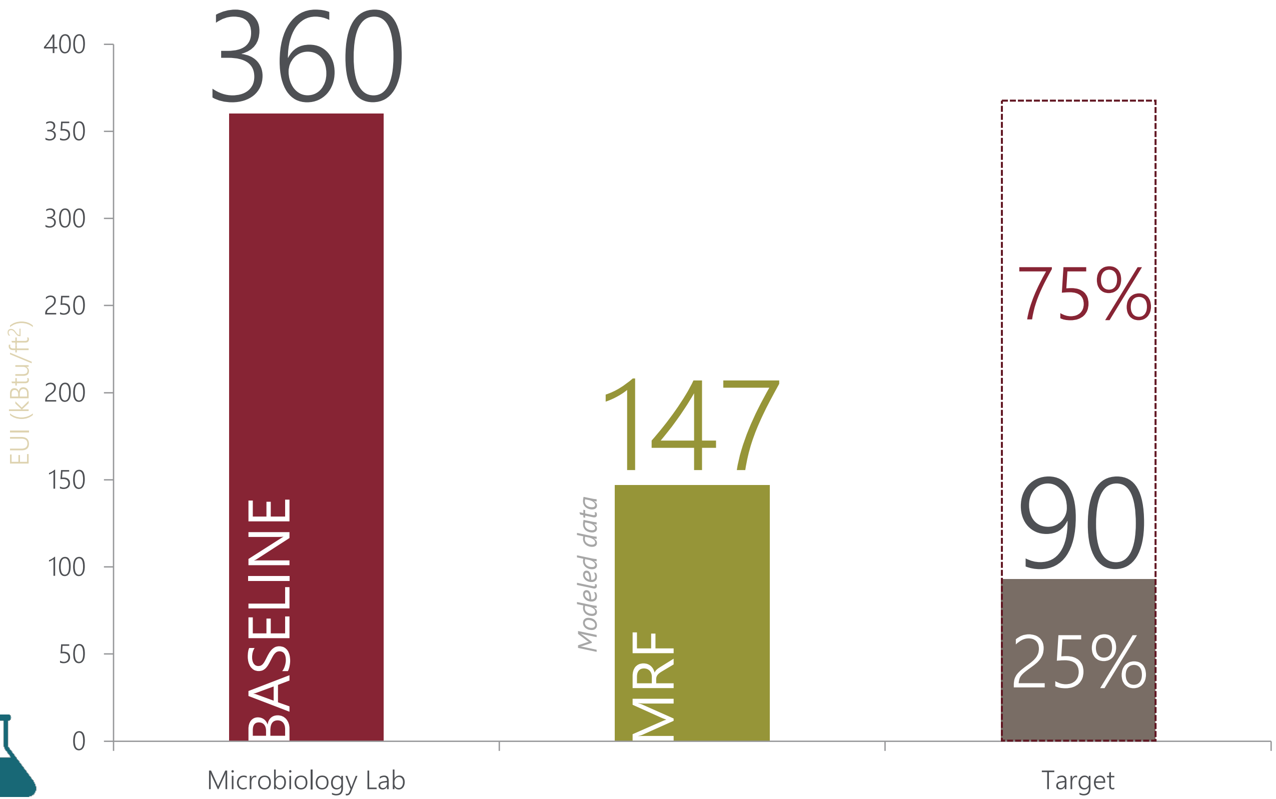
CASE STUDY
MICROBIOLOGY RESEARCH FACILITY

Minneapolis, MN
82,302 SF | 4 story Research Laboratory Facility
Designed 2013, construction complete November 2015

STRATEGIES

- Heat Recovery chiller
- Condensing boilers
- Decoupled Distribution: Chilled Beams & Fan Coil Units
- Laboratory Standard 6 ACH reduced to 2 ACH
- 120 Degree hot water
- Perimeter radiation for envelope heating loads
- Daylight harvesting

CASE STUDY
MICROBIOLOGY RESEARCH FACILITY

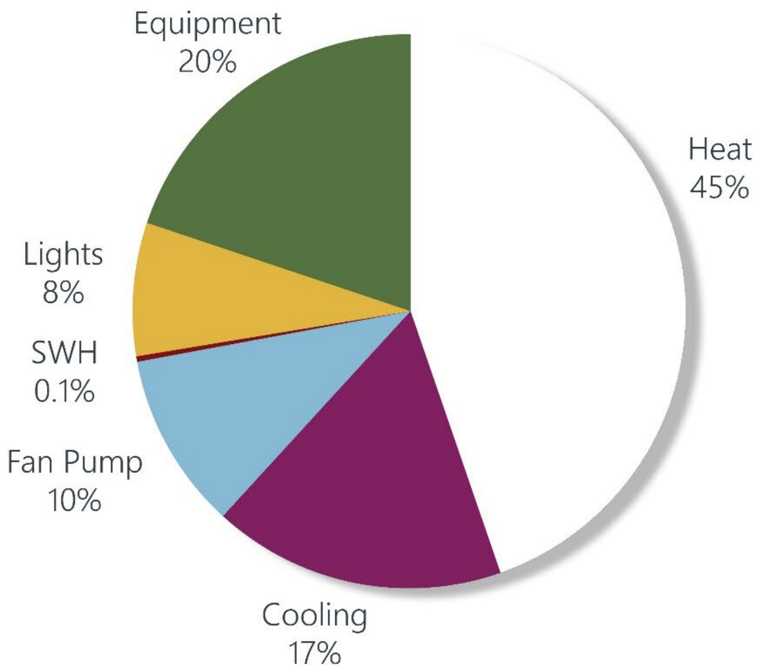


UNDERSTANDING OF SYSTEMS

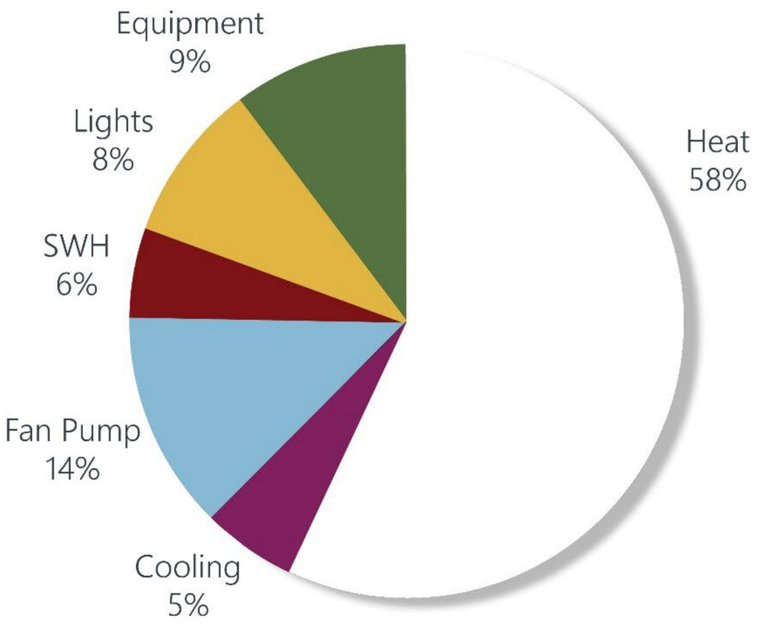
Strategies

WHY ARE WE LOOKING AT HVAC?

Heating, cooling, and ventilation account for a large percentage of a hospital's energy profile.



Site Energy



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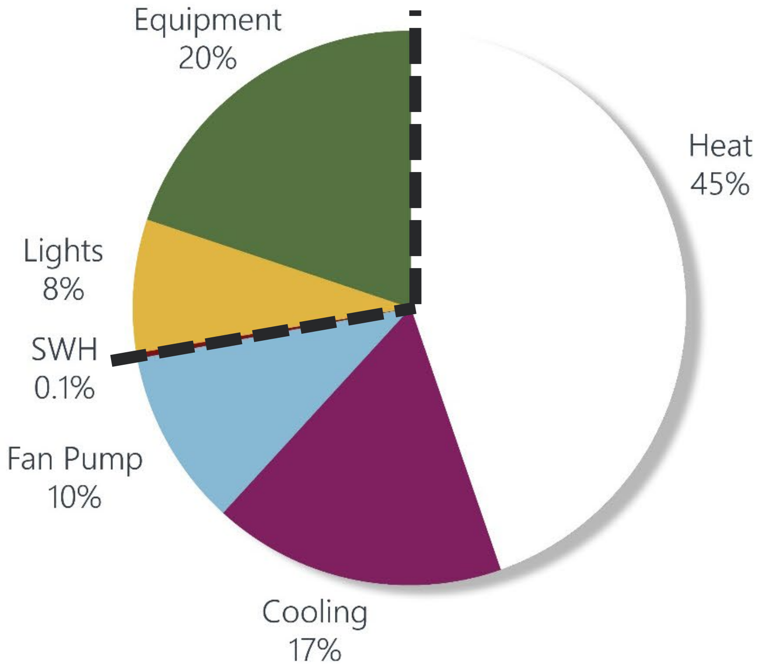
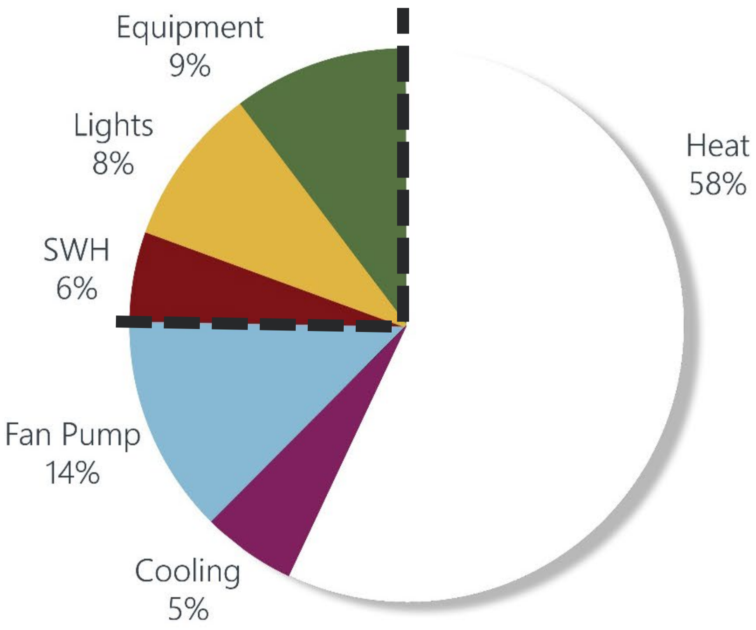


Site Energy



MECHANICAL STRATEGIES

Central Plant

Decrease power requirements

Create heating/cooling synergies

Distribution

Decouple ventilation from heating and cooling loads

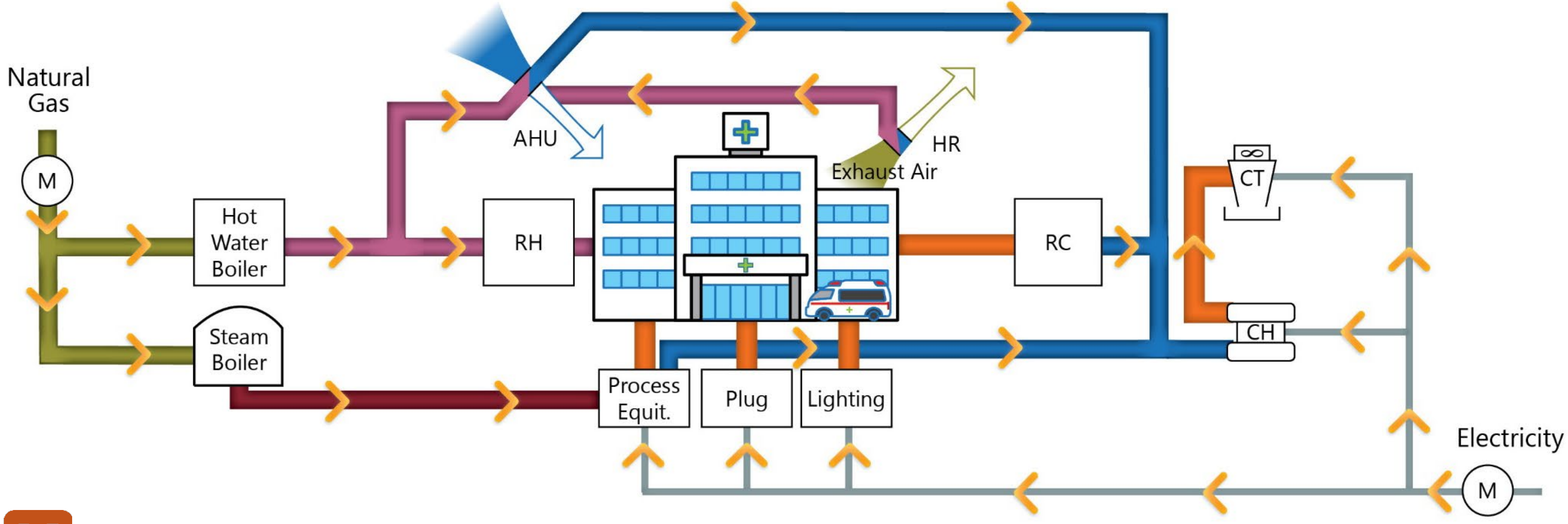
- Fan coils
- Chilled beams

Optimize Systems

Create hybrids based on location

- Local climate
- Site conditions

HOSPITAL ENERGY FLOW DIAGRAM



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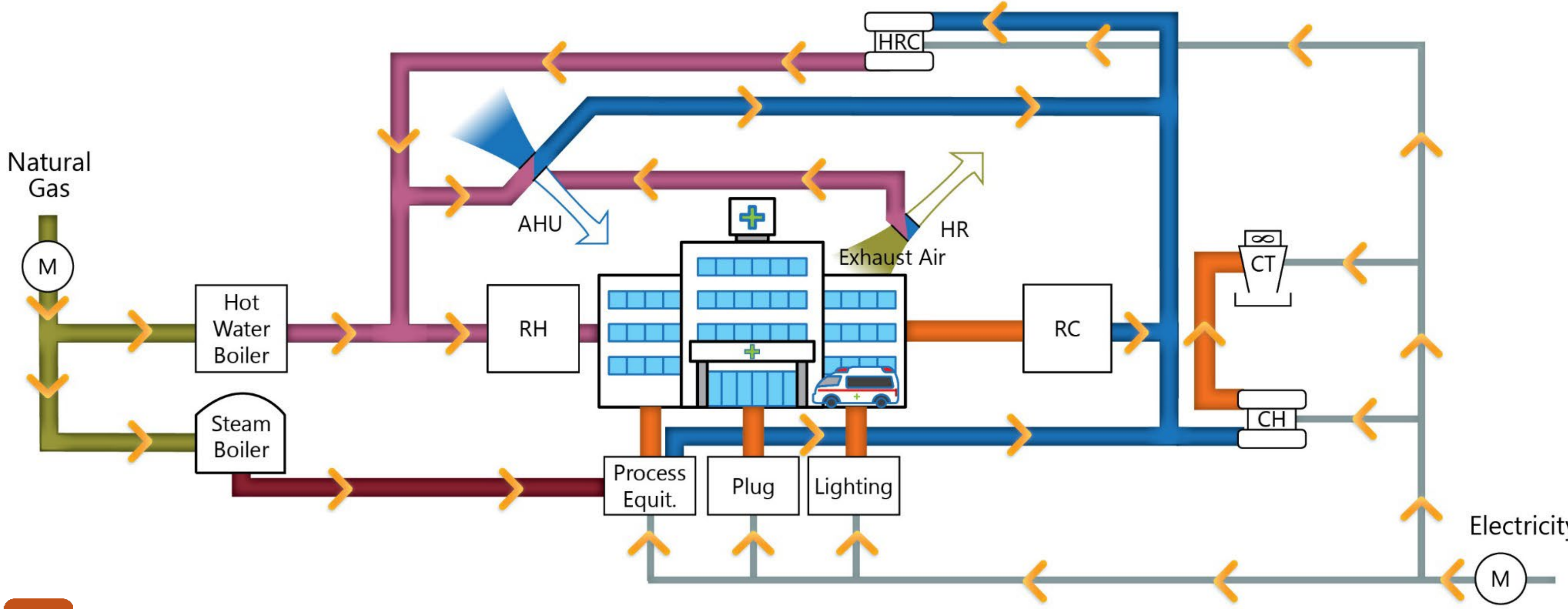

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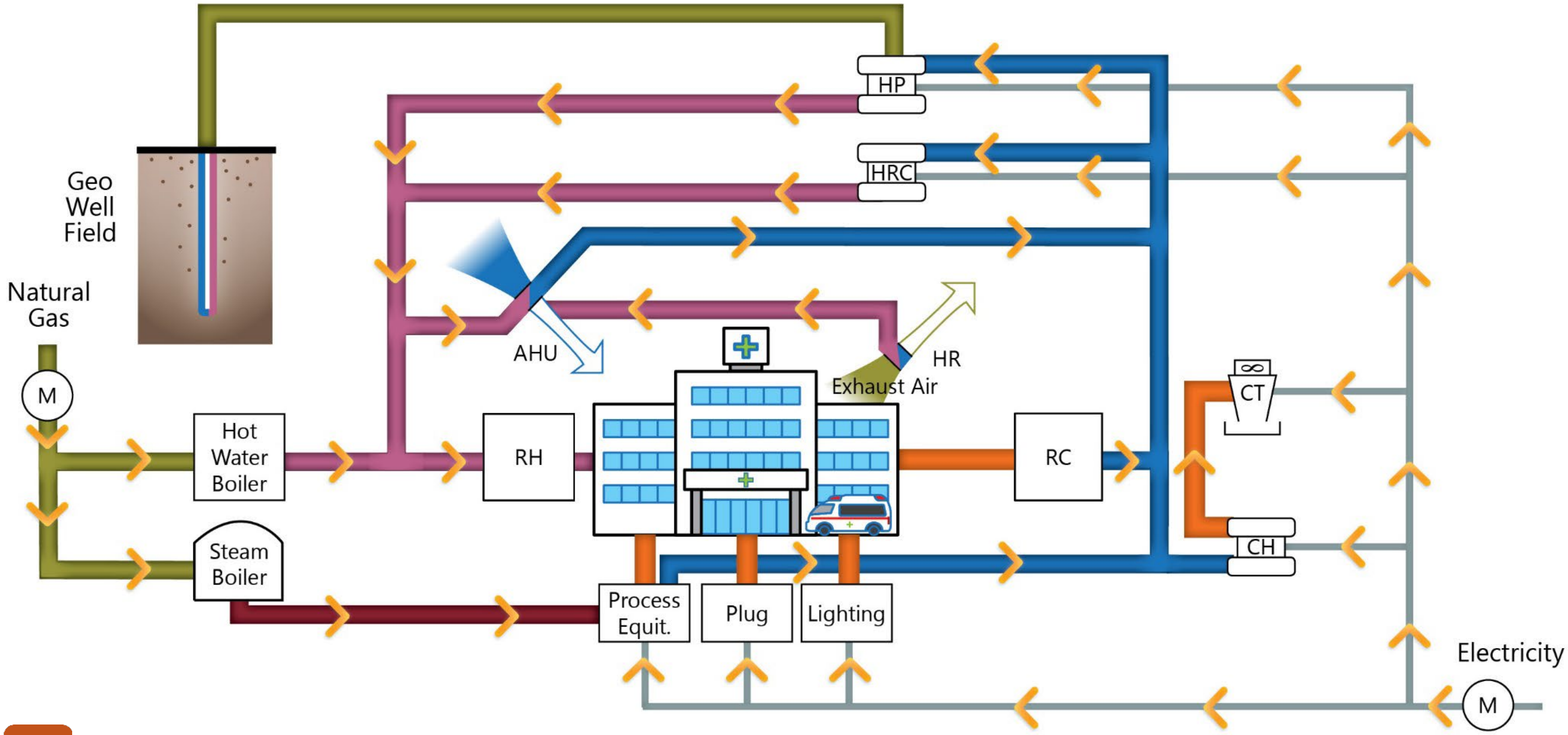

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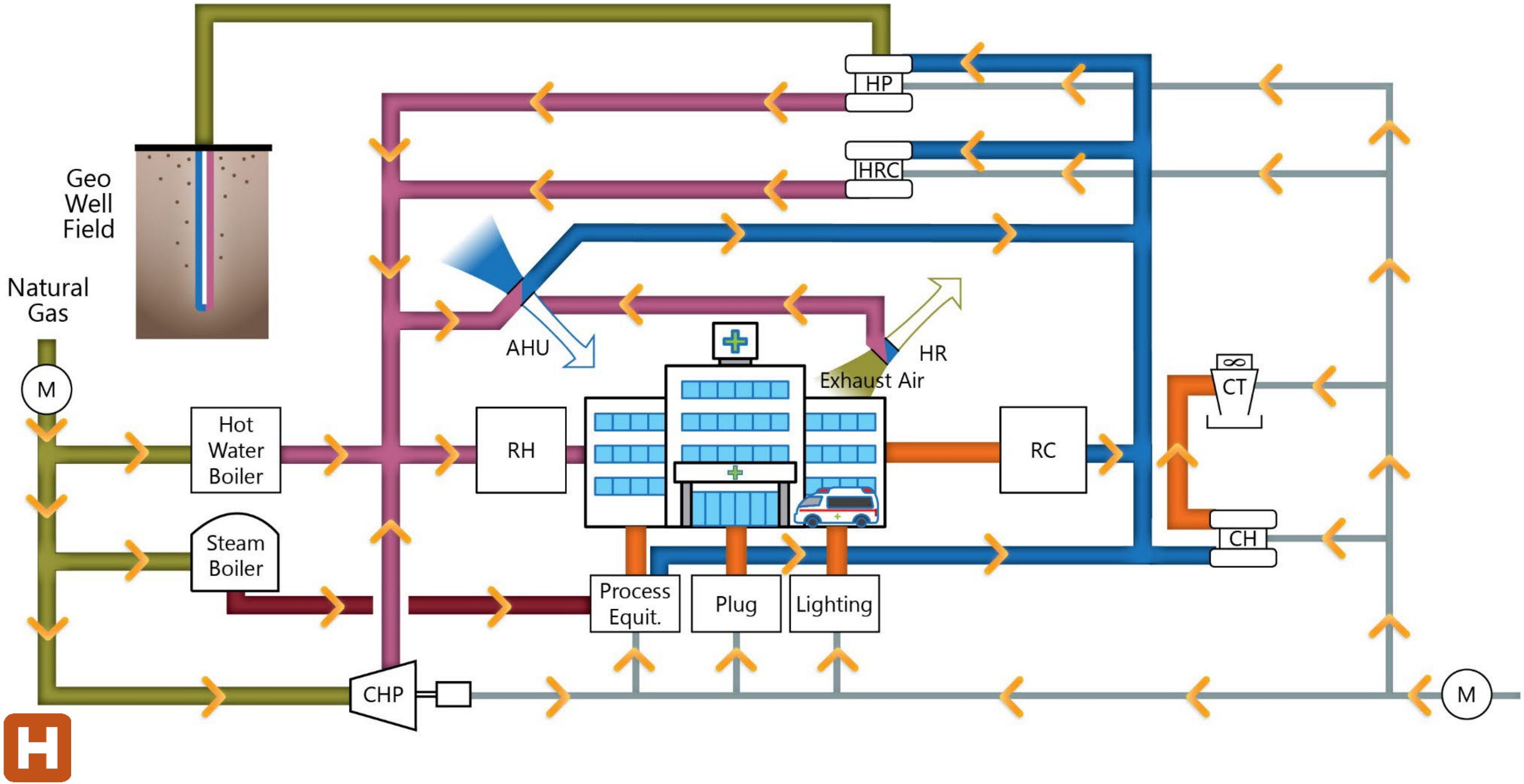

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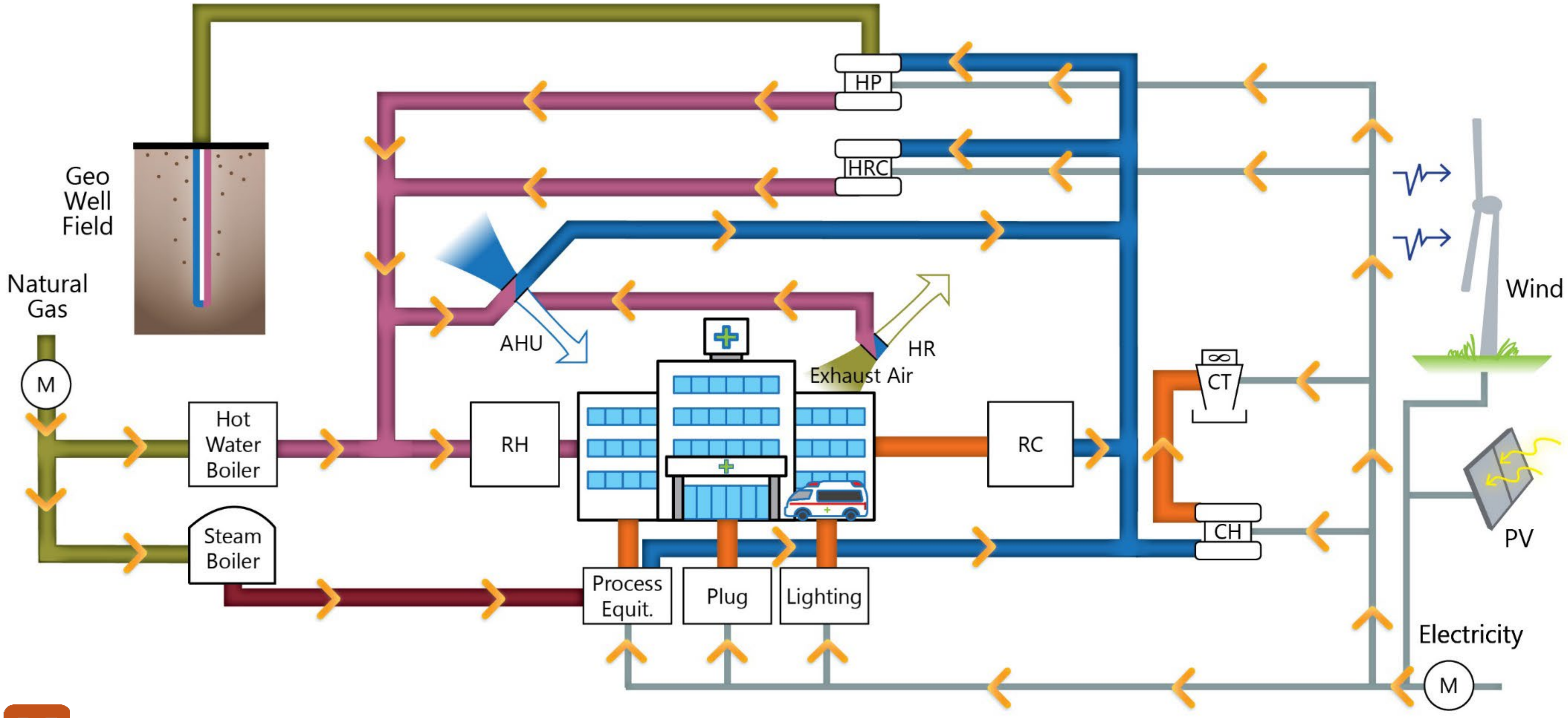
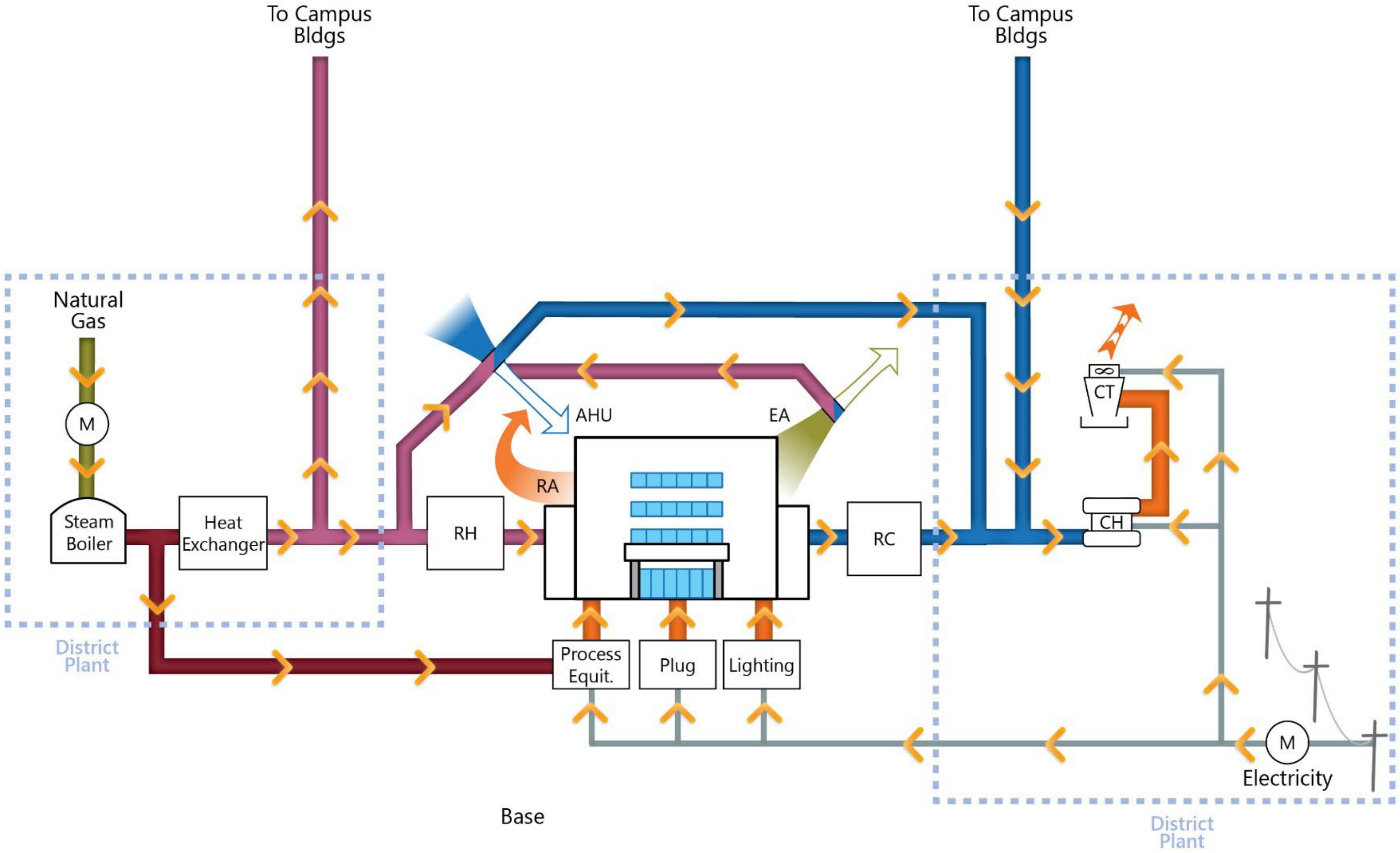
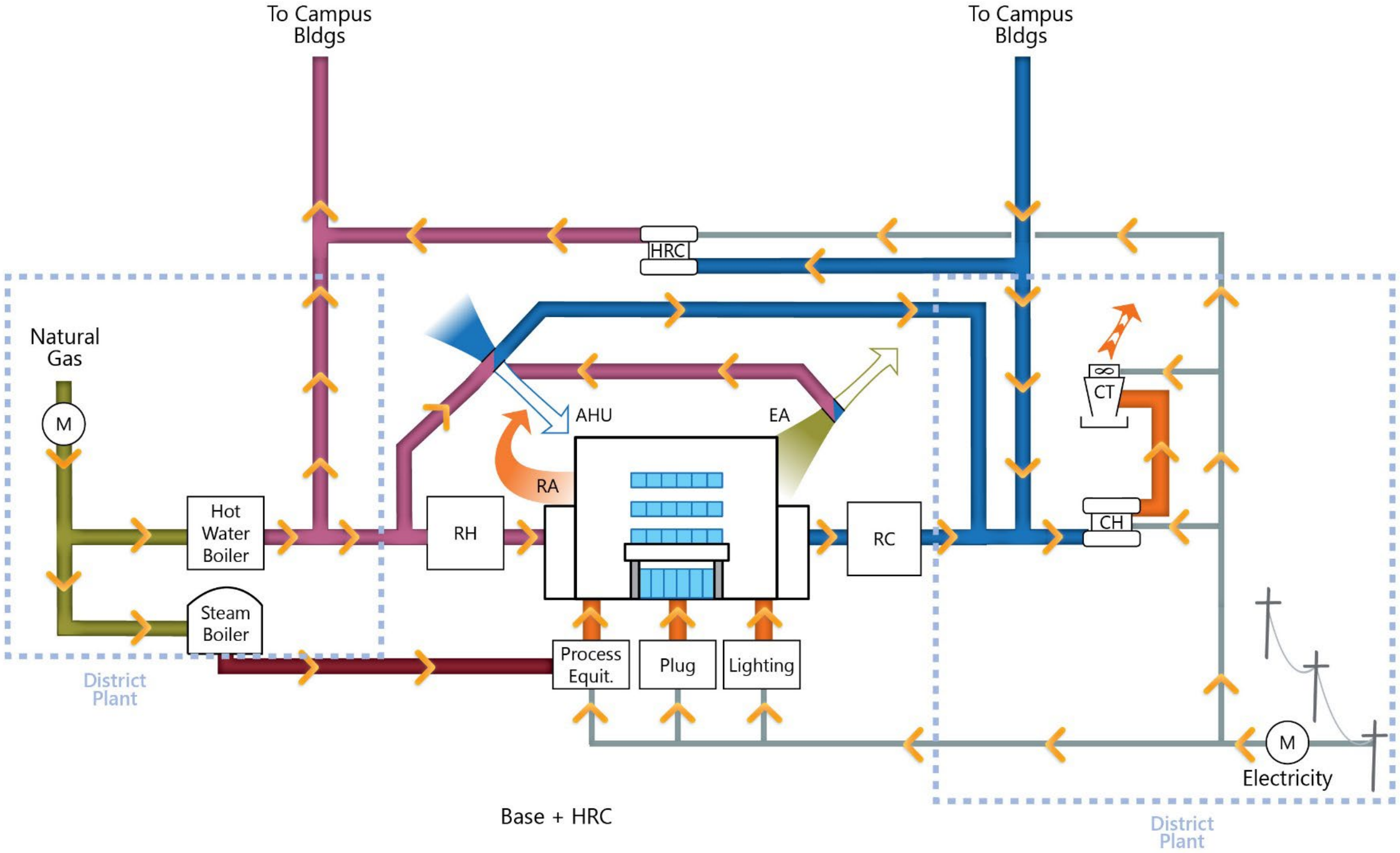


LAB ENERGY FLOW DIAGRAM

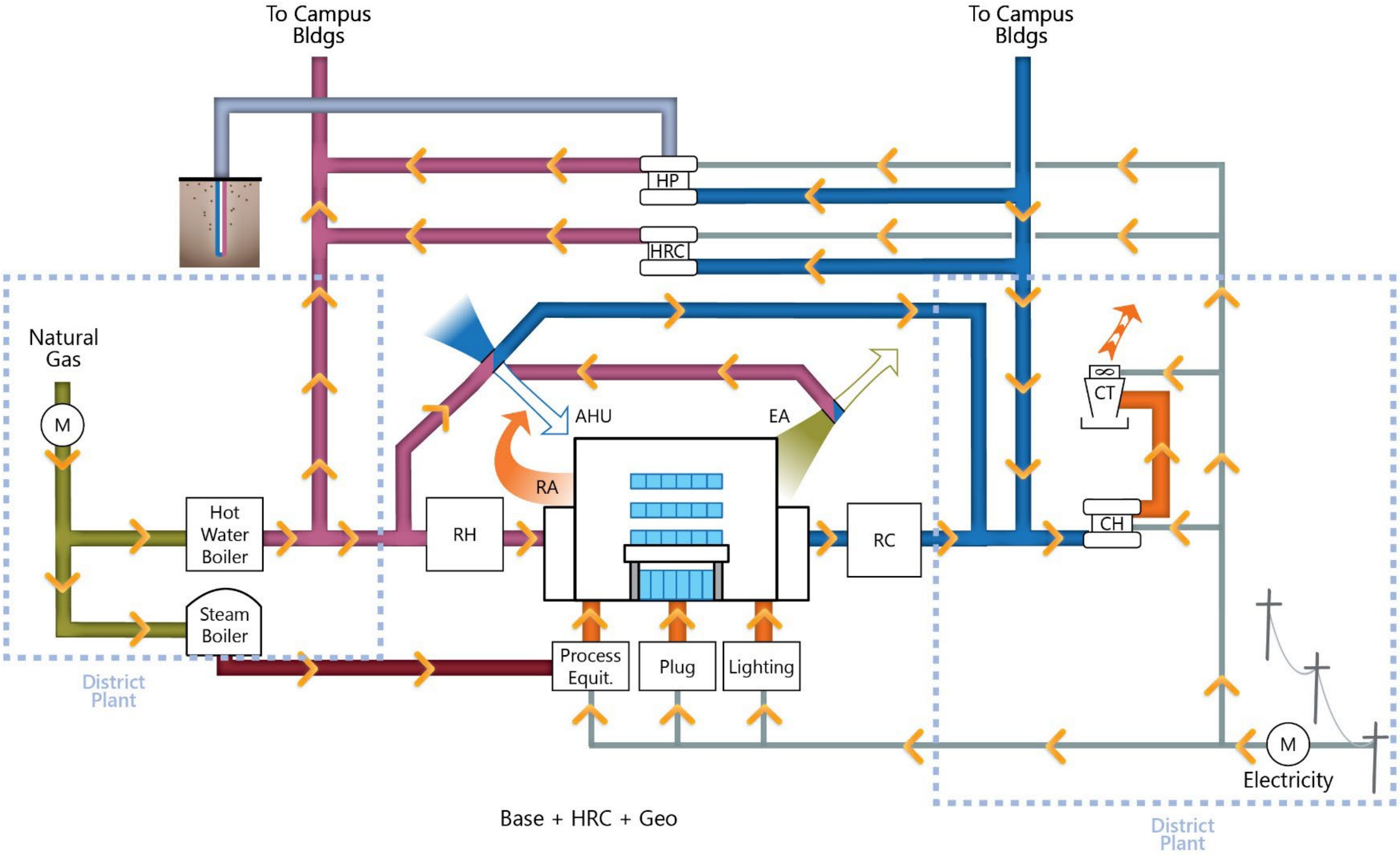


LAB ENERGY FLOW DIAGRAM



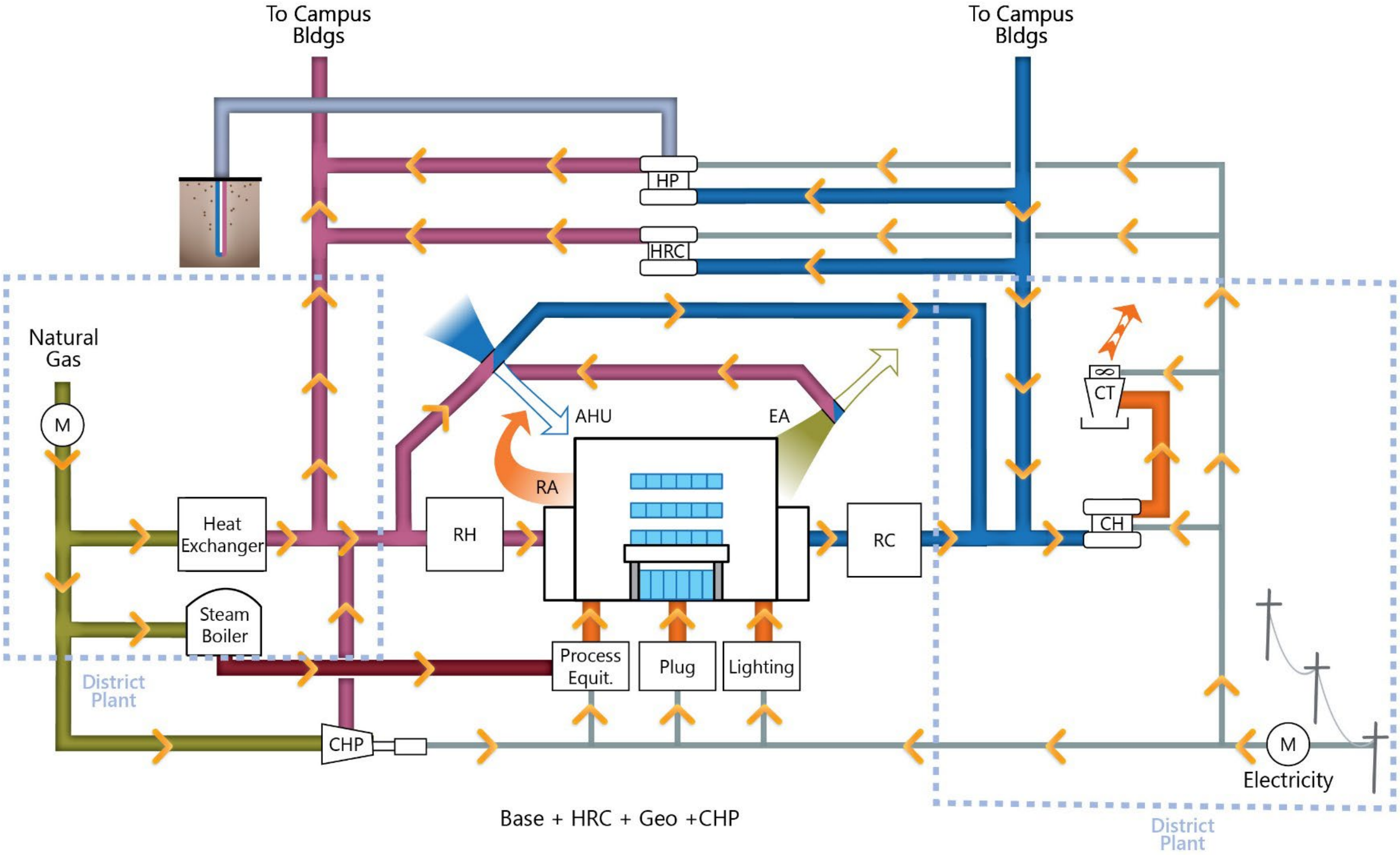
Base + HRC

LAB ENERGY FLOW DIAGRAM



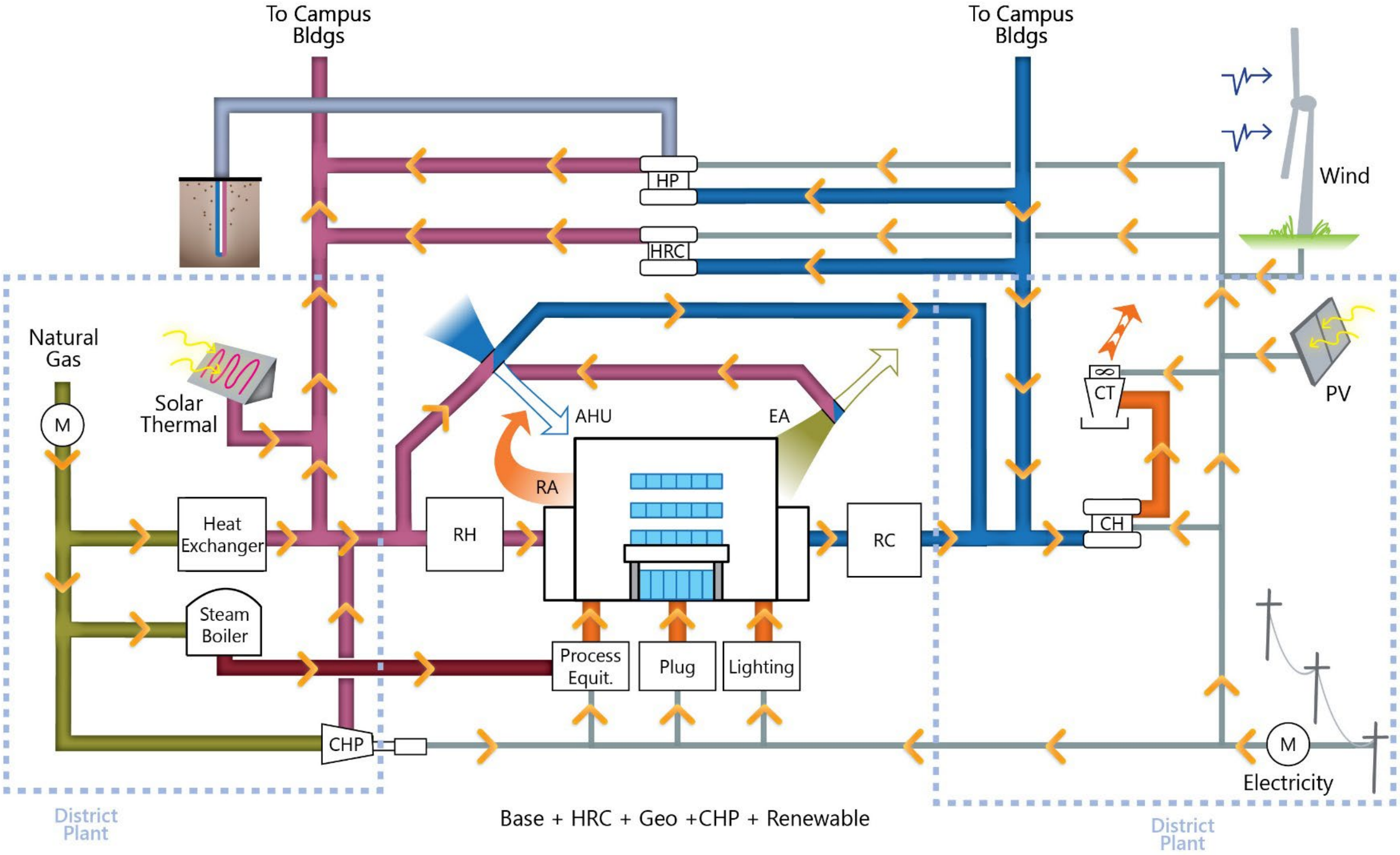
Base + HRC + Geo

LAB ENERGY FLOW DIAGRAM



Base + HRC + Geo +CHP

LAB ENERGY FLOW DIAGRAM

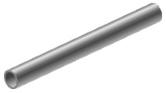


Base + HRC + Geo +CHP + Renewable

DISTRIBUTION STRATEGIES

DECOUPLE

- Conventional systems distribute conditioned air (heated, cooled) and air for ventilation together via air ducts
- Decoupling: separate/detach heating and cooling from ventilation



A ¾" diameter water pipe moves the same amount of energy as a 20"x12" air duct

DECOUPLING

Mechanically speaking,
a space requires two things:

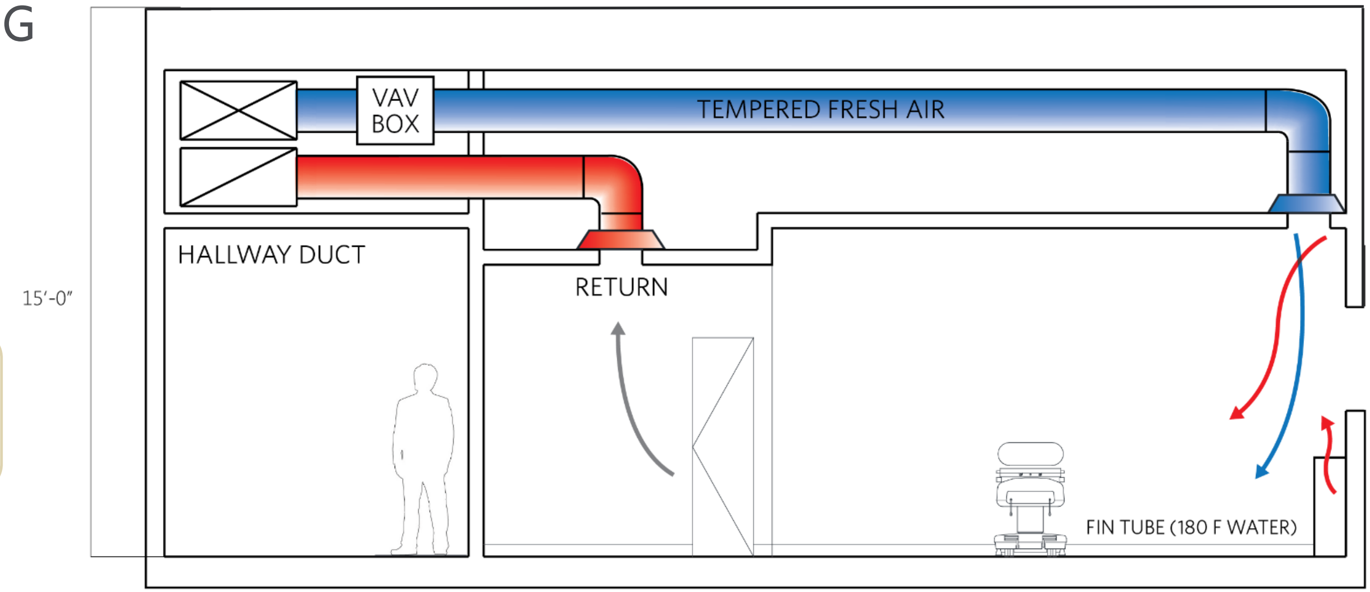
SPACE CONDITIONING

&

VENTILATION

WE NEED TO ISOLATE THE TWO EVENTS TO SAVE ENERGY

STANDARD VAV SYSTEM



DECOUPLING

Mechanically speaking,
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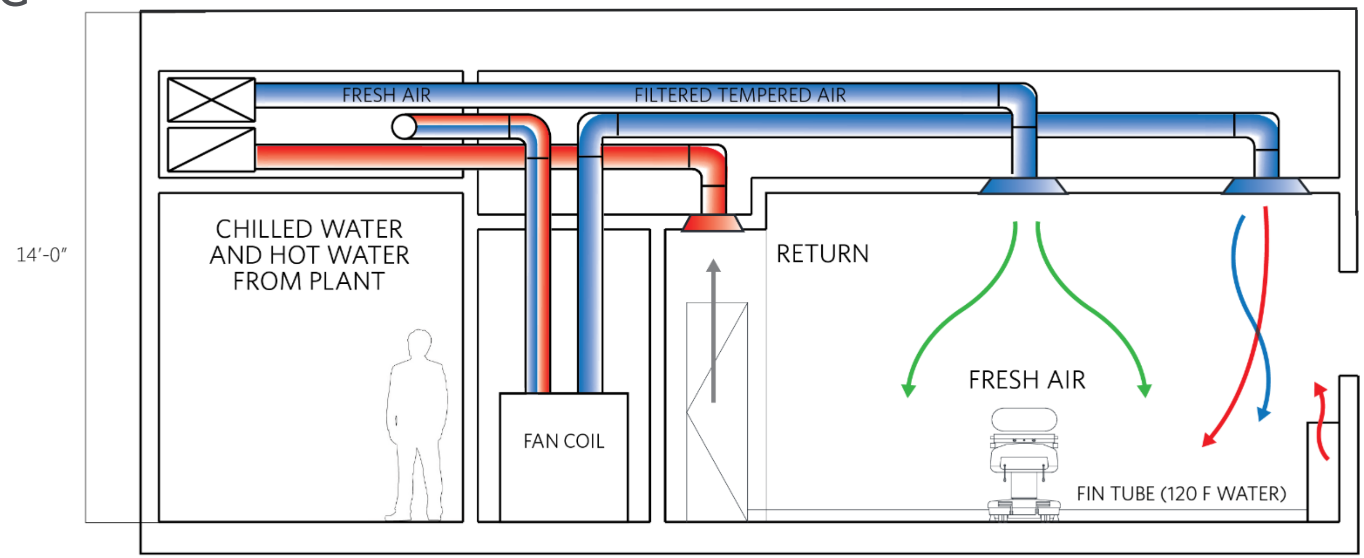
DECOUPLED FAN COIL SYSTEM



DECOUPLING

Mechanically speaking,
a space requires two things:

SPACE CONDITIONING

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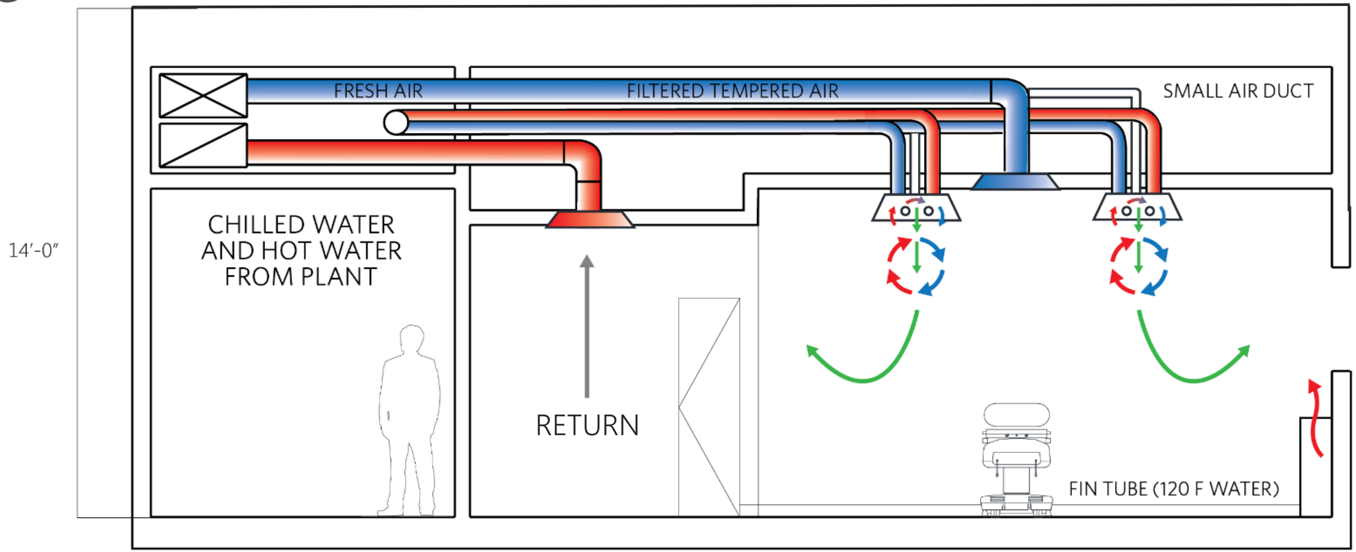
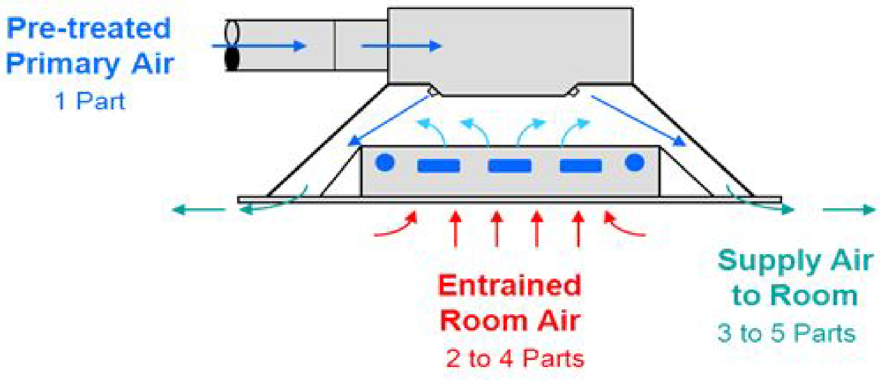
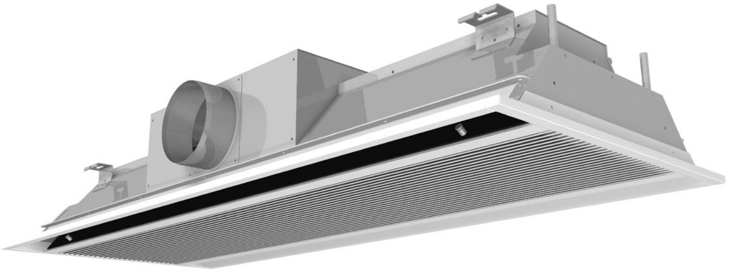
ACTIVE CHILLED BEAM SYSTEM

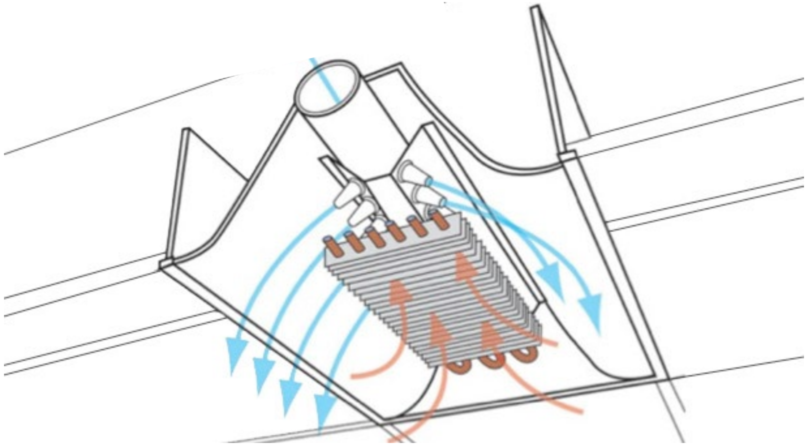


CHILLED BEAM



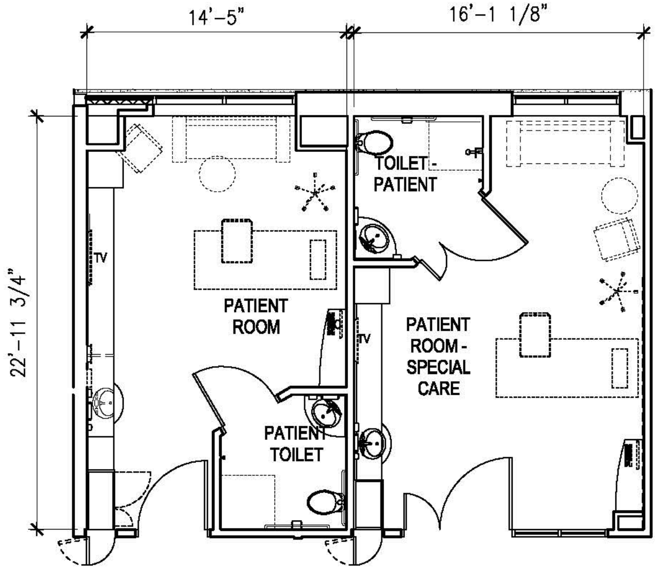
Active Chilled Beam (ACB)





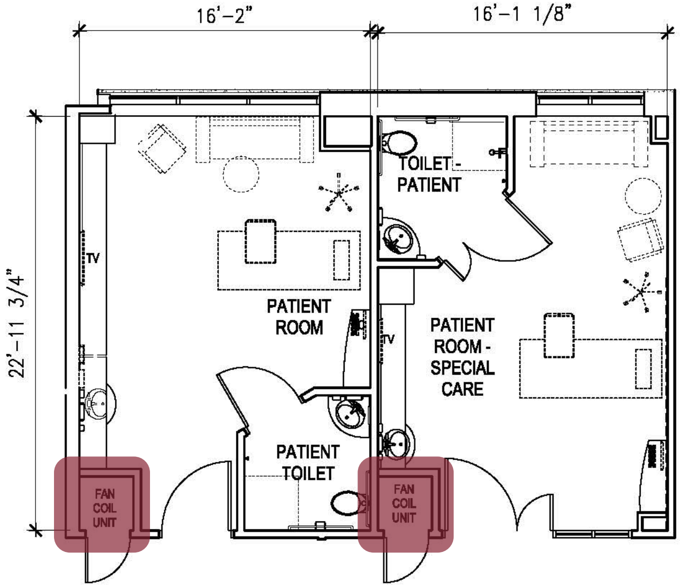
DECOUPLING

Space Planning for Fan Coil Units



MED/SURG ROOM
NO FAN COIL UNIT
NURSE SERVER
331 SF TOTAL

ICU ROOM
NO FAN COIL UNIT
NURSE SERVER
370 SF TOTAL

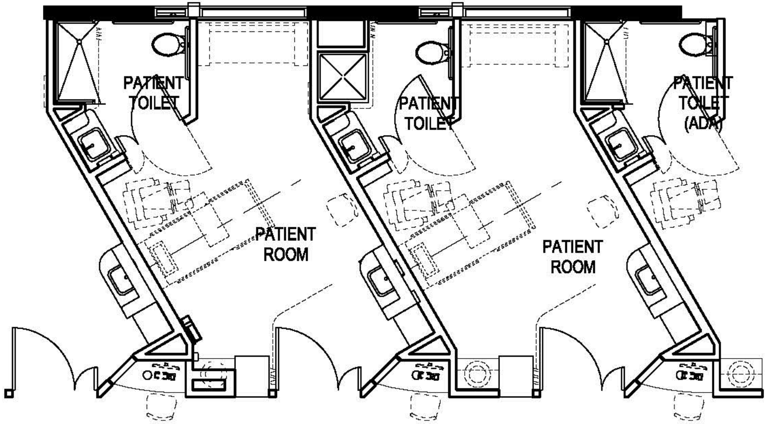


MED/SURG ROOM
DELETE NURSE SERVER
ADD 1'-9" TO ROOM WIDTH
371 SF TOTAL

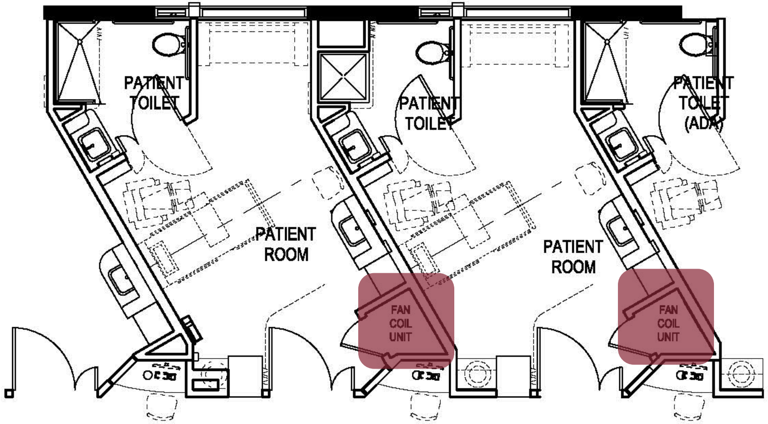
ICU ROOM
DELETE NURSE SERVER
NO NEED TO INCREASE ROOM WIDTH
370 SF TOTAL

DECOUPLING

Space Planning for Fan Coil Units



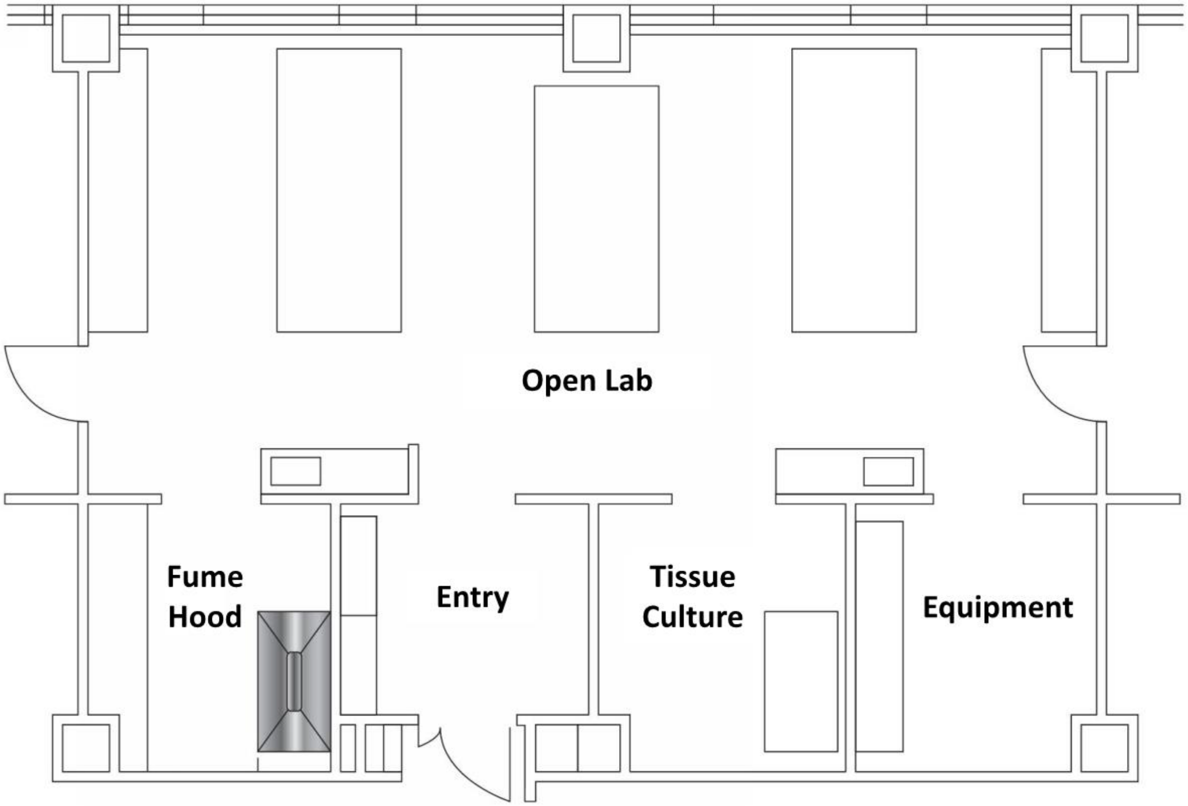
MED/SURG ROOM
NO FAN COIL UNIT
NURSE SERVER
DECENTRALIZED CHARTING
315 SF TOTAL



MED/SURG ROOM
FAN COIL UNIT WITHIN ROOM
NURSE SERVER
DECENTRALIZED CHARTING
315 SF TOTAL

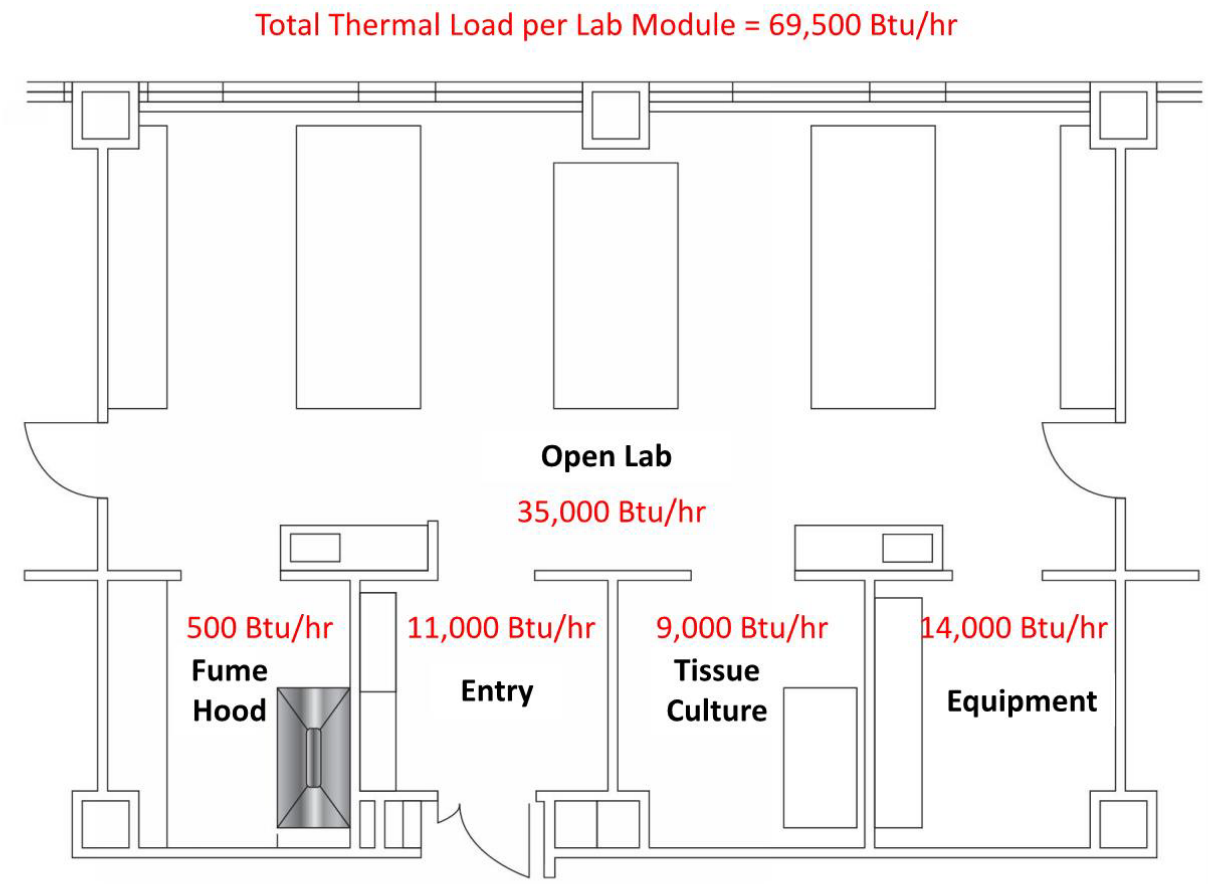
SUPPORT ALCOVE LAB PLANNING STRATEGY

Microbiology Laboratory

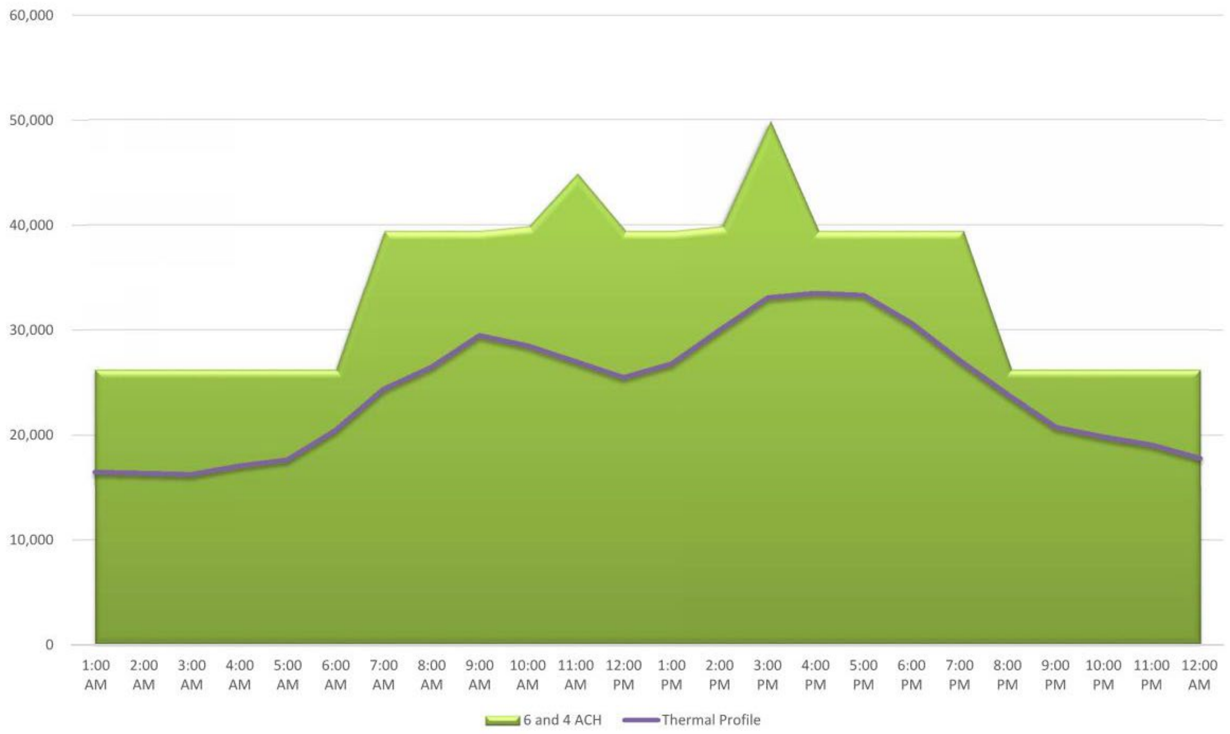


LAB VENTILATION PROFILE AT 4 AND 6 ACH

SUPPORT ALCOVE LAB PLANNING STRATEGY



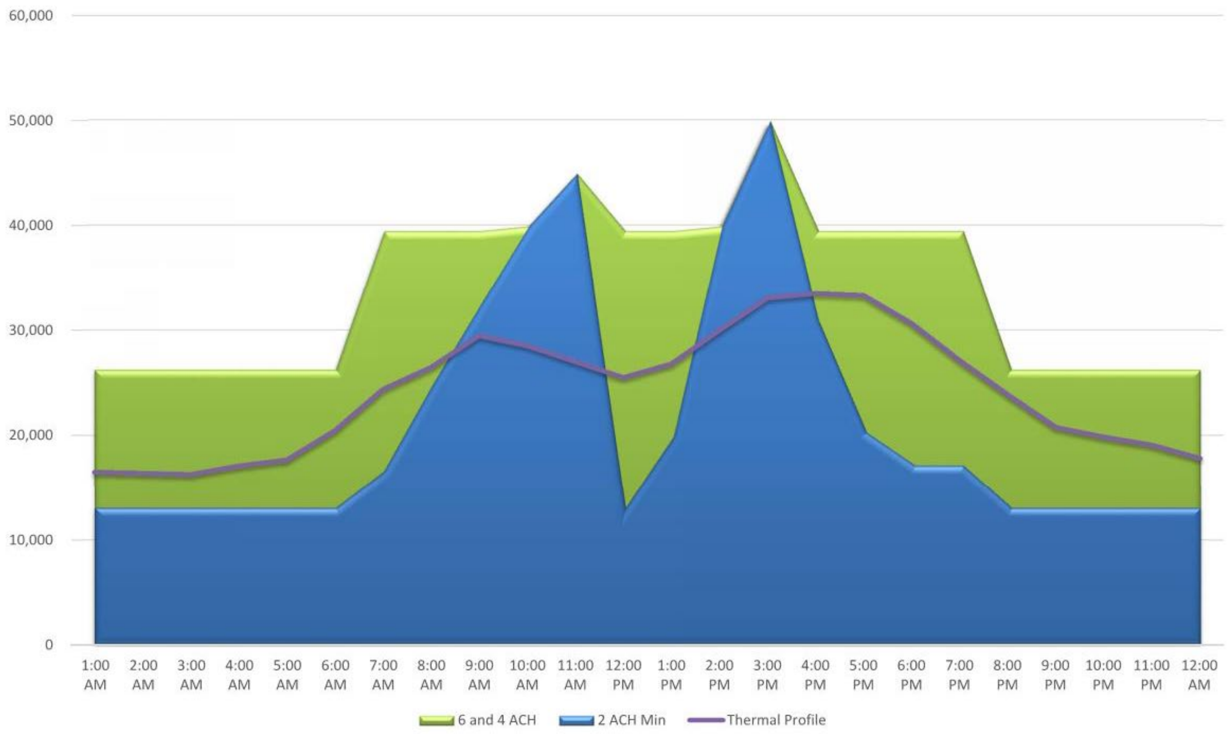
LAB VENTILATION AT 4 AND 6 ACH VS. THERMAL PROFILE



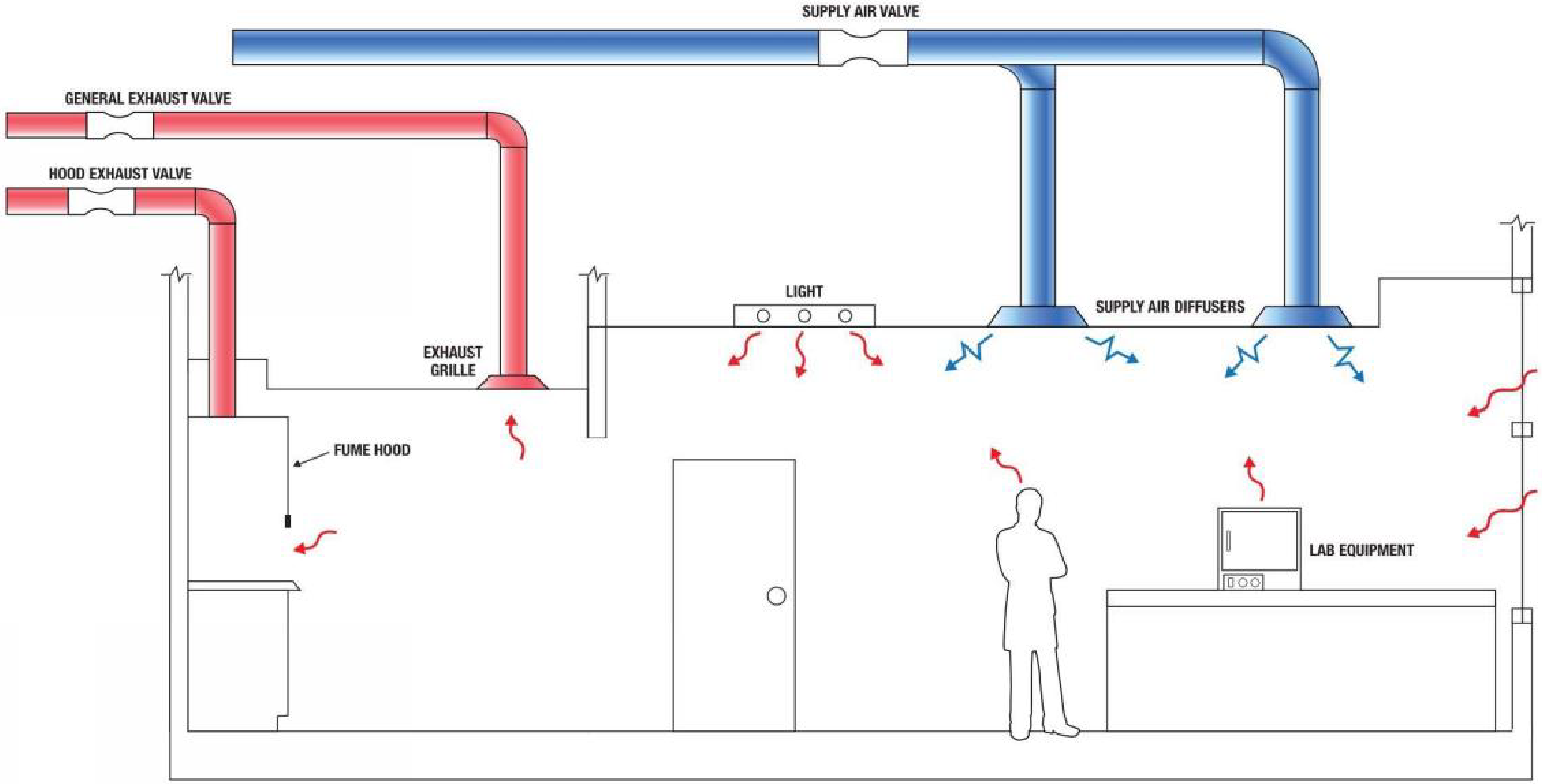
REDUCED ACH RATE

- Understand the program
- Fume Hood Density
- Thermal Loads vs. Ventilation Loads

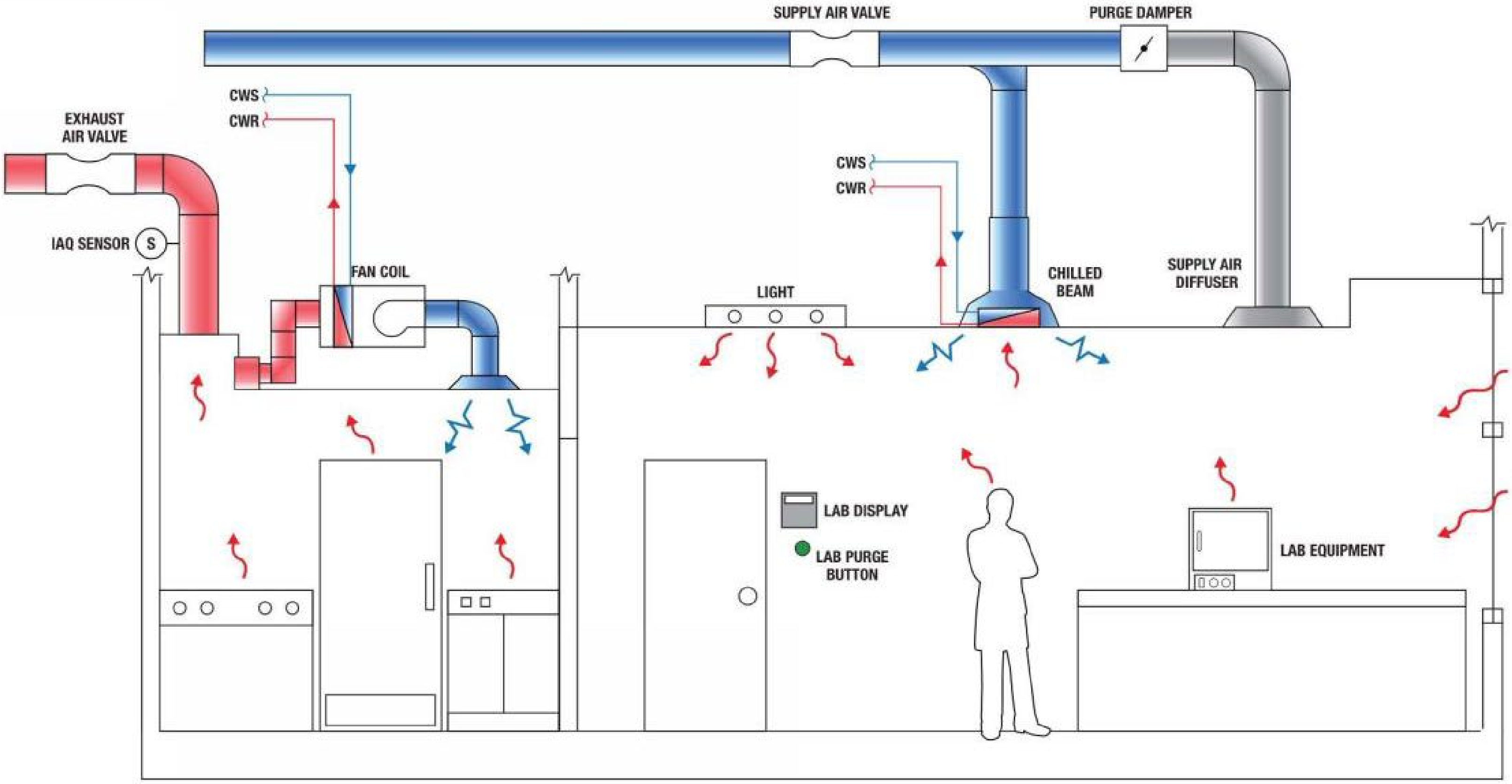
2 ACH VS. THERMAL LOAD



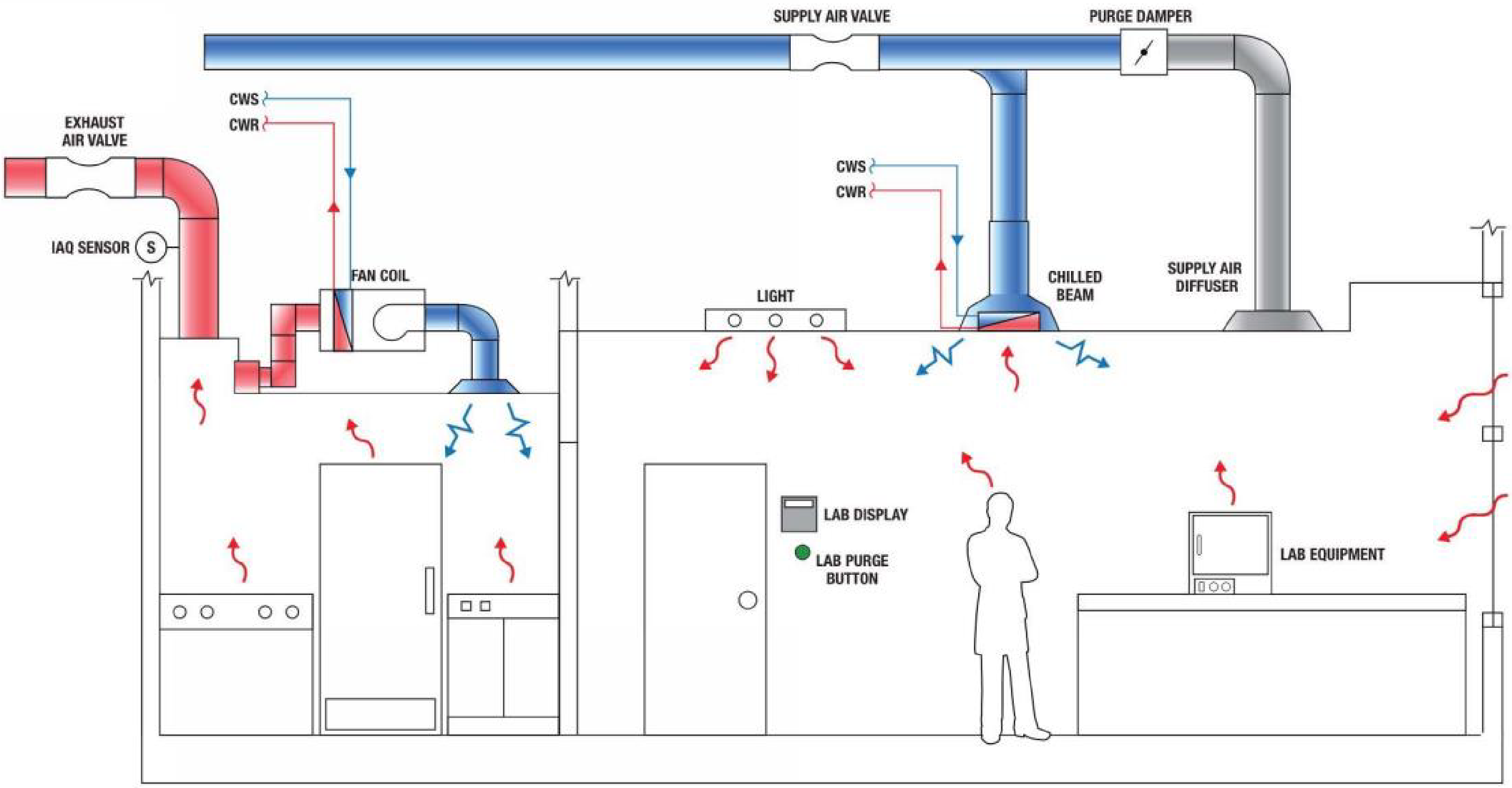
CONVENTIONAL APPROACH



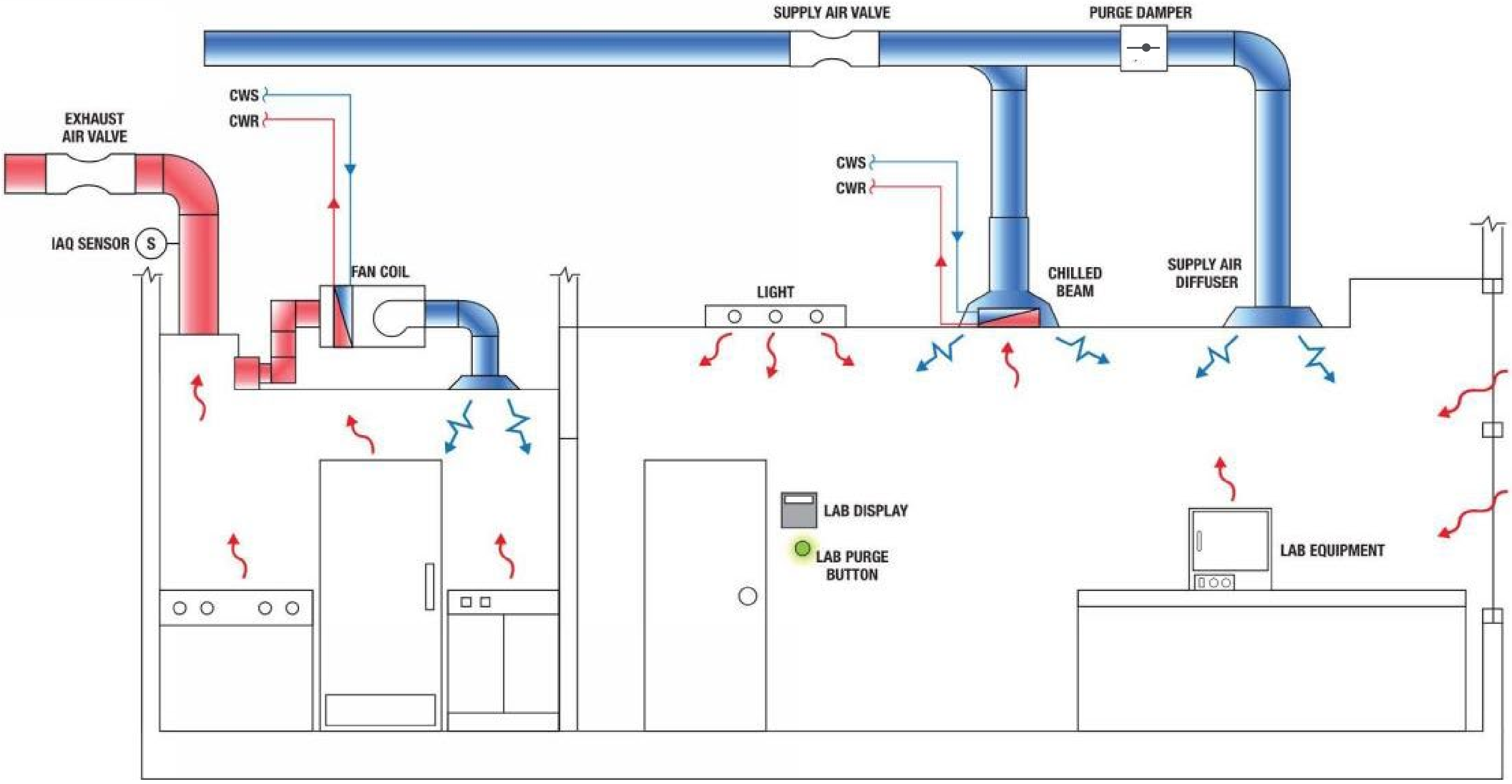
THERMAL DECOUPLED LAB STRATEGY



NORMAL OPERATING CONDITIONS



PURGE MODE

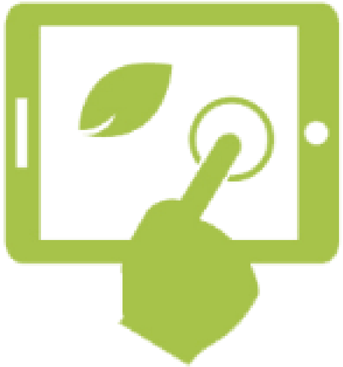


SUPPLY AIR VALVE
PURGE DAMPER
CWS
CWR
EXHAUST AIR VALVE
CWS
CWR
IAQ SENSOR
S
FAN COIL
CHILLED BEAM
SUPPLY AIR DIFFUSER
LIGHT
LAB DISPLAY
LAB PURGE BUTTON
LAB EQUIPMENT

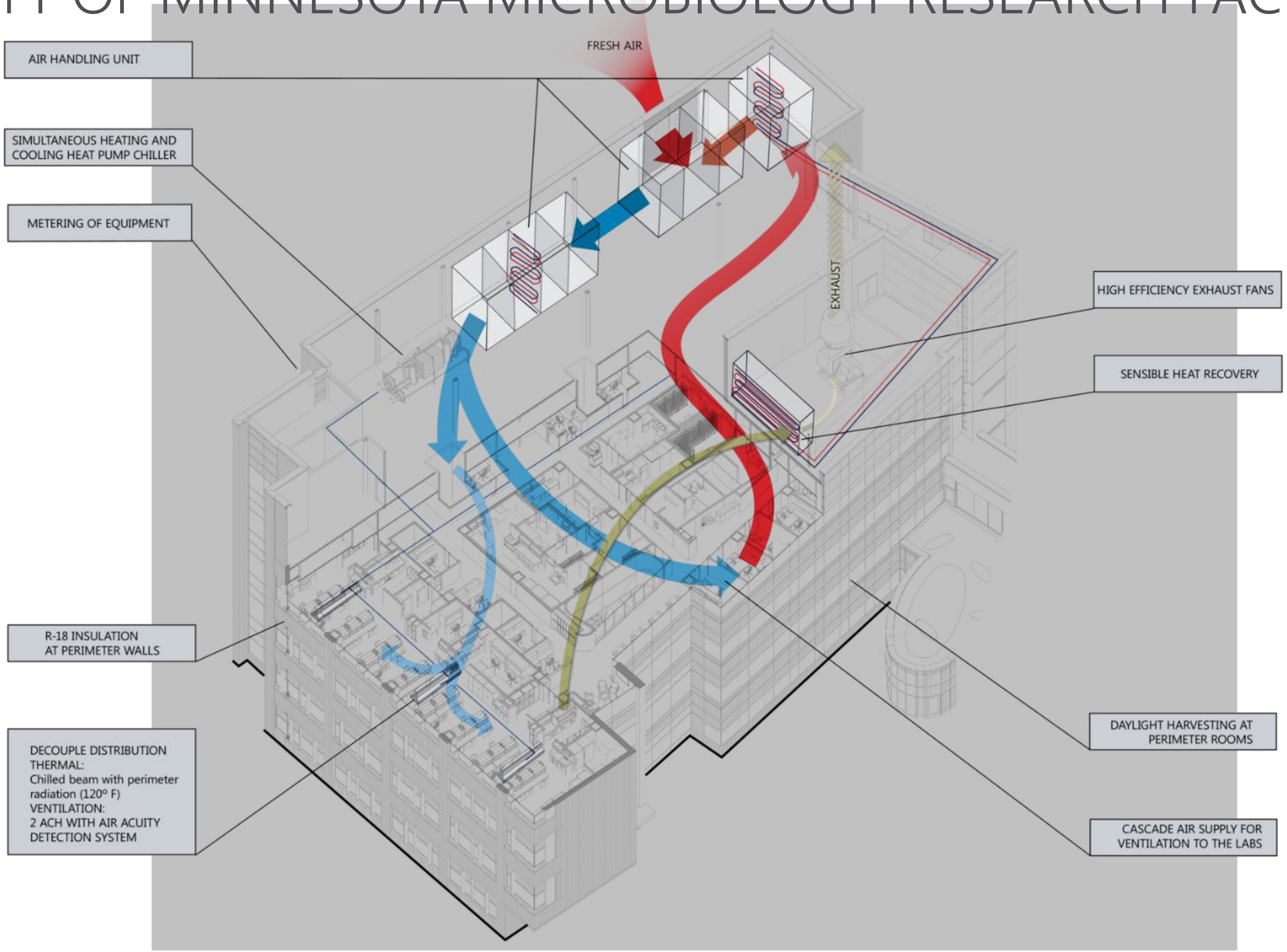
DECOUPLING

Advantages

- Allows us to heat and cool with *water*, instead of air
    - Water has 3500 times more volumetric thermal capacity than air
    - Water is 25 times more thermally conductive than air
    - Takes less fan/pump energy to distribute energy
- Air distribution for *ventilation only*
    - Smaller duct sizes
    - Smaller plenum sizes
- Enhances the opportunity for airside heat recovery from the exhaust stream

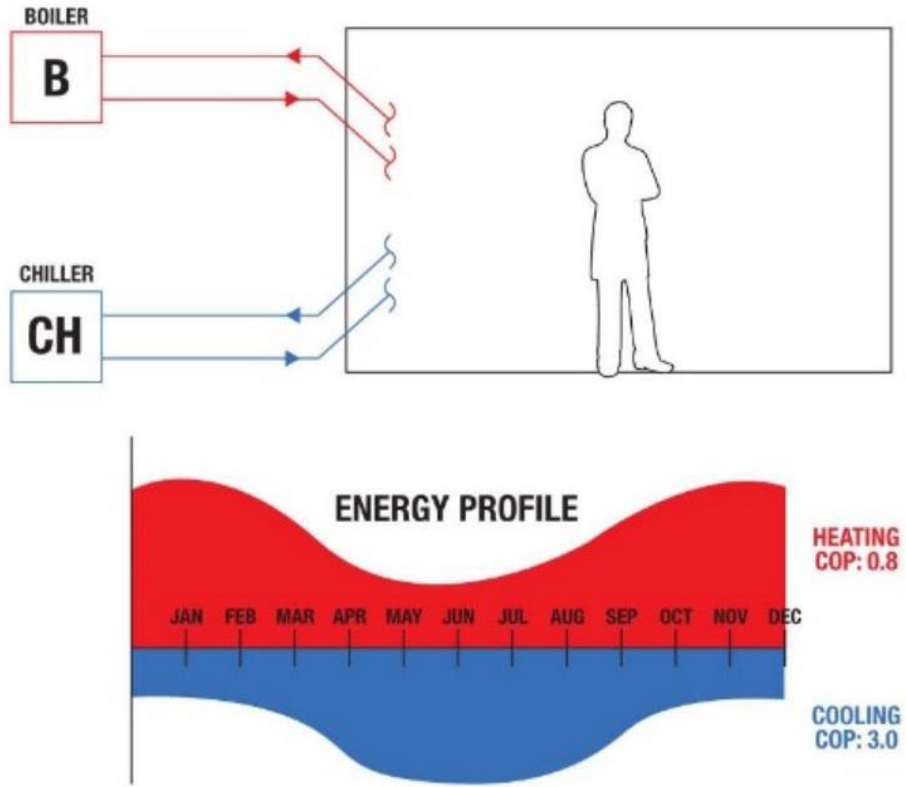


UNIVERSITY OF MINNESOTA MICROBIOLOGY RESEARCH FACILITY

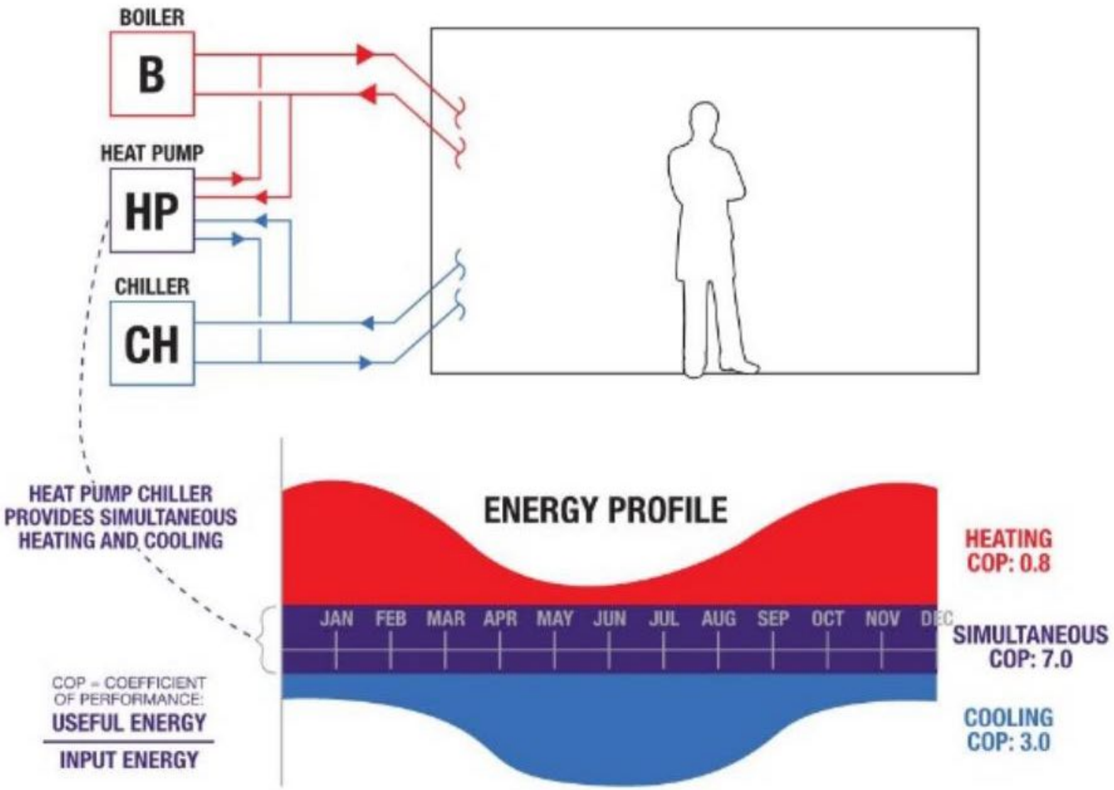


DISCOVERY DISTRICT AT UNIVERSITY OF MINNESOTA

CONVENTIONAL HEATING AND COOLING STRATEGY



SIMULTANEOUS HEATING AND COOLING STRATEGY



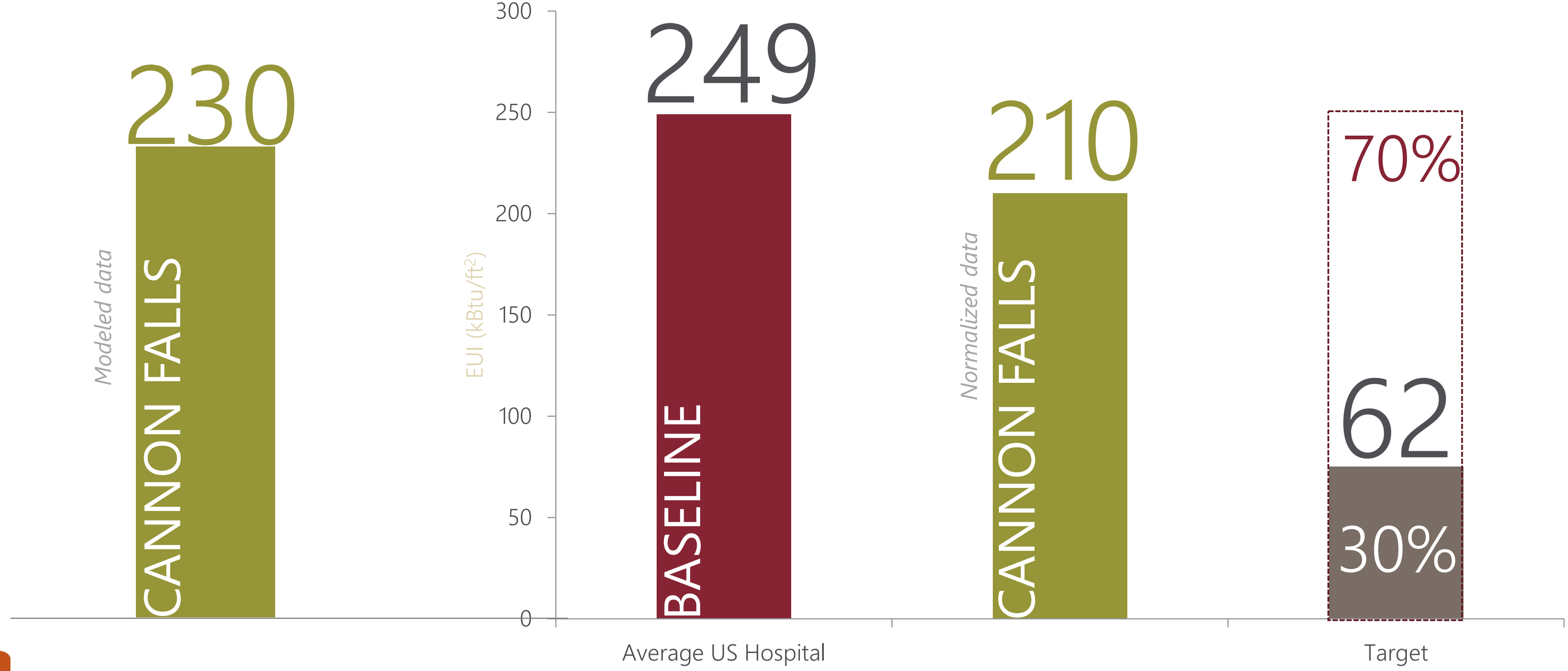
IMPLEMENTATION OF SYSTEMS

CASE STUDY
MAYO CLINIC HEALTH SYSTEM CANNON FALLS

Cannon Falls, MN
89,252 SF | 15-bed Critical Access Hospital
Designed 2012, construction complete July 2014

- Baseline Energy Use – As-Designed
- Normalized for 2015 Electrical Code
- Compare to series of options
- **Distribution system options**
- **Central plant options**

CASE STUDY – SITE EUI
MAYO CLINIC HEALTH SYSTEM CANNON FALLS



CASE STUDY
MAYO CLINIC HEALTH SYSTEM CANNON FALLS

Cannon Falls, MN
89,252 SF | 15-bed Critical Access Hospital

Program Elements →

Block	Note	Area	Airside System
Patient Room Wing	Patient Rooms 6,000 sf	15,000	Varied
Clinic		15,000	Varied
Admin		5,000	Varied
Conference & Support		11,000	Varied
Lobby Admit		13,000	Varied
Lab		9,000	Varied
Emergency Department		4,000	Varied
Kitchen Dining		5,000	Varied
OR		7,000	Held as VAV
Ambulance Garage		1,000	Held as UH
Mech		4,000	Held as UH
Total		89,000	

CASE STUDY
MAYO CLINIC HEALTH SYSTEM CANNON FALLS

Cannon Falls, MN
89,252 SF | 15-bed Critical Access Hospital

Program Elements

Unable to change **distribution** system in certain spaces
- Operating Room
- Ambulance Garage
- Mechanical

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Program Elements

Unable to change **distribution** system in certain spaces

- Operating Room
- Ambulance Garage
- Mechanical

Identified where **distribution** systems could be decoupled:

- Patient Room Wing
- Clinic
- Admin
- Conference & Support
- Lobby Admit
- Lab
- Emergency Department
- Kitchen Dining

Block	Note	Area	Airside System
Patient Room Wing	Patient Rooms 6,000 sf	15,000	Varied
Clinic		15,000	Varied
Admin		5,000	Varied
Conference & Support		11,000	Varied
Lobby Admit		13,000	Varied
Lab		9,000	Varied
Emergency Department		4,000	Varied
Kitchen Dining		5,000	Varied
OR		7,000	Held as VAV
Ambulance Garage		1,000	Held as UH
Mech		4,000	Held as UH
Total		89,000	

CASE STUDY
MAYO CLINIC HEALTH SYSTEM CANNON FALLS

Cannon Falls, MN
89,252 SF | 15-bed Critical Access Hospital

Distribution Options

Patient Room and Non-Critical Spaces Options

Option 1 – Conventional VAV

Option 2 – Four Pipe Fan Coils

Option 3 – Four Pipe Fan Coils with Displacement Ventilation

Option 4 – Active Chilled Beams

Option 5 – Water to Air Heat Pumps (Tabled)

Option 6 – Water to Air Heat Pumps with Displacement Ventilation

CASE STUDY
MAYO CLINIC HEALTH SYSTEM CANNON FALLS

Cannon Falls, MN
89,252 SF | 15-bed Critical Access Hospital

Central Plant Options

Patient Room and Non-Critical Spaces Options

Option A – DX Cooling and Condensing Boilers

Option B – Air Cooled Chillers and Condensing Boilers

Option C – Water Cooled Chiller and Condensing Boilers

Option D – Water to Water Heat Pumps with Geothermal Well Field

Option E – Water to Air Heat Pumps with Geothermal Well Field (Tabled)

Option F – Water to Air Heat Pumps with Fluid Cooler and Condensing Boiler (Tabled)

Option G – District Energy (Tabled)

CASE STUDY
MAYO CLINIC HEALTH SYSTEM CANNON FALLS

Cannon Falls, MN
89,252 SF | 15-bed Critical Access Hospital

Combination Matrix

Matrix of Airside and Plant Options

Plant / Airside	A Direct Expansion Cooling & Condensing Boiler	B Air Cooled Chiller & Condensing Boiler	C Water Cooled Chiller & Condensing Boiler	D Water to Water Heat Pump with Geothermal Wellfield	E Water to Air Heat Pumps with Geothermal Wellfield	F Water to Air Heat Pumps with Fluid Cooler & Condensing Boiler	G District Energy
1 – VAV with Hot Water Reheat	A1	B1	C1	D1	n/a	n/a	Tabled
2 – Four Pipe Fan Coil	n/a	B2	C2	D2	n/a	n/a	Tabled
3 – Displacement Four Pipe Fan Coil	n/a	B3	C3	D3	n/a	n/a	Tabled
4 – Active Chilled Beam	n/a	B4	C4	D4	n/a	n/a	Tabled
5 – Water to Air Heat Pumps	n/a	n/a	n/a	n/a	Tabled	Tabled	n/a
6 – Displacement Water to Air Heat Pumps	n/a	n/a	n/a	n/a	Tabled	Tabled	n/a

CASE STUDY
MAYO CLINIC HEALTH SYSTEM CANNON FALLS

Cannon Falls, MN
89,252 SF | 15-bed Critical Access Hospital

Combination Matrix

Matrix of Airside and Plant Options

Plant / Airside	A Direct Expansion Cooling & Condensing Boiler	B Air Cooled Chiller & Condensing Boiler	C Water Cooled Chiller & Condensing Boiler	D Water to Water Heat Pump with Geothermal Wellfield	E Water to Air Heat Pumps with Geothermal Wellfield	F Water to Air Heat Pumps with Fluid Cooler & Condensing Boiler	G District Energy
1 – VAV with Hot Water Reheat	A1	B1	C1	D1	n/a	n/a	Tabled
2 – Four Pipe Fan Coil	n/a	B2	C2	D2	n/a	n/a	Tabled
3 – Displacement Four Pipe Fan Coil	n/a	B3	C3	D3	n/a	n/a	Tabled
4 – Active Chilled Beam	n/a	B4	C4	D4	n/a	n/a	Tabled
5 – Water to Air Heat Pumps	n/a	n/a	n/a	n/a	Tabled	Tabled	n/a
6 – Displacement Water to Air Heat Pumps	n/a	n/a	n/a	n/a	Tabled	Tabled	n/a

MAYO CLINIC HEALTH SYSTEM CANNON FALLS

Savings

CASE STUDY
MAYO CLINIC HEALTH SYSTEM CANNON FALLS

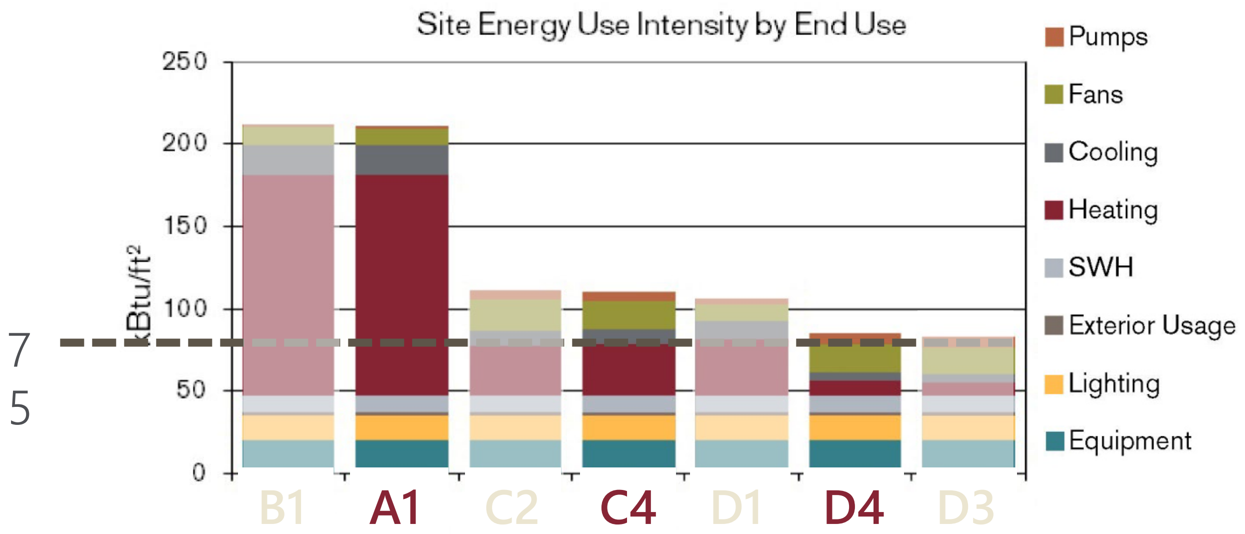
Cannon Falls, MN
89,252 SF | 15-bed Critical Access Hospital

Findings

CASE STUDY
MAYO CLINIC HEALTH SYSTEM CANNON FALLS

Cannon Falls, MN
89,252 SF | 15-bed Critical Access Hospital

Findings



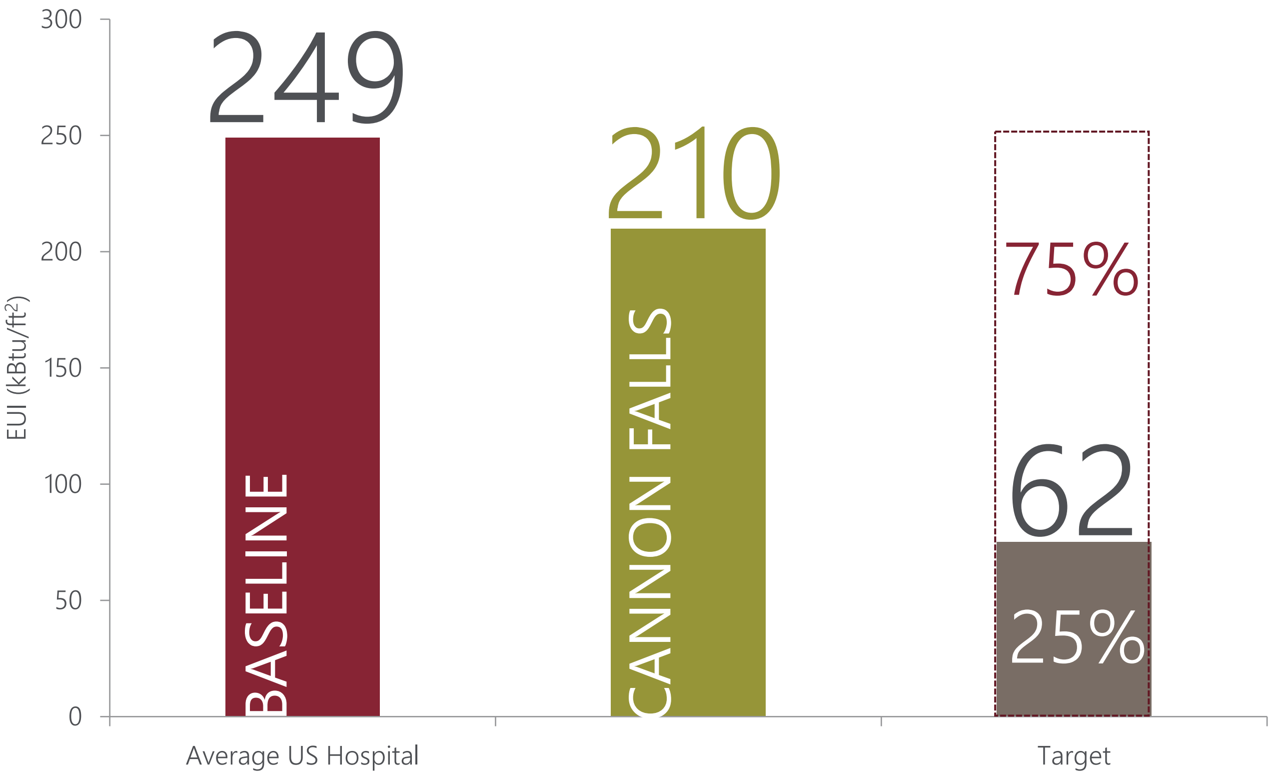
CASE STUDY
MAYO CLINIC HEALTH SYSTEM CANNON FALLS

Site EUI **A1**

<u>Distribution System</u>
VAV with Hot Water Reheat
- Conventional VAV Boxes
- Airflow Varied Down to 40-50% Flow
- Hot Water Reheat

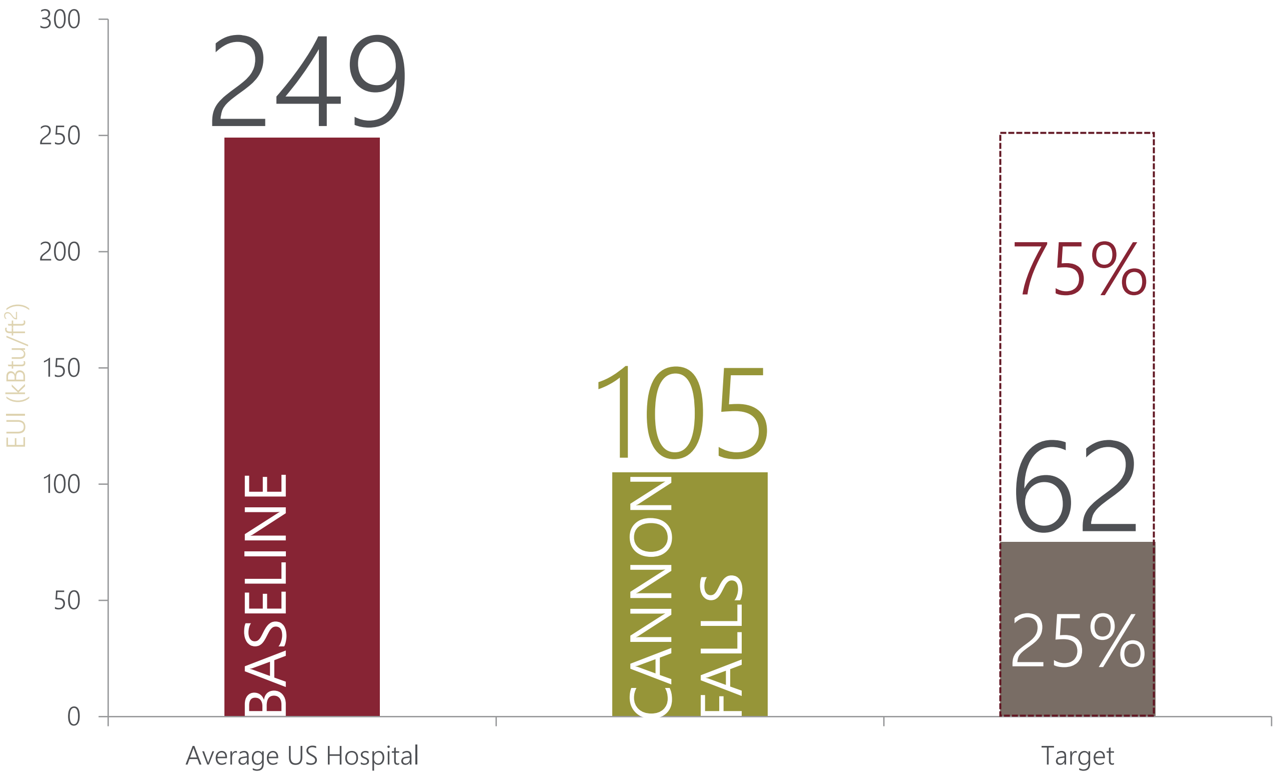
Perimeter Radiation for Envelope Heating Loads

<u>Central Plant</u>
DX Cooling & Condensing Boilers



CASE STUDY
MAYO CLINIC HEALTH SYSTEM CANNON FALLS

Site EUI **C4**



<u>Distribution System</u>
Active Chilled Beams

Perimeter Radiation for Envelope Heating Loads

Dedicated Outdoor Air System with Enthalpy Heat Recovery

<u>Central Plant</u>
Water Cooled Chiller & Condensing Boilers

CASE STUDY
MAYO CLINIC HEALTH SYSTEM CANNON FALLS

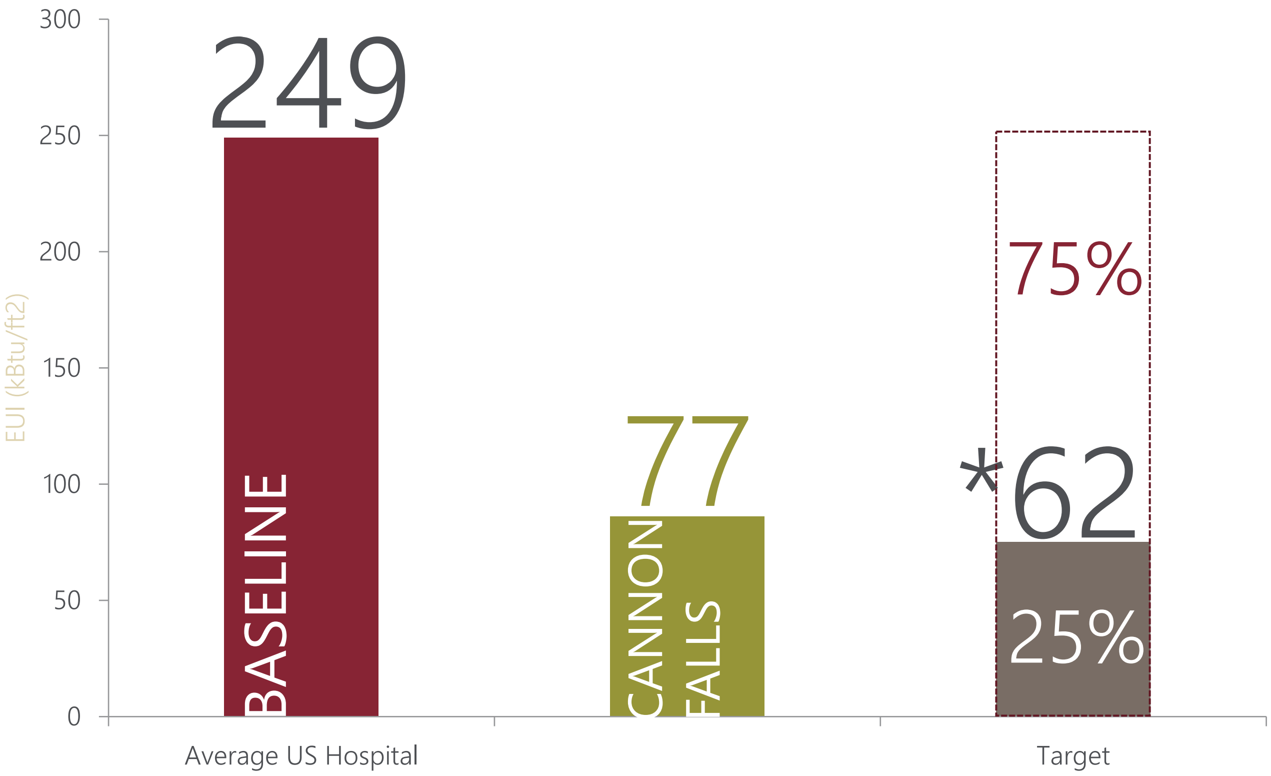
Site EUI D4

Distribution System
Active Chilled Beams

Perimeter Radiation for Envelope Heating Loads

Dedicated Outdoor Air System with Enthalpy Heat Recovery

Central Plant
Water to Water Heat Pumps with Geothermal Well Field



*At the time of the study the Target was 75.

CASE STUDY
MAYO CLINIC HEALTH SYSTEM CANNON FALLS

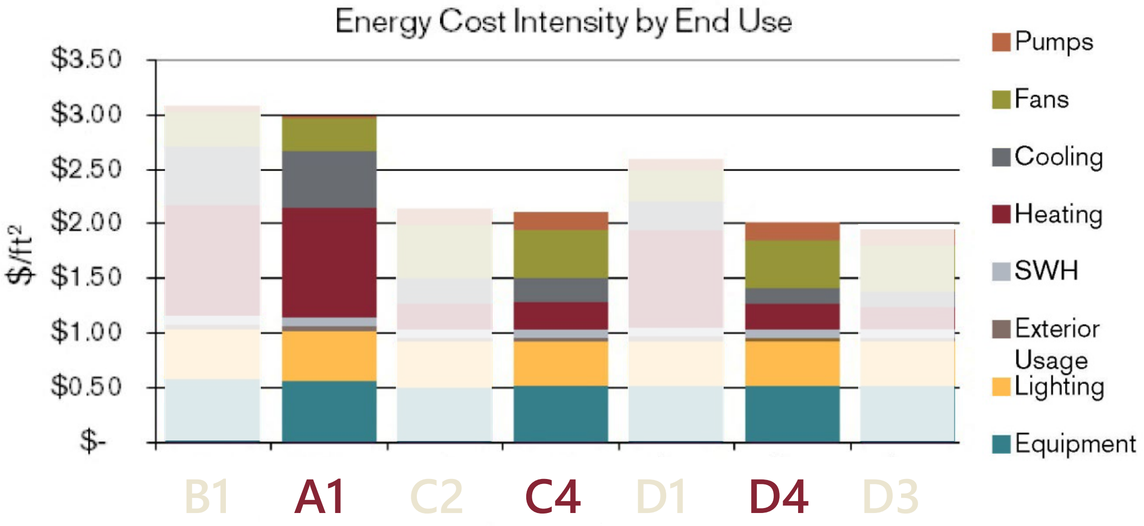
Cannon Falls, MN
89,252 SF | 15-bed Critical Access Hospital

Annual Unit Energy Costs

A1 - $2.83/SF/year

C4 - $1.90/SF/year

D4 - $1.81/SF/year



CASE STUDY

MAYO CLINIC HEALTH SYSTEM CANNON FALLS

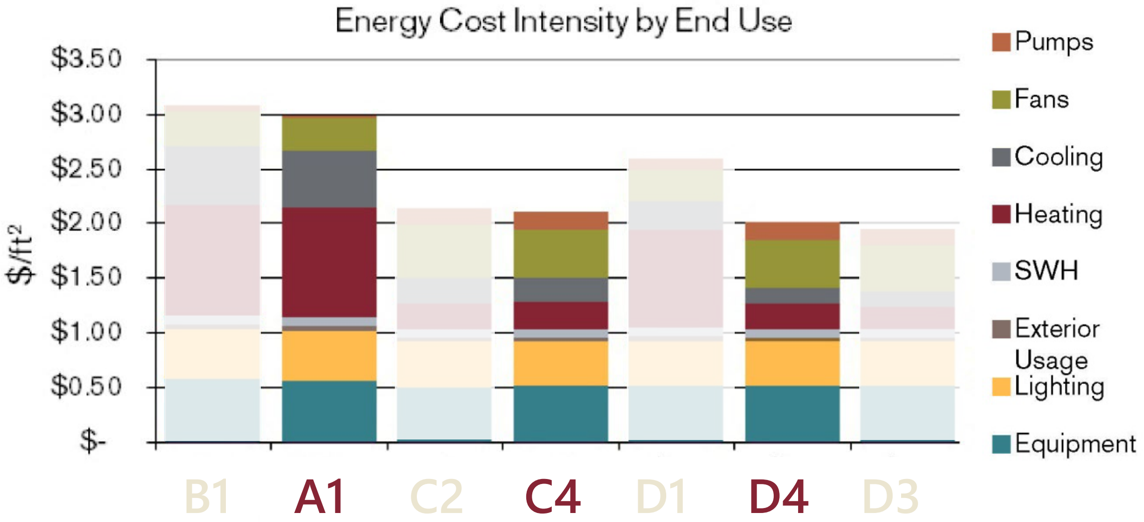
Cannon Falls, MN
89,252 SF | 15-bed Critical Access Hospital

Annual Energy Costs

A1 - $252,583/year

C4 - $169,579/year

D4 - $161,546/year



ENERGY COST COMPARISONS

STRATEGY	Premium Cost Cost/SF x 89,252 SF = Total	Pay Back – Years	% of Construction Cost (based on $22.5M)
A1	------------	---------	---------
C4	$7.92/SF = $707,000	8.5 years	3.1%
D4	$13.81/SF = $1,233,000	13.5 years	5.5%

Note:

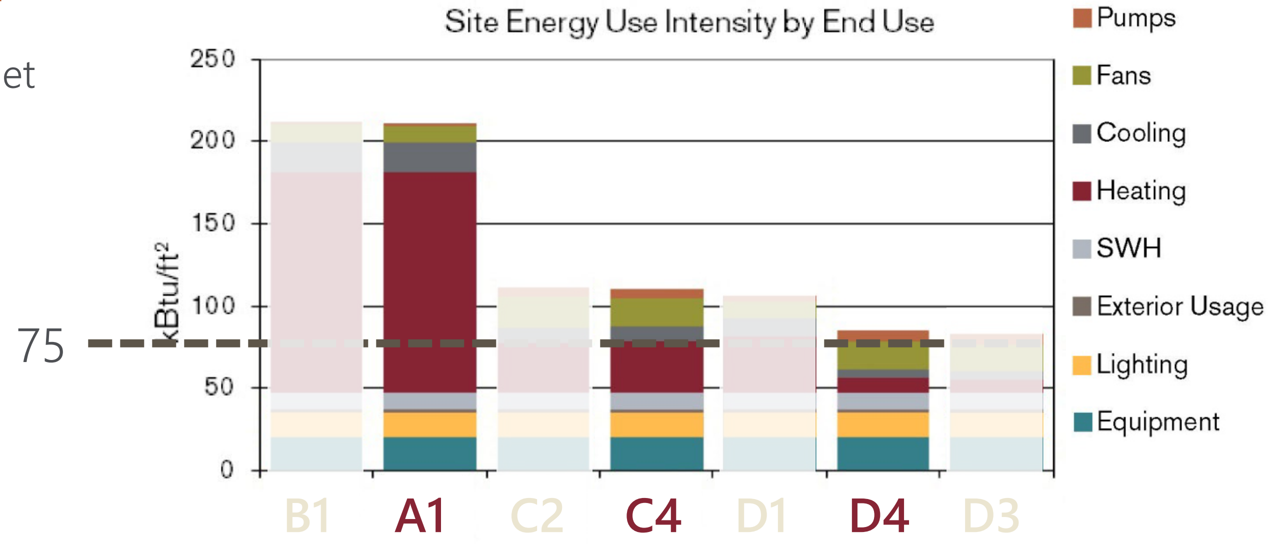
- Electrical costs were not included in this estimate – expectation is they would go down.
- Building Envelope reductions were not included.
- Escalation in energy costs were not factored in.

CASE STUDY
MAYO CLINIC HEALTH SYSTEM CANNON FALLS

Cannon Falls, MN
89,252 SF | 15-bed Critical Access Hospital

Mechanical strategies only get you so far…

What stays the same?



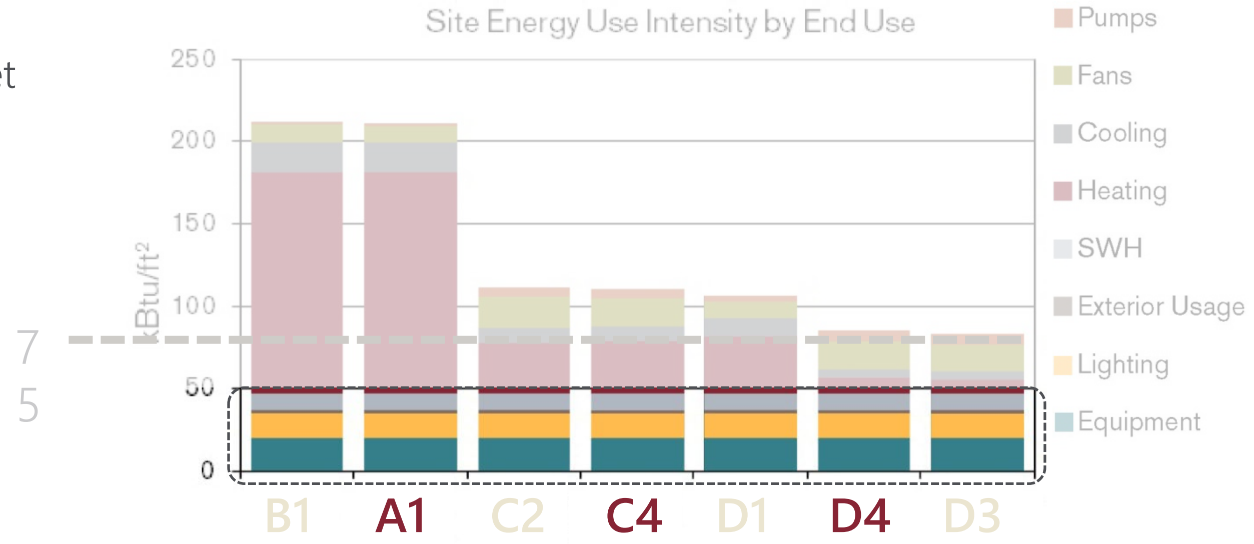
CASE STUDY
MAYO CLINIC HEALTH SYSTEM CANNON FALLS

Cannon Falls, MN
89,252 SF | 15-bed Critical Access Hospital

Mechanical strategies only get you so far…

What stays the same?

- Lighting
- Equipment
- Domestic Hot Water

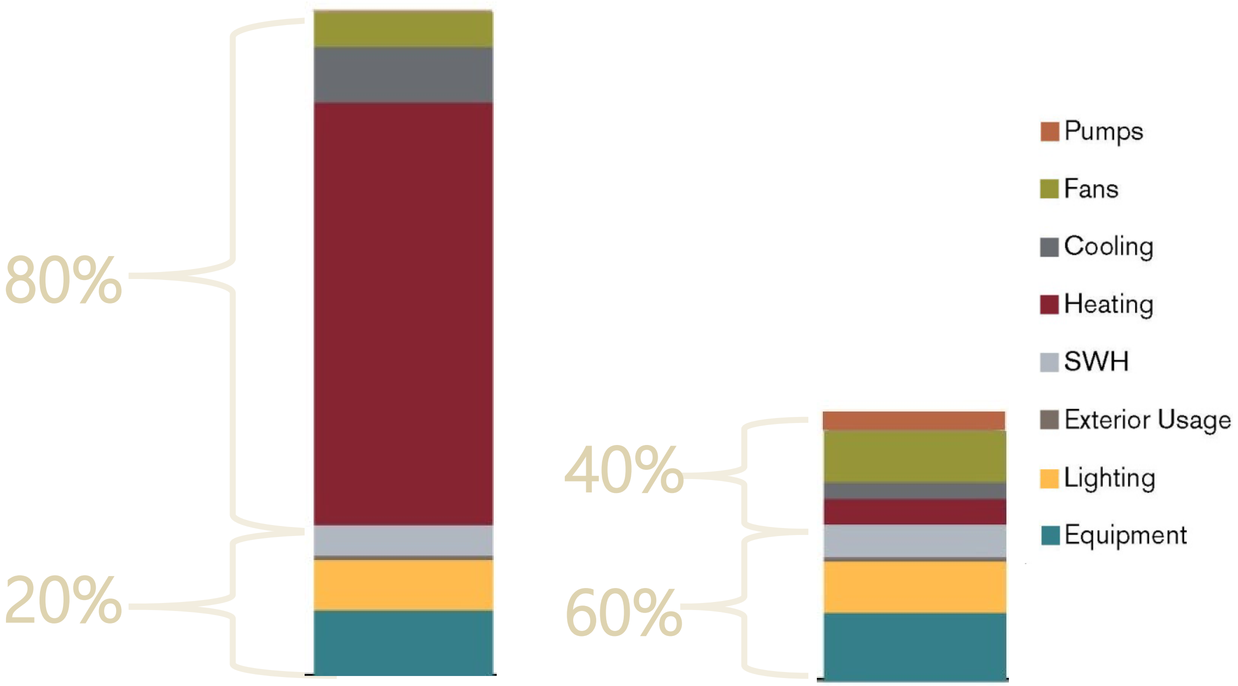


CASE STUDY
MAYO CLINIC HEALTH SYSTEM CANNON FALLS

Cannon Falls, MN
89,252 SF | 15-bed Critical Access Hospital

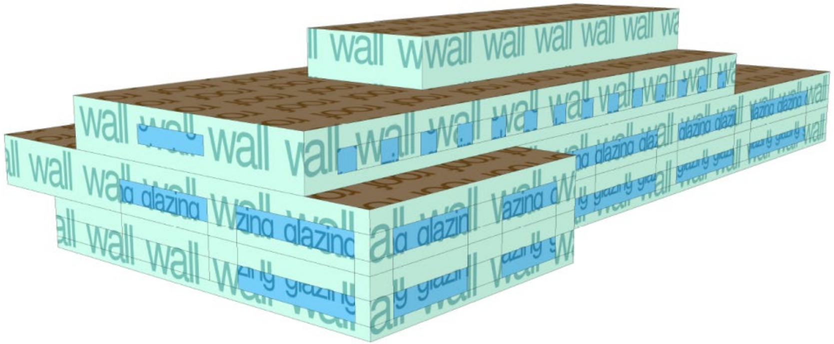
Mechanical strategies only get you so far…

When the heating and cooling EUI is reduced, everything else plays a more important role in reducing overall EUI

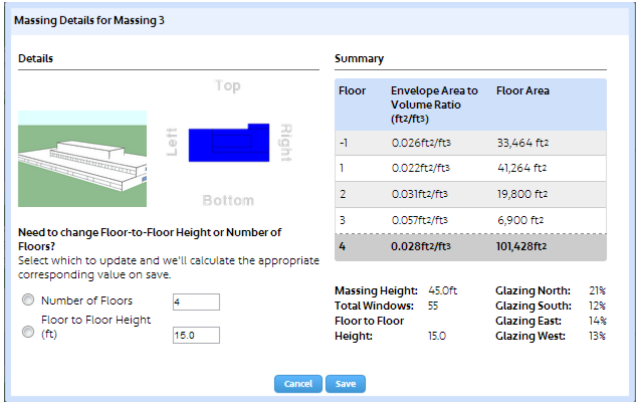


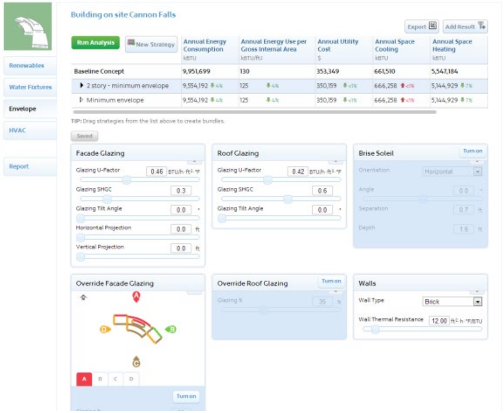
ADDITIONAL OPPORTUNITIES

What can the architecture contribute?



- Orientation
- Envelope Design
- Day Lighting
- Sensors/controls
- Reduced Lighting Energy
- Reduced Fan Energy





ADDITIONAL OPPORTUNITIES

What can the partnership of design team and owner contribute?

Plug Loads

Energy Star Equipment

Circuit Control

Interaction with Equipment Manufacturers

Codes

ADDITIONAL OPPORTUNITIES

Getting the rest of the way…

On-site Renewable Energy Sources:

- Wind Turbine
- PV Array
- Biomass Generation
- Green Power

CASE STUDY
MAYO CLINIC HEALTH SYSTEM CANNON FALLS

Size: 800 KW

Cost: $2.4 million

Payback: 15 years

CASE STUDY
MAYO CLINIC HEALTH SYSTEM CANNON FALLS

Size: 1,500 KW

Cost: $4.5 million

Payback = 27 years

POTENTIAL FOR FUTURE SAVINGS

Resource Cost

Our data illustrates **75%** decrease in the energy demand, but we only see a **36%** reduction in the annual energy costs.

Currently in this region of the country natural gas is relatively inexpensive as compared to electric.

The cost of natural gas will increase over time. It is a depleting resource.

- Energy company Reimbursements

Example: Some energy districts in this region will give 100% reimbursement for installation of a **geo-thermal well field**.

- Equipment prices go down

As equipment like chilled beams get more popular their price will go down.

OWNER'S ADVANTAGE

Low Temp Water Distribution

Opens up a variety of central plant options for future use
Liquid Medium is 25 times more efficient than air for moving heat

Smaller Plenums

Lower floor-to-floor heights
Lower total building volume
Less building skin.

Lower Operating Costs

Every Dollar saved in operation allows for a $20 Dollar reduction in revenue generation for the hospital. Which in this case adds up to **$1.8 million** dollars/year with Scheme D4 and **$3.2 Million dollars/year net zero system.**

System Flexibility

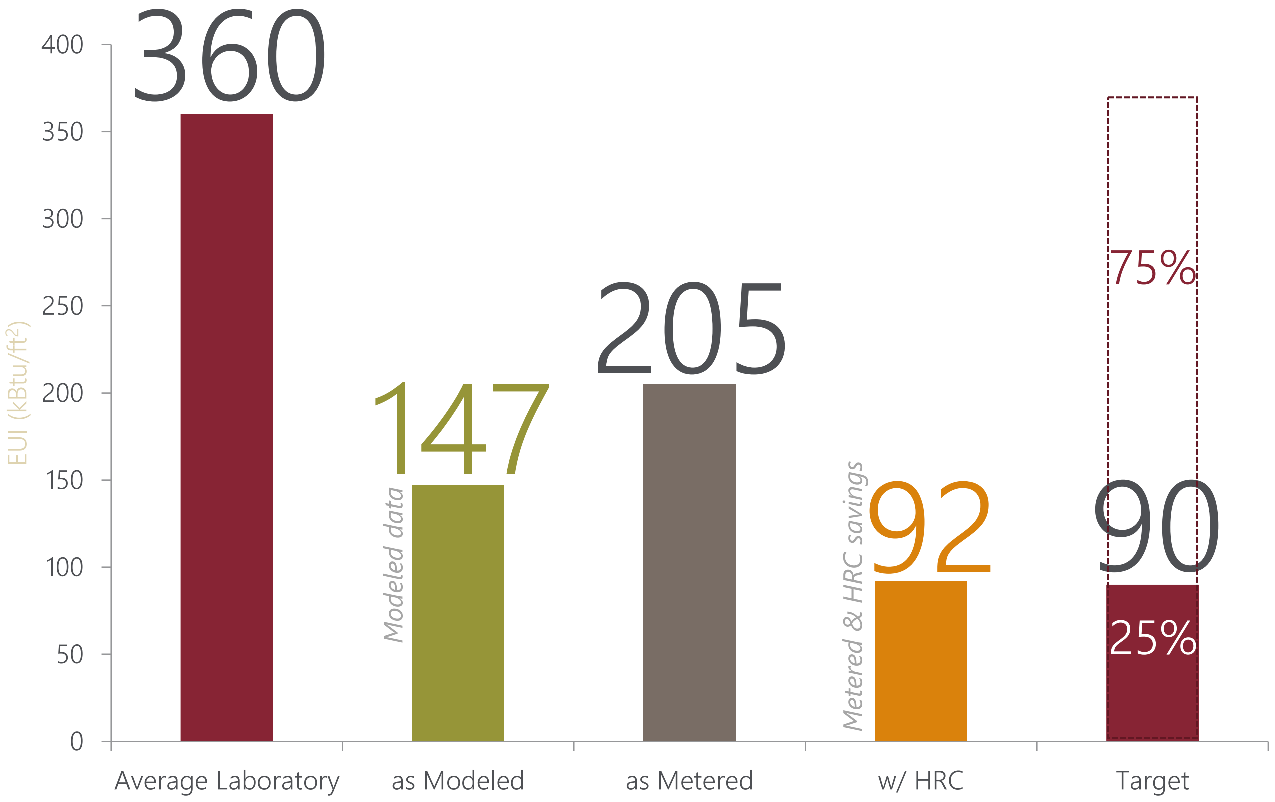
Opens up potential for future well field (geothermal heating and cooling)
Options for hybridization with other systems

MICROBIOLOGY RESEARCH FACILITY

MICROBIOLOGY RESEARCH FACILITY

CASE STUDY
MICROBIOLOGY RESEARCH FACILITY

Site EUI



CASE STUDY
MICROBIOLOGY RESEARCH FACILITY

FUME HOOD DECOMMISSIONING CAN ALLOW FOR A 7.5 EUI DECREASE IN A RESEARCH FACILITY

$$92 - 7.5 =$$

84.5 EUI

*Even further decrease in an academic setting

ADDITIONAL OPPORTUNITIES

Getting the rest of the way…

On-site Renewable Energy Sources:

- Wind Turbine
- PV Array
- Biomass Generation
- Green Power

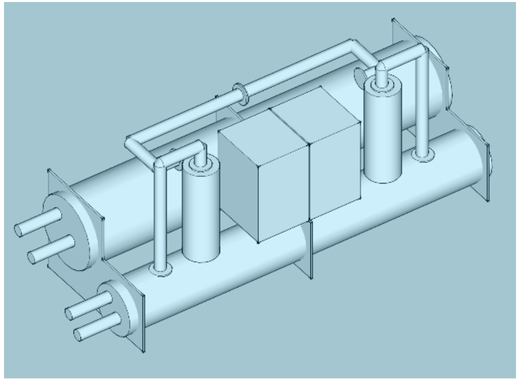
MICROBIOLOGY RESEARCH FACILITY

Strategies for site energy production

DISTRICT APPROACH TO NET ZERO

Total Energy into the Discovery District

DISTRICT APPROACH TO NET ZERO



23,240 MMBtu/yr
Savings to Campus

\-

16,872 MMBtu/yr
Consumption

=

6368MMBtu/yr
Excess savings

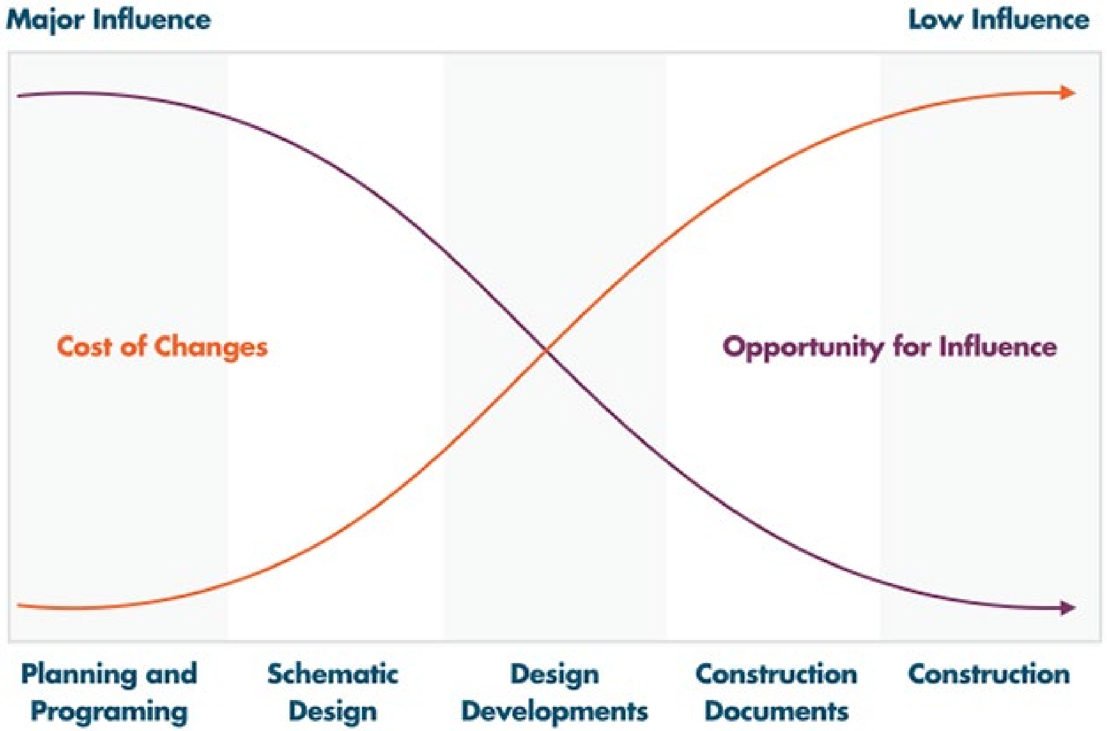
DISTRICT APPROACH TO NET ZERO

minus

6368MMBtu/yr
Excess savings

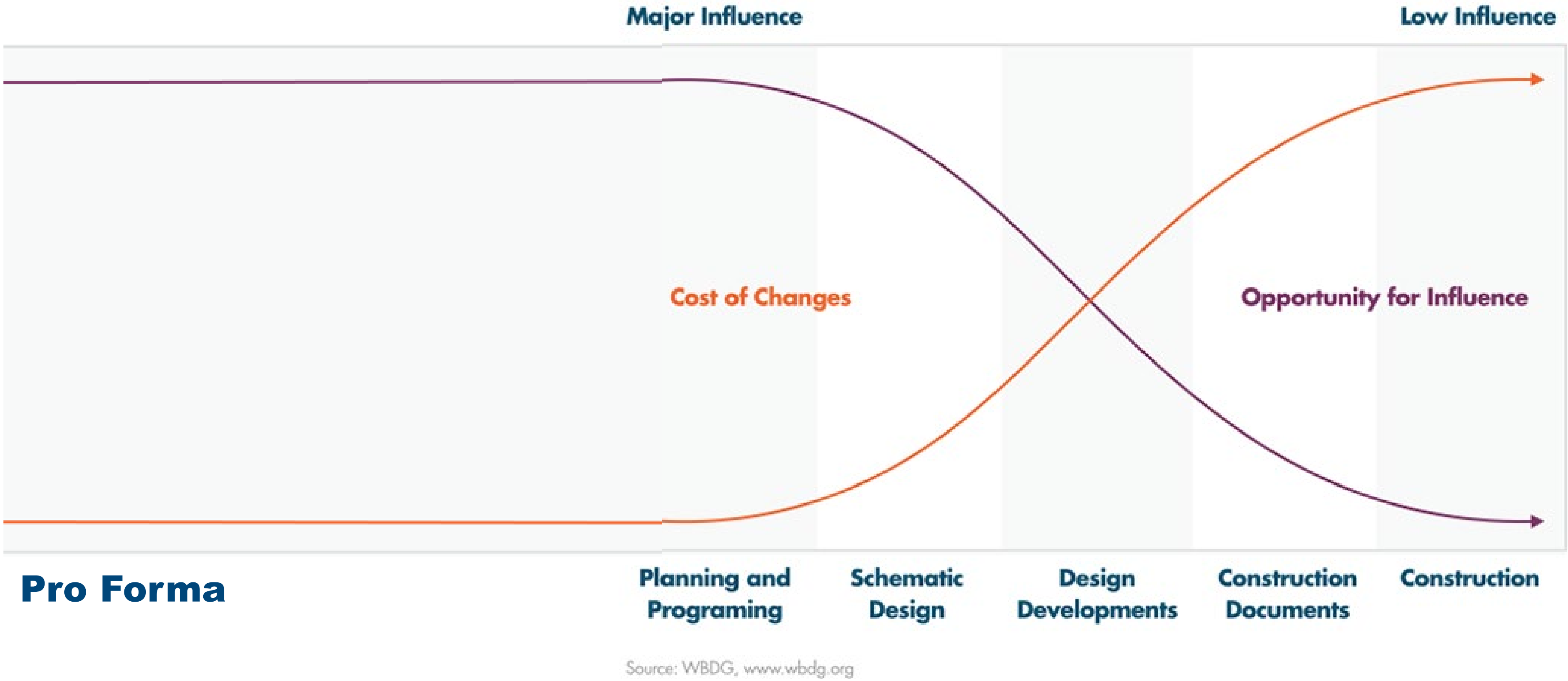
ENGAGING CLIENTS EARLY, OFTEN & SPREAD THE WORD

DESIGN DECISION TIMING



Source: WBDG, www.wbdg.org

SYSTEMS DECISION TIMING



Pro Forma

TODAY'S FOCUS

Necessity

Strategies

Savings

Timing

Q&A

Thank you for your time.