Commercial Technology

Jason Forsyth, Moseley Architects
Manisa Pipattanasomporn, BEM Controls
Mark Jackson, Community Housing Partners (moderator)

Sponsored by BEM CONTROLS

Commercial Technology Panel
Maximizing Energy Performance

2017 Fall Meeting
November 2, 2017

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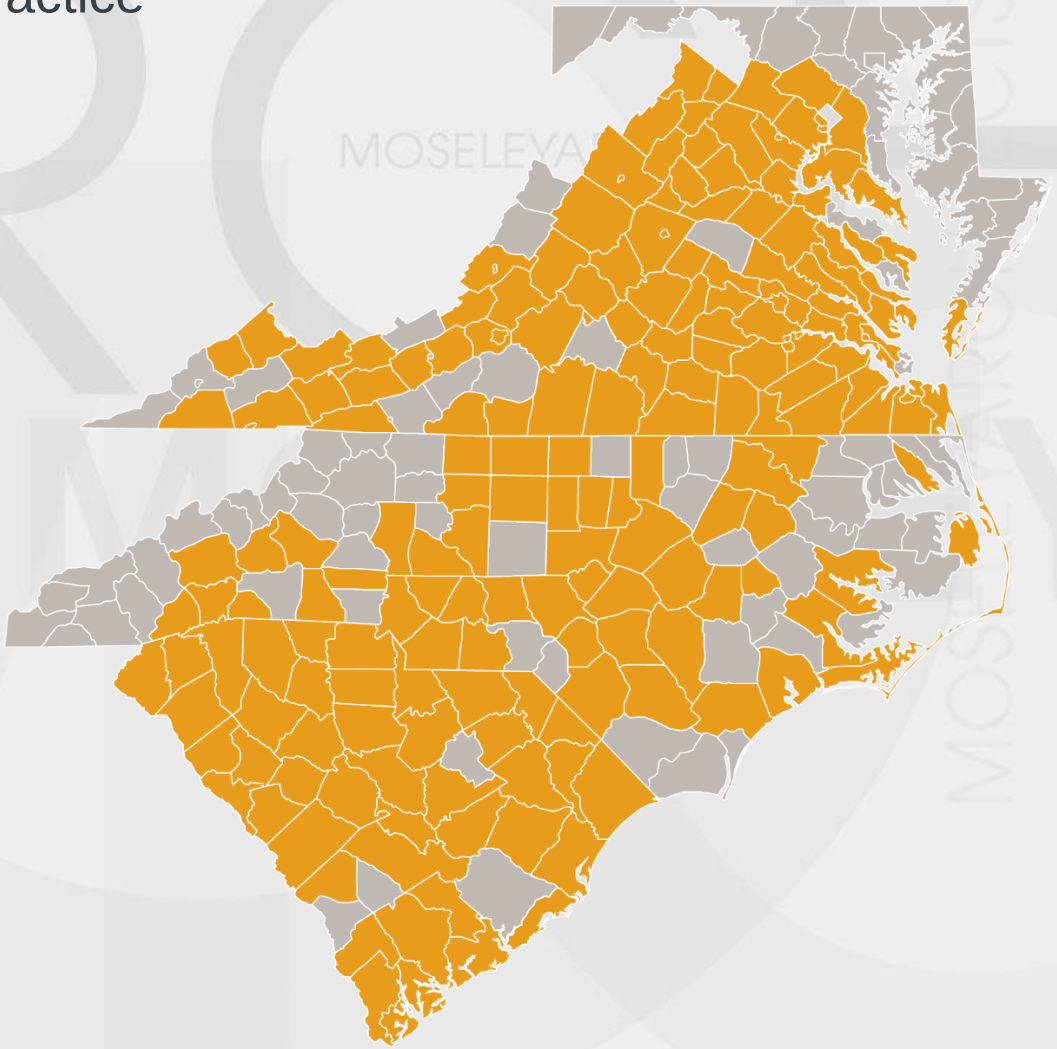
VAEEC
VIRGINIA ENERGY EFFICIENCY COUNCIL

Moseley Architects

- 48 years of continuous practice
- Over 220 employees
- Offices
  - Richmond - HQ
  - Fairfax
  - Harrisonburg
  - Roanoke
  - Virginia Beach
  - Warrenton
  - Charlotte
  - Raleigh
  - Columbia



Moseley Architects

- Sectors
  - Civic
  - Justice
  - Higher Education
  - Senior Living
  - K-12
  - Commercial

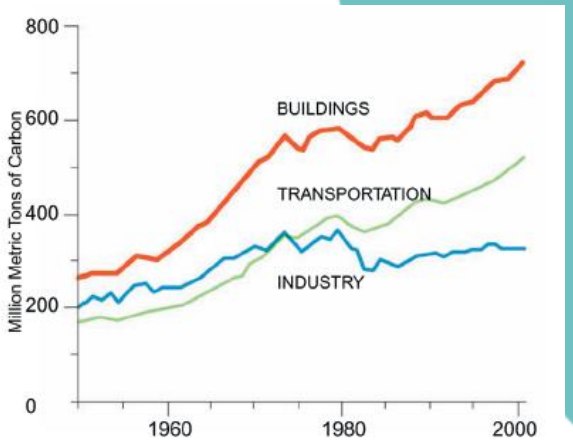
- Architecture
- Mechanical, electrical, plumbing, and structural engineering
- Fire protection engineering
- Interior design
- Project management
- Programming
- CIP planning and feasibility studies
- Security system design
- High performance/sustainable design
- Construction administration

U.S. ENERGY CONSUMPTION

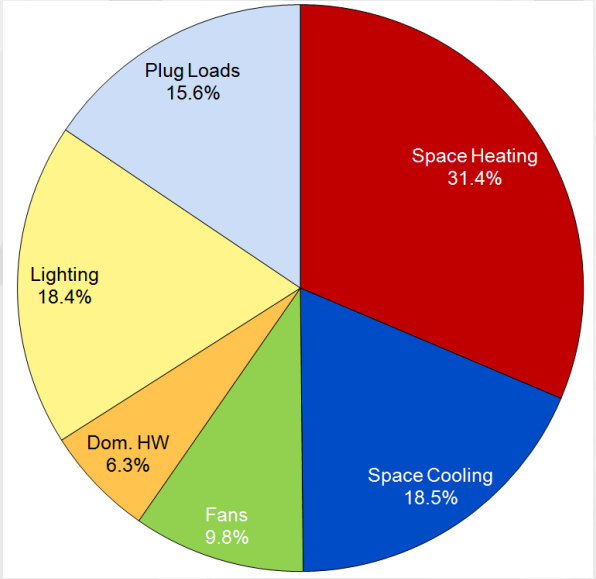
BUILDINGS 39%

INDUSTRY 29%

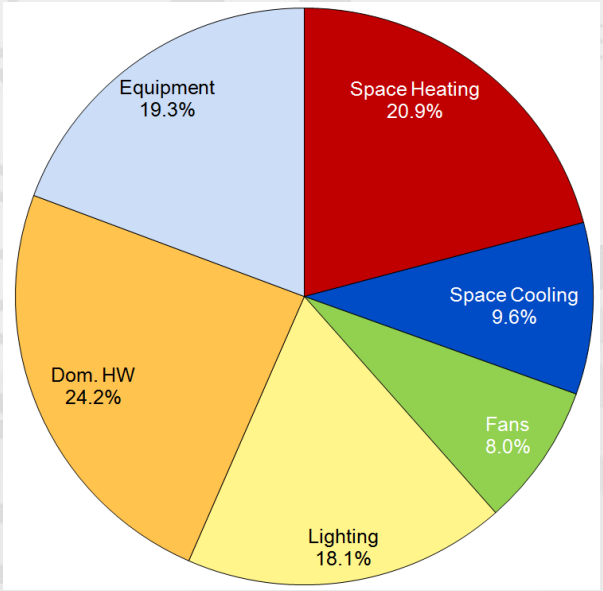
TRANSPORTATION 32%



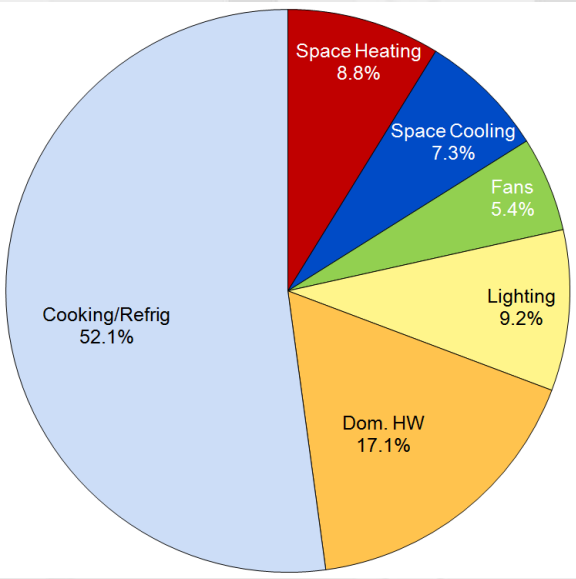
Mechanical Systems



K-12



Corrections



Dining Halls

Maximizing Energy Efficiency

- Code requirements
- Energy modeling
- Building Systems
  - Mechanical systems
  - Electrical systems

Code Requirements

- What does the code indicate for energy requirements?

CHAPTER 13: ENERGY EFFICIENCY

Section 1301: GENERAL

ENERGY EFFICIENCY

User note: Code change proposals to this chapter will be considered by the International Energy Conservation Code Development Committee during the 2016 (Group B) Code Development Cycle. See explanation on page iv.

SECTION 1301
GENERAL

[E] 1301.1 Scope. This chapter governs the design and construction of buildings for energy efficiency.

[E] 1301.1.1 Criteria. Buildings shall be designed and constructed in accordance with the *International Energy Conservation Code.*

Code Requirements

- So what does the IECC indicate?

CHAPTER 4 [CE]: COMMERCIAL ENERGY EFFICIENCY

Section C401: GENERAL

COMMERCIAL ENERGY EFFICIENCY

SECTION C401
GENERAL

C401.1 Scope. The provisions in this chapter are applicable to commercial buildings and their building sites.

C401.2 Application. Commercial buildings shall comply with one of the following:

1. The requirements of ANSI/ASHRAE/IESNA 90.1.
2. The requirements of Sections C402 through C405. In addition, commercial buildings shall comply with Section C406 and tenant spaces shall comply with Section C406.1.1.
3. The requirements of Sections C402.5, C403.2, C404, C405.2, C405.3, C405.4, C405.6 and C407. The building energy cost shall be equal to or less than 85 percent of the standard reference design building.

C401.2.1 Application to replacement fenestration products. Where some or all of an existing fenestration unit is replaced with a new fenestration product, including sash and glazing, the replacement fenestrationunit shall meet the applicable requirements for U-factor and SHGC in Table C402.3.

Exception: An area-weighted average of the U-factor of replacement fenestration products being installed in the building for each fenestration product category listed in Table C402.3 shall be permitted to satisfy the U-factor requirements for each fenestration product category listed in Table C402.3. Individual fenestration products from different product categories listed in Table C402.3 shall not be combined in calculating the area-weighted average U-factor.

Code Requirements

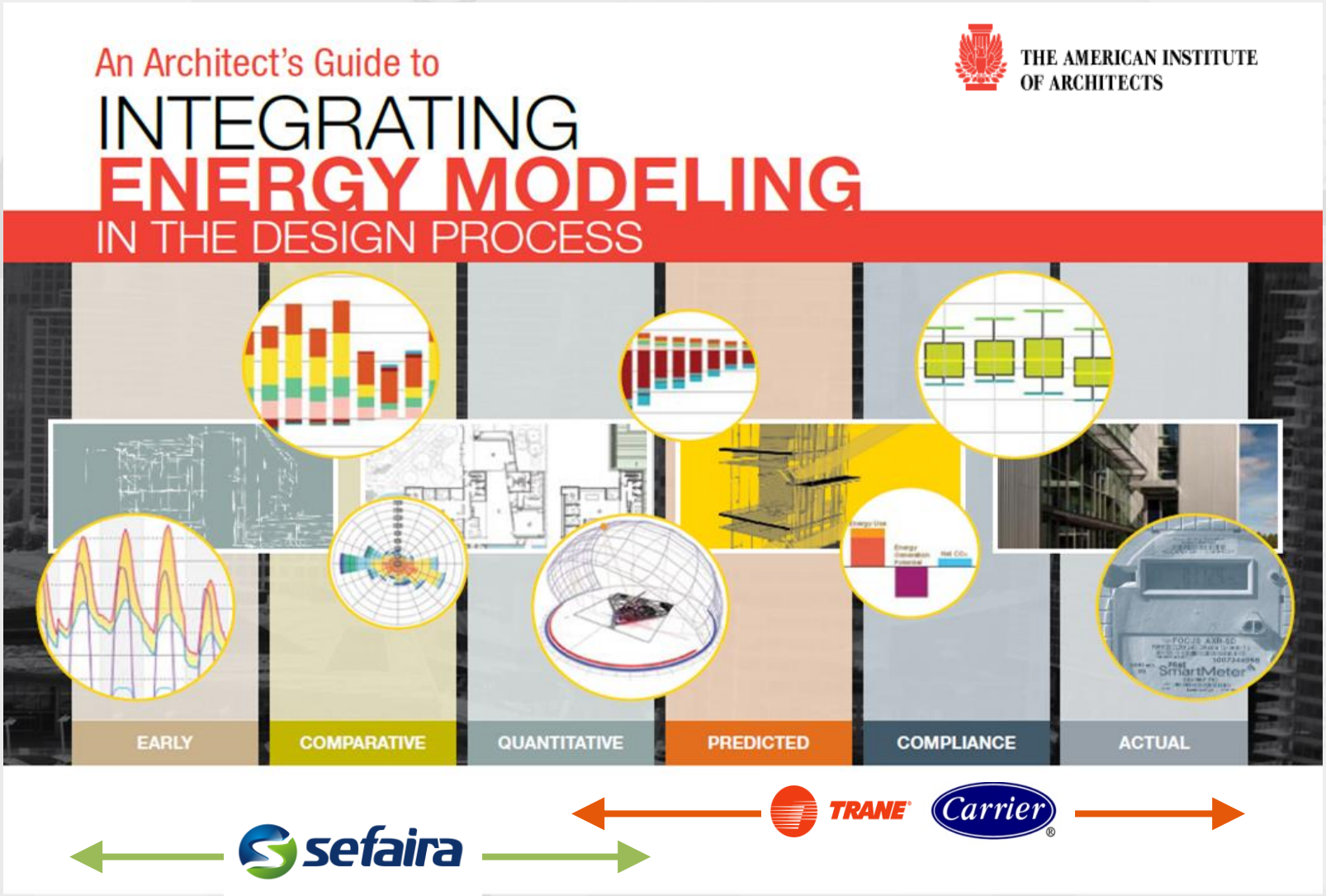
- ASHRAE Standard 90.1
- Two compliance paths
  - Prescriptive
  - Energy Cost Budget Method (Energy Modeling)

- Appendix G – Performance Rating Method
  - Baseline HVAC Systems

TABLE G3.1.1A Baseline HVAC System Types

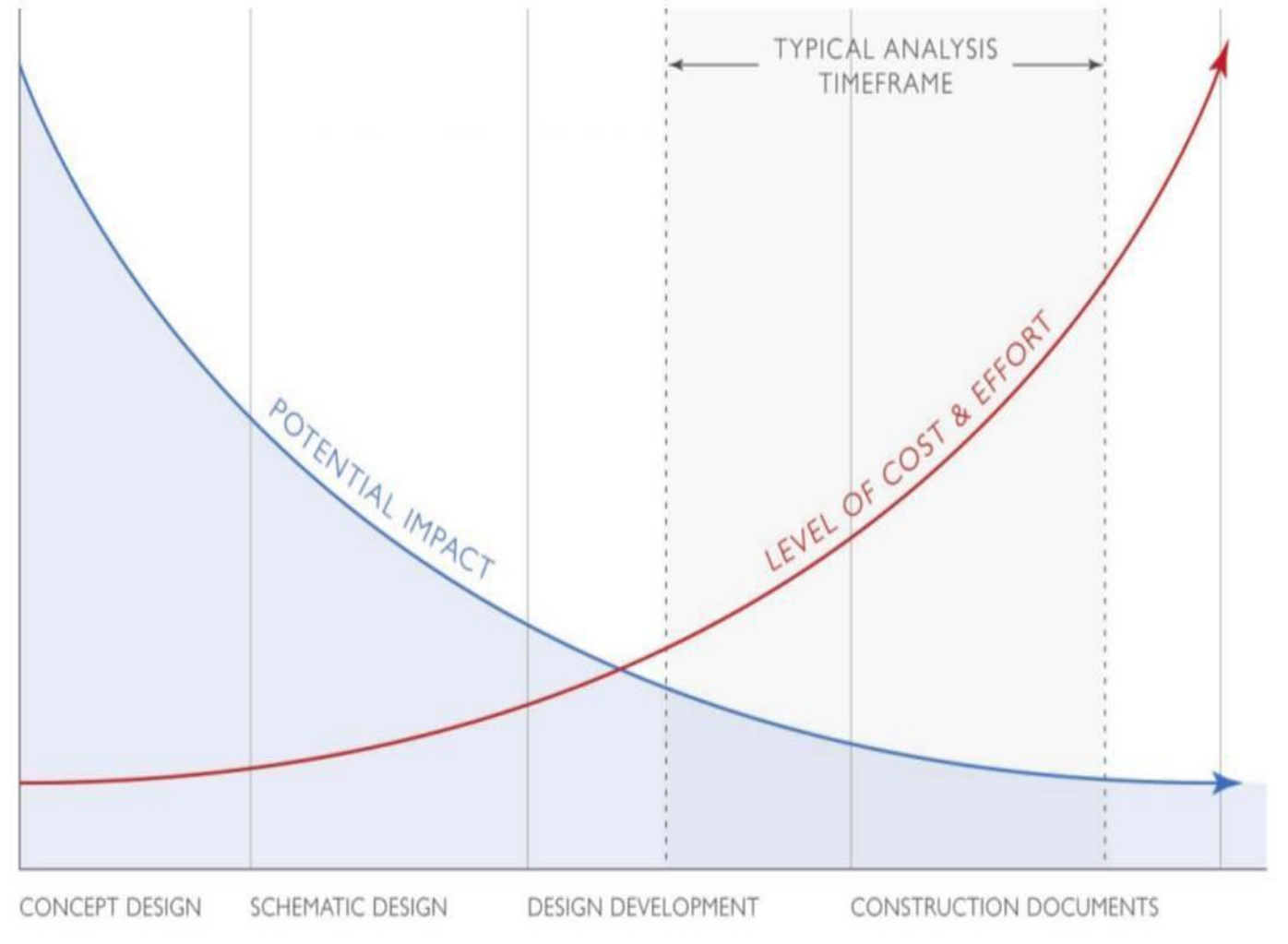
Building Type	Fossil Fuel, Fossil/Electric Hybrid, and Purchased Heat	Electric and Other
Residential	System 1—PTAC	System 2—PTHP
Nonresidential and 3 Floors or Less and <25,000 ft^2	System 3—PSZ-AC	System 4—PSZ-HP
Nonresidential and 4 or 5 Floors and <25,000 ft^2 or 5 Floors or Less and 25,000 ft^2 to 150,000 ft^2	System 5—Packaged VAV with Reheat	System 6—Packaged VAV with PFP Boxes
Nonresidential and More than 5 Floors or >150,000 ft^2	System 7—VAV with Reheat	System 8—VAV with PFP Boxes
Heated Only Storage	System 9—Heating and Ventilation	System 10—Heating and Ventilation

Energy Modeling



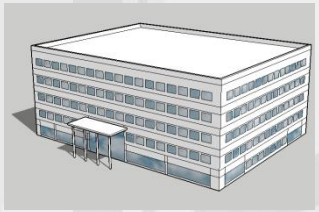
Energy Modeling

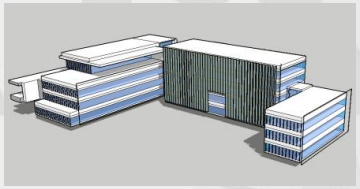
- Use as an iterative design tool

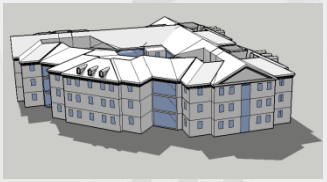


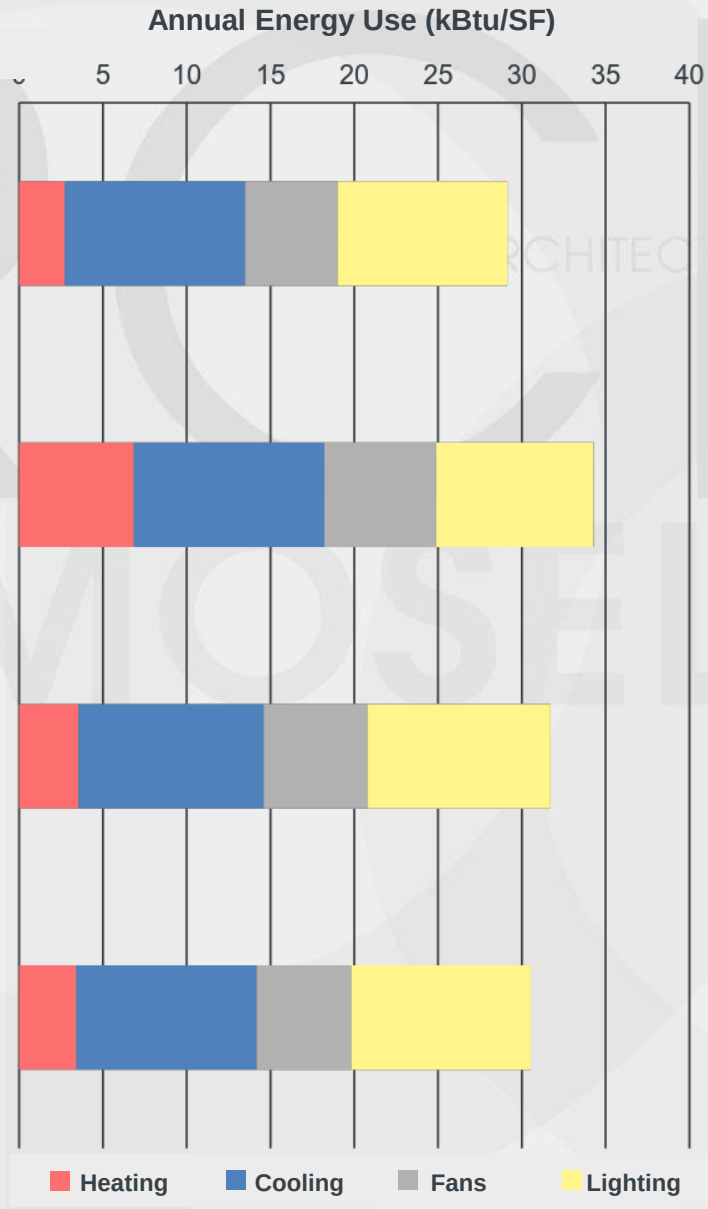
Energy Modeling

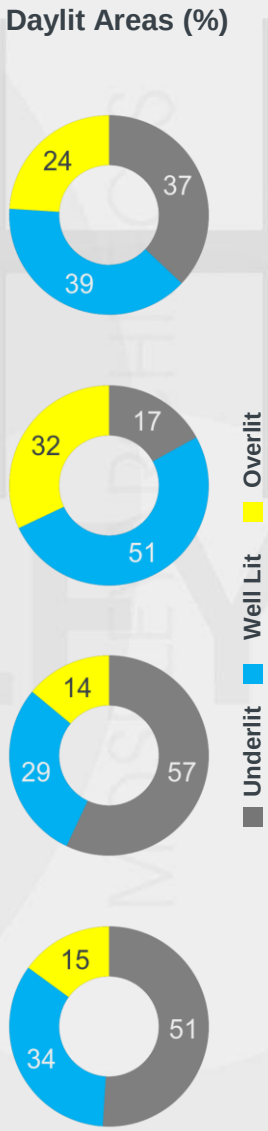
BLOCK	PLAZA	3-STORY	4-STORY
29.1 kBtu/SF	34.3 kBtu/SF	31.7 kBtu/SF	30.5 kBtu/SF
63% Daylit	83% Daylit	43% Daylit	49% Daylit











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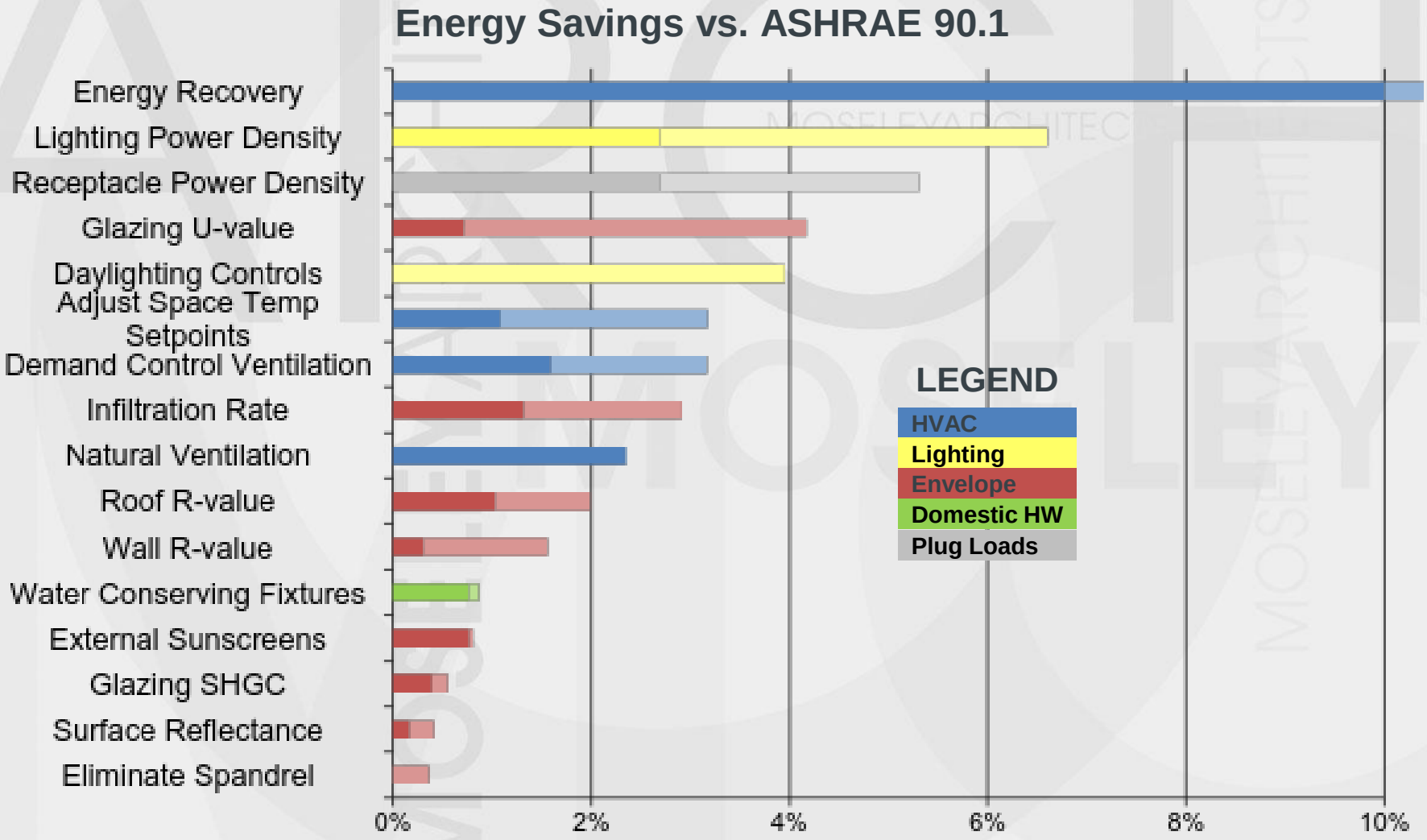
Energy Modeling

- Use as an iterative design tool



Energy Modeling

- Use as an iterative design tool

Recommended Strategies

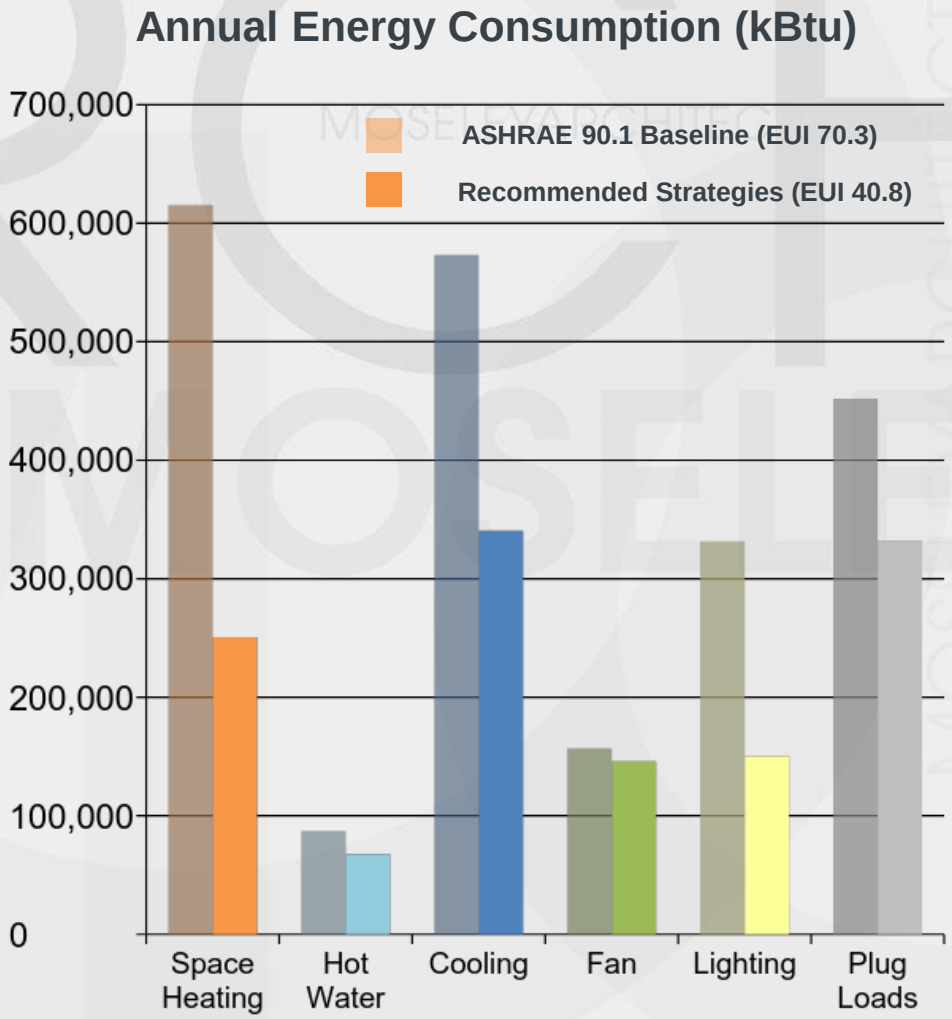
ENVELOPE
R-17.3 Walls (2” c.i.)
R-30 Roof Insulation
Proposed TPO Roof Membrane
Guardian SNX 62/27 Glazing
Continuous Air Barrier System

HVAC
Energy Recovery (70% Effectiveness)
Demand Control Ventilation (12 Rooms)

LIGHTING
Increased Interior Finish Reflectances
0.6 W/SF Interior Lighting Power Density
Daylight Dimming in All Perimeter Rooms

PLUG LOADS
1.0 W/SF Receptacle Power Density (combination of all AEDG recommendations)

DOMESTIC HOT WATER
Lavatories with IR Sensors (12s / cycle)
1.5 gpm Break Room Sinks
ENERGY STAR Dishwasher



Energy Modeling

- Use as an iterative design tool

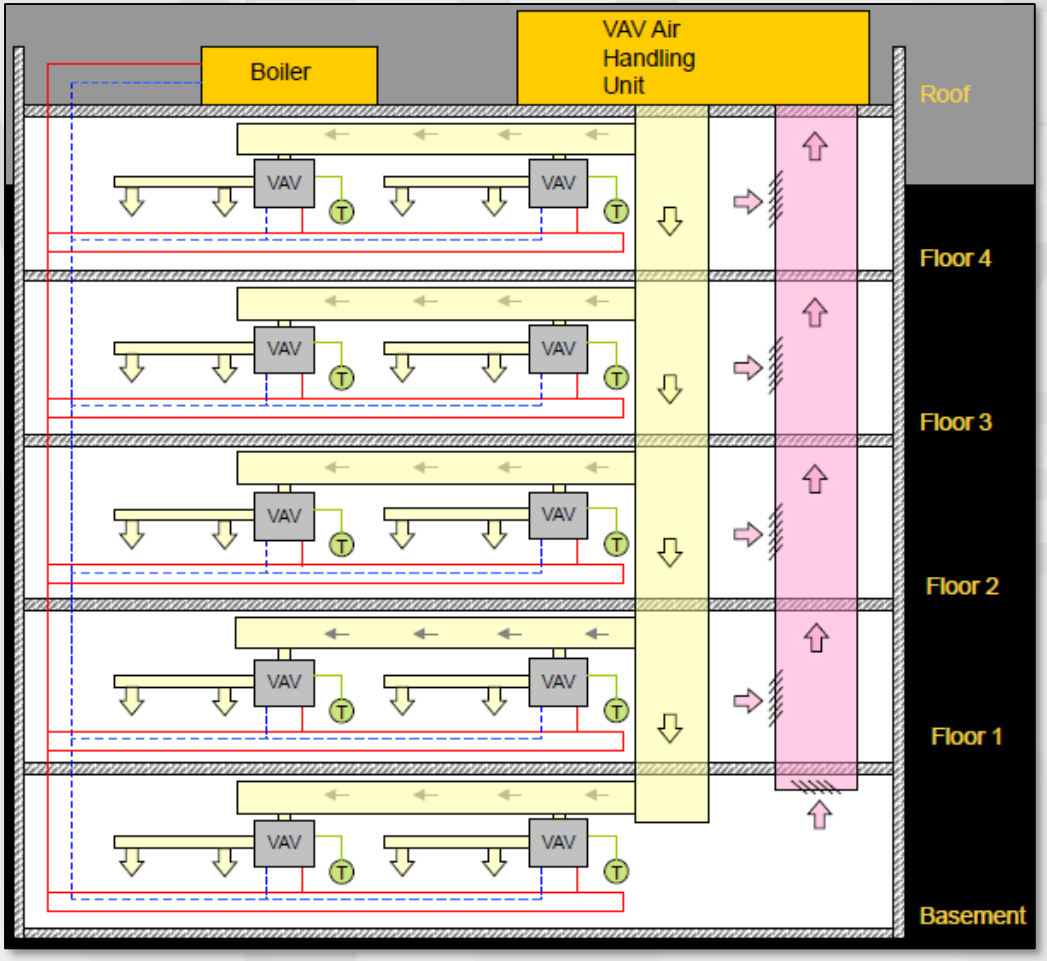
	Baseline	Design	Savings
ANNUAL UTILTY COST			
Energy	$57,749	$34,465	40.3%
PEAK HEATING DEMAND (MBH)	690.0	354.7	48.6%
PEAK COOLING DEMAND (TONS)	127.9	75.6	40.9%

Building Systems

- Airside Systems
  - Variable Air Volume (VAV)
  - Energy Recovery Wheels
  - Variable Refrigerant Flow (VRF)
  - Chilled Beams
- Waterside Systems
  - Geothermal
  - Heat Recovery Chillers
  - Condensing Boilers
- Electrical
  - Lighting Systems
  - Power Systems

Mechanical Systems

- VAV System



Mechanical Systems

- VAV Systems

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Building Type	Fossil Fuel, Fossil/Electric Hybrid, and Purchased Heat	Electric and Other
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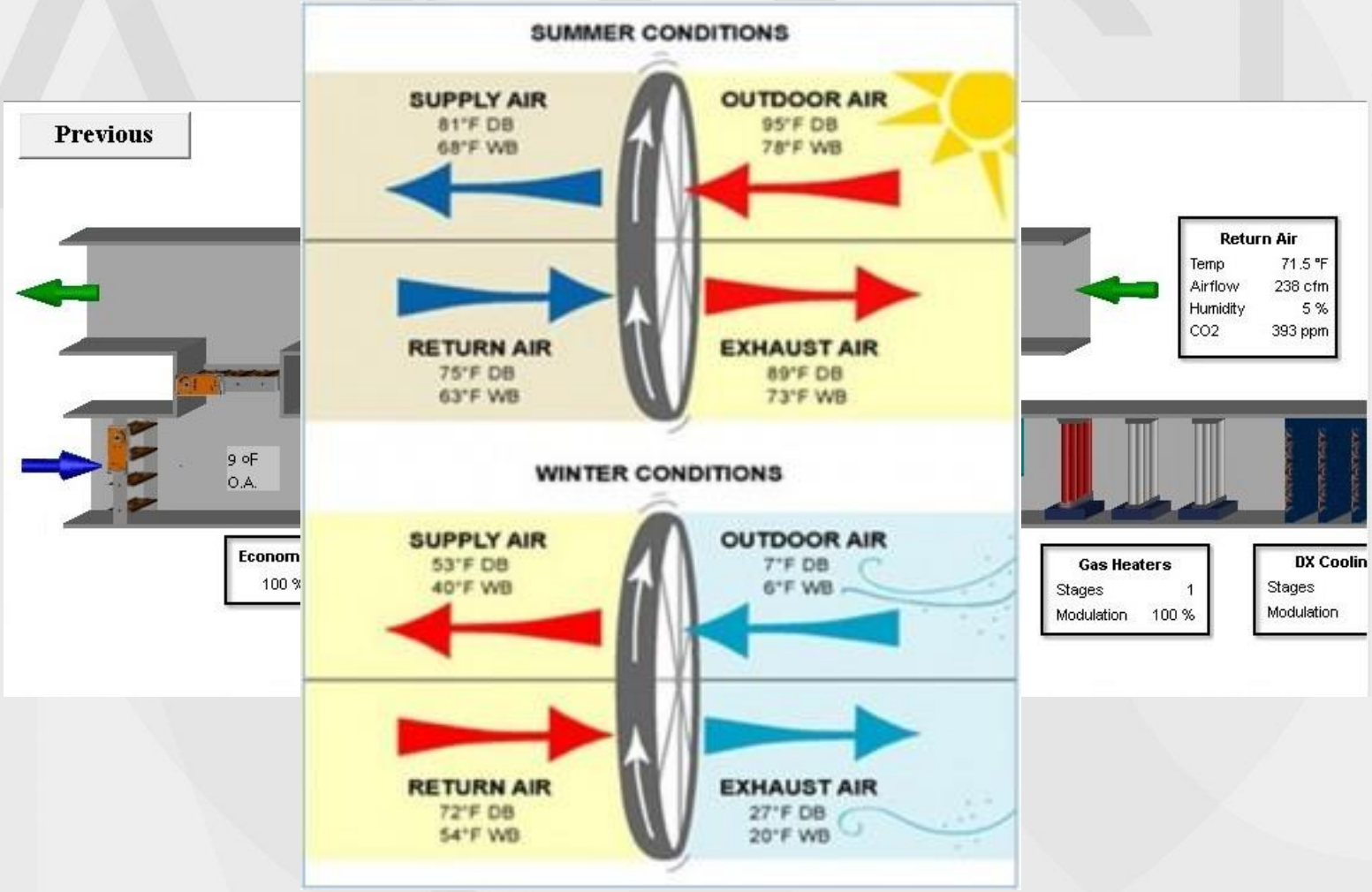
Nonresidential and More than 5 Floors or >150,000 ft²	System 7—VAV with Reheat	System 8—VAV with PFP Boxes
Heated Only Storage	System 9—Heating and Ventilation	System 10—Heating and Ventilation

Mechanical Systems

- Energy Recovery Wheels



Mechanical Systems

- Energy Recovery Wheels
- Essentially required by ASHRAE 90.1 now for all systems

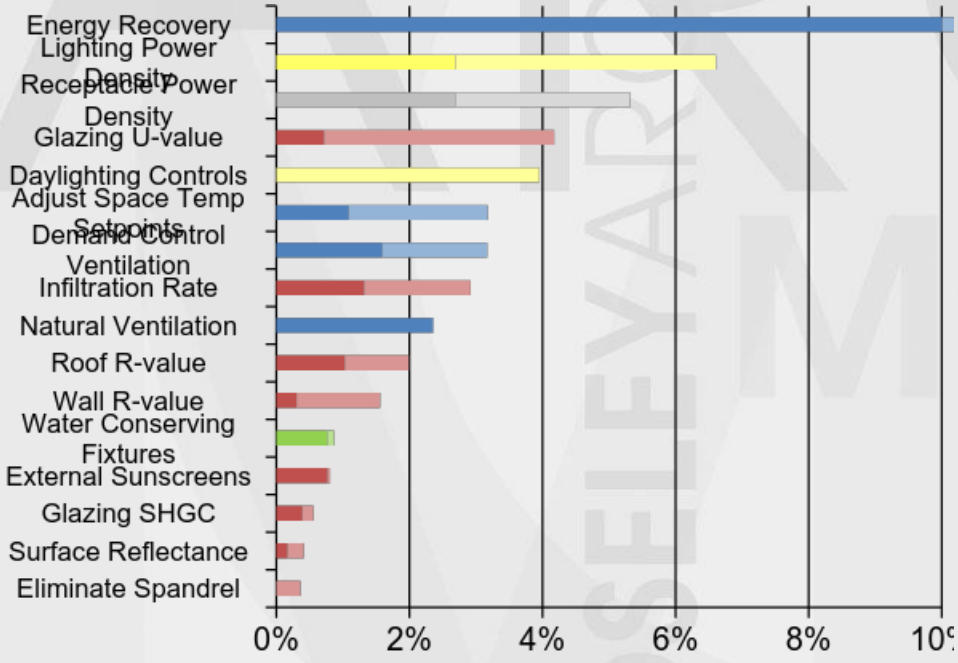


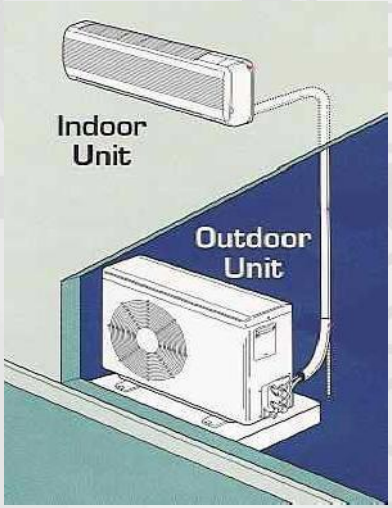
TABLE 6.5.6.1 Energy Recovery Requirement

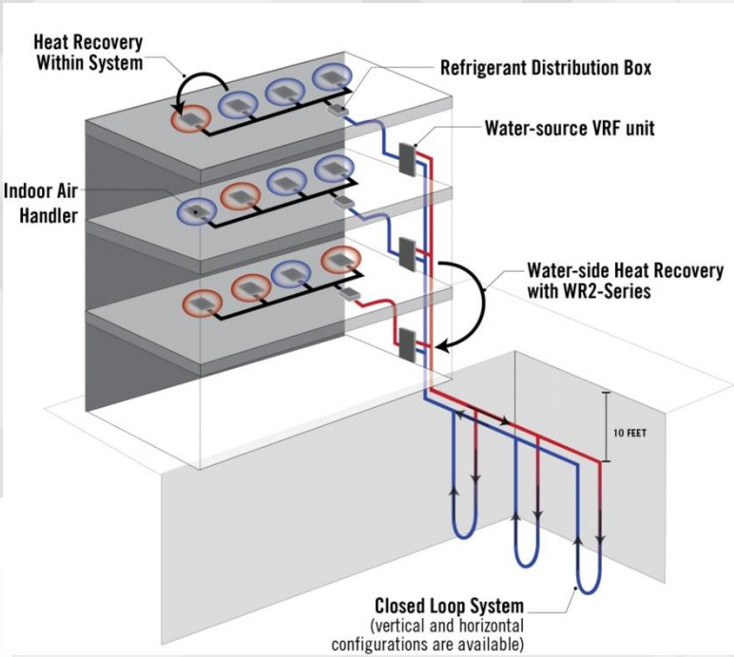
Zone	% Outdoor Air at Full Design Airflow Rate					
	≥30% and < 40%	≥40% and < 50%	≥50% and < 60%	≥60% and < 70%	≥70% and < 80%	≥80%
	Design Supply Fan Airflow Rate (cfm)					
3B, 3C, 4B, 4C, 5B	NR	NR	NR	NR	≥5000	≥5000
1B, 2B,5C	NR	NR	≥26000	≥12000	≥5000	≥4000
6B	≥11000	≥5500	≥4500	≥3500	≥2500	≥1500
1A, 2A, 3A, 4A, 5A, 6A	≥5500	≥4500	≥3500	≥2000	≥1000	>0
7,8	≥2500	≥1000	>0	>0	>0	>0

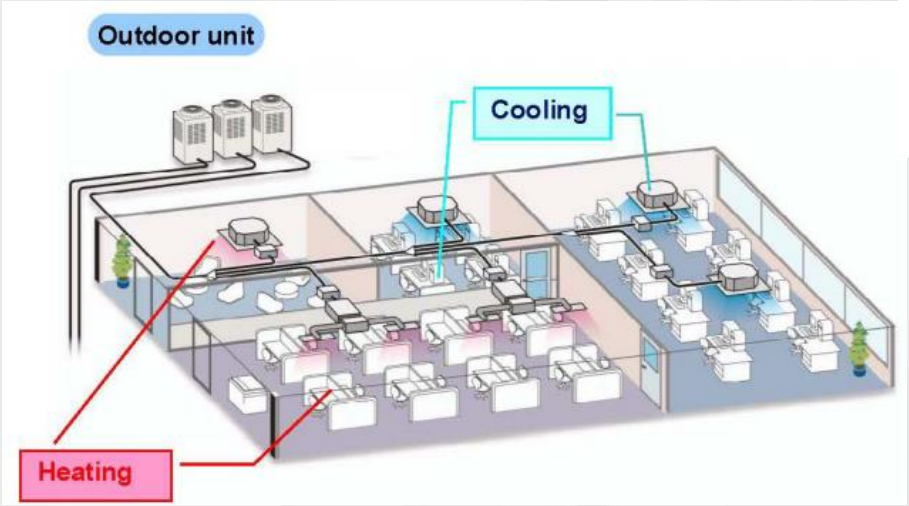
NR—Not required

Mechanical Systems

- Variable Refrigerant Flow (VRF)







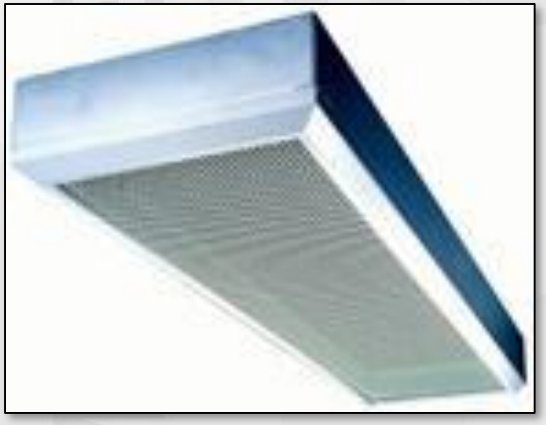
Mechanical Systems

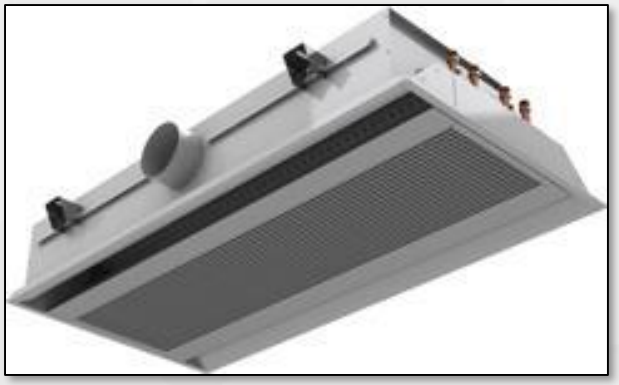
- Chilled Beams

Mechanical Systems

- Radiant heating and cooling devices
  - Radiant floors
  - Radiant panels
  - Chilled sails
  - Chilled beams

- Terminology can be confusing

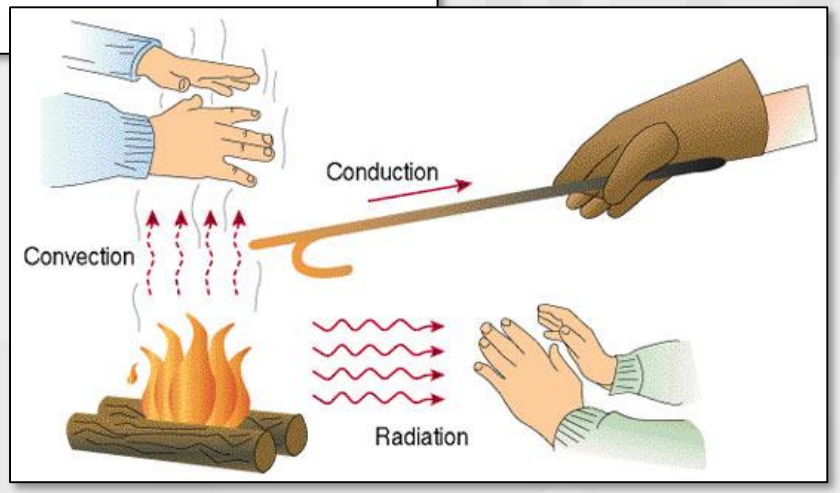




Mechanical Systems

- Modes of Heat Transfer

Conduction (via direct contact)	Convection (via fluid)	Radiation (via electromagnetic Radiation)
• Conduction is the direct flow of heat through a material resulting from physical contact.	• heat transfer between a surface and adjacent fluid (gas, air or liquid) and by the flow of fluid from one place to another, induced by temperature	• No transfer medium required • It's the transfer of thermal energy through matter of space by electro-magnetic waves.

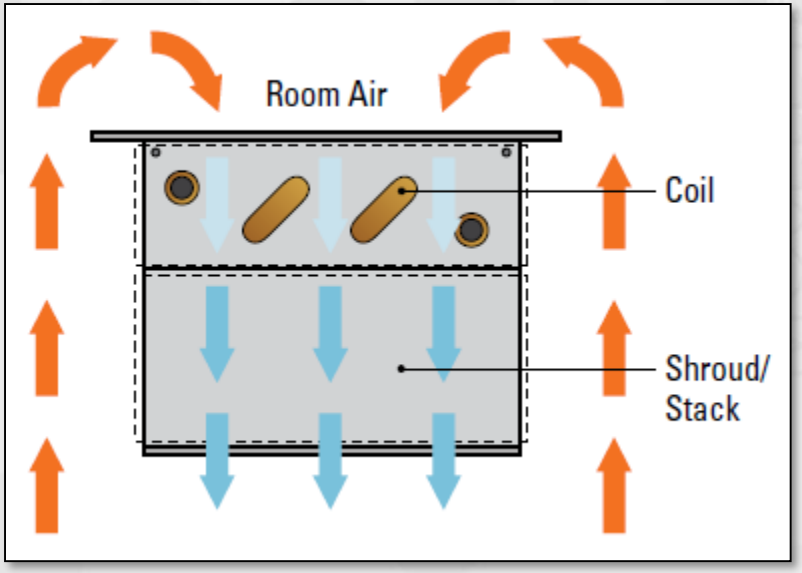


Mechanical Systems

- Chilled Beams
  - Mode of heat transfer – Convection with a little radiation
  - Provides both heating and cooling
  - Two types
    - Passive
    - Active

Mechanical Systems

- Chilled Beams - Passive
  - Provides cooling via natural convection
    - Primarily used for cooling with limited heating via radiation
  - Independent ventilation system
  - Similar to chilled sails where it requires a return air path
  - Limited capacity due to natural convection process (~155 (BTU/h)/ft)



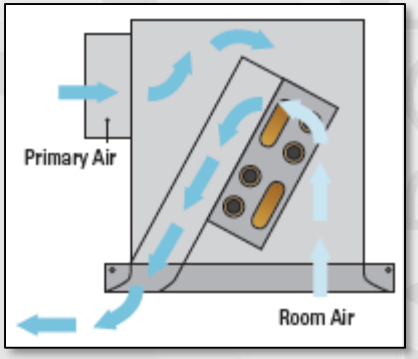
Mechanical Systems

- Chilled Beams - Active
  - Provides cooling and heating via forced convection
  - Integrated ventilation system with beams
    - Ventilation air introduced into plenum on beams
    - Induces room air across coil, mixes with ventilation air and delivers it to the space
    - Typical induction ratio is between 1:3 and 1:5
  - Increased capacity due to forced convection process

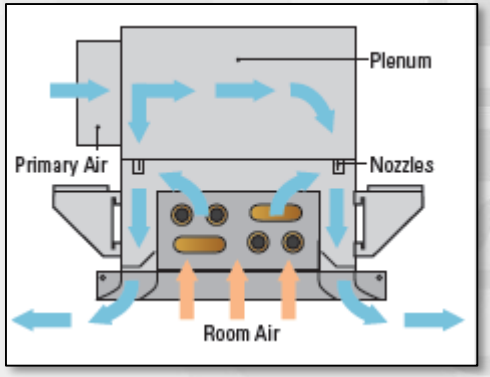
    ~260 (BTU/h)/ft

Mechanical Systems

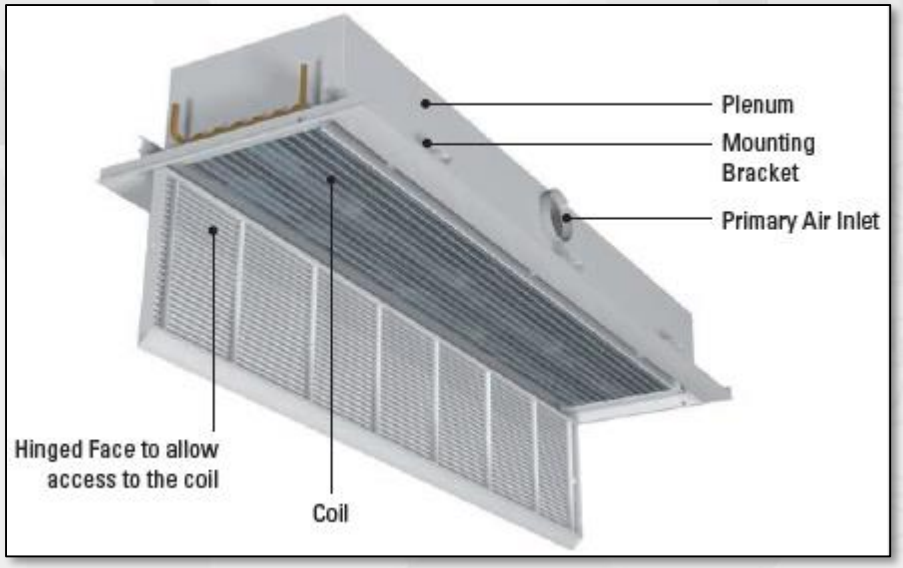
- Chilled Beams - Active
  - 1-way, 2-way, or 4-way air discharge patterns



1-way pattern

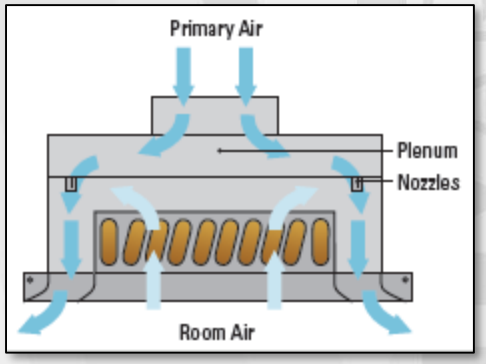


2-way pattern

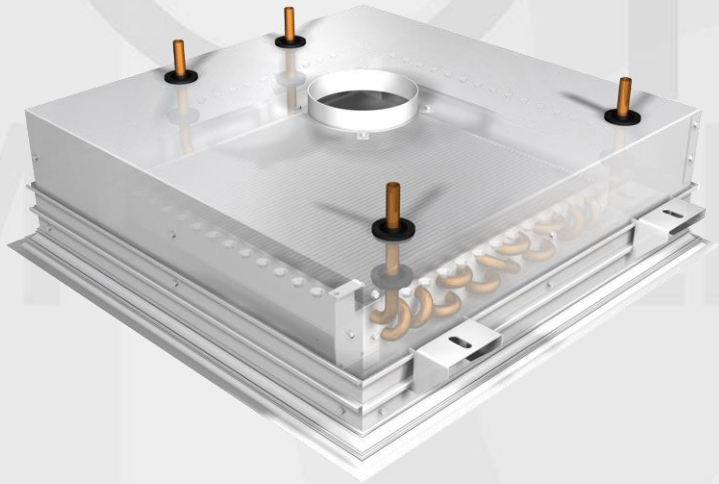


Mechanical Systems

- Chilled Beams - Active
  - 1-way, 2-way, or 4-way air discharge patterns

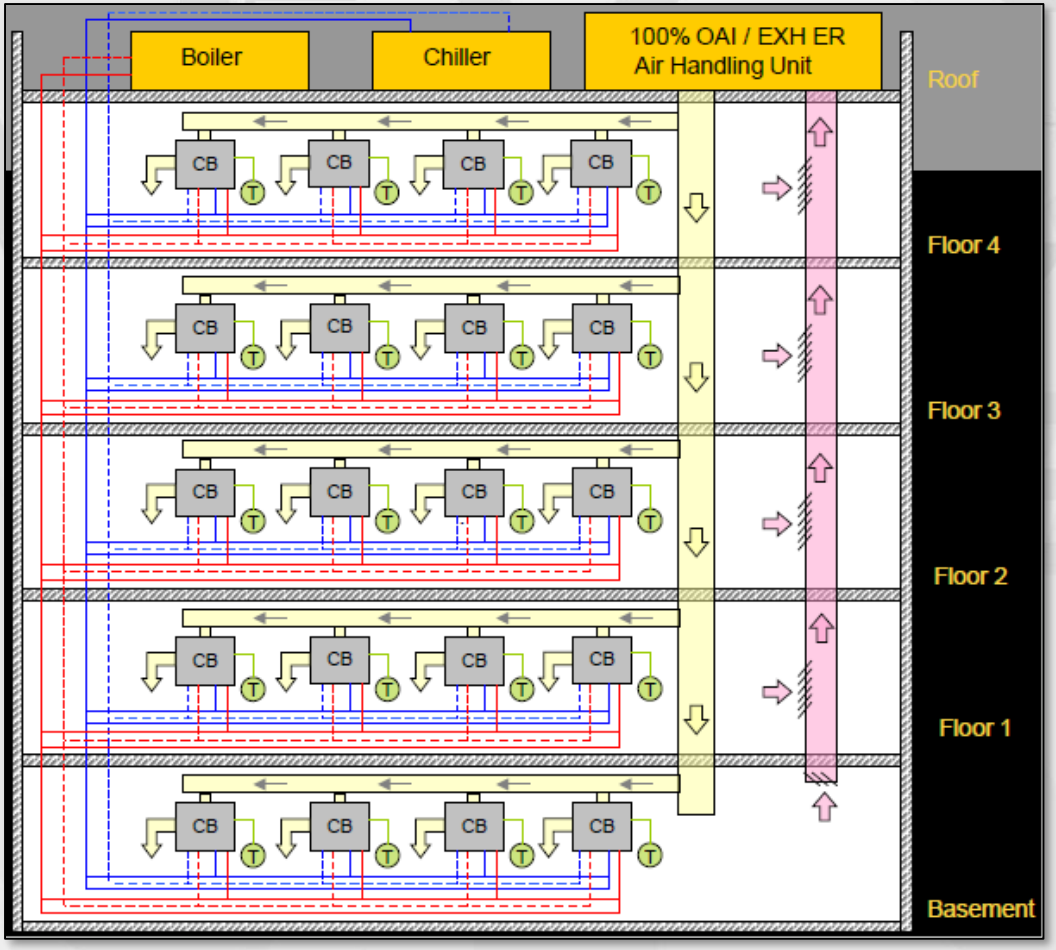


4-way pattern



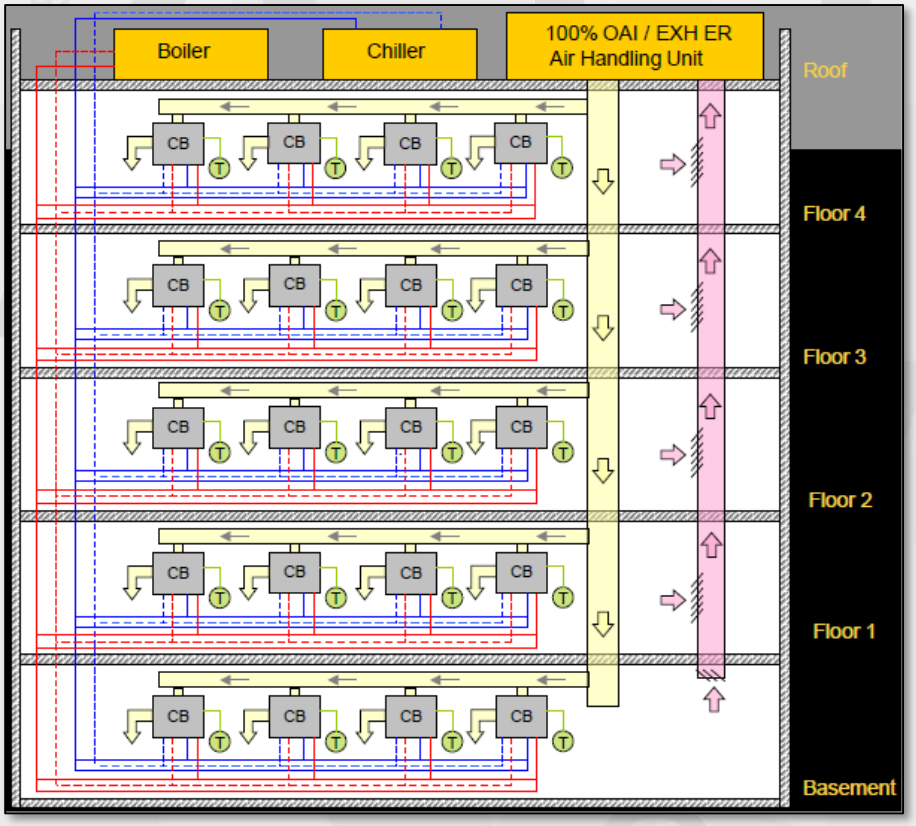
Mechanical Systems

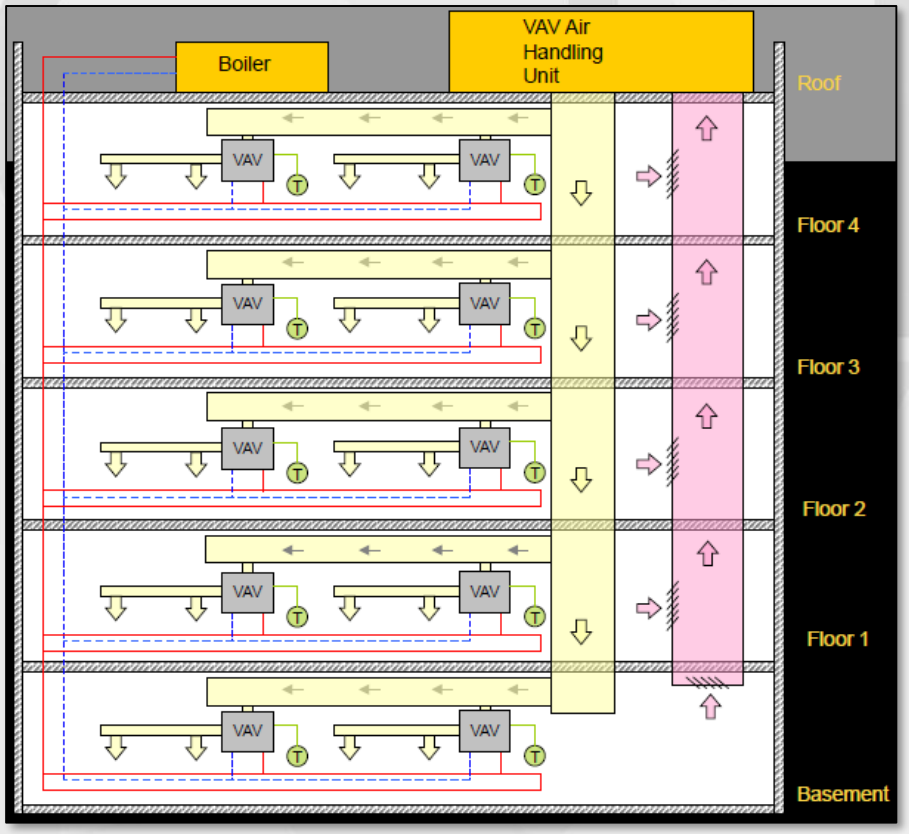
- Chilled Beam System



Mechanical Systems

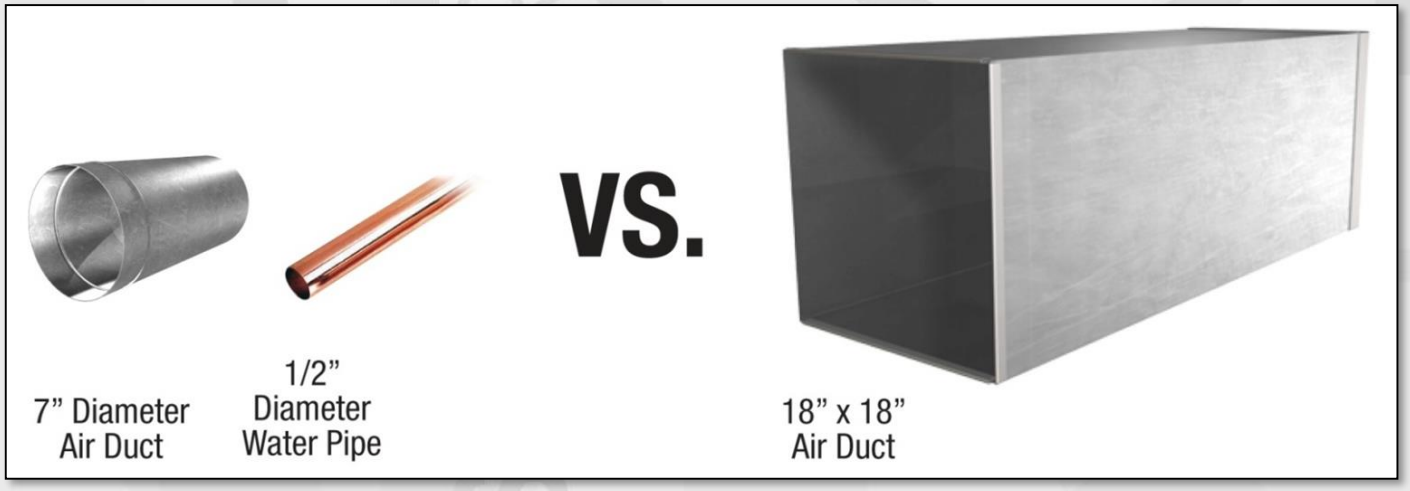
- Chilled Beam System vs VAV System





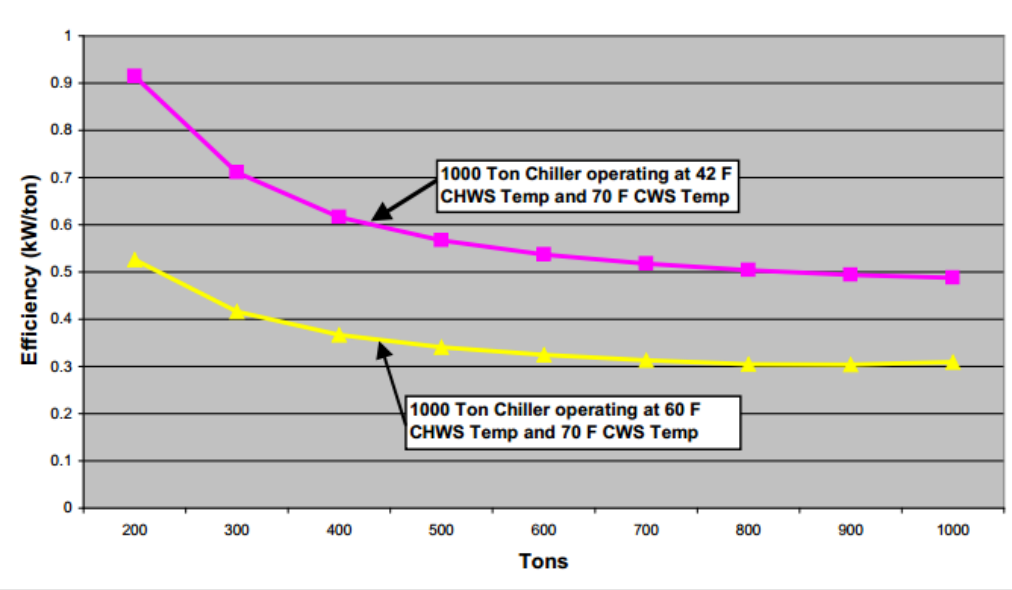
Mechanical Systems

- Energy efficiency
  - 1 cubic foot of chilled water transports 3500 times more cooling energy than 1 cubic foot of air
  - Pumps more efficient than fans



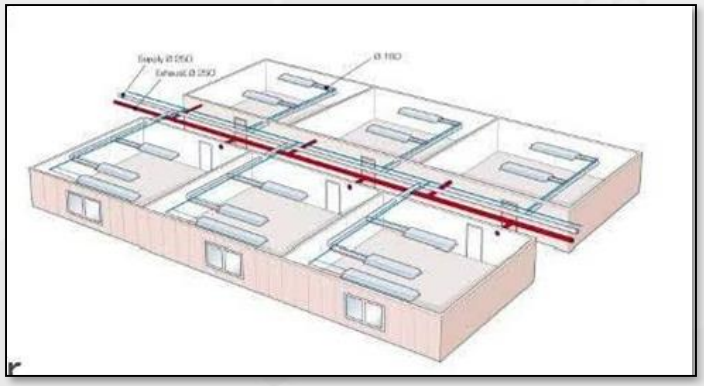
Mechanical Systems

- Energy efficiency
  - Reduced fan energy versus all air systems
  - Chiller COP
  - Waterside economizer
    “Free cooling”



Mechanical Systems

- Reduced mechanical footprint
  - Reduced floor-to-floor heights
    - Potential for 6-18 inches saved per floor
    - Less building skin can contribute to energy savings
    - Construction cost savings or higher ceilings
  - Reduced floor space
    - Smaller shafts due to smaller ductwork
    - DOAS air handling units are smaller

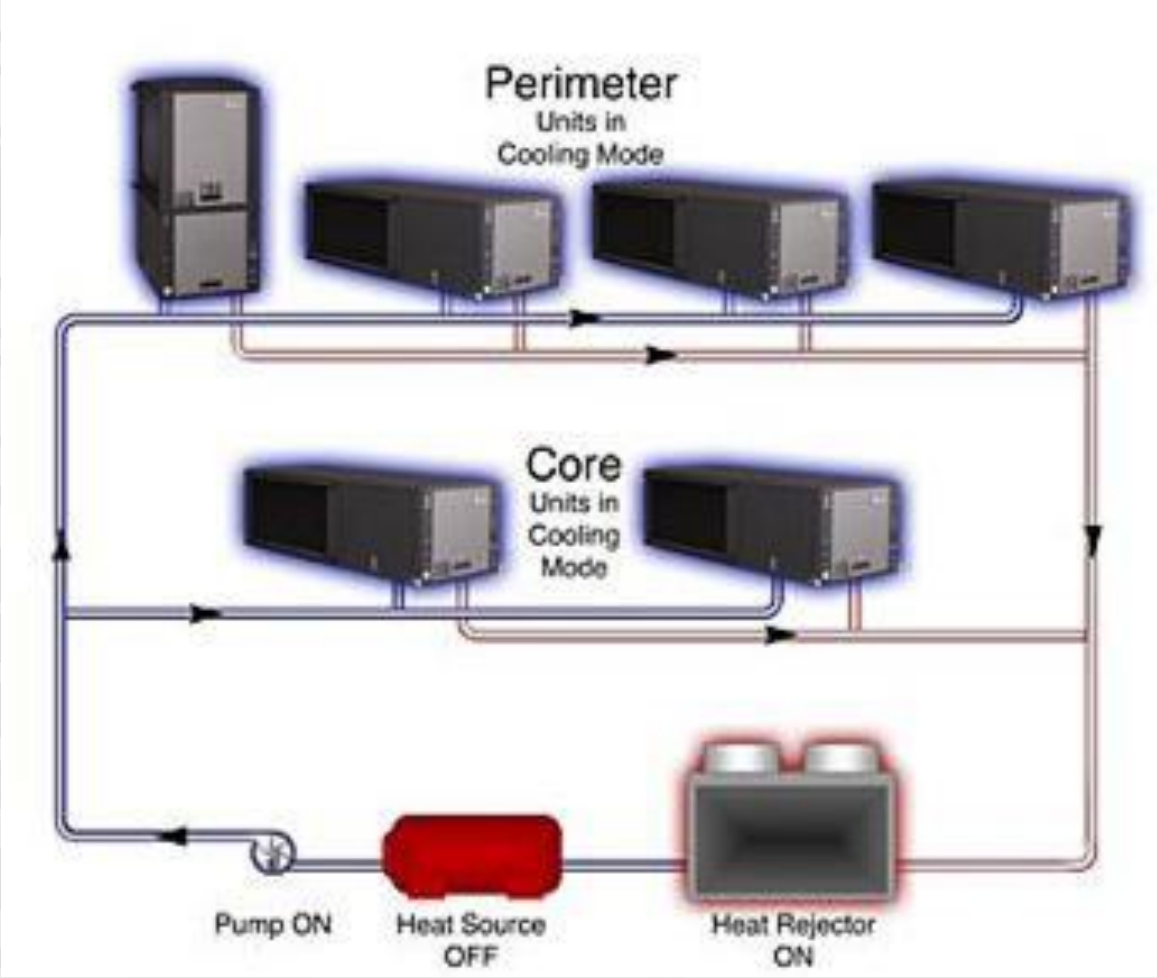


Mechanical Systems

- Reduced maintenance
  - No moving parts
    - No fans
    - No motors
    - No power requirements
  - No filter
  - Recommended to vacuum coils every 5-10 years

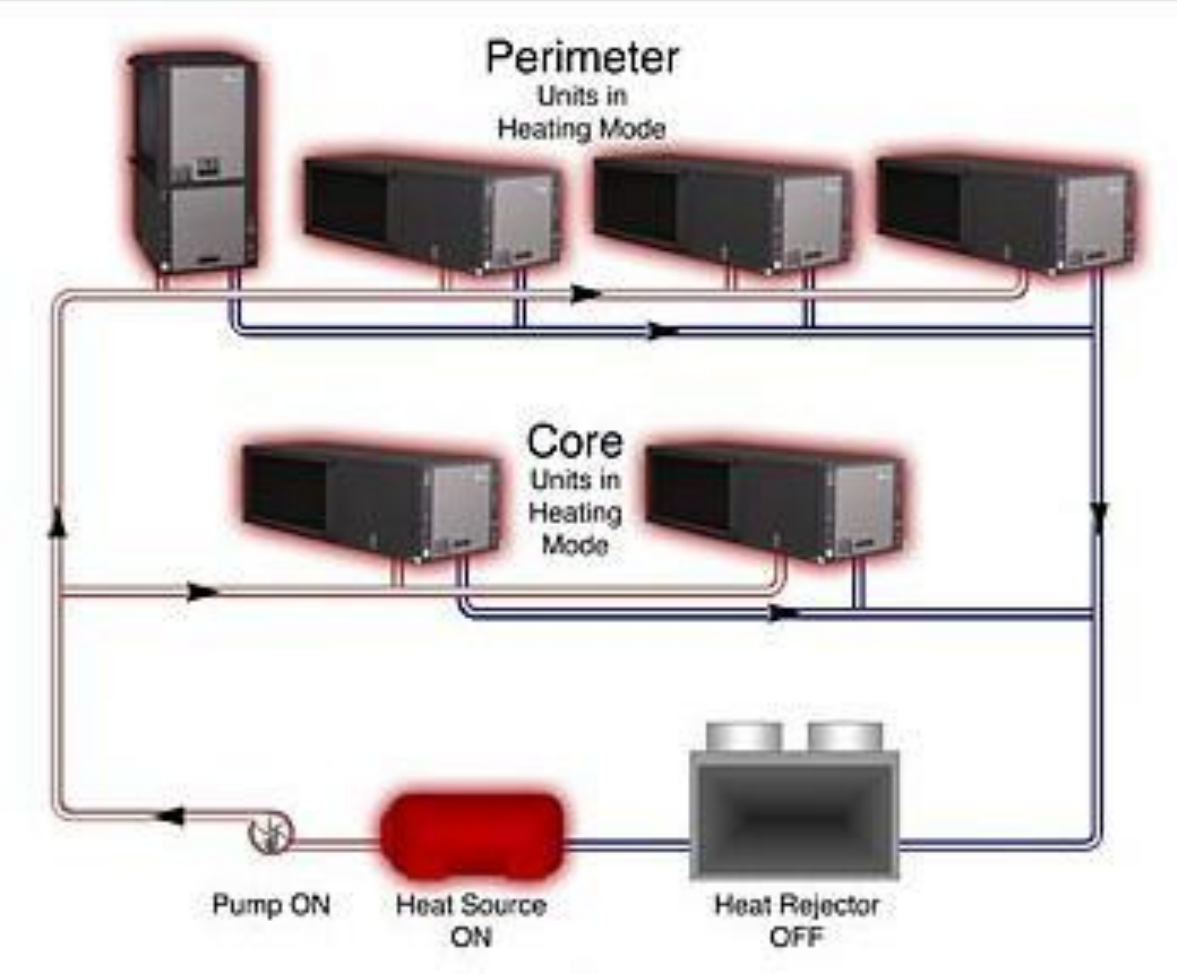
Mechanical Systems

- Water Source Heat Pump System
  - In hot weather/ cooling mode



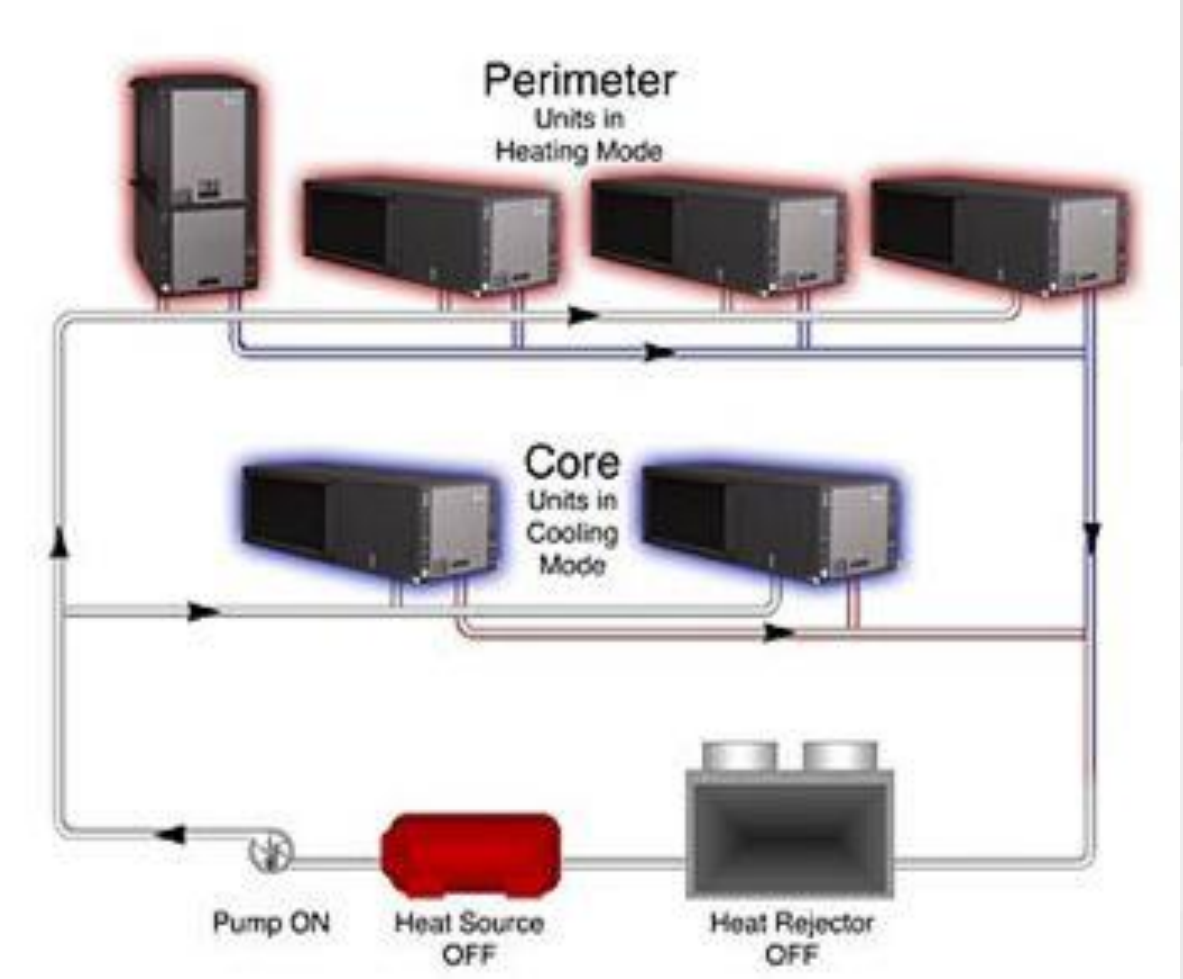
Mechanical Systems

- Water Source Heat Pump System
  - In cold weather/ heating mode



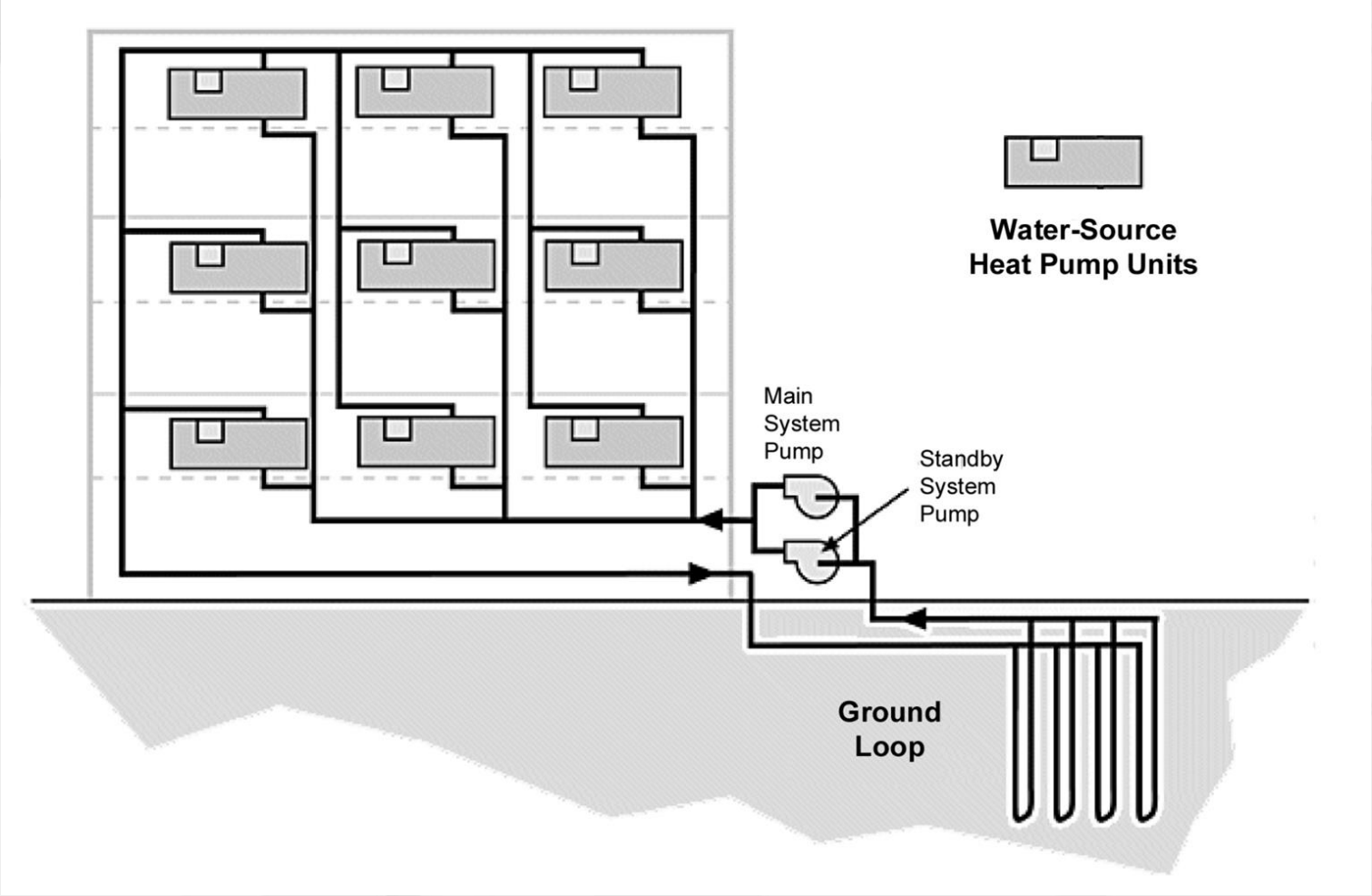
Mechanical Systems

- Water Source Heat Pump System
  - Balanced operation



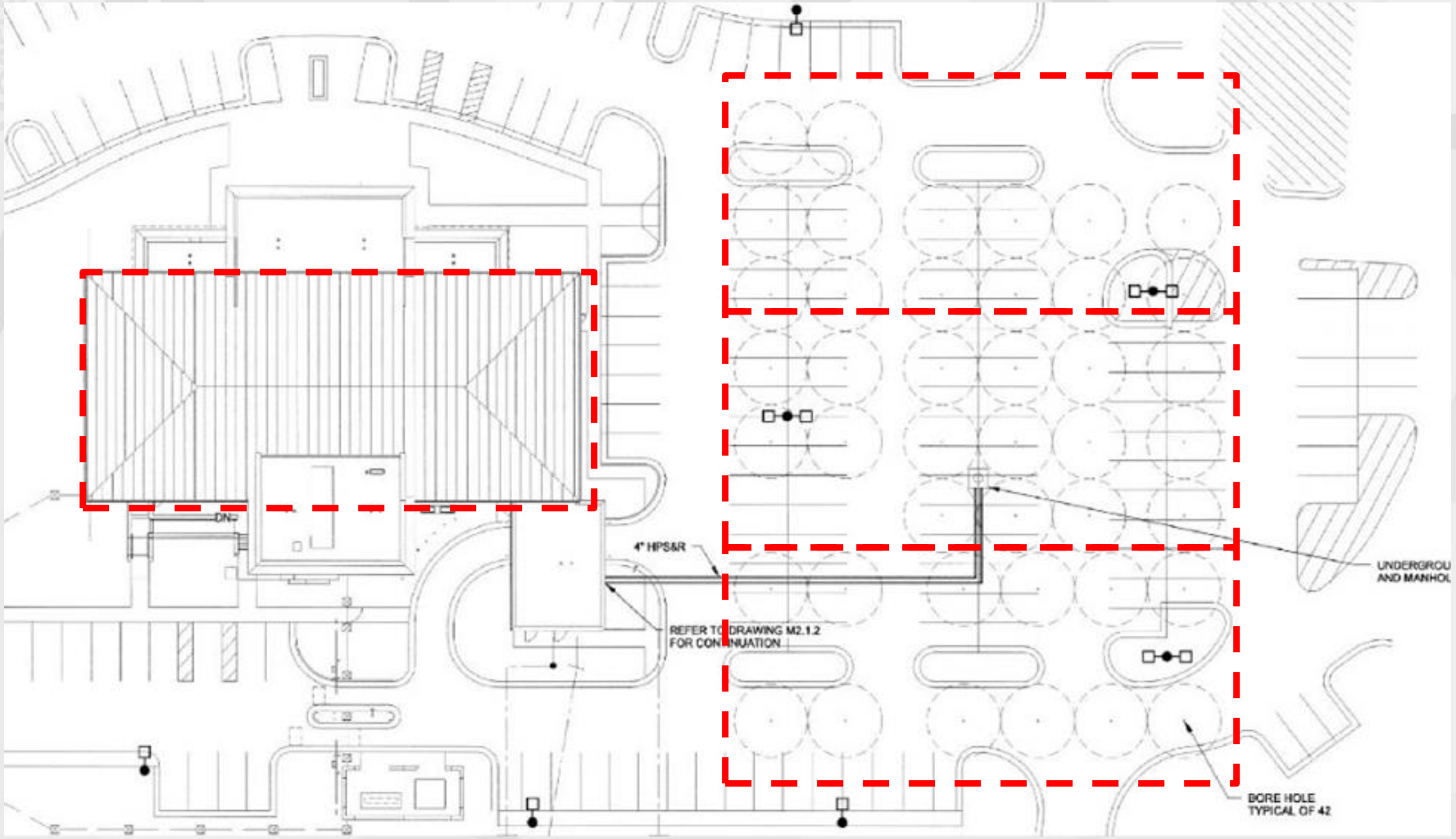
Mechanical Systems

- Geothermal Heat Pump System



Mechanical Systems

- Geothermal Heat Pump System



Mechanical Systems

- Geothermal Heat Pump System

Energy Cost Budget / PRM Summary

By MOSELEY ARCHITECTS

Project Name: Loudoun County JDC | Date: August 15, 2011

City: Leesburg, VA | Weather Data: Washington, DC

Note: The percentage displayed for the "Proposed/ Base %" column of the base case is actually the percentage of the total energy consumption.

* denotes the base alternative for the ECB study.

		*Alt-4: 90.1-2004 Baseline Bldg PTHP's & Electric resistance DWH			Alt-1: Central geothermal VAV w/ heated slab & geothermal DWH			Alt-2: Geothermal terminal GCHPs & geothermal DWH			Alt-3: WC Chiller & Natural Gas Boiler for space heating & DWH		
		Energy 10^6 Btu/yr	Proposed / Base %	Peak kBtuh	Energy 10^6 Btu/yr	Proposed / Base %	Peak kBtuh	Energy 10^6 Btu/yr	Proposed / Base %	Peak kBtuh	Energy 10^6 Btu/yr	Proposed / Base %	Peak kBtuh
Lighting - Conditioned	Electricity	486.5	15	95	390.5	80	76	390.5	80	76	390.5	80	76
Space Heating													
Space Cooling													
Pumps													
Heat Rejection													
Fans - Conditioned													
Receptacles - Conditio													
Domestic Water Heat (DWH)													
Total Building Cons													

Lowest LCC

Comparative Present-Value Costs of Alternatives

(Shown in Ascending Order of Initial Cost, * = Lowest LCC)

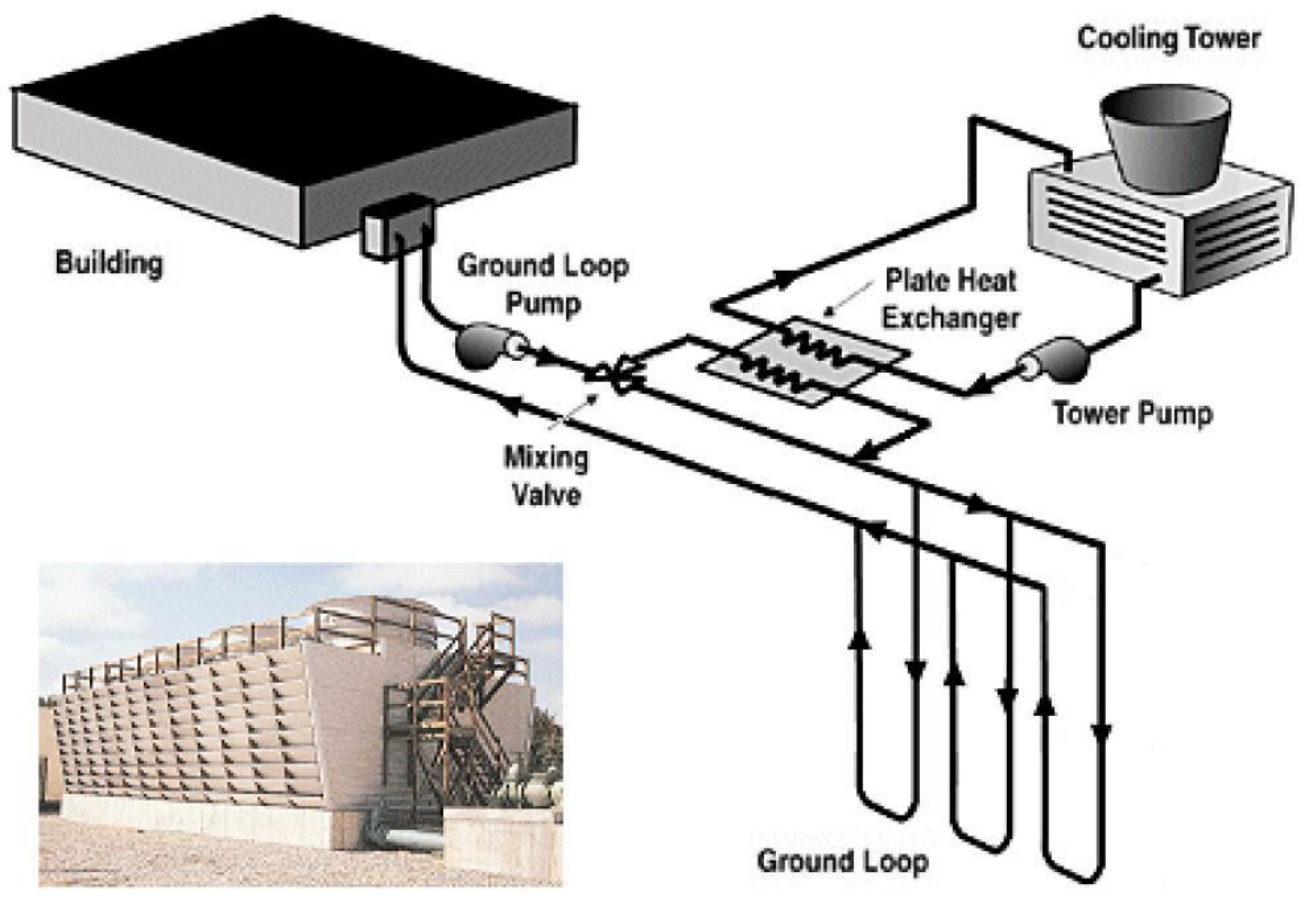
Alternative	Initial Cost (PV)	Life Cycle Cost (PV)
3: WC chilled water and condensing boiler hot water plant, VAV w/ radiant slab heating	$1,104,341	$1,938,221
2: Terminal Geothermal GCHP with DOAU	$1,272,319	$2,170,809
1: Central Geothermal VAV w/radiant slab heating	$1,413,446	$1,829,386 *

		* Alt-4	Alt-1	Alt-2	Alt-3
Total	Number of hours heating load not met	217	257	1	257
	Number of hours cooling load not met	75	0	0	0

	* Alt-4		Alt-1		Alt-2		Alt-3	
	Energy 10^6 Btu/yr	Cost/yr $/yr	Energy 10^6 Btu/yr	Cost/yr $/yr	Energy 10^6 Btu/yr	Cost/yr $/yr	Energy 10^6 Btu/yr	Cost/yr $/yr
Electricity	3,164.8	79,239	1,206.3	30,461	1,960.1	49,236	1,187.7	29,999
Gas	0.0	0	0.0	0	0.0	0	801.4	10,137
Total	3,165	79,239	1,206	30,461	1,960	49,236	1,989	40,136
			61.6% Cost Savings		37.9% Cost Savings		41.7% Cost Saving	

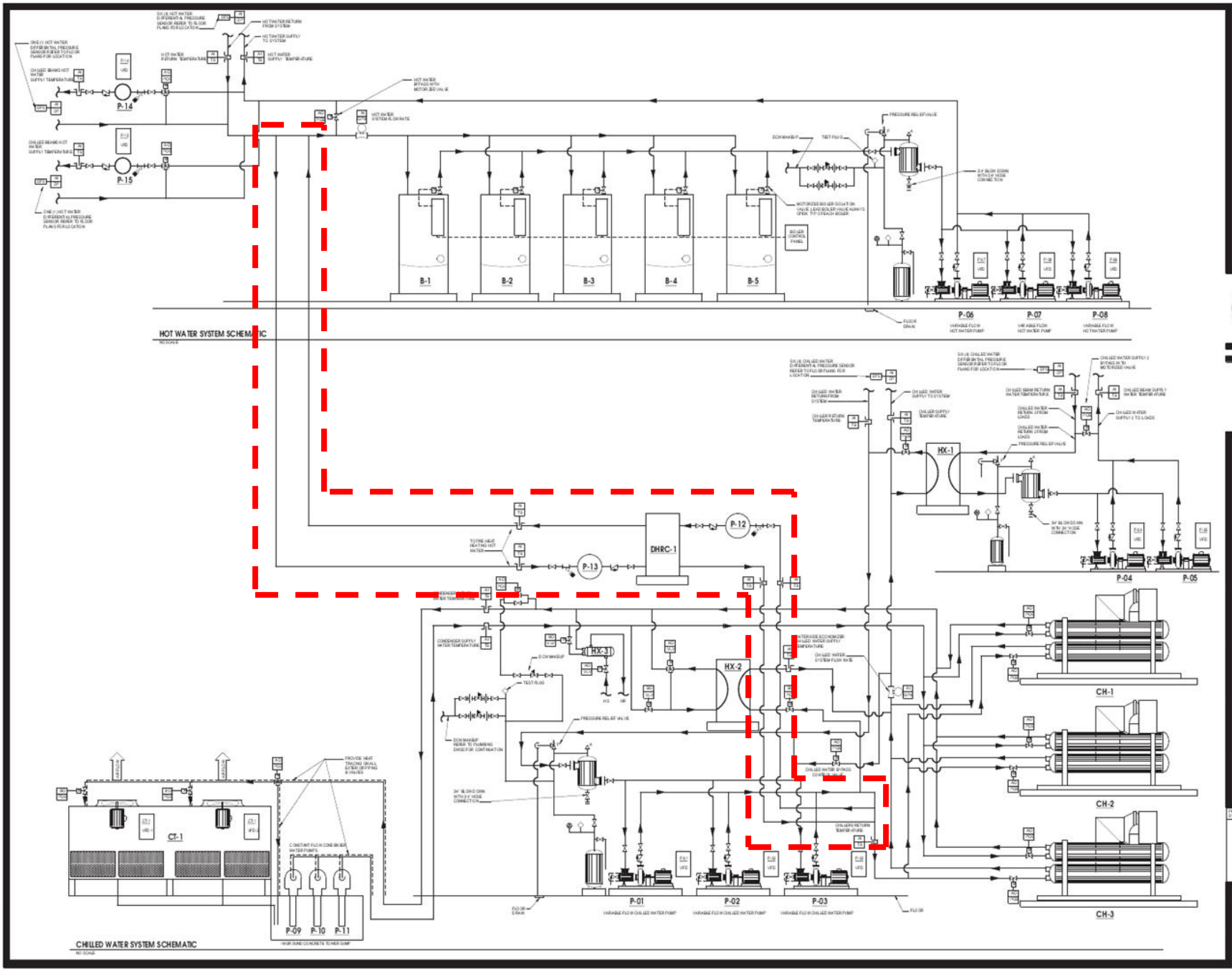
Mechanical Systems

- Geothermal Heat Pump System
  - Hybrid System – Reduce first cost



Mechanical Systems

- Heat Recovery Chillers
  - Instead of “throwing” heat away into the atmosphere, capture it and utilize it
    - Space heating
    - Domestic water heating
    - Snow melting



MOSELEY ARCHITECTS

12TH HIGH SCHOOL
STATE PROJECT CODE # SDE No (75-109-00-100)
13833 DUMFRIES ROAD
MANASSAS, VA 20112-3724

SYSTEM SCHEMATICS

M6.1

Electrical Systems

- Lighting Systems
  - LED light fixtures
  - Hanover County Circuit Court Renovation
  - 418 light fixtures
    - $135/fixture for T5 fluorescent
    - $172/fixture for LED
    - Payback 1.26 years

Calculated Results	Product 1	Product 2
Initial cost (?)	$ 107,927.60	$ 123,393.60
Annual cost of operation (?)	$ 20,229.85	$ 7,914.25
Energy cost	$ 16,245.05	$ 7,914.25
Total maintenance cost (the 2 cost below added)	$ 3,984.80	$ -
Relamping cost	$ 1,341.35	$ -
Amortized ballast cost	$ 2,643.45	$ -
Annual cost savings (?)	-	12,315.60
% Saved	-	60.9%
KW Load (?)	48.906	23.826
Load Reduction	-	51.3%

Electrical Systems

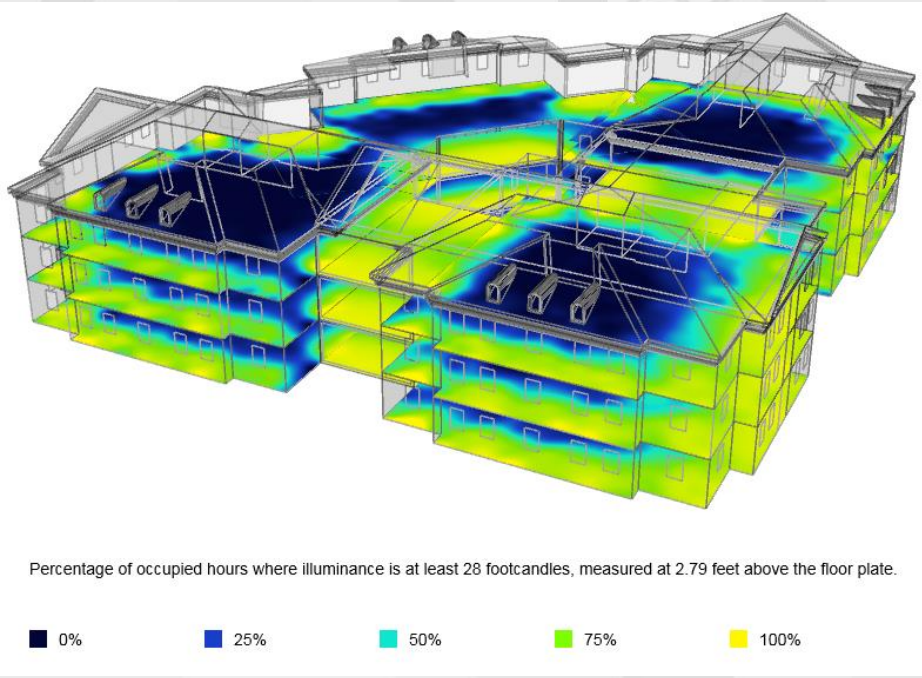
- Lighting Systems - Controls
  - Occupancy sensors
  - ASHRAE 90.1 requires automatic lighting shutoff for ***all*** spaces

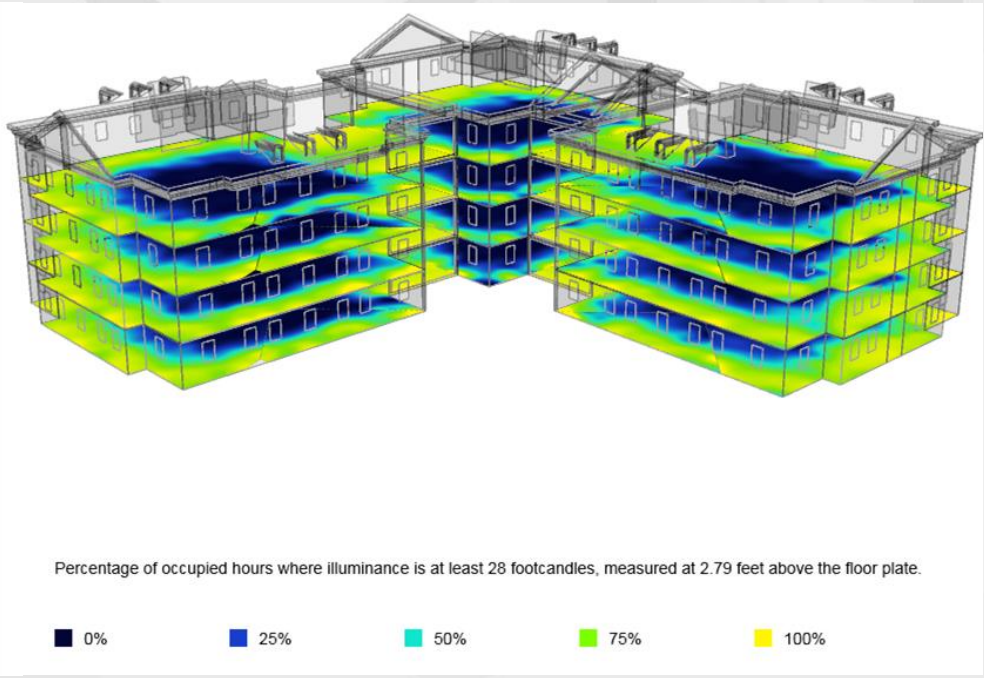
Table 1. Energy waste for the 14-day period and energy savings for the 5- and 20-minute time delay simulations.

Application	Energy waste[1]	Energy savings using the 5-min time delay[2]	Energy savings using the 20-min time delay[2]
Break Room	39%	29%	17%
Classroom	63%	58%	52%
Conference Room	57%	50%	39%
Private Office	45%	38%	28%
Restroom	68%	60%	47%

Electrical Systems

- Lighting Systems – Controls
  - Daylighting
  - ASHRAE 90.1 starting to require automatic daylighting controls for certain areas



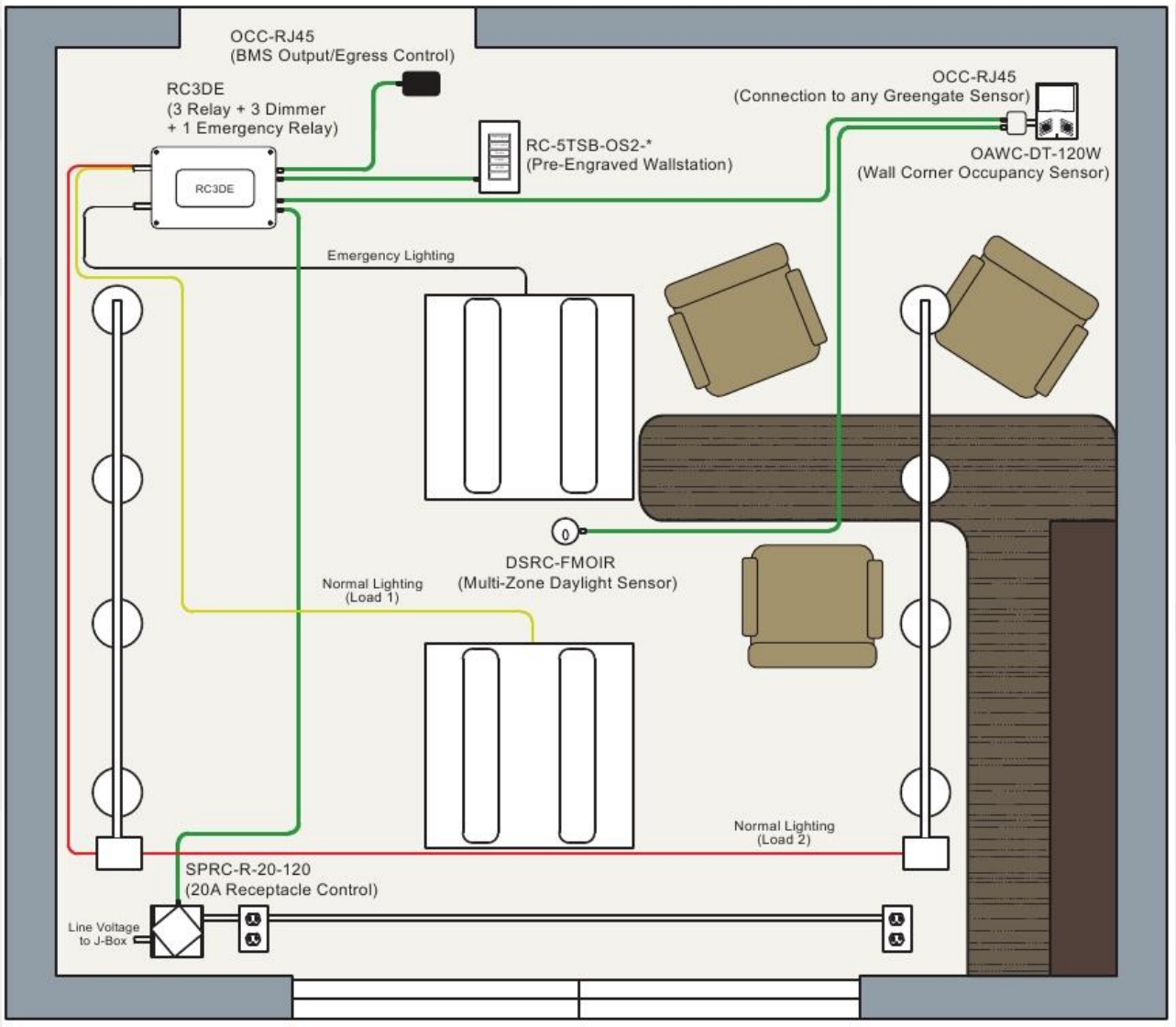


Electrical Systems

- Power Systems
  - Receptacle controls
  - ASHRAE 90.1 requires automatic control for at least 50% of receptacles in private offices, open offices, and computer classrooms

- Coordinated solution for lighting, daylighting, and receptacle controls

Electrical Systems



Thanks!

Building Energy Management Open-Source Software (BEMOSS)

Manisa Pipattanasomporn, Ph.D.
Associate Professor, Virginia Tech & CTO, BEM Controls
November 2, 2017

What is BEMOSS?

BEMOSS is a Building Energy Management Open Source Software (BEMOSS) solution that is engineered to improve sensing and control of equipment in small- and medium-sized commercial buildings.

BEMOSS monitoring and control:

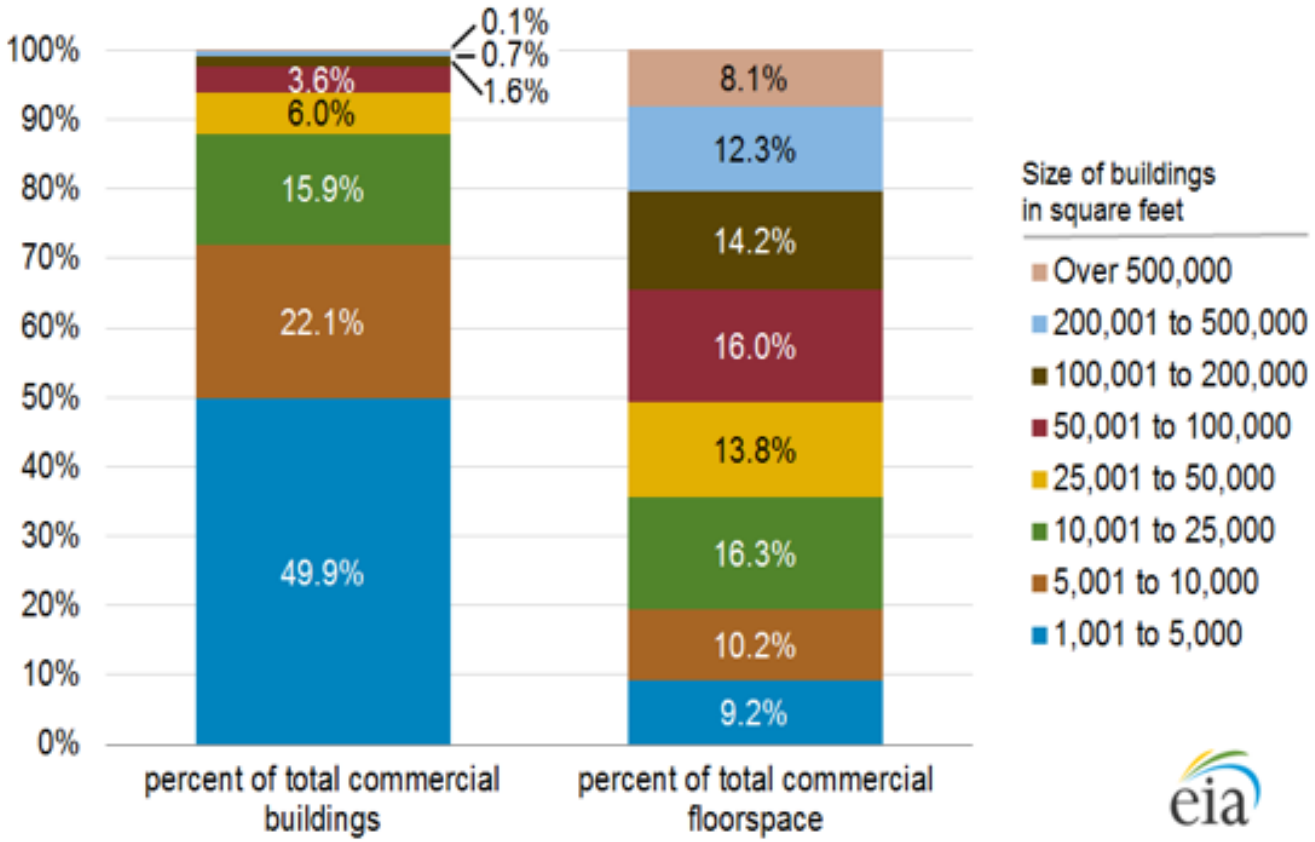
Three major loads in buildings
- HVAC
- Lighting loads
- Plug loads

BEMOSS value:

Improves energy efficiency and facilitates demand response implementation in buildings.

Why BEMOSS ?

- Buildings consume over 40% of the total energy consumption in the U.S. Over 90% of the buildings in the U.S. are either small-sized (<5,000 square feet) or medium-sized (between 5,000 sqft and 50,000 sqft).
- These buildings typically do not use Building Automation Systems (BAS) to monitor and control their building systems from a central location.



54

BEMOSS Advisory Committee

BEMOSS is developed in consultation with industry

BEMOSS advisory committee has representatives from 22 organizations:

BEMOSS Interoperability

Communication Technologies

- ❑ Ethernet (IEEE 802.3)
- ❑ Serial Interface (RS-485)
- ❑ ZigBee (IEEE 802.15.4)
- ❑ WiFi (IEEE 802.11)

Data Exchange Protocols

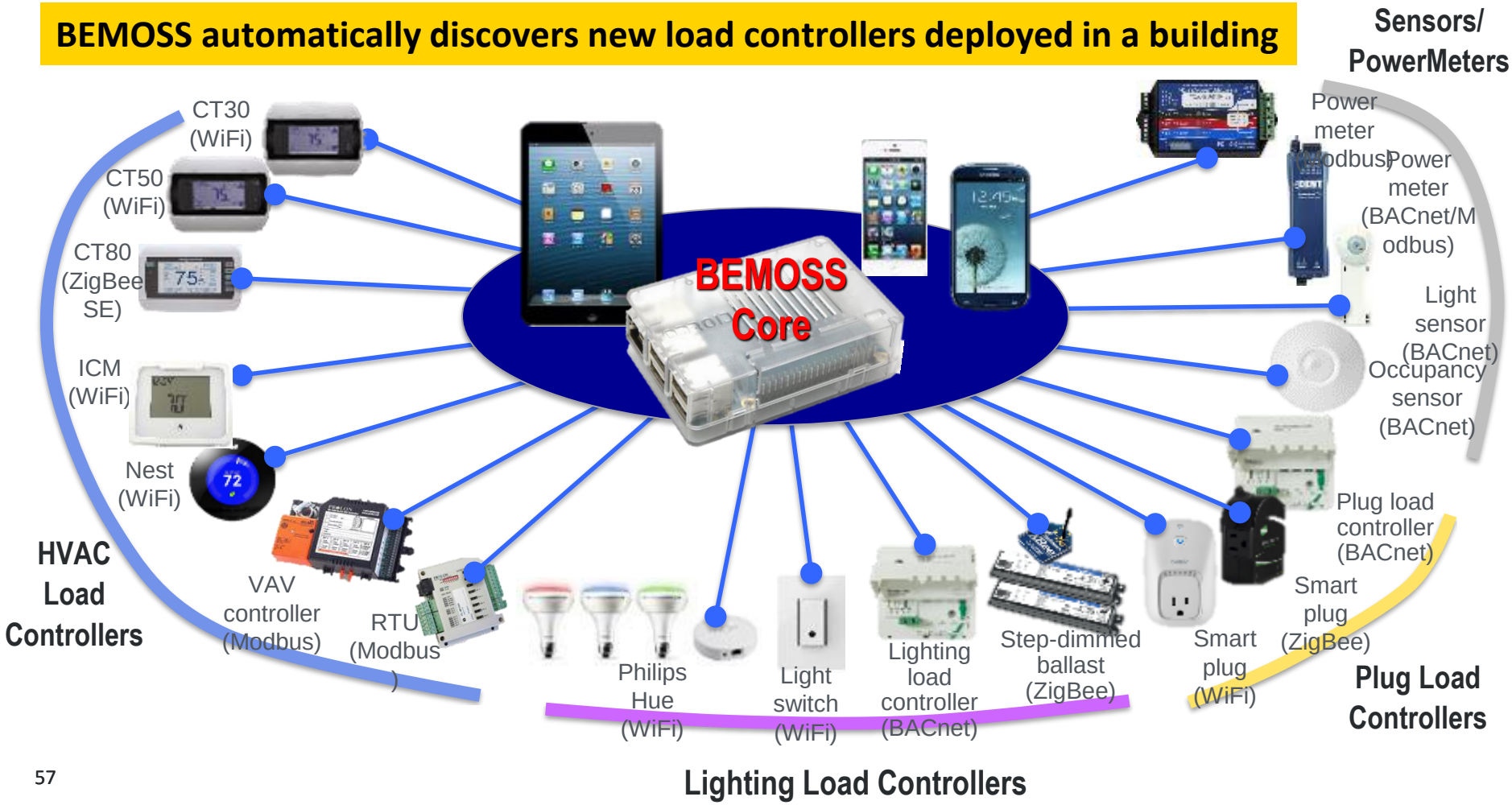
- ❑ BACnet (IP and MS/TP)
- ❑ Modbus (RTU and TCP)
- ❑ Web (e.g., XML, JSON, RSS/Atom)
- ❑ ZigBee API
- ❑ Smart Energy (SE)
- ❑ OpenADR (Open Automated Demand Response)

BEMOSS Plug & Play

With BEMOSS discovery agent, we know:

- The device is present in the building.
- Device model number, e.g., 3M-50.
- What the device can do, e.g., monitor temperature and adjust set point.

BEMOSS automatically discovers new load controllers deployed in a building



BEMOSS Deployment in Buildings

Building 1 – Virginia Tech Architecture Building

- Location: Alexandria, VA
- Demonstration: HVAC, plug load control

Building 2 – Equipment Bureau

- Location: Arlington, VA
- Demonstration: Lighting control

Building 3 – Virginia Tech building

- Location: Blacksburg, VA
- Demonstration: HVAC control

Building 1 – VT Building in Alexandria, VA

1021 Prince St.,
Alexandria, VA 22314

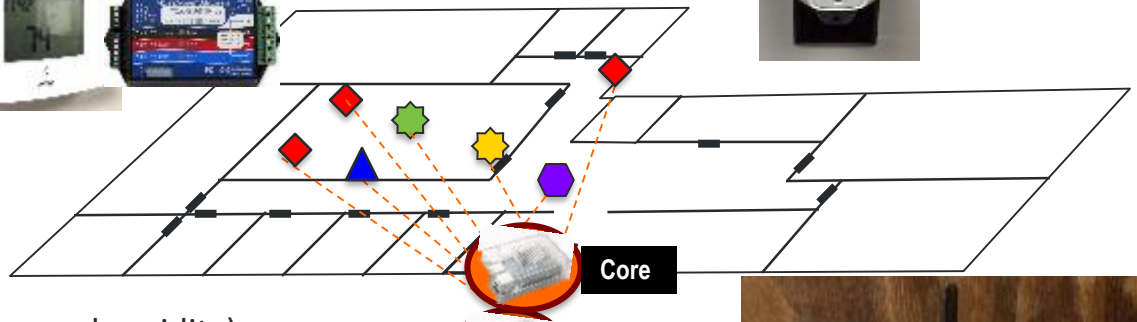
Area: 25,000 SF
Energy: 14-25 MWh/mo.
Peak load: 61 kW

Deployment Setup

- Thermostats (WiFi)
- Plug load controllers (WiFi)
- Motion sensor (WiFi)
- Environment sensor (WiFi)
- Power meter (Modbus)

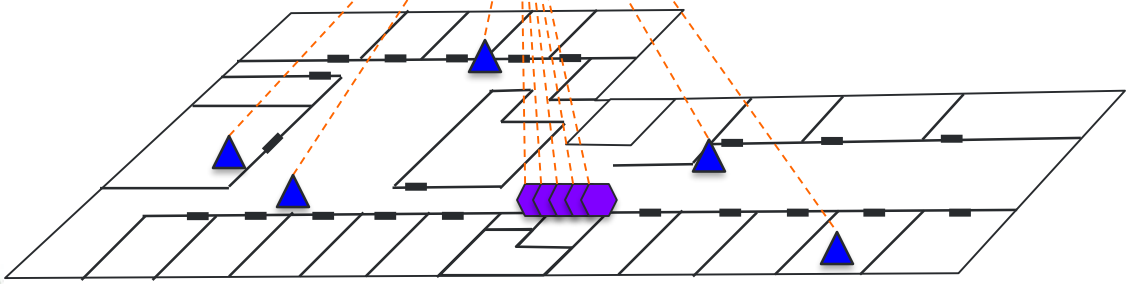
Floor 3 – Classroom

- 1 thermostat
- 3 plug load controllers
- 1 motion sensor
- 1 environment sensor (CO_2, temp, humidity)
- 1 power meter
- BEMOSS core
- BEMOSS node



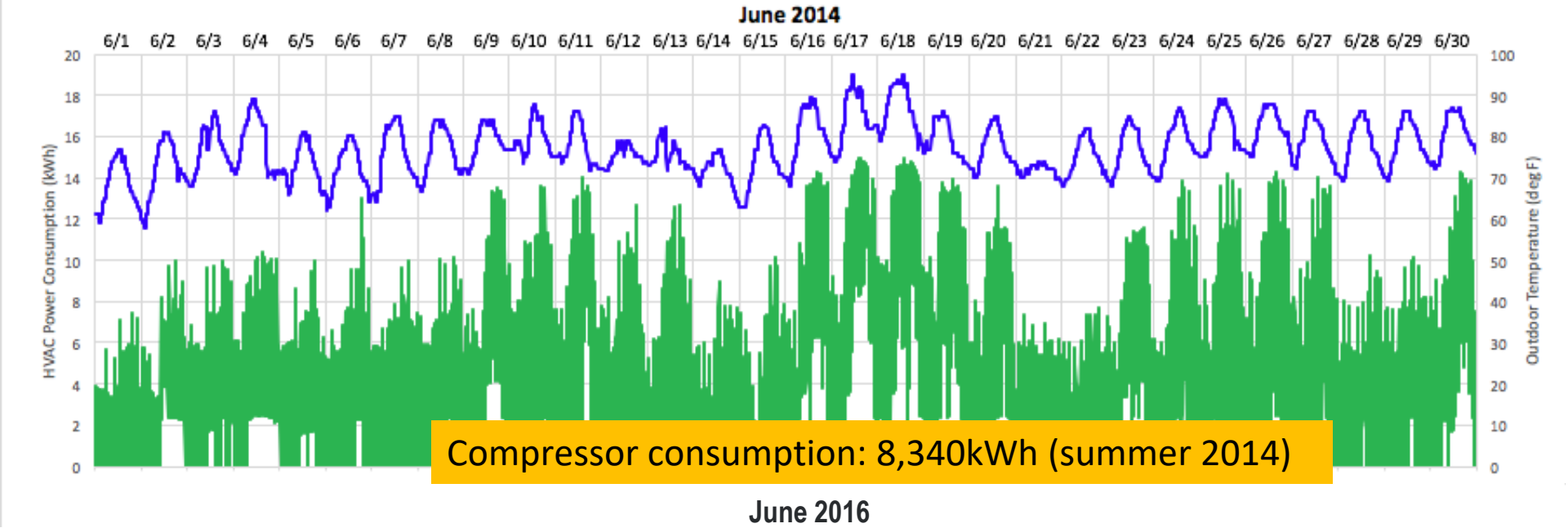
Floor 2

- 5 thermostats
- 5 power meters

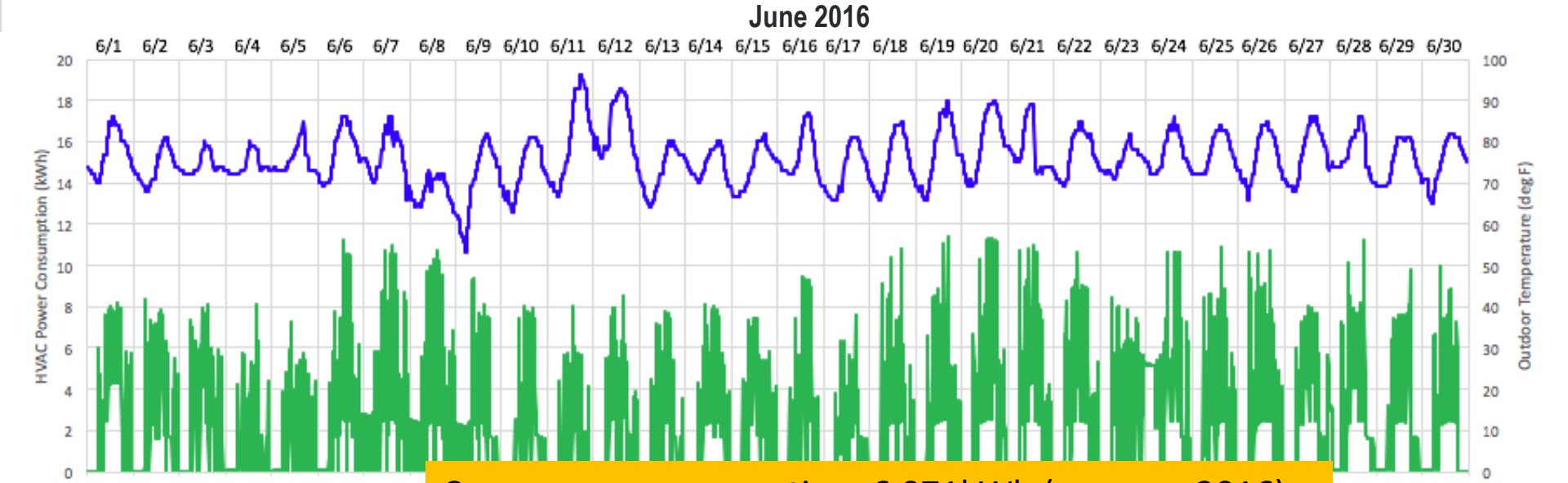


Building 1: Alexandria

26.8% Energy Savings before and after BEMOSS



Compressor consumption: 8,340kWh (summer 2014)



Compressor ocnsumption: 6,071kWh (summer 2016)

Building 2 – Equipment Bureau Building

2701 S Taylor St, Arlington, VA 22206

Building 2 – BEMOSS Deployment

Building 2: Arlington

Energy Savings by controlling light intensity

Based on occupant requirements, light intensity level was reduced. Results indicate **the average kWh savings of about 36%**.

Month	%Savings
Dec 2016	34.4%
Jan 2017	33.4%
Feb 2017	35.9%
Mar 2017	36.2%
Apr 2017	35.0%
May 2017	36.0%
Jun 2017	36.3%
Jul 2017	36.0%
Aug 2017	35.0%
Average	35.4%

Note: Scheduled dimming level from 6:30am to 9:00pm. Open office area A: 50%; Open office area B: 45%; Chief office's desk area: 30%; Chief office's meeting area: 30%; Conference room A: 50%; Conference room B: 45%. Lights are off after 9:00pm.

Building 3 – Commercial Building in Blacksburg, VA

460 Turner St, Blacksburg, VA 26041

Retail building: ~50,000 sqft
Peak demand: ~160kW
Electricity consumption: 46-65MWh/month

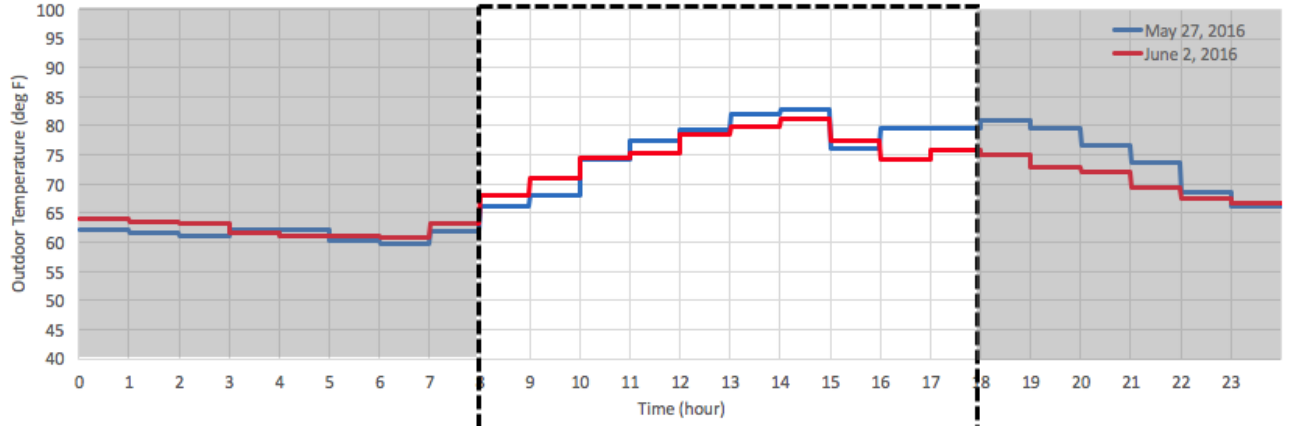
Building 3 – BEMOSS Deployment

Building 3 – Energy Savings Potentials

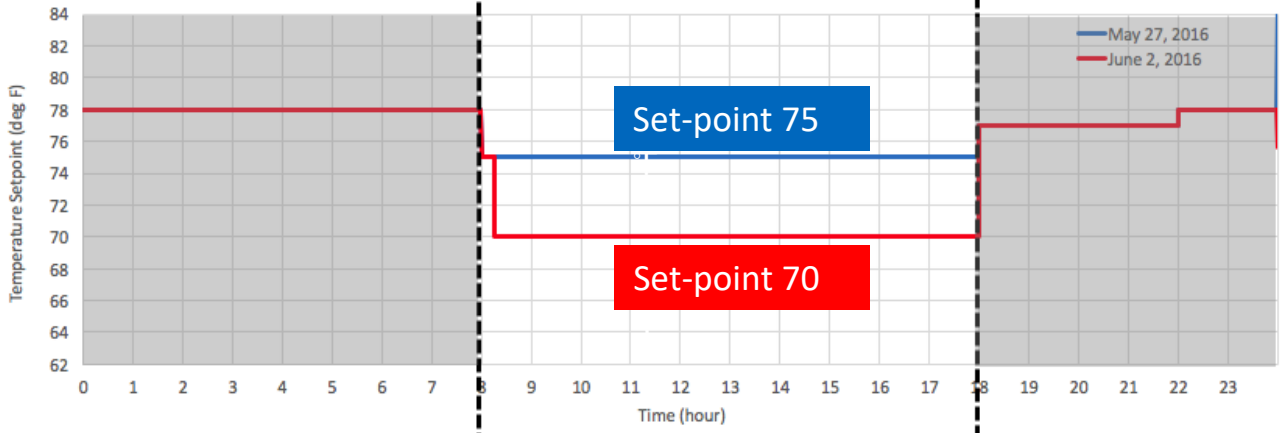
~40,000 sqft building in Blacksburg, VA

Raising the set point by 5˚F from 8am-6pm demonstrates 20% energy savings in HVAC load.

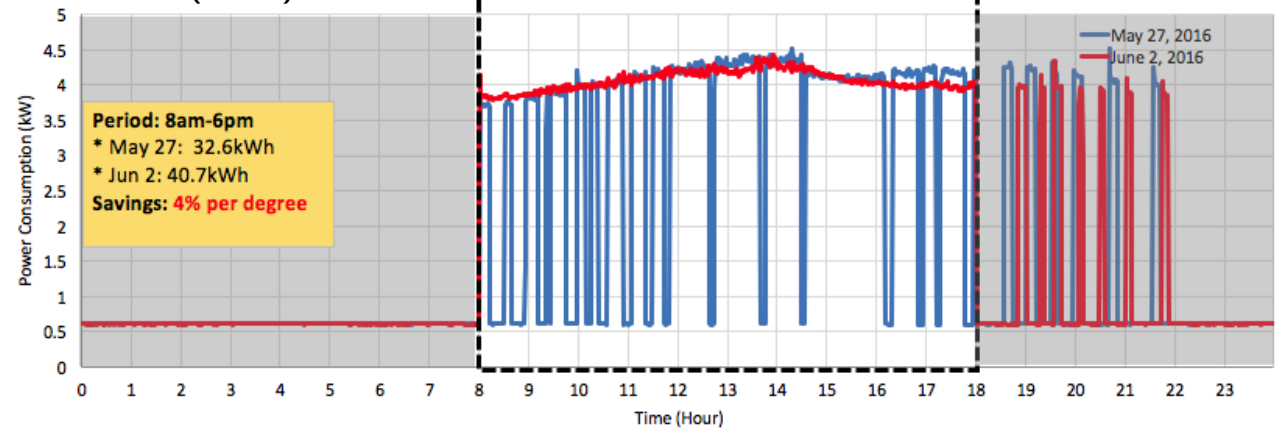
Outdoor temperature profiles:



Indoor temperature set-points:



HVAC load (1 AC):



www.BEMOSS.org

Transitioning from a Research Project to a Business

SBIR/STTR
SMALL BUSINESS INNOVATION RESEARCH
SMALL BUSINESS TECHNOLOGY TRANSFER

CIT
CENTER FOR INNOVATIVE TECHNOLOGY

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www.bemcontrols.com

Solar PV and Smart Inverter Integration

BEMOSS

- HOME
- DISCOVER NEW DEVICES
- DISCOVER/MANAGE 1
- NETWORK STATUS
- ALARMS & NOTIFICATIONS
- MANAGE USERS 0
- MISC SETTINGS
- APPLICATIONS
- NODE1 18
- LOG OUT

Node1 : Der1

Power

INCIDENT	DC	AC
35361.2 W	5140.15 W	4958.0 W

Efficiency

PANEL	
14.54 %	96.46 %

Voltage

DC	AC
357.7 V	212.3 V

Current

DC	AC
14.37 A	23.51 A

Energy

TOTAL
6.52 MW

Irradiance

ARRAY	HORIZONTAL
865.0 W/m^2	W/m^2

Temperature

AMBIENT	MODULE
84.0 °F	93.0 °F

Wind Velocity

0.0 m/s

10105.01 lbs

Smart inverter control

REAL POWER CONTROL

Real Power limit 100%

0 100 Real

Power limit Value 100.

POWER FACTOR

Power factor limit 100%

85 100

Power factor limit 100.

✔Submit All Changes | View Past Usage and Set Points

Battery Storage Integration

BEMOSS

4 Admin Log Out

HOME
DISCOVER NEW DEVICES
DISCOVER/MANAGE 2
NETWORK STATUS
ALARMS & NOTIFICATIONS
MANAGE USERS 0
MISC SETTINGS
LOG OUT

Tumalow Energy Ingenuity : Battery_Storage3

BATTERY STORAGE

CURRENT STATUS

ACTIVE

CURRENT READINGS

STATE OF CHARGE

98.9 %

OUTPUT POWER

-0.013 kW

CHARGING

View Past Values

Weather Sensor Integration

Security Camera Integration

BEMOSS

Admin | Log Out

- HOME
- DISCOVER NEW DEVICES
- DISCOVER/MANAGE 0
- NETWORK STATUS
- ALARMS & NOTIFICATIONS
- MANAGE USERS 0
- MISC SETTINGS
- APPLICATIONS
- NODE1 5
- LOG OUT

Node1 : Camera1

Location:
Alexandria, VA

Building type:
Office

View:
Indoor

Point of contact:
Building Engineer (xxx-xxx-xxxx)

2013-2017 © Building Energy Management Open Source Software.

Thank You

Manisa Pipattanasomporn, Ph.D.

Associate Professor, Virginia Tech (mpipatta@vt.edu)

CTO, BEM Controls (manisa@bemcontrols.com)

Questions?

Commercial Technology

Jason Forsyth, Moseley Architects
Manisa Pipattanasomporn, BEM Controls
Mark Jackson, Community Housing Partners (moderator)

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