Taming the 900-Pound Gorilla

Using Integrated Design to Create a Net-Zero Dining Hall

NESEA

Building Energy

Boston, MA
March 9, 2016

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MaclayArchitects
CHOICES IN SUSTAINABILITY

PROCTOR

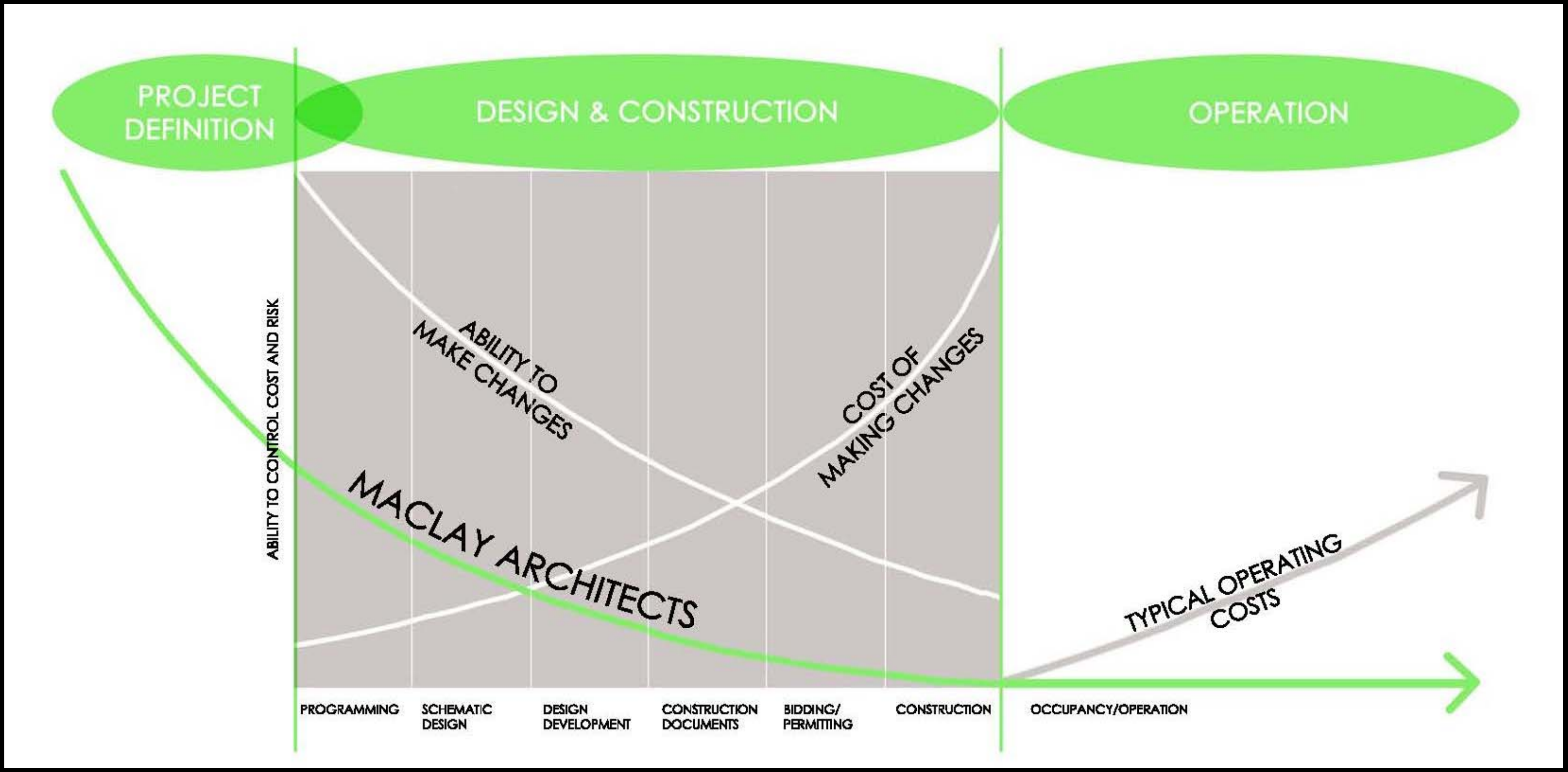
Live to Learn. Learn to Live

Dining Commons

- 16,000 sf dining hall and commercial kitchen
- 350 seats
- Experiential Servery/Food Forest Layout
- Site Responsive Design
- Campus Social Center
- Net Zero Ready

GETTING TO NET ZERO

- Select an experienced team
- Use integrated design & delivery
- Set clear goals, metrics, EUI
- Commit, COLLECTIVELY, to metrics



PROCTOR

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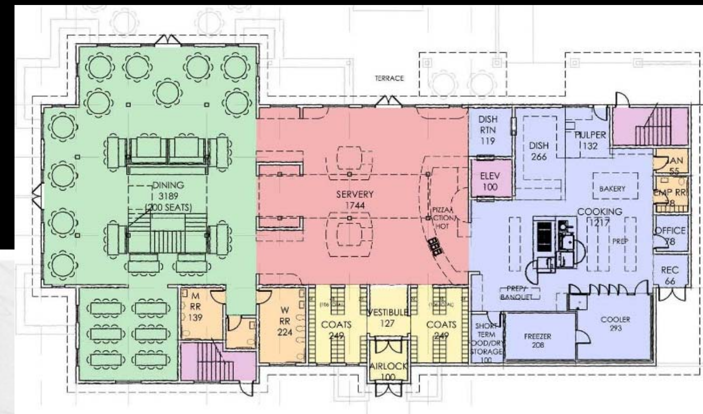

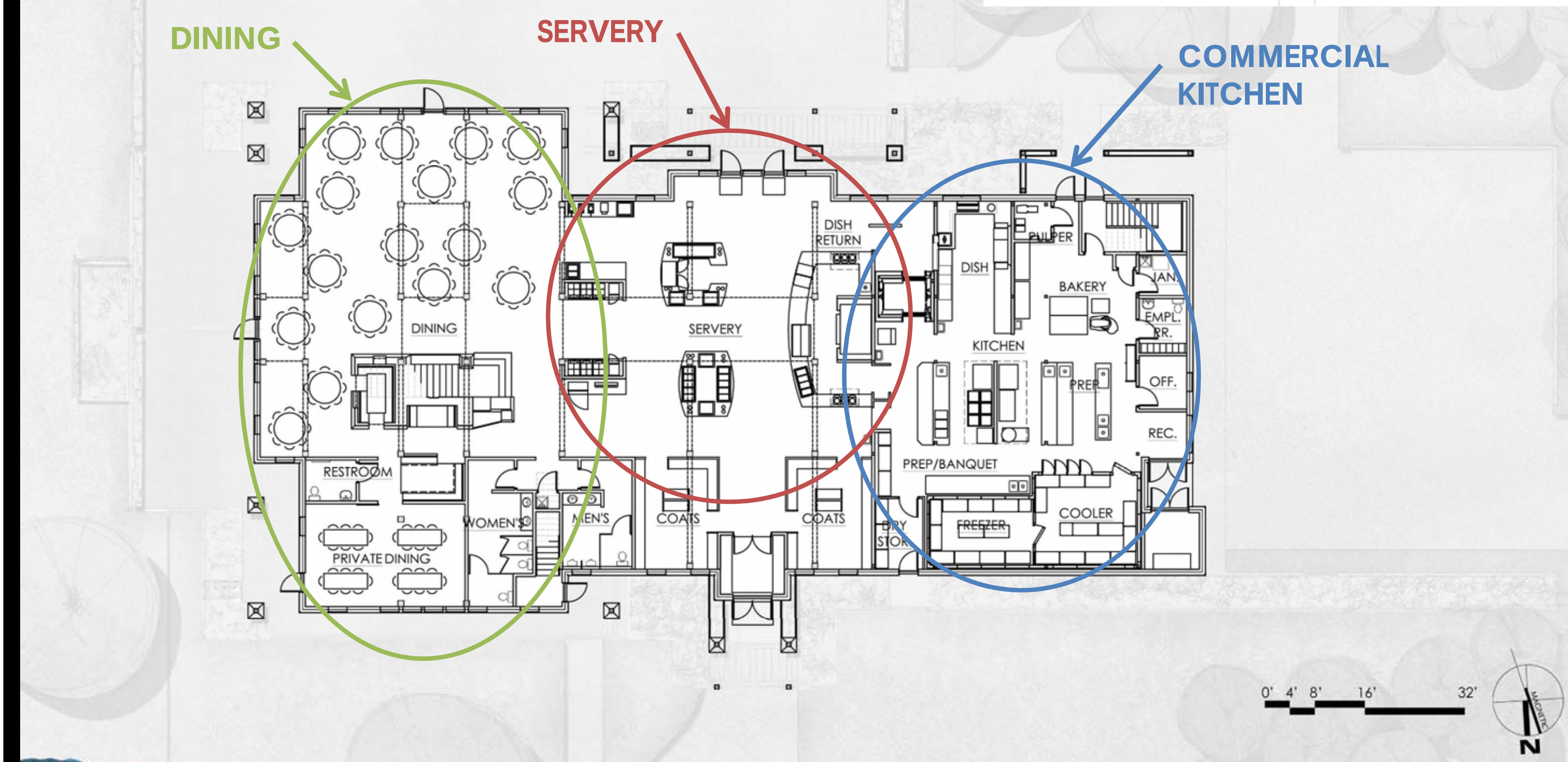

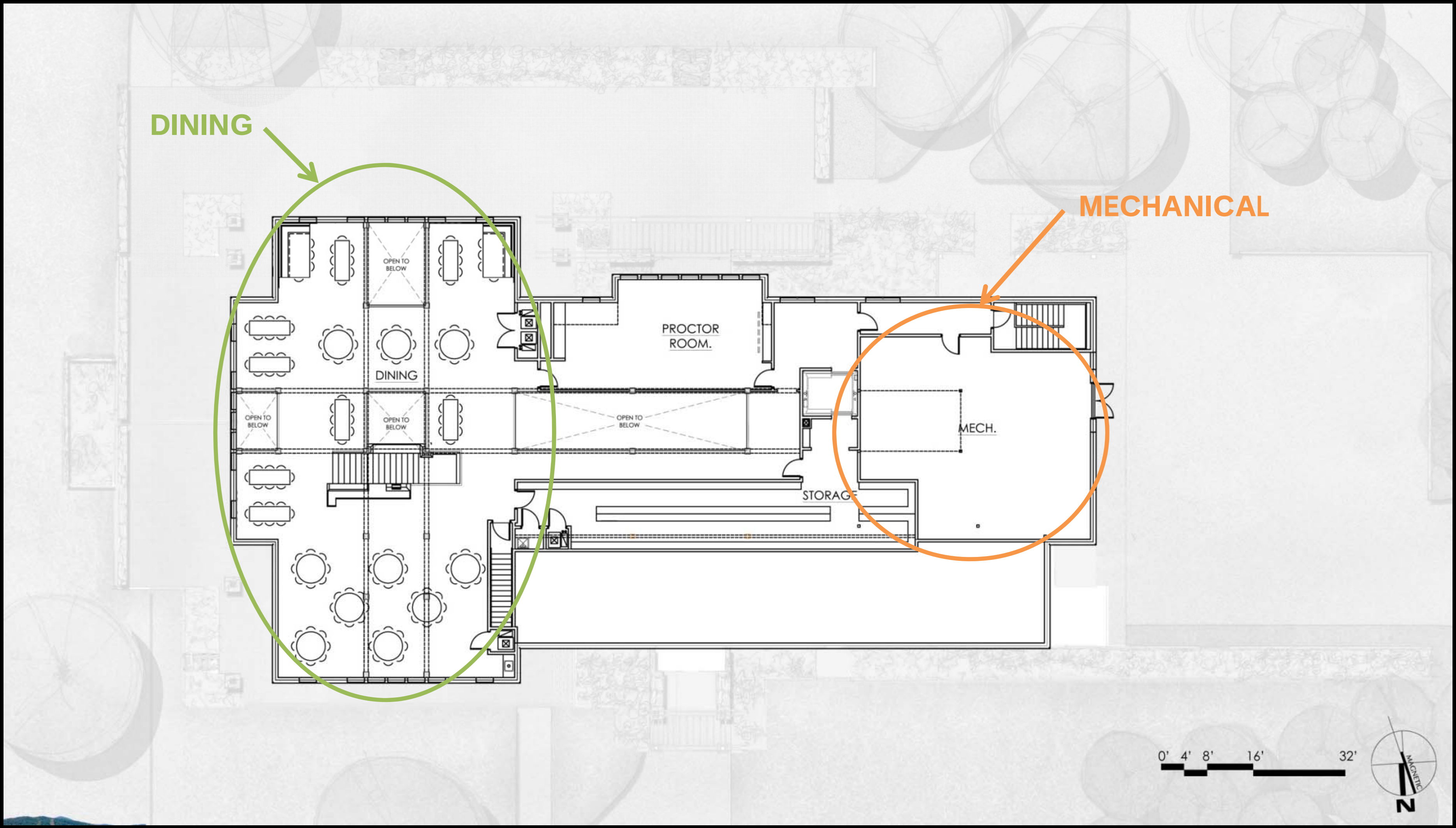
DINING
MECHANICAL
OPEN TO BELOW
PROCTOR ROOM.
DINING
OPEN TO BELOW
STORAGE
MECH.
0' 4' 8' 16' 32'
N

PROCTOR

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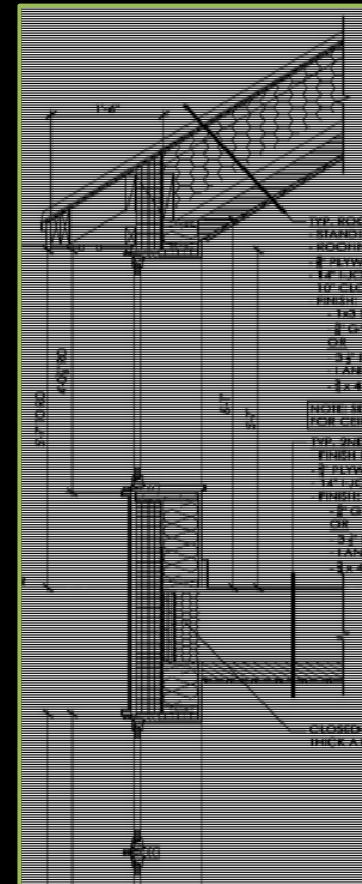
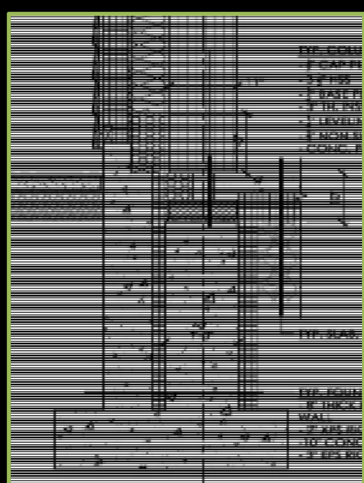
ACHIEVING NET ZERO READY?

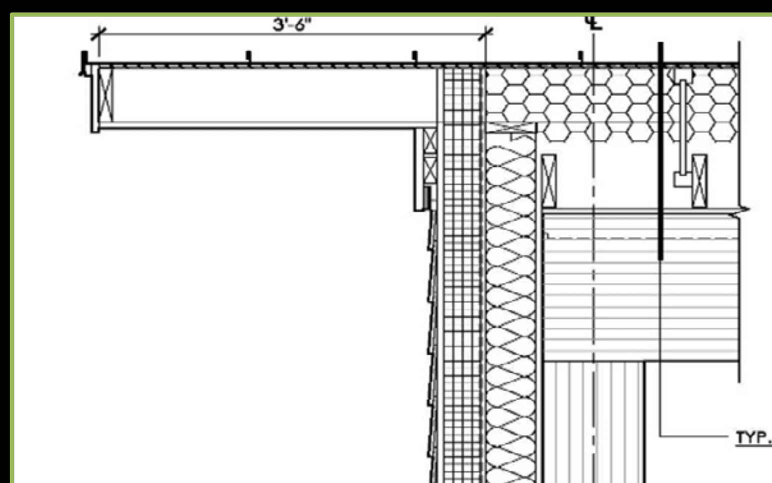
- Reduce envelope loads
- Reduce kitchen loads
- Efficient Mechanical Systems

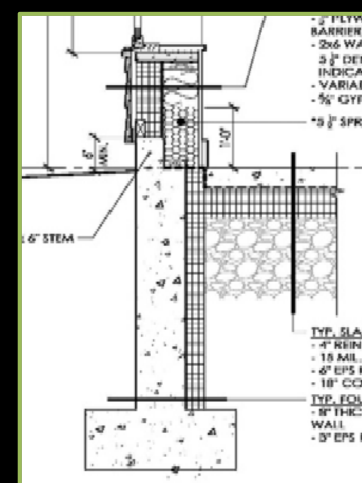
- Reduce envelope loads

Floor/Slab Assembly R-value:	R-27 to R-18 (6”-4” EPS)
Wall Assembly R-Value:	R-38 (5.5” cellulose w/ 4” polyiso)
Roof Assembly R-Value:	R-54 (13” HFO Two part PU Spray)
Windows:	Triple-glazed, Argon Paradigm U-0.23, R-4.35
Envelope Infiltration Rate:	0.1 CFM50 / sq. ft.









- Modeled Options
  - Building Envelope
  - Hoods

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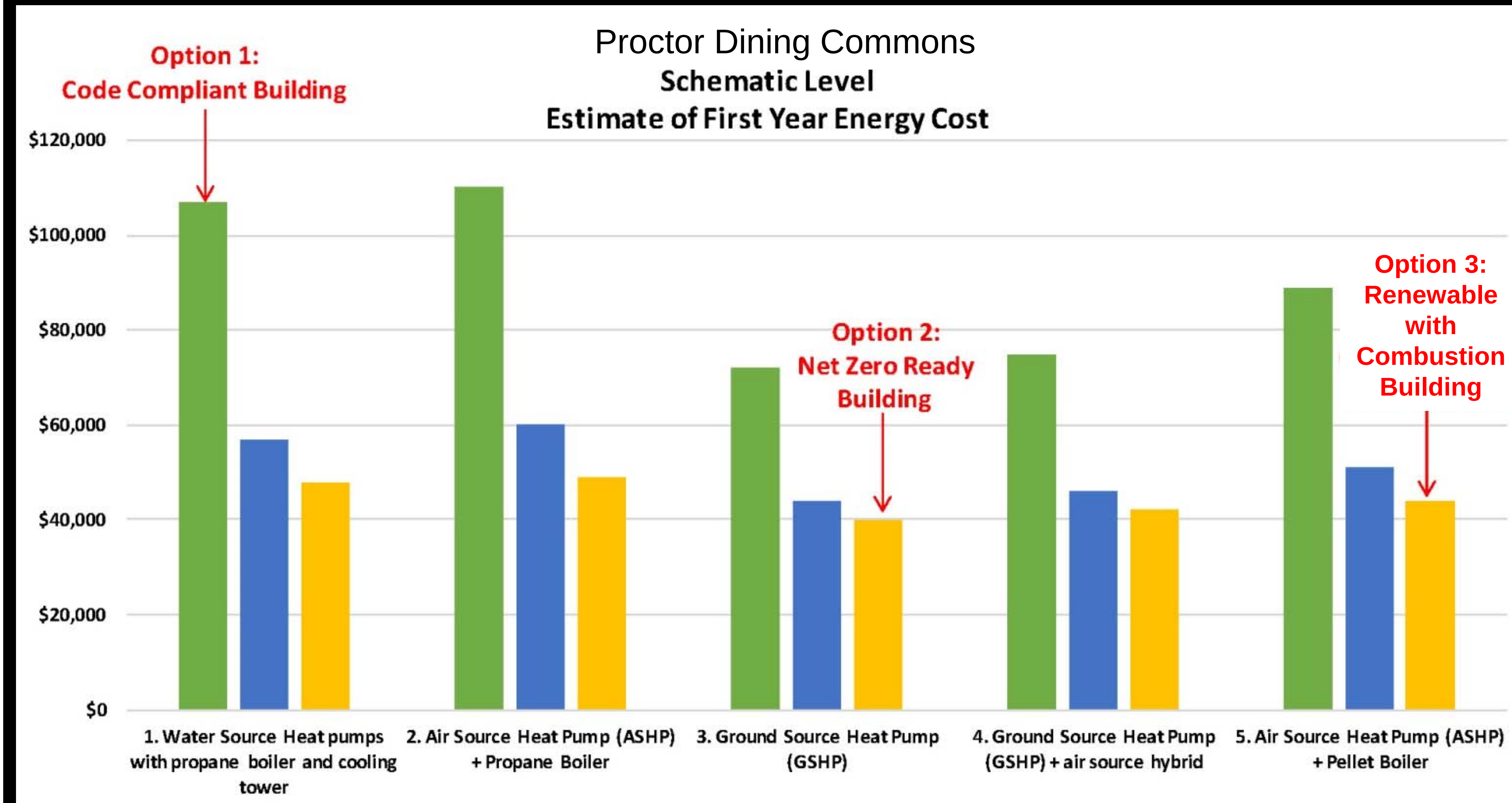
- Schematic Phase modeling for system selection

Code Complaint building with fixed speed hood
Net Zero Ready building with variable speed hood
Net Zero Ready building with variable speed hood with heat recovery



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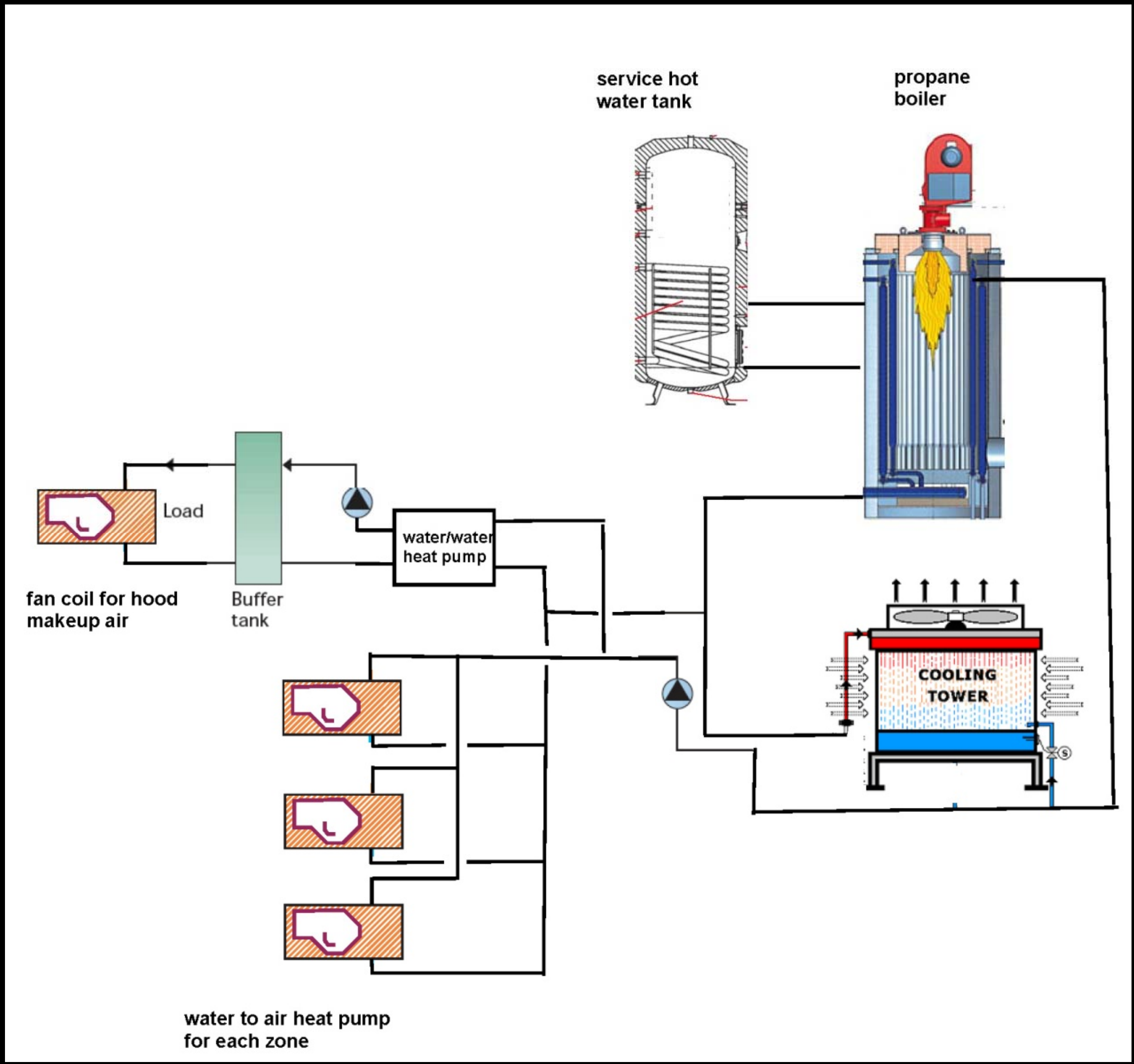
- Efficient Mechanical Systems

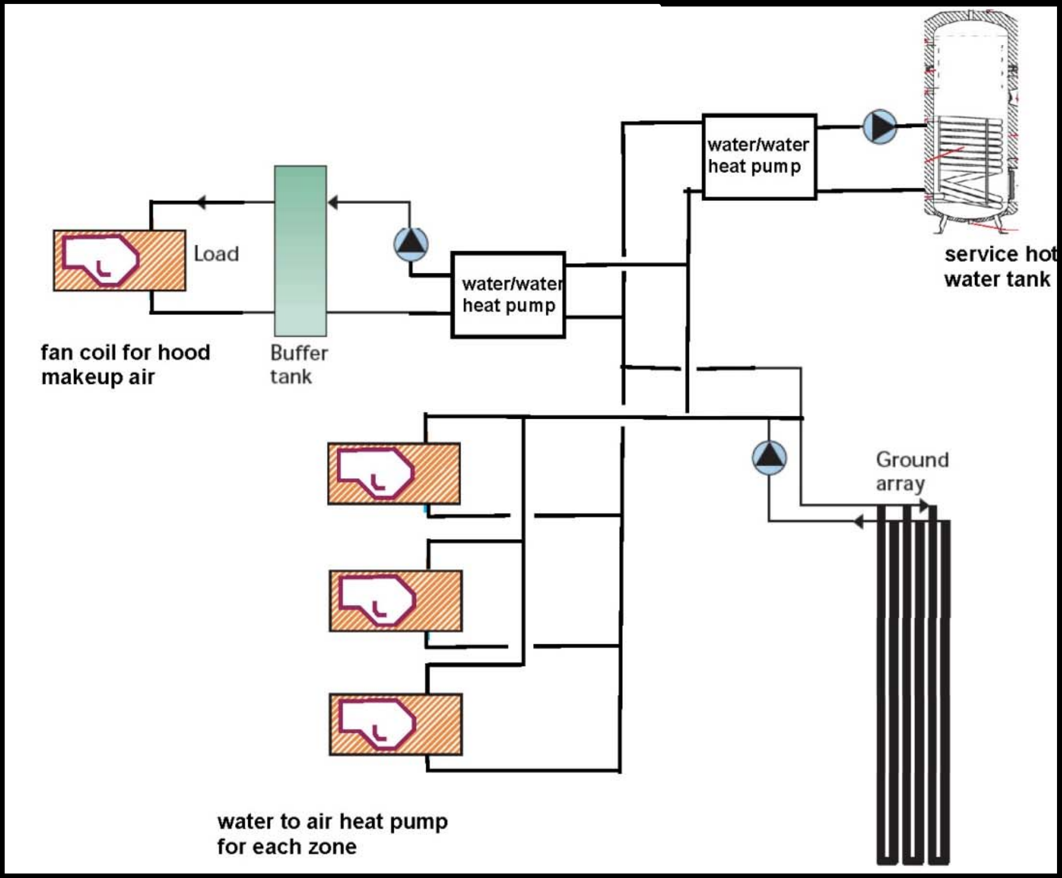
LN CONSULTING

- HVAC OPTION 1: CODE
  - Propane Fired Conventional Water Source Heat Pump System

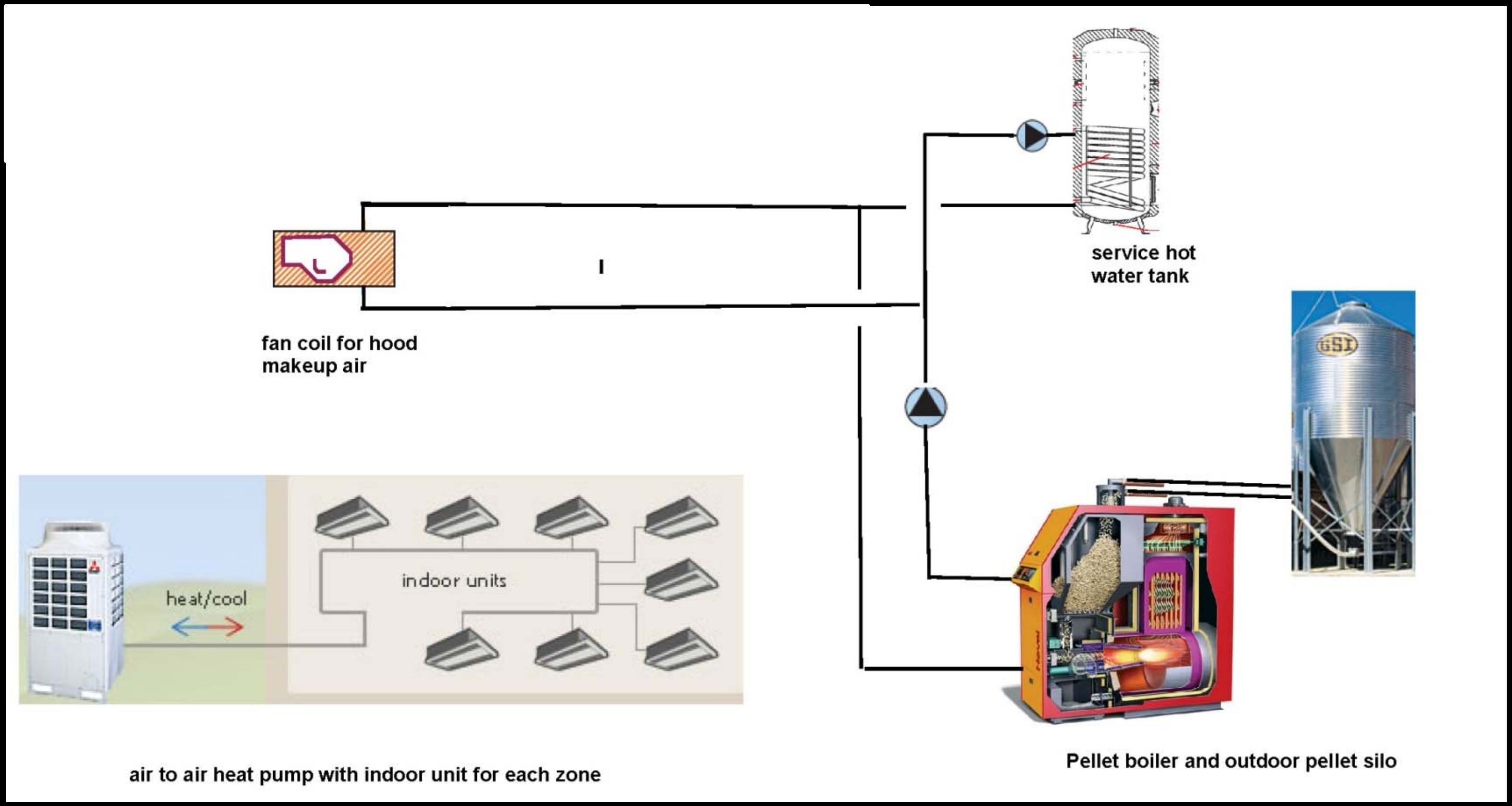


Efficient Mechanical Systems

- HVAC OPTION 2: NET ZERO
  - Ground Source Heat Pump System



- Efficient Mechanical Systems
    - HVAC OPTION 1: ALL RENEWABLE, INCLUDES COMBUSTION
        - Air Source Heat Pump System for Building Conditioning
        - Wood Pellet Boiler for Hot Water and Make-up Air



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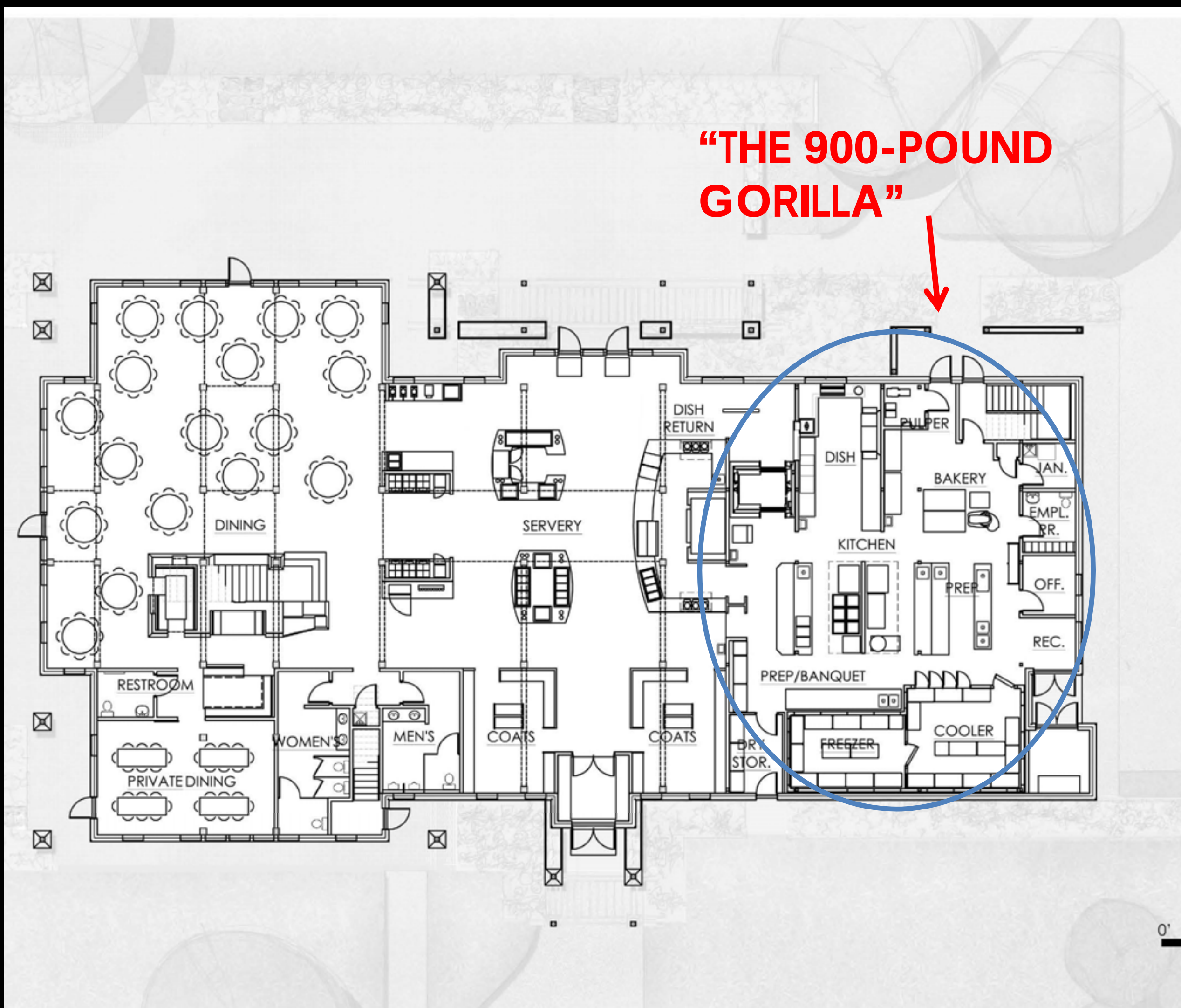
- Reduce process loads (kitchen)



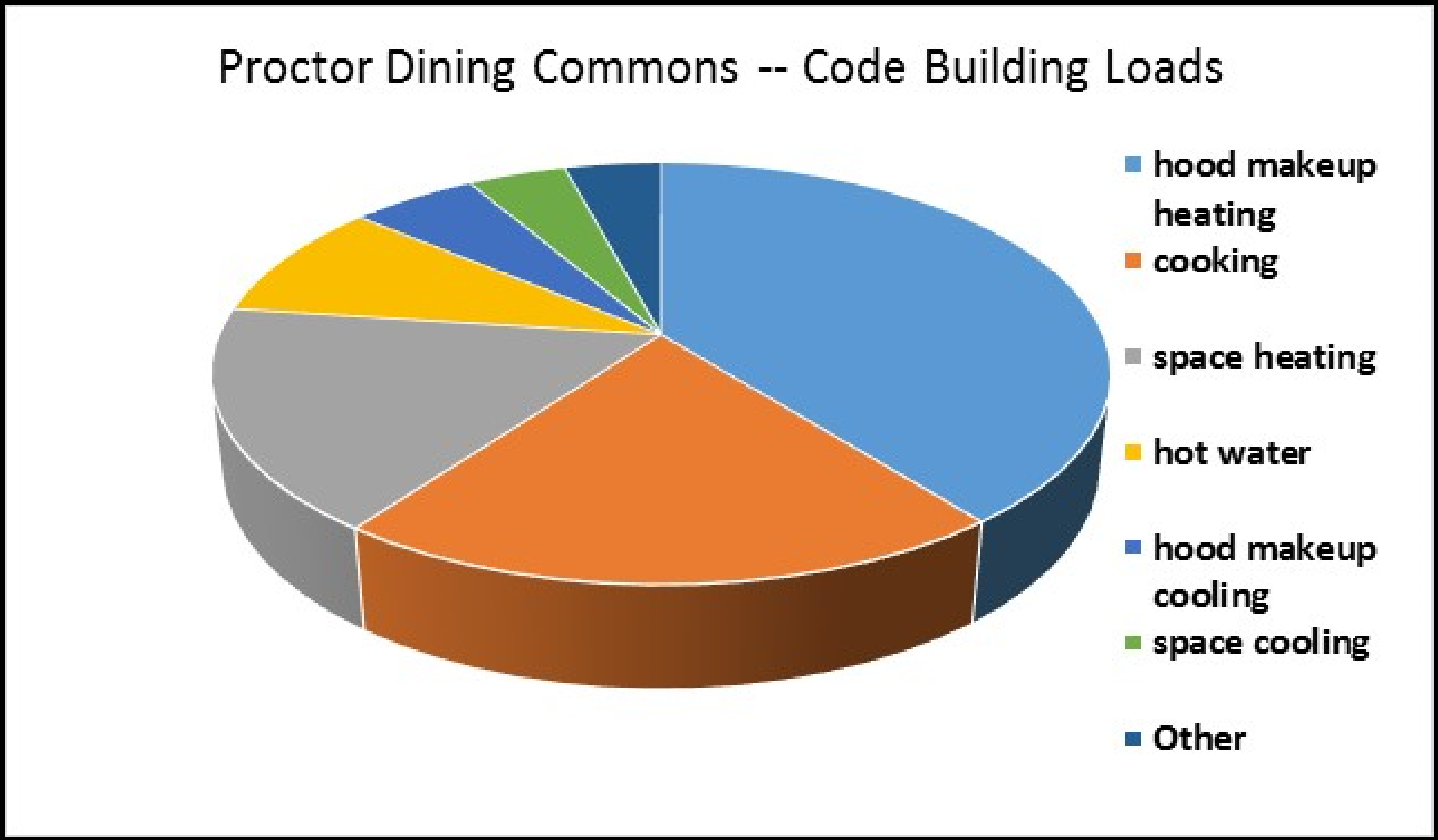
Energy Modeling and Optimizing Systems

- What are the Loads?

Schools Year Schedule			
222	days kitchen serves during year		
# meals/day			
200	breakfast		
375	lunch		
260	dinner		
835	**total**		
Summer Schedule			
75	days		
# meals/day			
75	breakfast		
75	lunch		
75	dinner		
225	**total**		

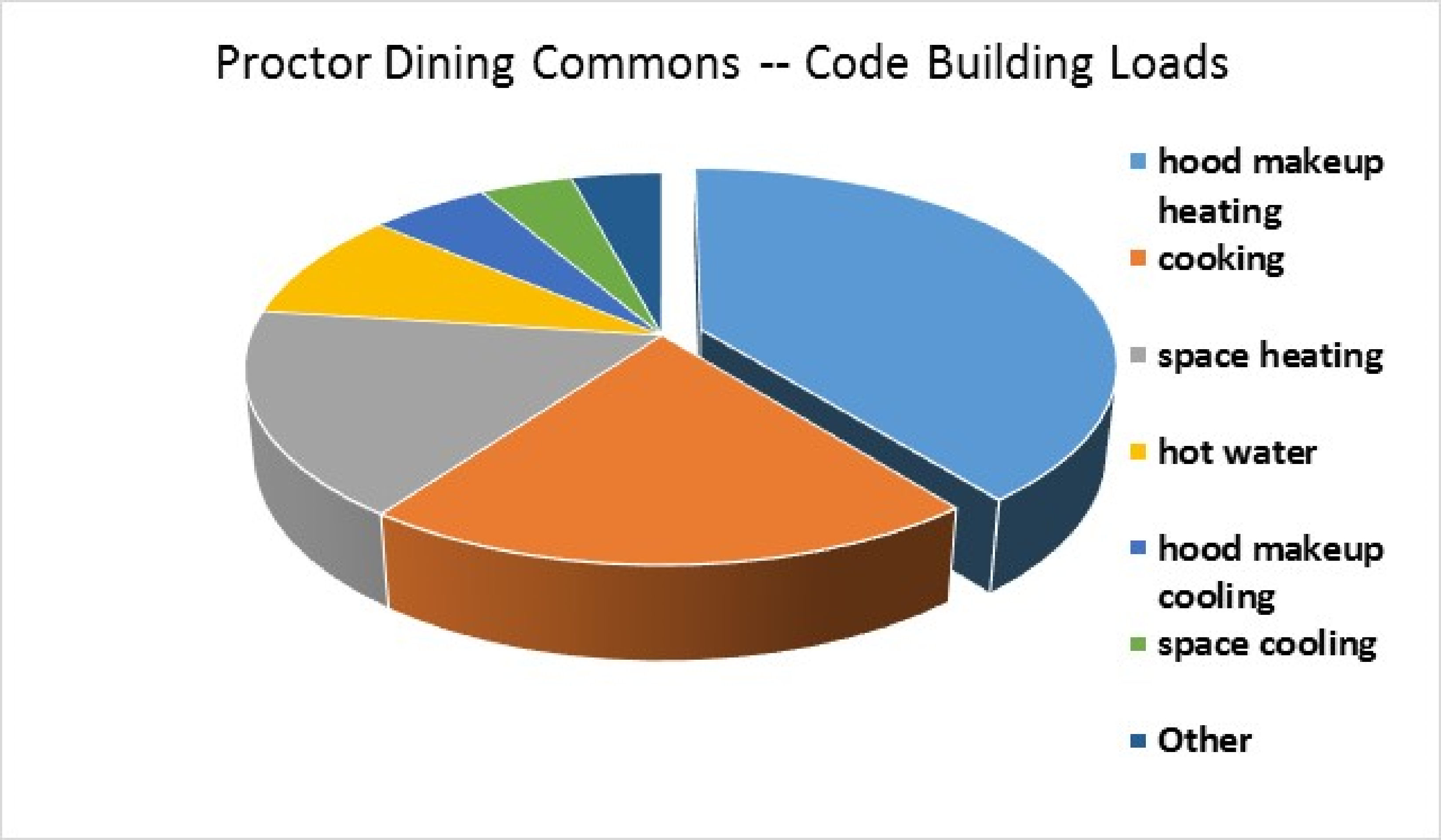
Energy Modeling and Optimizing Systems

- Question #1: What are the Loads?



Energy Modeling and Optimizing Systems

- Biggest Slice: ***<u>Hood Makeup Air</u>***



- Client Commitments and Goals
  - Healthy Food Fresh Local Ingredients
  - Continued “From Scratch” Cooking and Baking
  - No Menu Sacrifices
  - Sustainability

“Sustainability is not so much a technical problem, but more so a people problem.”

- Reduce Hood Make-up Air
  - Objective #1 – Minimize hood lengths
- Client Commitments and Goals
  - Healthy Food Fresh Local Ingredients
  - Continued from Scratch Cooking and Baking
  - No Menu Sacrifices
  - Sustainability

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MORE COMPACT LAYOUT =

Less SF/Less building

- 100 SF /smaller kitchen
- 17 fewer LF of hood
- Significant Building Cost Savings

Additional Cost for Equipment ($50,000)

- 1st Year Energy Savings ($40,000)

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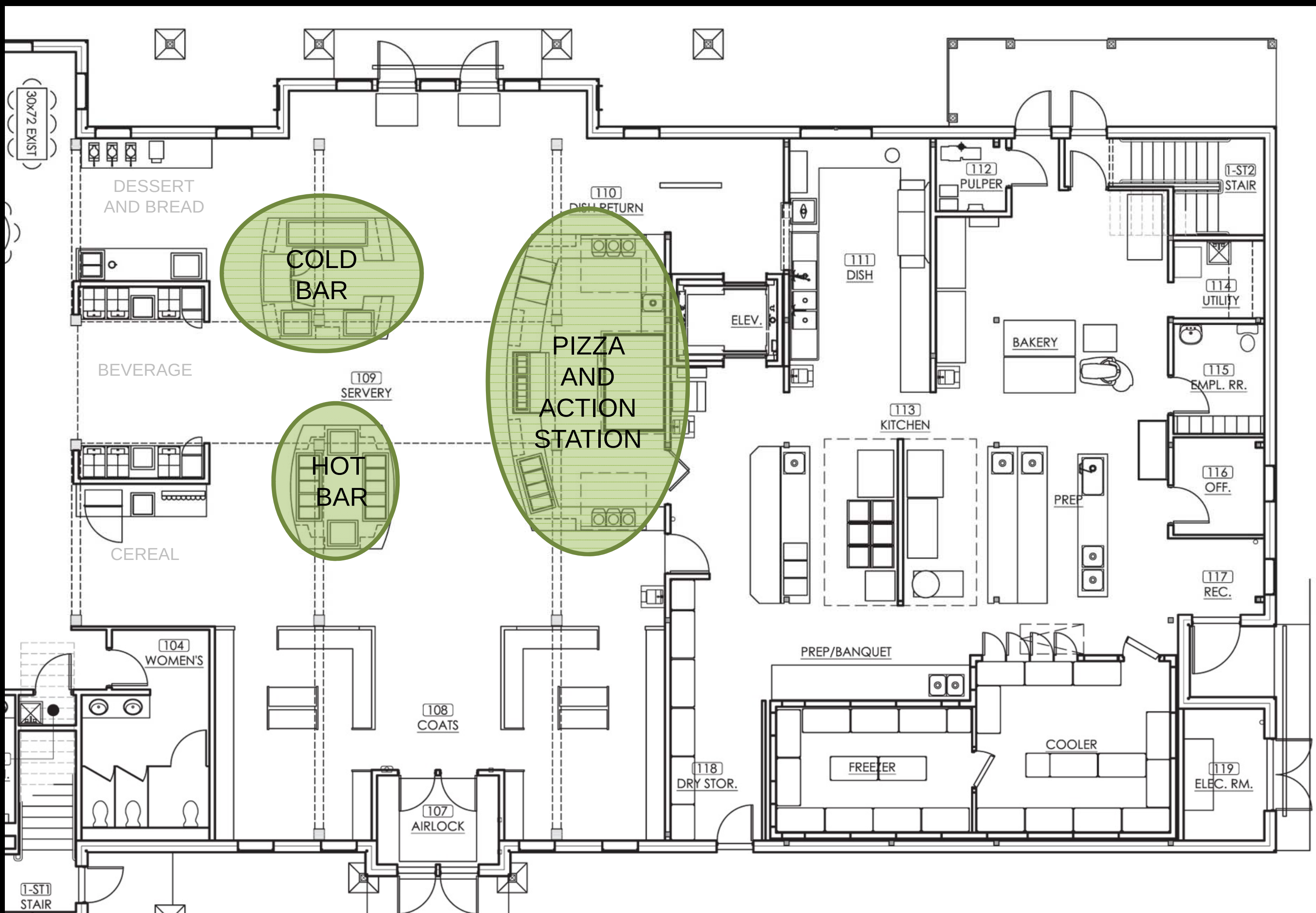
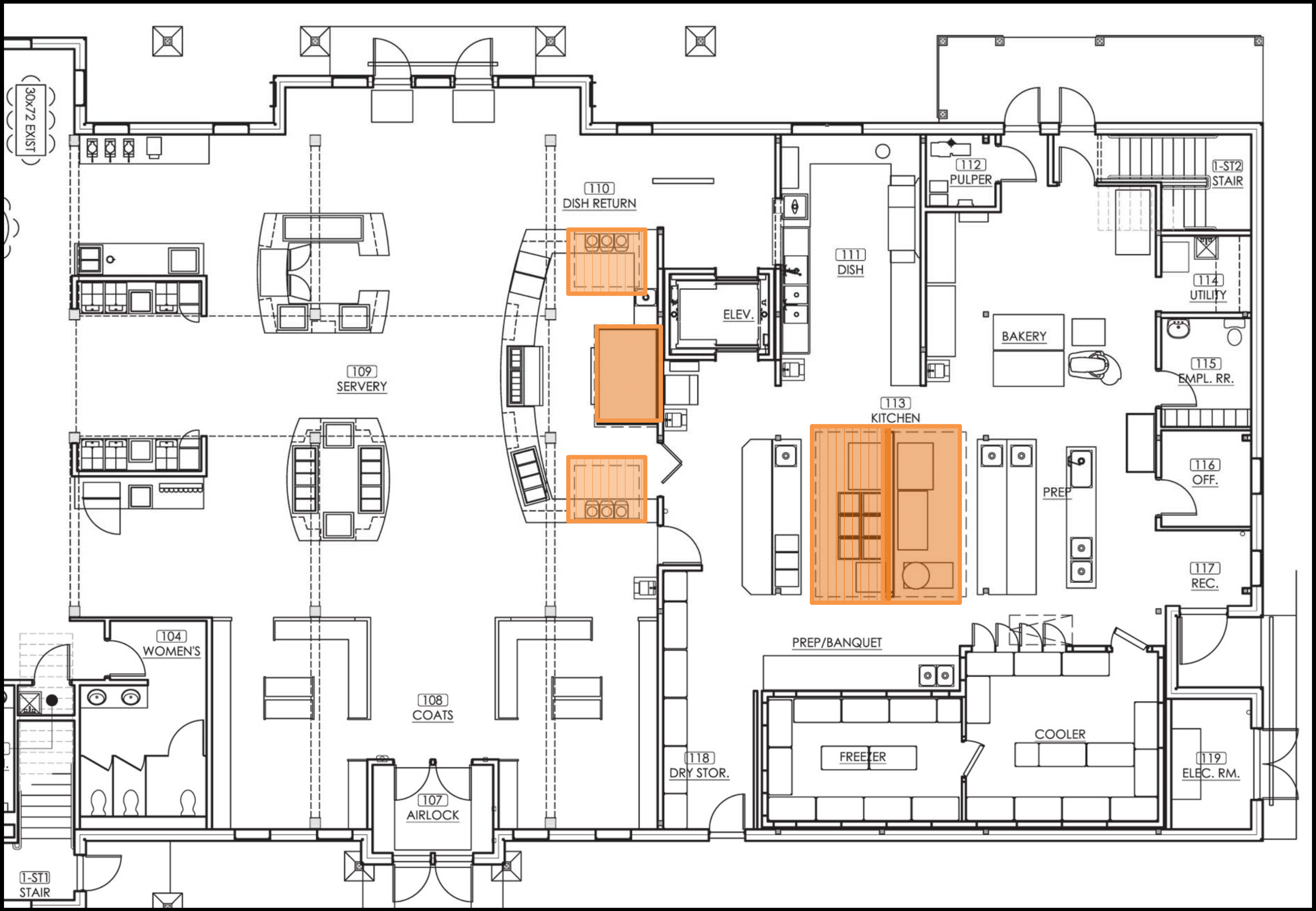
- Reduce Hood Make-up Air
  - Objective #1 – Minimize hood lengths
  - Objective #2 – Minimize number of hoods

- Client Commitments and Goals
  - “Food Forest”
  - Face to Face/Personal Staff and Student Connection

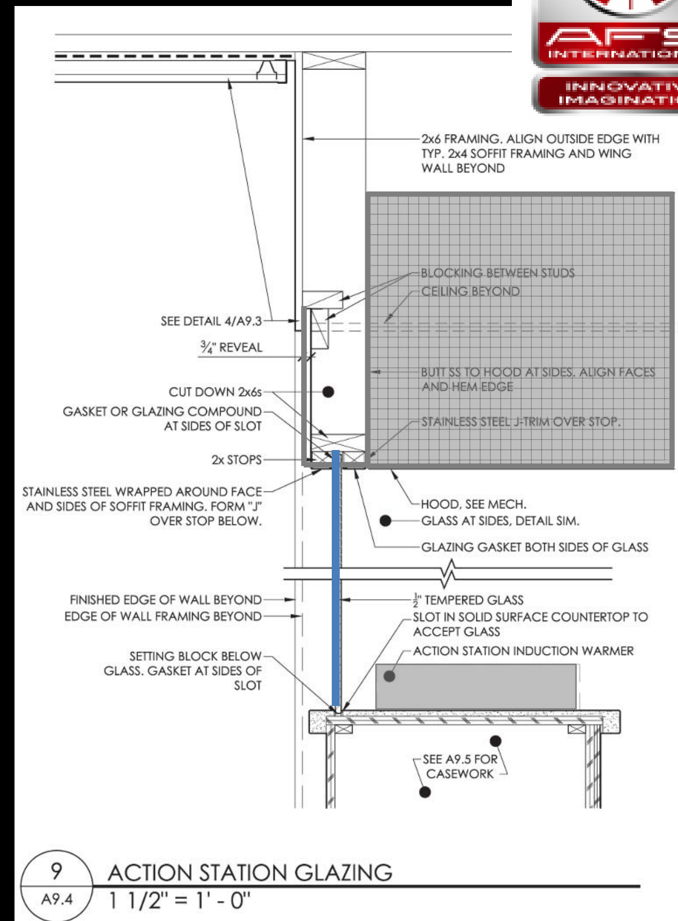


DESSERT
AND BREAD
COLD
BAR
BEVERAGE
109
SERVERY
HOT
BAR
CEREAL
110
DISH RETURN
PIZZA
AND
ACTION
STATION
ELEV.
111
DISH
112
PULPER
1-ST2
STAIR
114
UTILITY
BAKERY
115
EMPL. RR.
113
KITCHEN
PREP
116
OFF.
117
REC.
PREP/BANQUET
104
WOMEN'S
108
COATS
107
AIRLOCK
118
DRY STOR.
FREEZER
COOLER
119
ELEC. RM.
1-ST1
STAIR
30x72 EXIST

FOOD FOREST = MULTIPLE HOODS !



- Reduce Hood Make-up Air
  - Objective #1 – Minimize hood lengths
  - Objective #2 – Minimize number of hoods
  - Objective #3 – Maximize Hood Efficiencies
- Client Commitments and Goals
  - Energy (Net Zero)
  - Cost



ISLAND MOUNT vs. WALL MOUNT

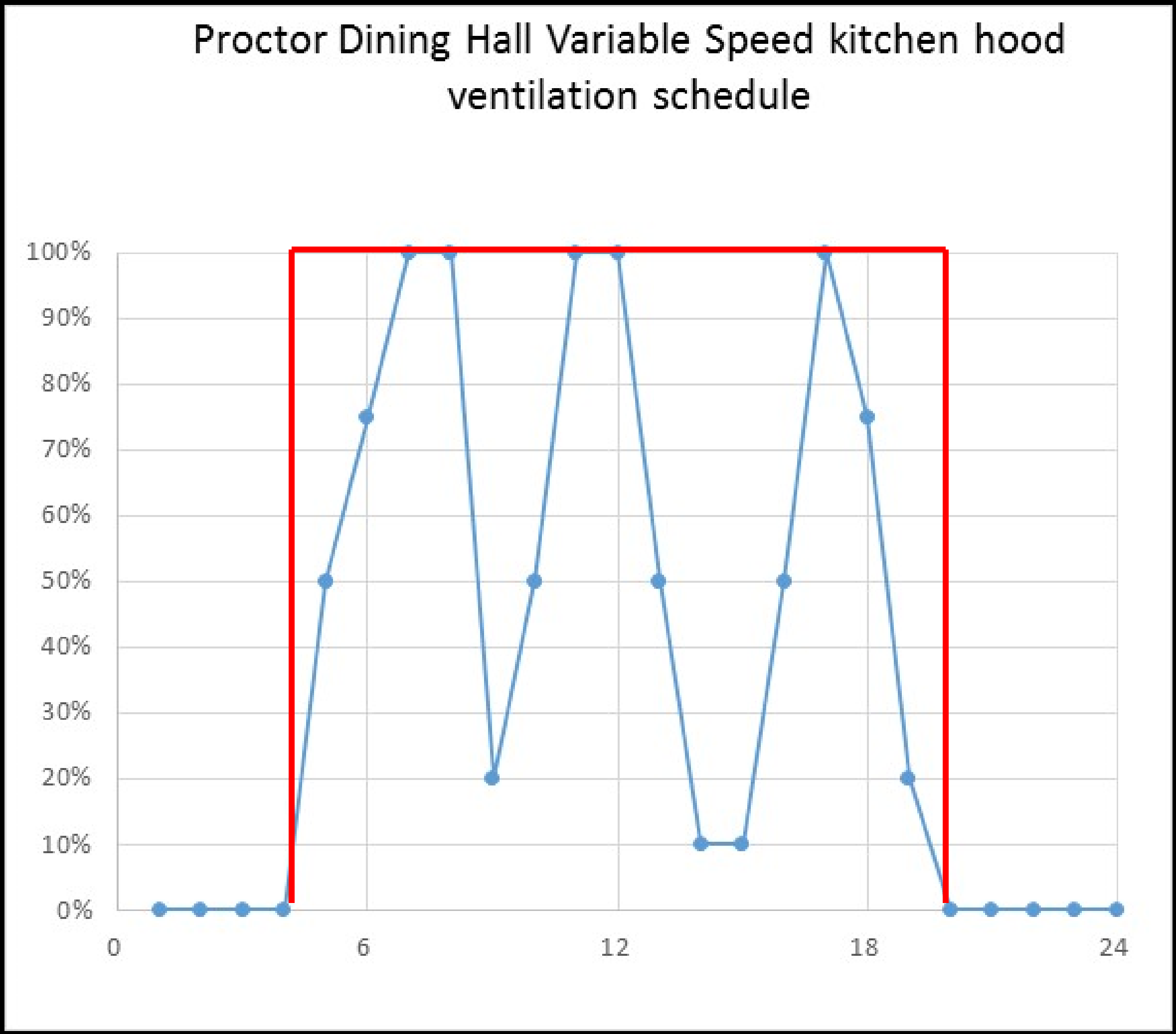
Energy Modeling and Optimizing Systems

- Kitchen Hood – **6,000+ cfm**

Base Case: On/off control, no heat recovery

Peak Load,
- ~500kBtu/hr
- (150kw) heating

Annual Load:
- ~980 MMBtu/yr
- (286 MWh/yr)



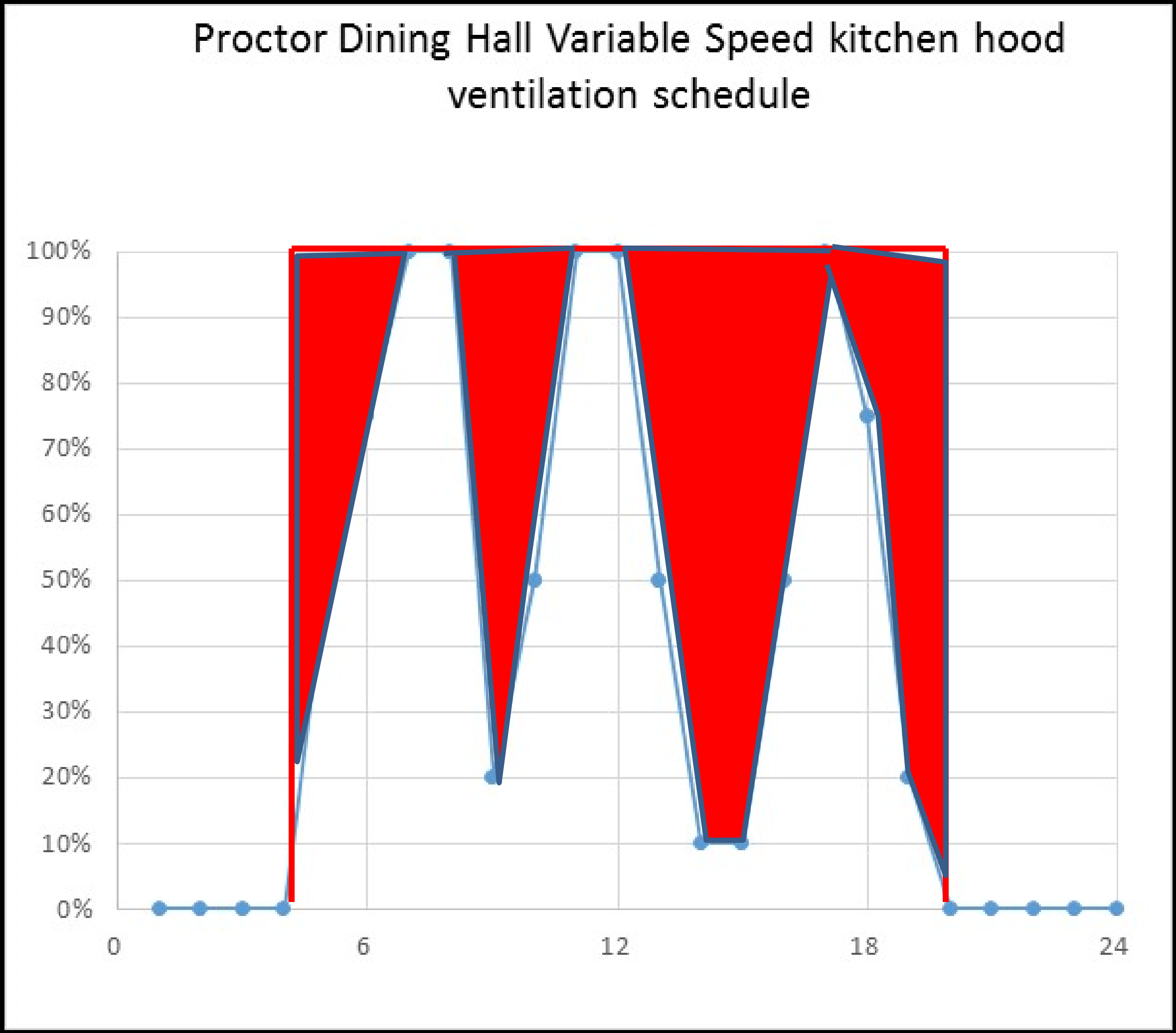
Energy Modeling and Optimizing Systems

- Kitchen Hood – **6,000+ cfm**

Demand control, no heat recovery

Peak Load,
- ~500kBtu/hr
- (150kw) heating

Annual Load:
- **~550** MMBtu/yr
- (159 MWh/yr)



Energy Modeling and Optimizing Systems

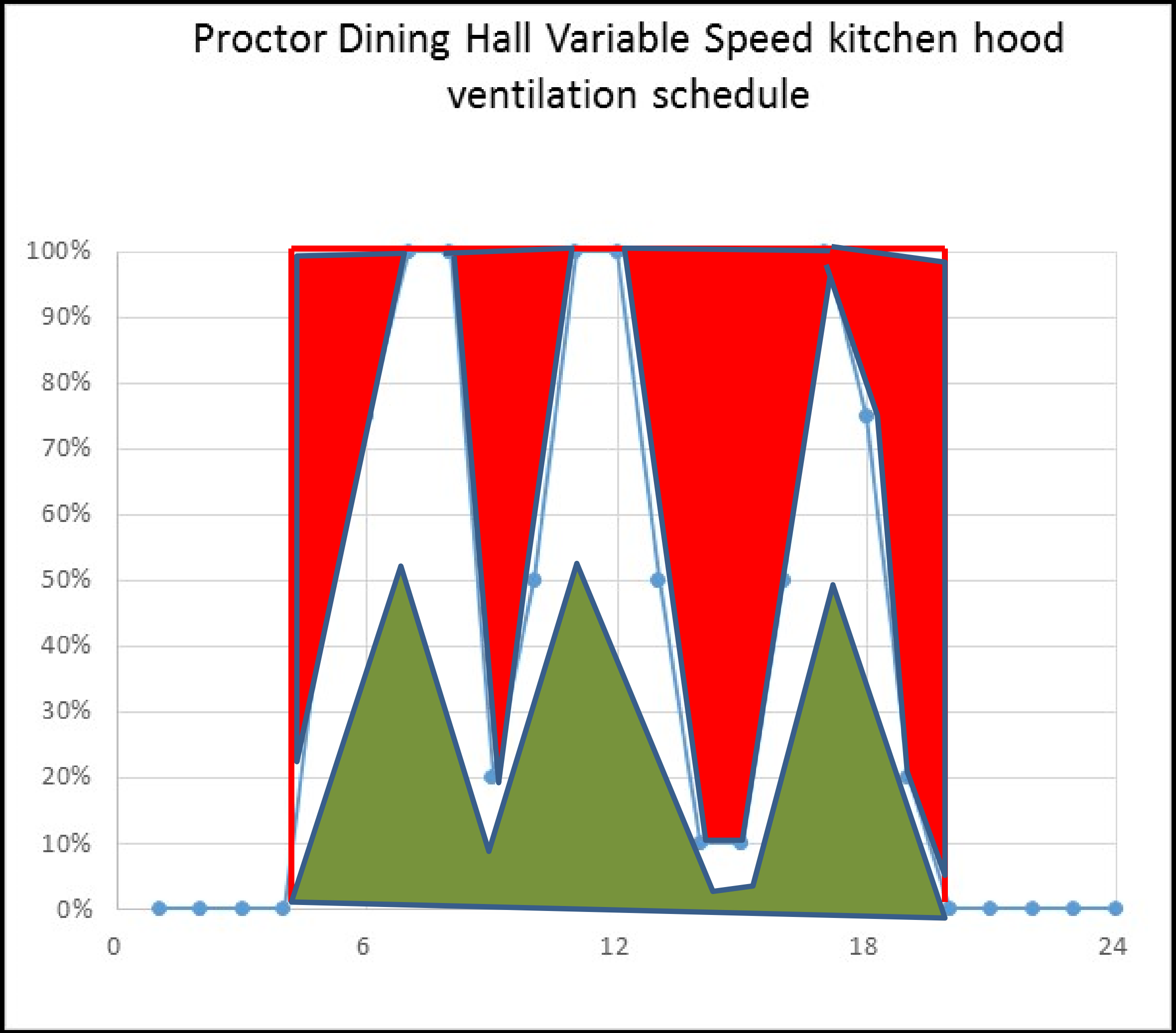
- Kitchen Hood – **6,000+ cfm**

Peak Load, **Demand control, WITH heat recovery**

- **~250 k**Btu/hr
- (150kw) heating

Annual Load:

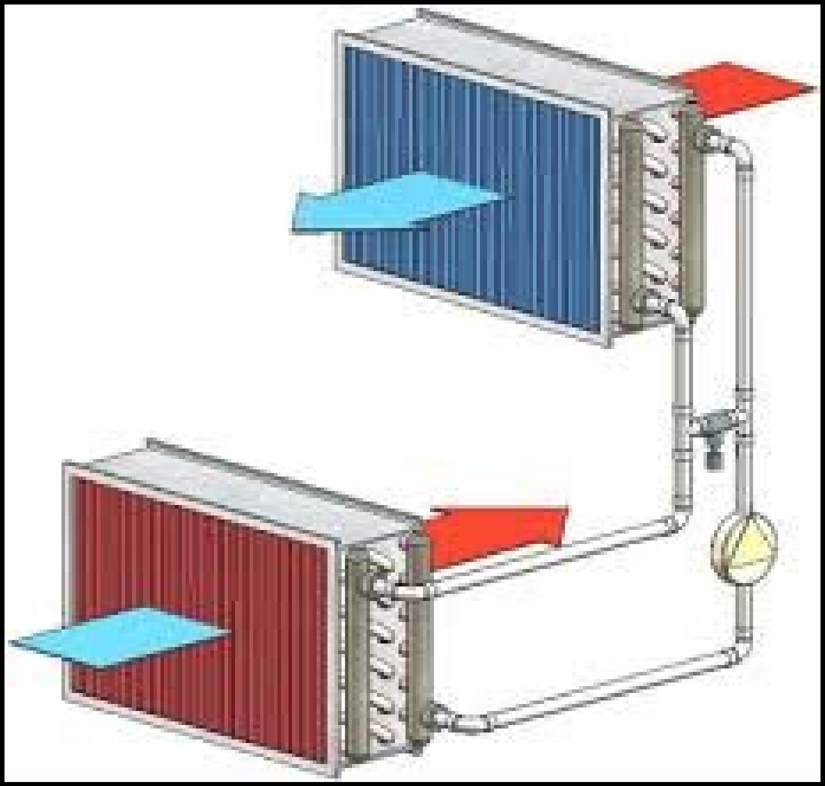
- **~270** MMBtu/yr
- (80 MWh/yr)



Kitchen Hood Exhaust and Make-Up Air

- Exhaust: 6,871 CFM
  - Lot of effort to reduce cfm
  - 5 hoods variable volume
  - Damper closes when not in use
- Make-up: 6,185 CFM
  - ~50% heat recovery (Halton)
  - Some excess exhaust reduces dining ERV

Exhaust Air



Makeup Air

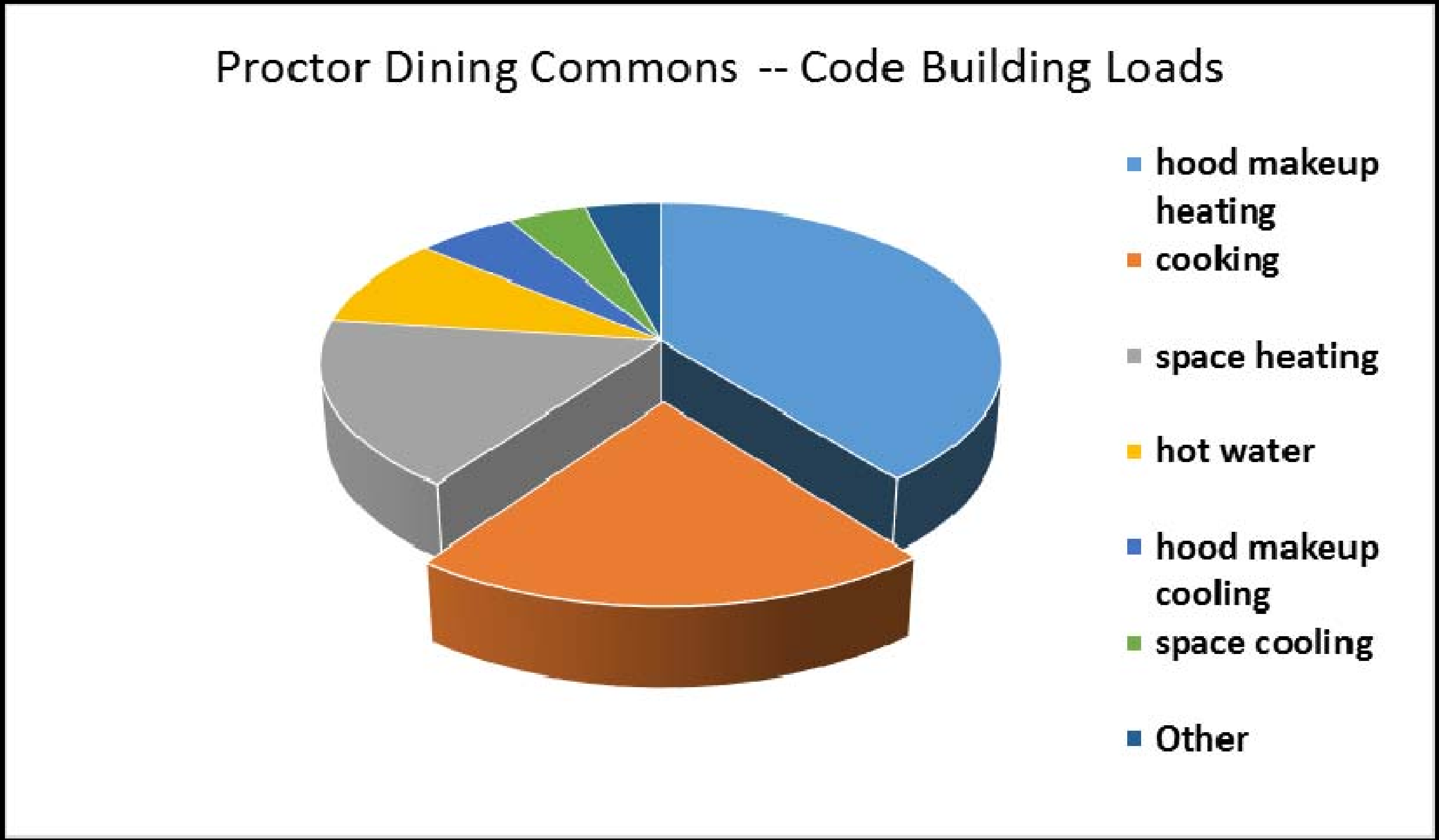
Energy Modeling and Optimizing Systems

2nd Biggest Slice: Kitchen Equipment

Peak Load:

- ~100 kW (rough)

Annual Load:
~150,000 kWh/yr



- Client Commitments and Goals
  - Healthy Food Fresh Local Ingredients
  - Continued “From Scratch” Cooking and Baking
  - No Menu Sacrifices
  - Net Zero

- Kitchen Equipment
  - Objective #1 – All Electric (+ Highly Efficient)
  - Objective #2 – Meet/Address staff needs and concerns

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- Kitchen Equipment
  - New Technology

Justin Silverthorn

Advanced Foodservice Solutions, Inc.

- Kitchen Equipment
  - New Technology

Occasional Use only

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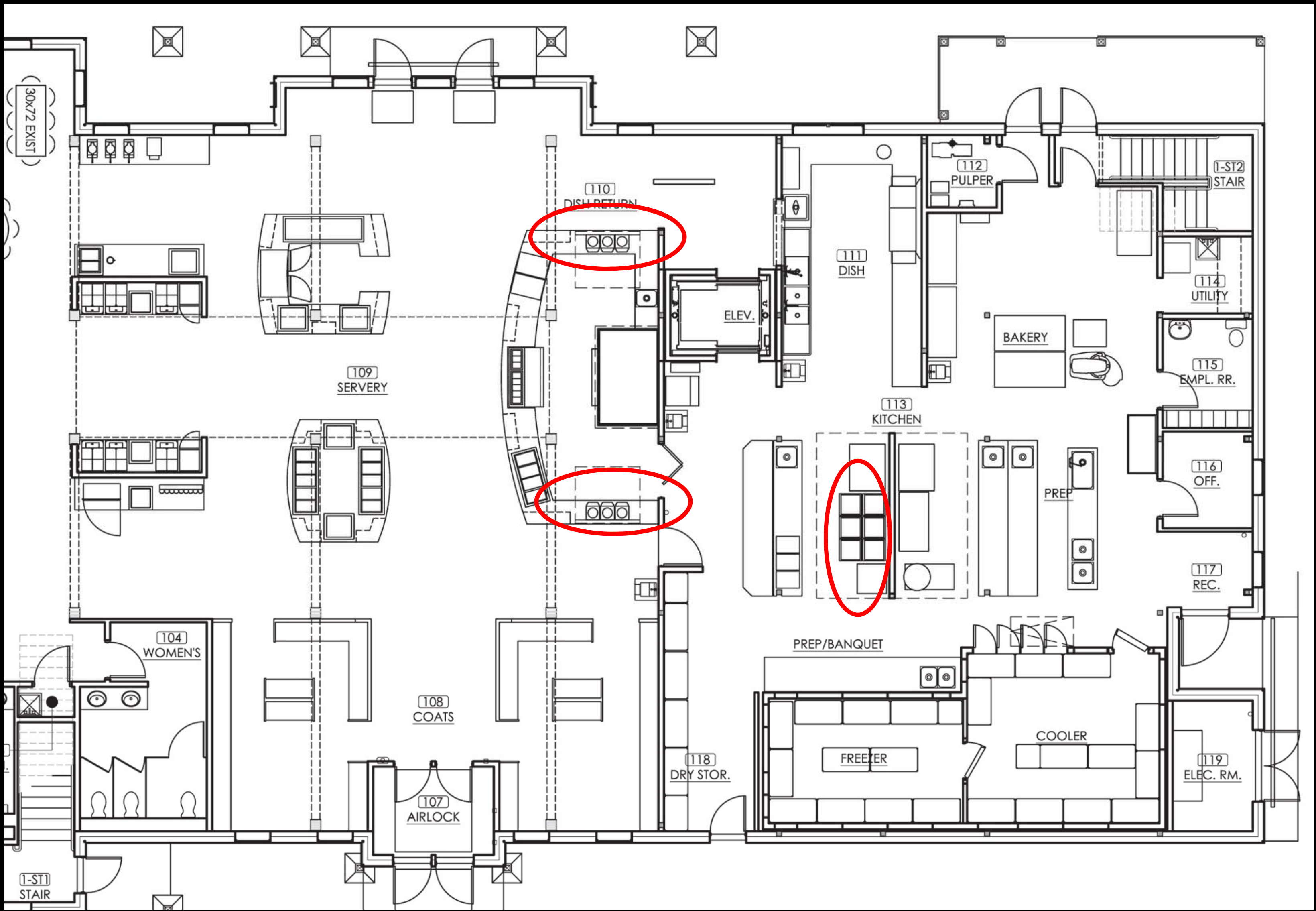

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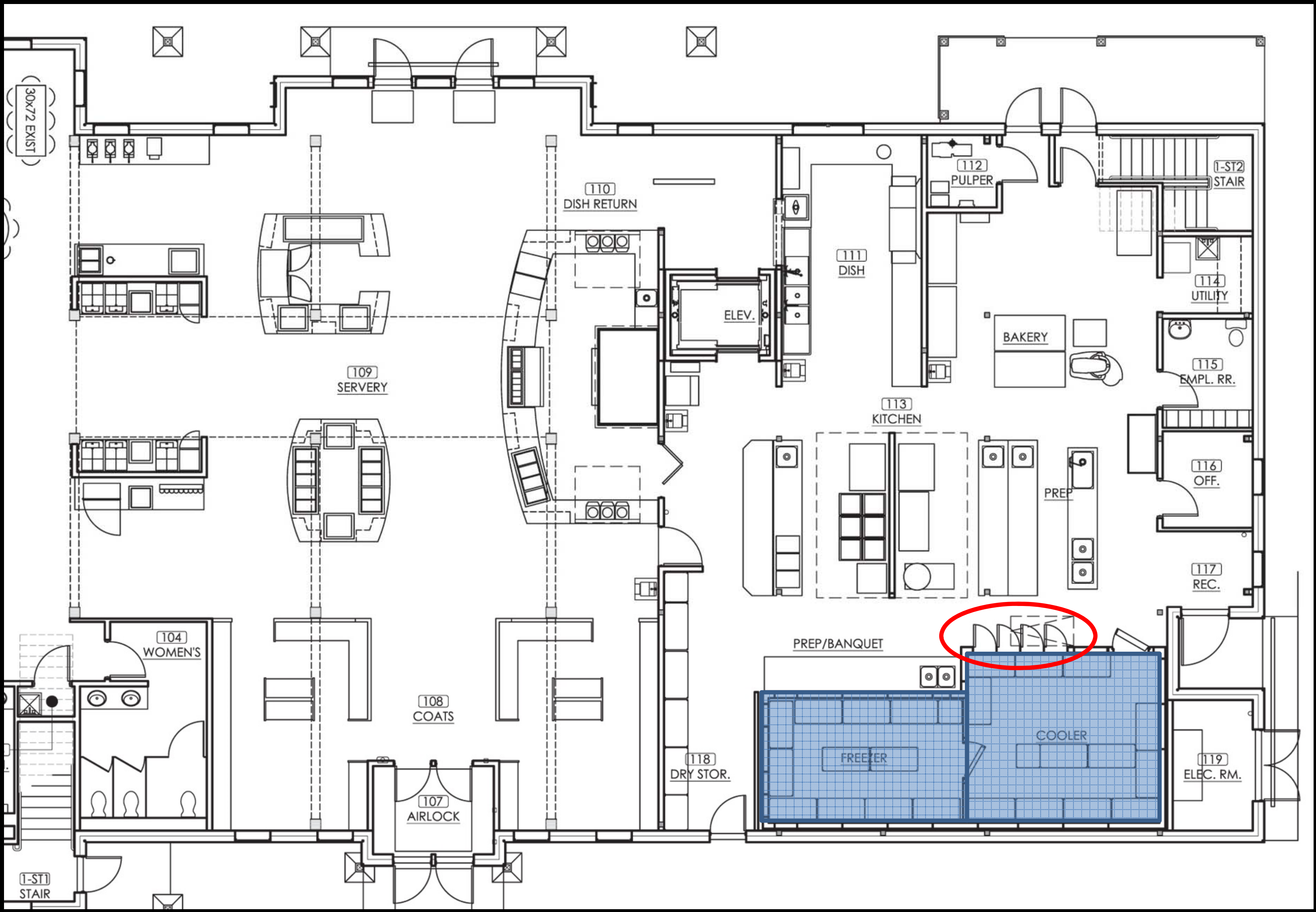
AFS INTERNATIONAL

INNOVATIVE IMAGINATION

- Kitchen Equipment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Energy Modeling and Optimizing Systems

2nd Biggest Slice: Kitchen Equipment

	Kitchen Energy Use Estimate	
	Kitchen Loads	
Item Number	Description	Location
3	beverage cooler	Servery
4	UC reach-in cooler	Servery
6	Milk cooler	Servery
8	Ice cream freezer	Servery
10	Waffle iron	Servery
12	5-comp drop in hot well	Servery
13	5-comp drop in hot well LED and heat lamp	Servery
14	2-comp drop in refrig well	Servery
16	48" UC refrigerator	Servery
17	Toaster	Servery
18	2-comp drop in hot well	Servery
19	Panini press	Servery
21	6-comp drop in refrig well	Servery
25	mobile induction cooktop	Servery
26	Drop in heated shelf	Servery
28	4-comp drop in hot well	Servery
30	Pizza refrigerated prep table	Servery
31	Gas fired stone hearth oven	Servery
41	Cooking hold	Kitchen
43	Countertop induction range	Kitchen
45	Dbl stack elecc convection oven, L2	Kitchen
45	Dbl stack elecc convection oven, L1	Kitchen
50	TILTING KETTLE	Kitchen
51	60" GRIDDLE	Kitchen
53	COMBI OVEN with stand, 48"	Kitchen
65	60 quart floor mixer	Kitchen
65	Mixer 20qt.	Kitchen
66	Holding Cabinet	Kitchen
75	Ice Machine	Kitchen
76	Walk-In Cooler 35F	Kitchen
80	Evaporator Coil fans - walk-in 35F	Kitchen
81	Walk-in cooler compressor 35F	Kitchen
84	Walk-In Freezer	Kitchen
85	Evaporator Coil - Walk-in Freezer	Kitchen
85	Walk-In Cooler/Freezer Door Heaters/Controller	Kitchen
86	Remote compressor, walk-in freezer, -10F	Kitchen
100	waste disposer w/controls	Kitchen
103	High Temp. Dish Machine w/ Energy Recovery	Kitchen
103	High Temp. Dish Machine boosters	Kitchen
110	pulper system	Kitchen
	Food Processor	Kitchen

Energy Modeling and Optimizing Systems

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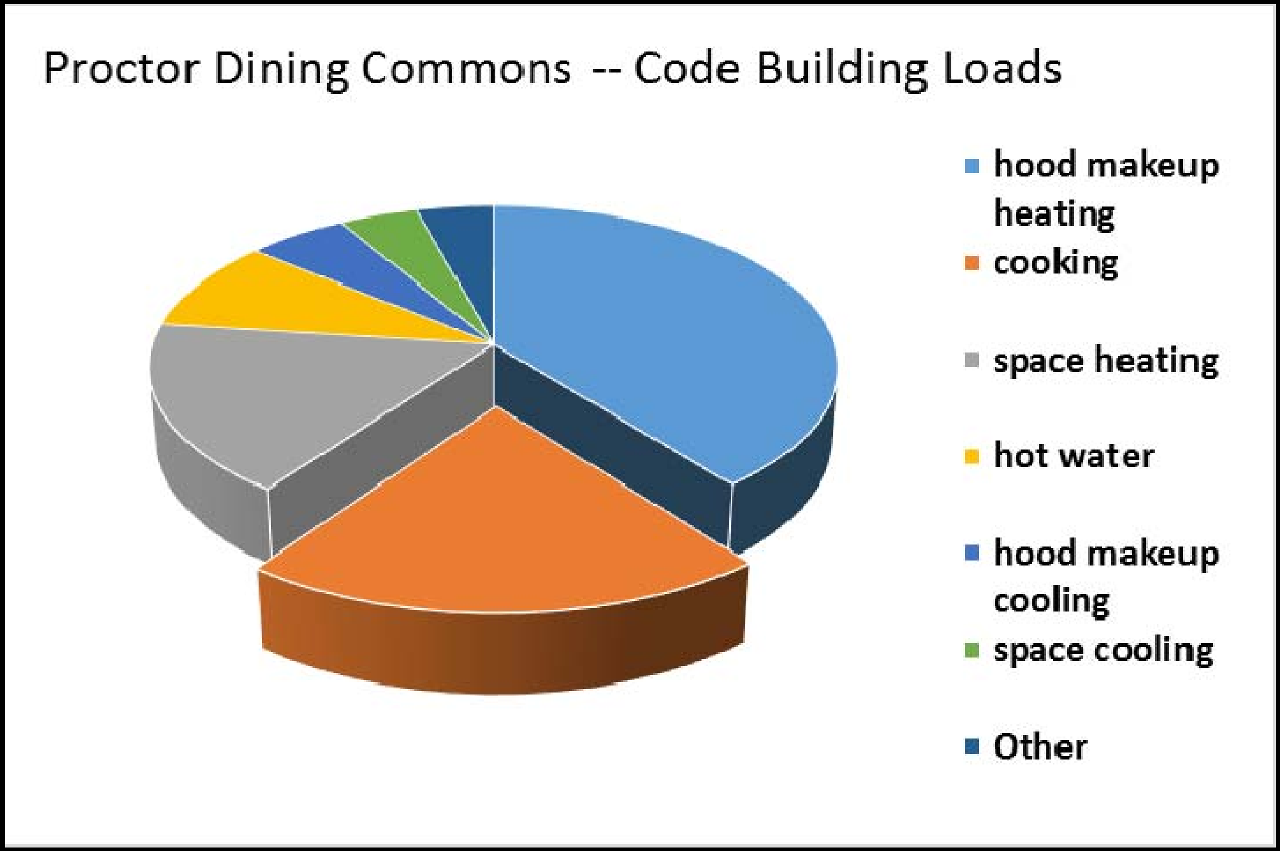
Energy Modeling and Optimizing Systems

2nd Biggest Slice: Kitchen Equipment

Approaches:

- Energy Star Equipment
- Recover heat from compressors or FreeAire for medium temp walk-in
- Estimated 10% energy reduction (15MWh) -- out of 150MWh
- Little peak load reduction



Energy Modeling and Optimizing Systems

Wild Card – Gas Pizza Oven

Approaches:

- Burn wood?
- Offset with more PV?
- Make methane?
- Student boycott of gas-fired pizza?

Gas Fired Pizza Oven

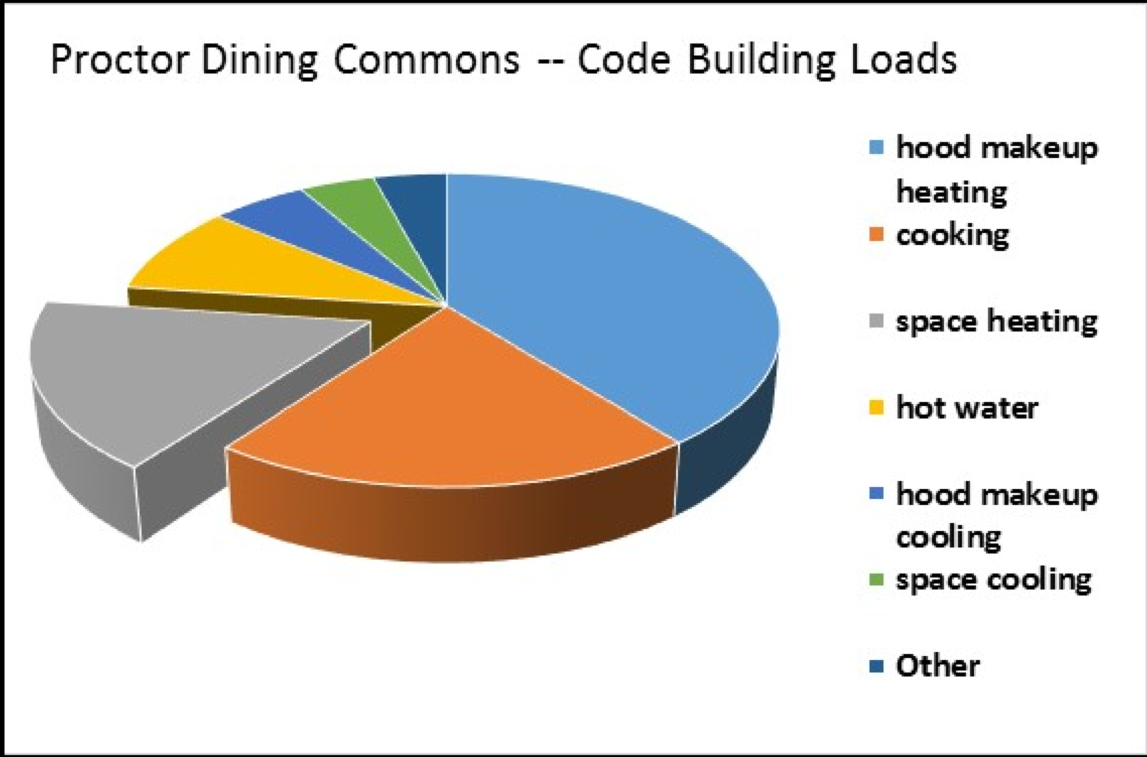
Hrs/ day	Hours/ year	Avg%full load	MMBtu/ yr	Total Btu/hr	**gal/yr. propane**
4	1,038	0.25	91	350,000	**993**

Energy Modeling and Optimizing Systems

3rd Biggest Slices: Space Heat

Code building energy

- 369 MMBtu/yr (110 MWh/yr)



Energy Modeling and Optimizing Systems

3rd Biggest Slice: Space Heat

NZR building energy

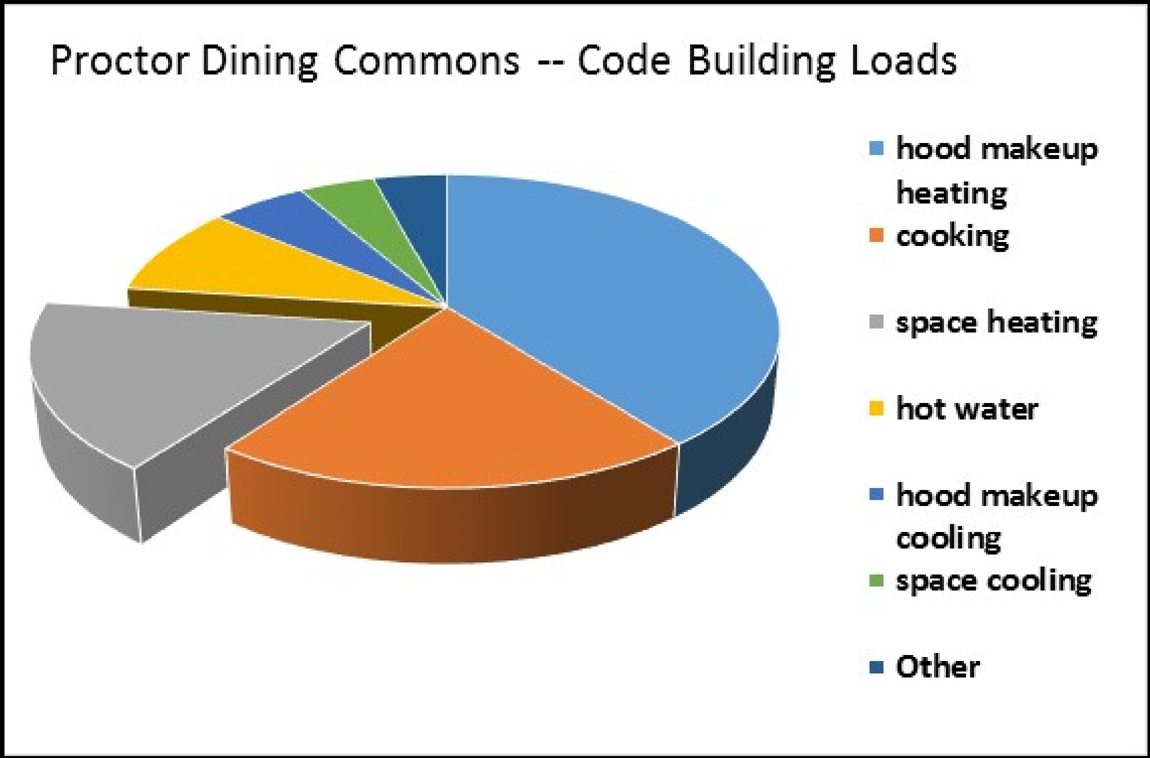
- **36 MMBtu/yr (14 MWh/yr)**

Approaches:

Super-insulate

- 0.1 cfm50/sq.ft. shell
- R- 5 windows
- R-20 slab
- R-40 walls
- R-60 roof

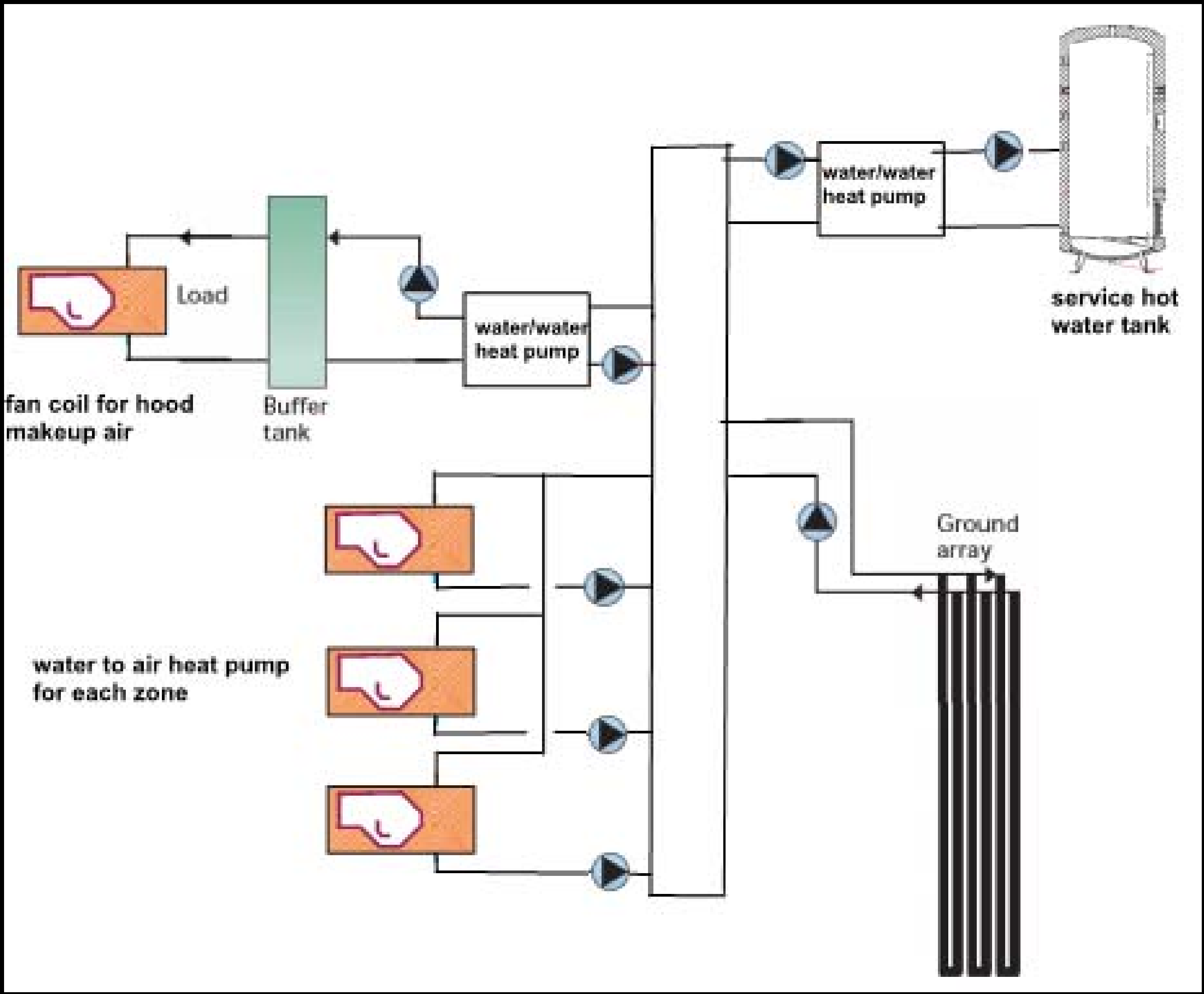
- ***GSHP with heat recovering water source heat pump loop***



Ground Source Heat Pump System

Recovers heat

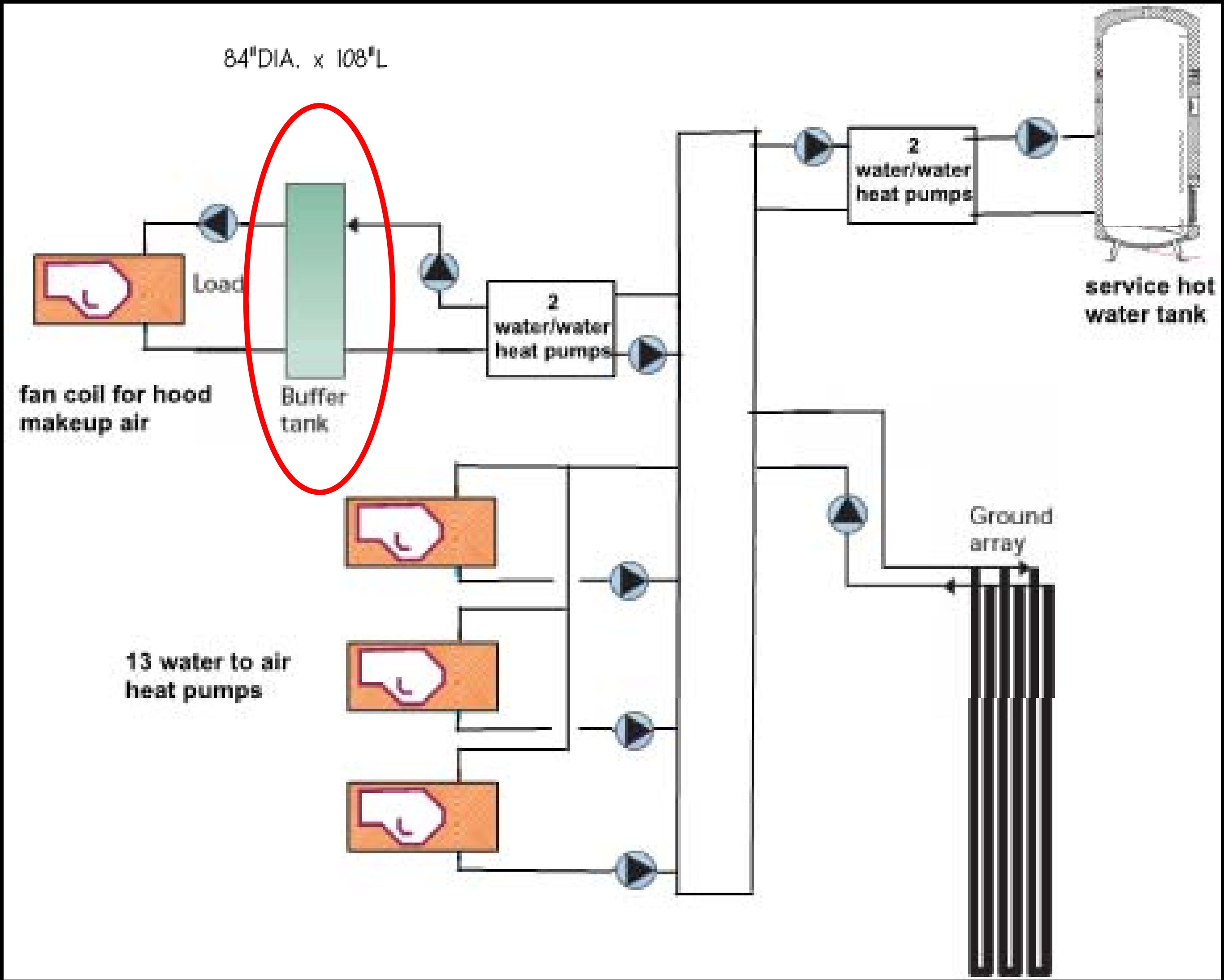
- Space cooling to hot water
- Cooling kitchen while heating space
- AC heats earth for space heating later in year
- Heating cools earth for AC later



Ground Source Heat Pump System

BIG buffer tank for Makeup Air

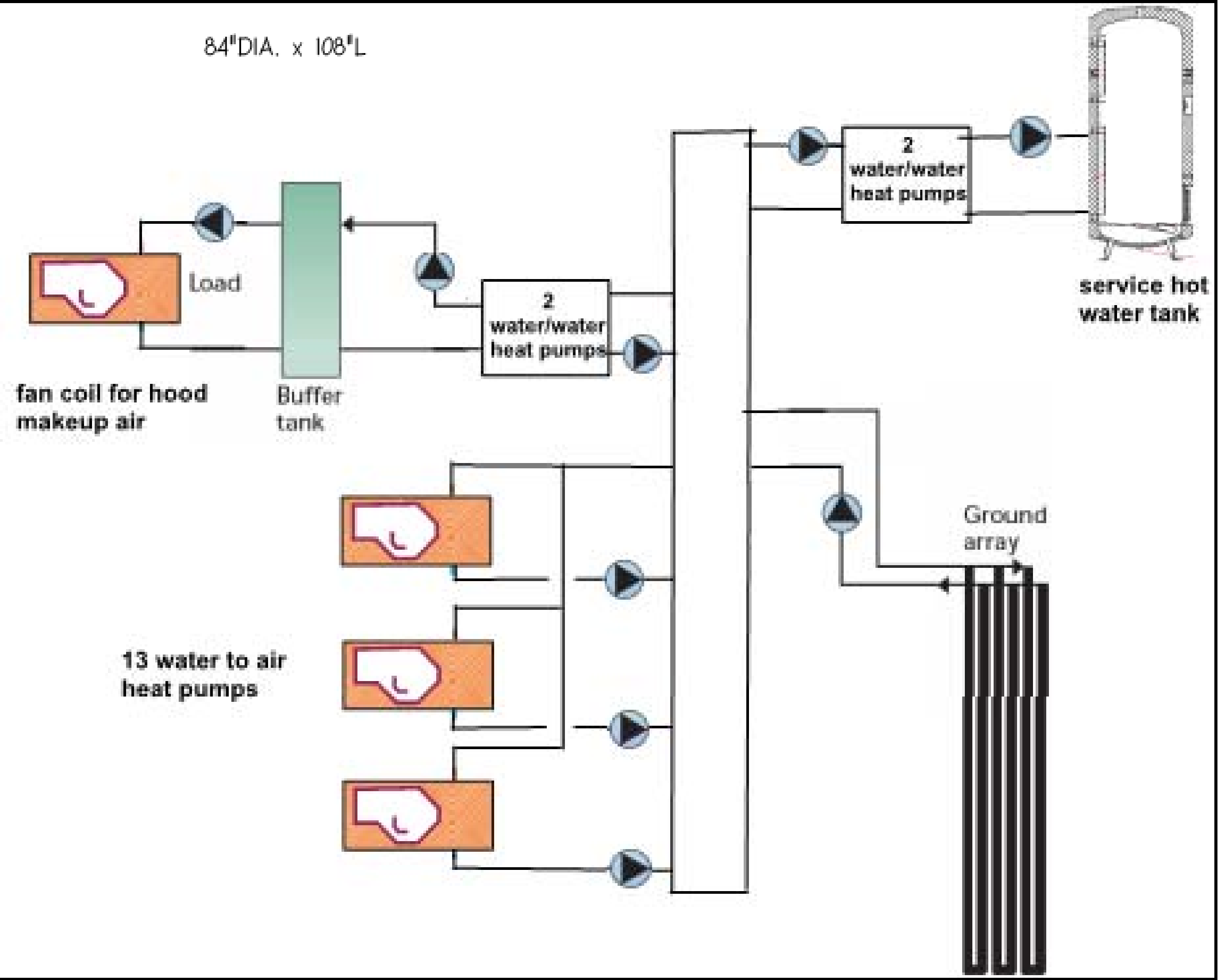
- 3,000 gallons
- Allows “dumb” heat pumps to meet varying loads
- Reduces peak load on heat pumps
- Reduces peak load on borehole field



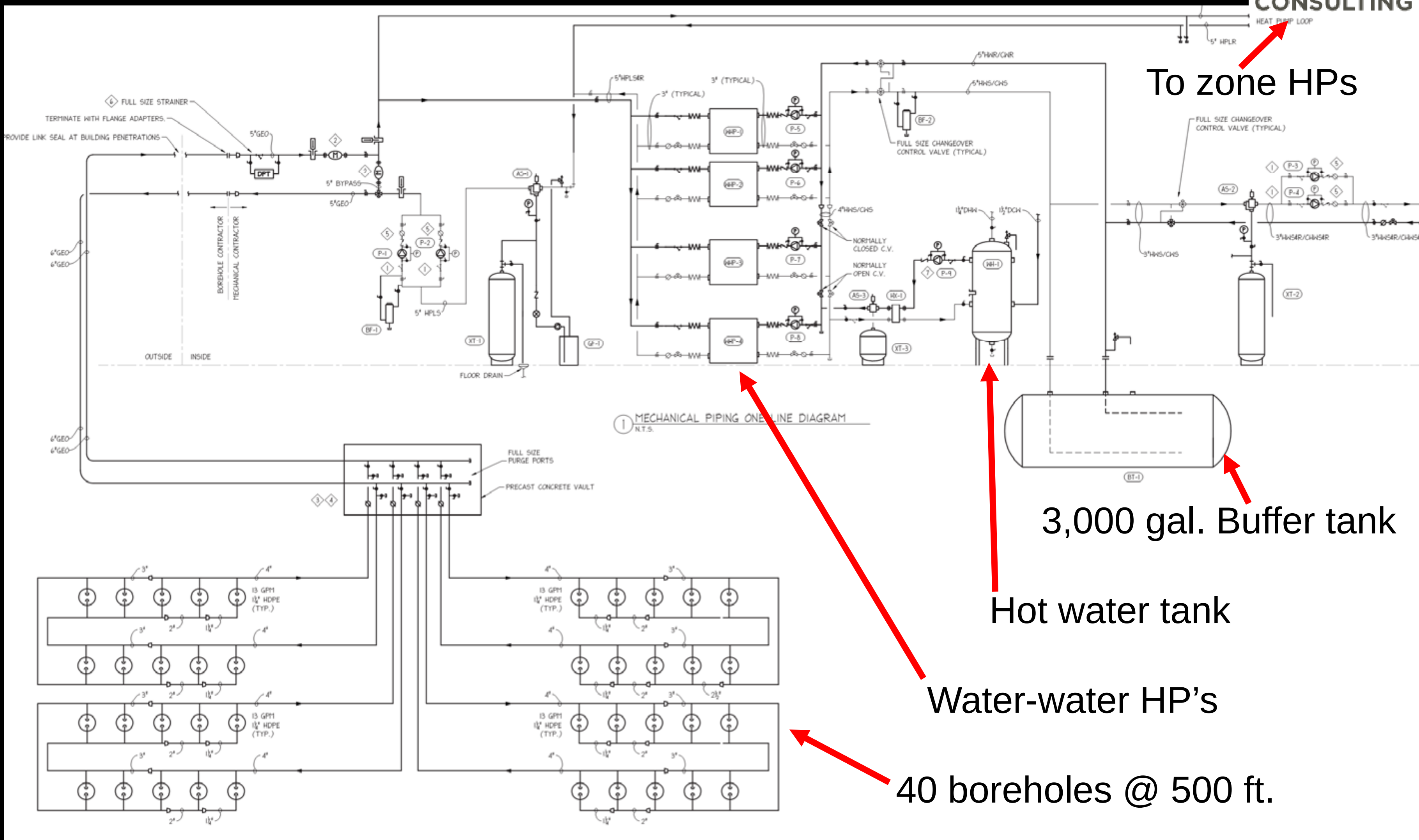
Ground Source Heat Pump System

Projected Heat Pump COPs *(including pumping)*

- Heat: 4.4
- Cooling: 3.0
- Hot Water: 2.1
  - (2.1 overall including pumping and some resistance heating – HP rated at 2.6 COP)



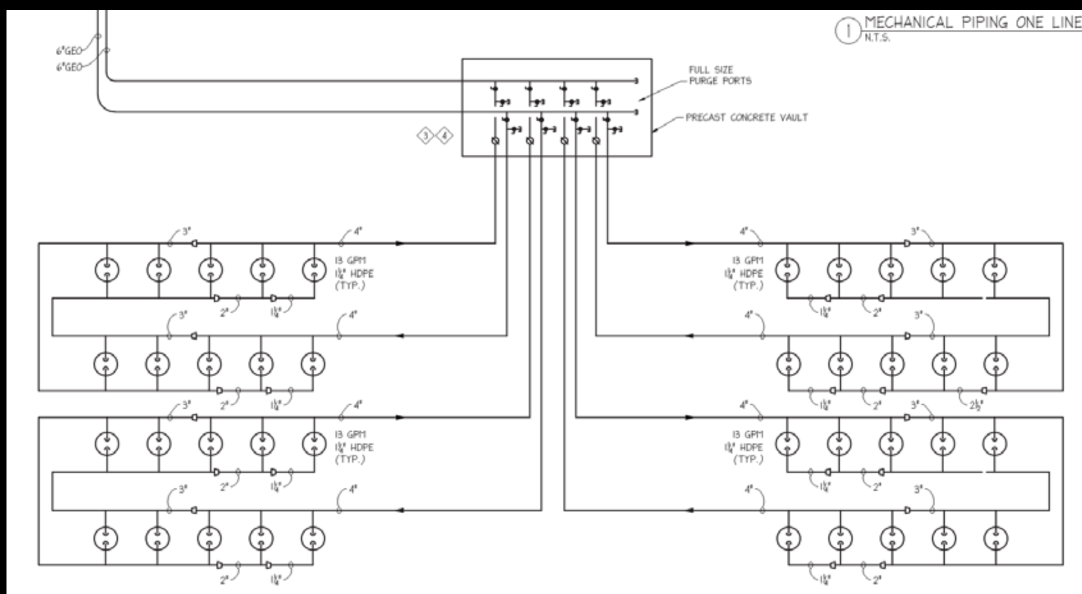
Ground Source Heat Pump System



Ground source heat pumps -- Summary

- – Water-to-air for building heat/cool
- – Water-to-air for ventilation post-heat/cool
- – Water-to-water make-up air heat/cool
- – Water-to-water + resistance for hot water

- Borehole heat exchanger size:
  20,000 LF (40 wells @ 500 ft.)



Energy Modeling and Optimizing Systems

4th Biggest Slice: Service Hot Water

Code Load

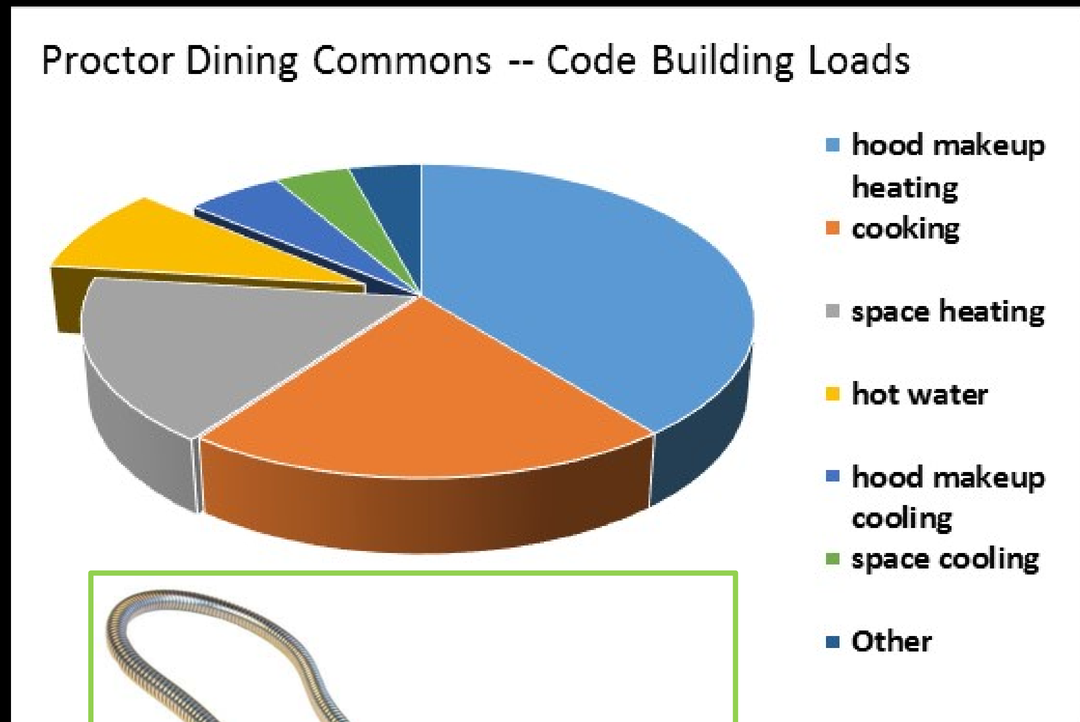
- 276 MMBtu/yr (80 MWh/yr)

Approaches:

- Conservation
- ***GSHP net COP of 2+***

NZR Annual Usage

- 38 MWh/yr



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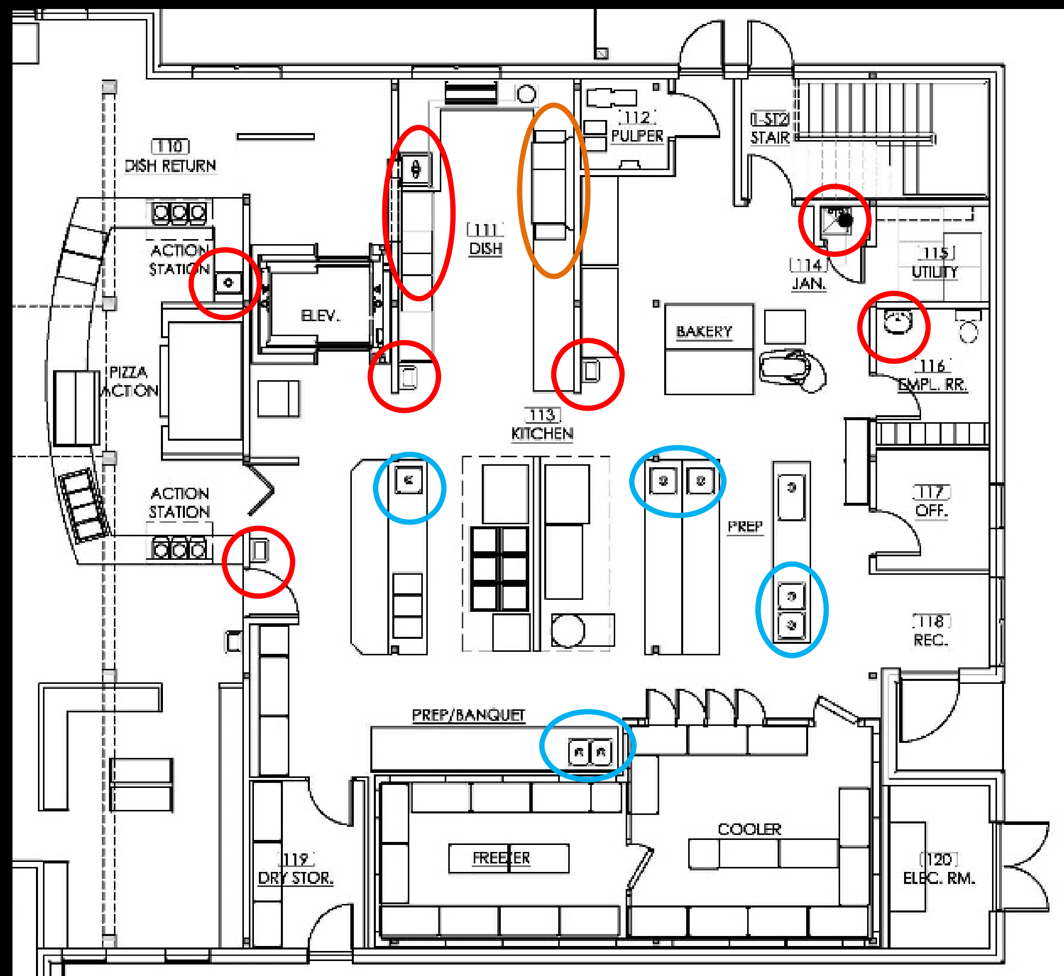
- Client Commitments and Goals
  - Energy and Environment
- Reduce hot water loads/needs
  - Dishwashing
    - Cold vs. Hot Wash
  - Handwashing and Food Prep
    - Efficient Flows/Min. Usage
    - Lower Water Temp



Ventilation

- Single energy recovery unit
- 6,500 CFM
- Water-source heat pump post conditioning with hot gas reheat (Aaon)
- Demand controlled
- Multi-zone
  - Demand controlled ERV assumed for both Code or Net Zero Ready

Modeling and Costing: Capital Costs

- Comparative cost analysis during Schematic Design for mechanical systems
- Option 1: Code v. Option 2: Net Zero Ready

Building Component	1. Code Compliant Building	2. Net Zero Ready building/GSHP	Added Cost
Windows	double glazed argon filled Marvin Ultimate Windows	triple glazed argon filled Marvin Ultimate Windows	
Air/Vapor Barrier	Infiltration is 0.2 CFM50/sf	Infiltration is 0.1 CFM50/sf	
Insulation	Walls: R-20 cavity insulation	Walls: R-40	
	Roof: R-49	Roof: R-60	
			$95,153
Kitchen	Convential Kitchen with fixed speed exhaust hood	All electric kitchen with variable speed heat recovery hood	$59,550
Commissioning	Envelope and Mechanical Systems	Envelope and Mechanical Systems	-
Solar Hot Water	None	Included	$60,000
HVAC	Water Source Heat Pump with propane boiler and cooling tower	Ground Source Heat Pump (GSHP)	$412,654
		Total Added Cost	**$630,000**
		Added Envelope Cost Per Square Foot	**$6**
		Total Added Cost Per Square Foot	**$42**
		Total Added Cost As A Percentage Of Total Construction Cost	**17%**

Source: Maclay Architects' File "BldgEnergyFinance"

Modeling and Costing: Capital Costs

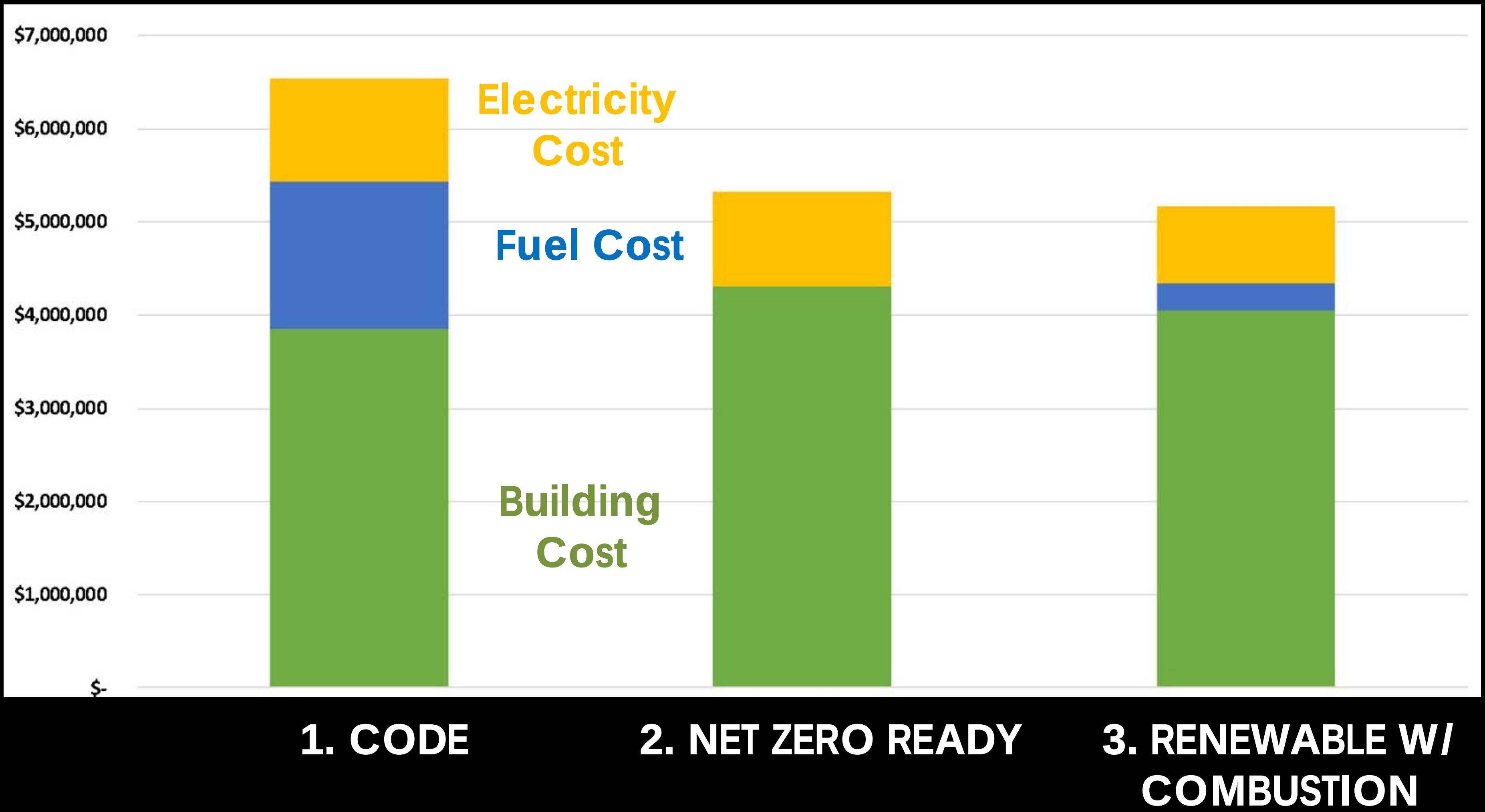
- Comparative cost analysis during Schematic Design for mechanical systems
- Option 1: Code v. Option 3: Renewable w/ combustion

Building Component	1. Code Compliant Building	3. Carbon Neutral Ready Building/ ASHP + Pellet Boiler	Added Cost
Windows	double glazed argon filled Marvin Ultimate Windows	triple glazed argon filled Marvin Ultimate Windows	
Air/Vapor Barrier	Infiltration is 0.2 CFM50/sf	Infiltration is 0.1 CFM50/sf	
Insulation	Walls: R-20 cavity insulation	Walls: R-40	
	Roof: R-49	Roof: R-60	
			$95,153
Kitchen	Convential Kitchen with fixed speed exhaust hood	All electric kitchen with variable speed heat recovery hood	$59,550
Commissioning	Envelope and Mechanical Systems	Envelope and Mechanical Systems	-
Solar Hot Water	None	Included	$60,000
HVAC	Water Source Heat Pump with propane boiler and cooling tower	Ground Source Heat Pump (GSHP)	$155,074
		Total Added Cost	**$370,000**
		Added Envelope Cost Per Square Foot	**$6**
		Total Added Cost Per Square Foot	**$24**
		Total Added Cost As A Percentage Of Total Construction Cost	**10%**

Source: Maclay Architects' File "BldgEnergyFinance"

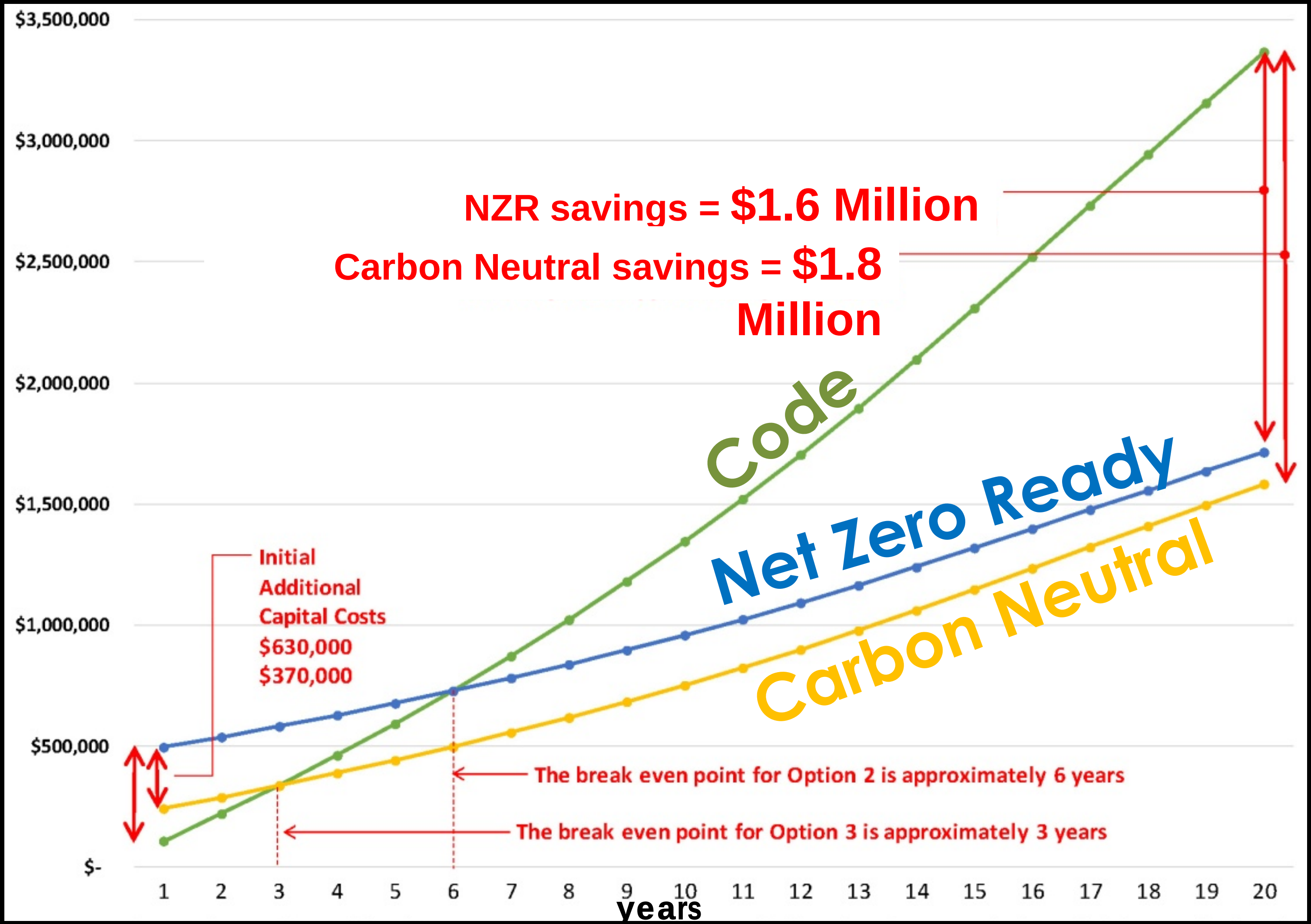
SD Modeling and Costing: Operating Costs

- 20-year construction and energy costs



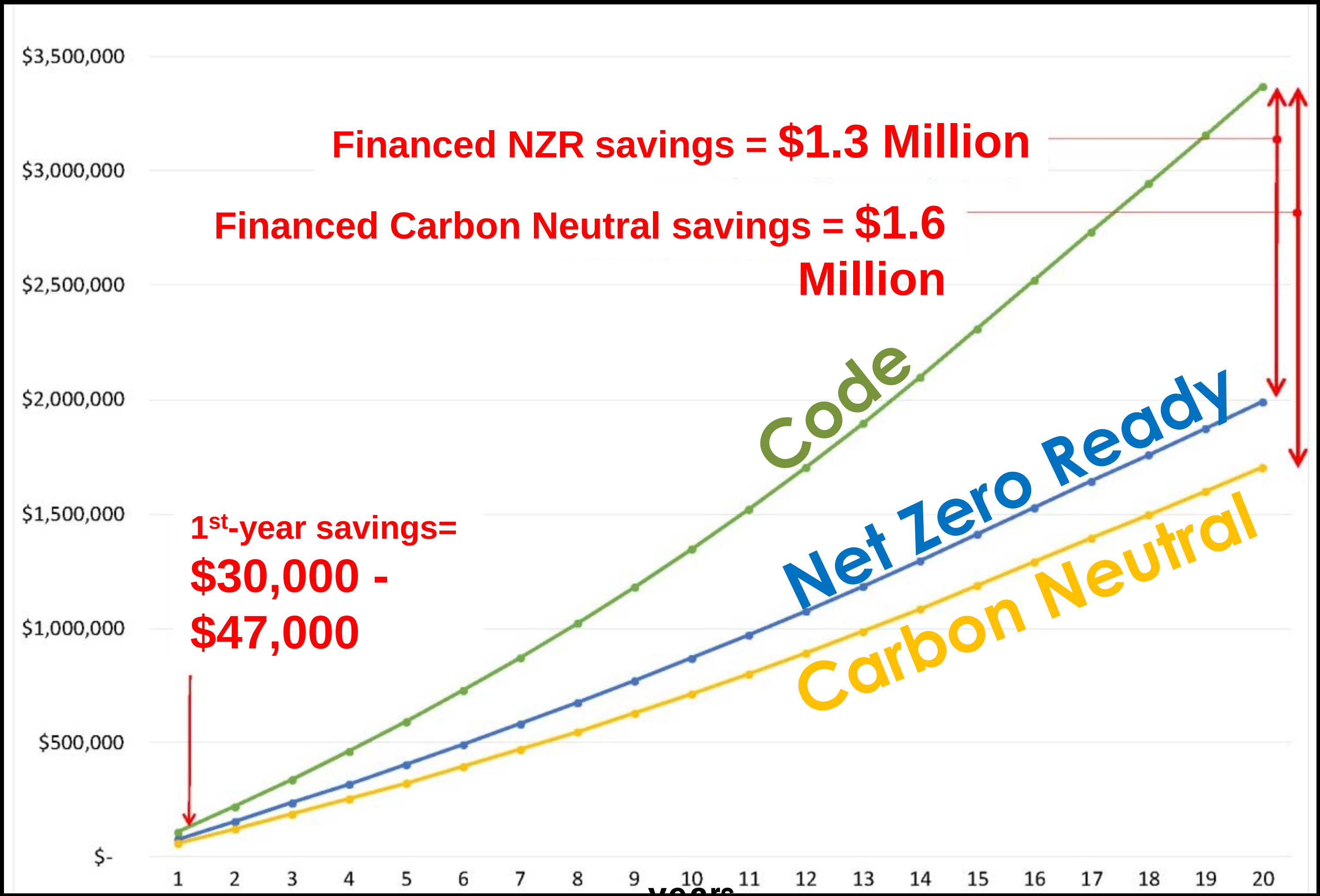
SD Modeling and Costing: Operating Costs

- Capital and cumulative energy costs

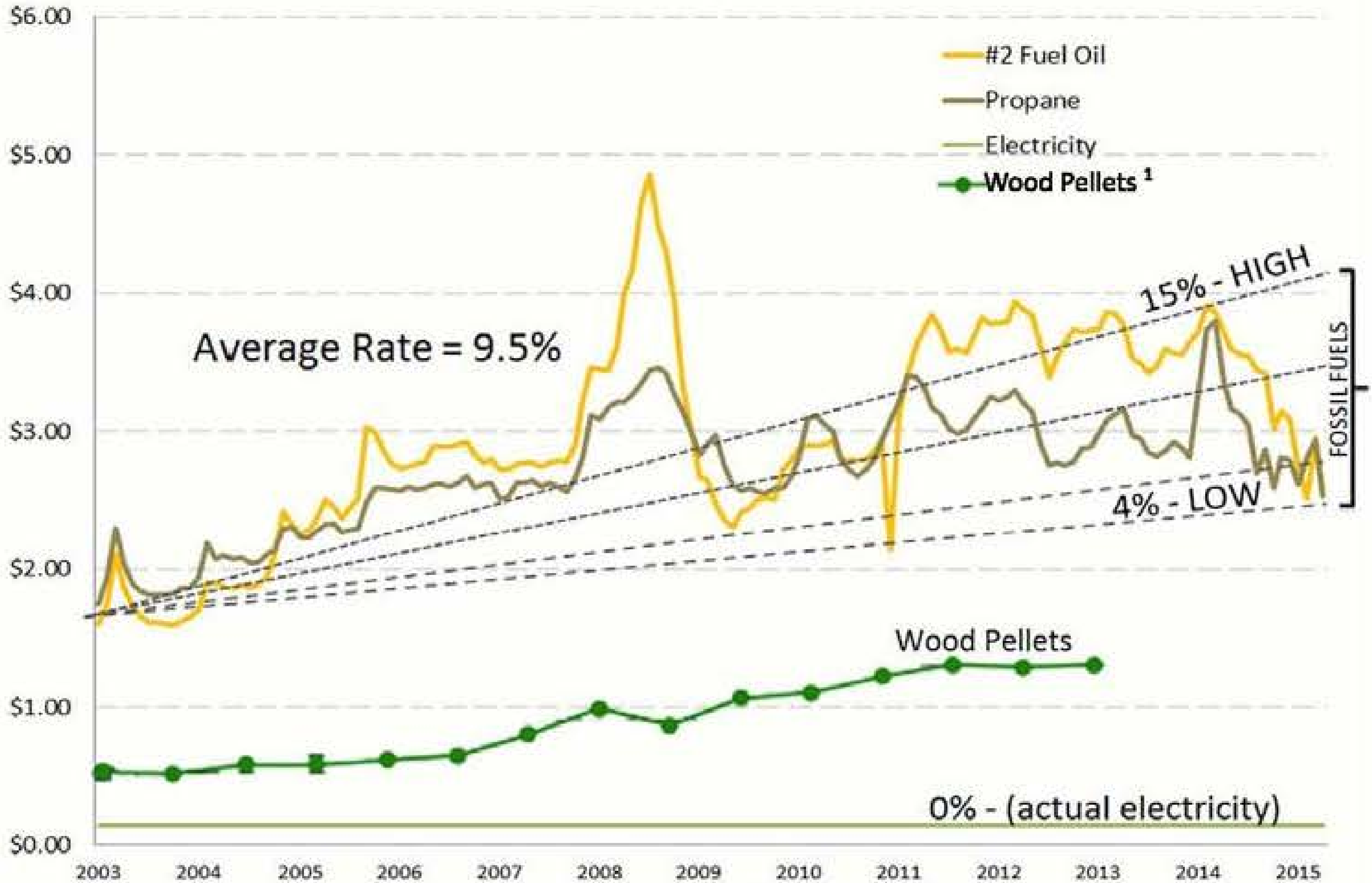


SD Modeling and Costing: Operating Costs

- Financed capital (5%/20 yrs) and cumulative energy costs



Vermont Fuel Price 2003-April 2015 *adjusted for inflation



Propane from 2003-2014 increased from $1.74/gal to $3.75/gal = 115% total or (11.5% / yr)
Propane from Feb 2013-Feb 2015 decreased from $3.08/gal to $2.84 = (-)7% total or -3.5% / yr
Fuel Oil #2 from 2003- 2014 increased from $1.60/ gal to $3.60/gal = 125% total or (12% / yr)
Fuel Oil #2 from Feb 2013-Feb 2015 decreased from $3.86/gal to $2.51/gal = (-)35% total or 17.5% / yr

Note: The Vermont FuelPrice Report is published monthly by the Vermont Department of Public Service. Prices are collected on or about the first Monday of each month and reflect dealer discounts for cash or self-service, except propane prices, which are an average of the credit and discount price. Propane prices are based on 1,000 + gallons. For more information please contact Mike Kundrath at (802) 828-4081 or by email at michael.kundrath@state.vt.us

Source: Maclay Architects' File "VT Fuel Summary"

1 Wood Pellet data source: www.nh.gov/oep/index.htm
All other Energy data from The Vermont Fuel Price Report

How to Get to Net Zero: Design Summary Report

- Transforming market demand for NZEB
- Replicable/reliable method for success

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XXXX Dining Hall
Energy Analysis Report for
Net-Zero and Carbon-Neutral Energy Options

June 4, 2014

SECTION 1.0 Executive Summary

The following four sections include the executive summary: recommendations, justifications, benefits and unique accomplishments.

SECTION 1.1 Recommendations

Based on our analysis, the Net-Zero Ready Energy option using the Ground Source Heat Pumps is the recommended approach for achieving net-zero consumption most efficiently and cost effectively. Both the Net-Zero Ready and Carbon Neutral Ready options offer reduced 20 year capital and operating costs as well as positive cash flow from year one when energy and potential financing costs are considered and analyzed against the code compliant base case.

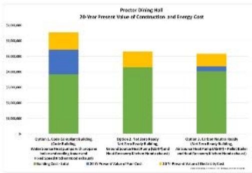
SECTION 1.2 Justifications

Based on the analysis included herein, the Net Zero Ready Energy option using the Ground Source Heat Pumps is recommended. Even though the Carbon Neutral Ready option appears to be a slightly better investment than the Net Zero Ready Energy (with an additional savings over 20 years of $200,000 without financing and $300,000 with financing), there are some additional considerations related to the on-going reliance on wood pellets that are difficult to quantify. Additionally, the inclusion of a combustible fuel source has environmental implications that must be considered, and the Carbon Neutral Ready Energy option contains a wood pellet system that has greater on-going operational and maintenance requirements in comparison to the Ground Source Heat Pump option. For these reasons, the Carbon Neutral Ready Energy option (Air Source Heat Pump with Wood Pellet Boiler system) is viewed as less desirable, and therefore this system is not recommended.

SECTION 1.3 Benefits

The Net Zero Ready Energy option achieves the following:

- 74% improved energy consumption per building area when compared to the Median Site EUI for Cafeterias and Restaurants
- An additional cost of approximately $6/SF for the improved envelope
- $1,600,000 in savings over the base case after twenty years of operation including capital and operating costs
- If financed, $30,000 of savings in the first year and approximately $1,300,000 of savings after 20 years, thus a positive cash flow from year one
- Annual reduced carbon dioxide emissions of 360,000 lbs, which is equivalent to the amount of carbon sequestered in 134 acres of US forests in one year or the carbon emitted by driving a passenger car 390,000 miles[1]



See Section 8.0 for the 20 year capital and operating cost graph

[1] The net annual energy use was used for the CO2 calculation from the Net Zero Ready Energy option above the base case. Greenhouse Gas Equivalencies Calculator used on the US EPA website: http://www.epa.gov/cleanenergy/energy-resources/calculator.html

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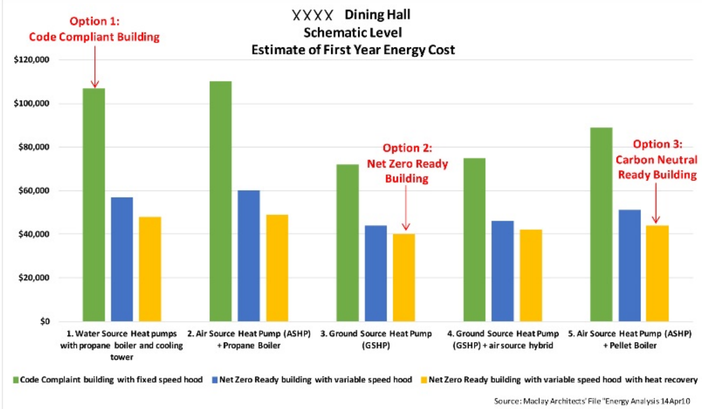
SECTION 4.0 Considered Systems and Options

To begin our process, multiple mechanical systems were considered related to XXXX's goals and priorities for the project, balanced with the programmatic and performance requirements of the new dining facility. Utilizing the existing central district biomass plant as a source of heat was reviewed as an option along with a number of other approaches. Based on existing conditions, existing infrastructure and required performance, the field of initial options was narrowed to 5 mechanical system strategies. These 5 strategies are shown below in the bar graph, each of which considers 3 different building enclosures and kitchen exhaust hood combinations related to the 5 mechanical systems. As this graph illustrates, estimates of First Year Energy Costs were considered relative to one another.



SECTION 5.0 Energy Usage Intensity Comparison

Commercial kitchens have sizeable equipment loads due to their cooking and dishwashing operations. Occupant loads are significant while also being concentrated within narrow windows of time at meals and events. Additionally, the extensive exhaust ventilation requirements of the kitchen increase the energy use and related operational expenses while also adding to the complexity of the mechanical systems.

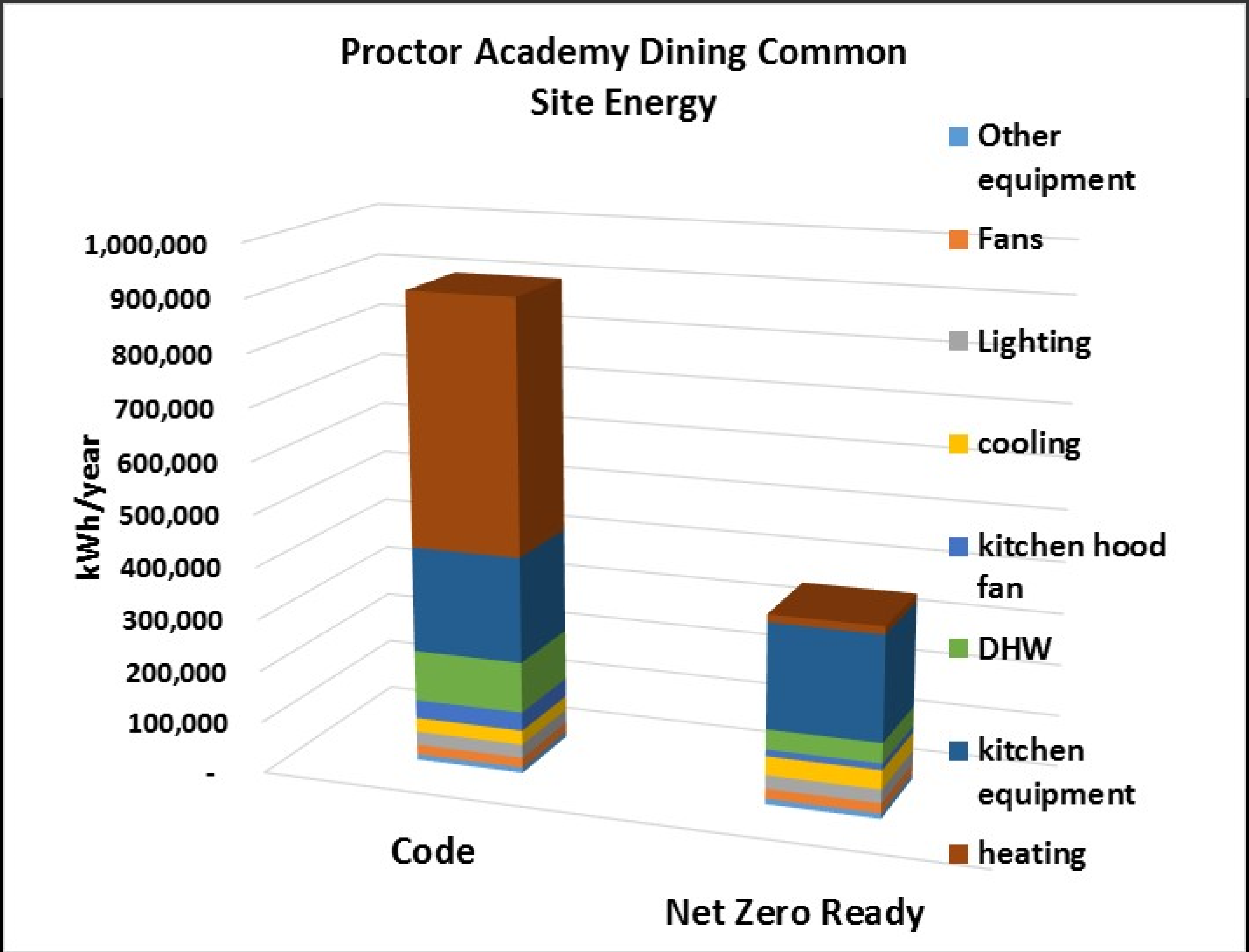
The following table summarizes the Energy Usage Intensity (EUI) [3] of each of the options.

Energy Usage Intensity Comparison

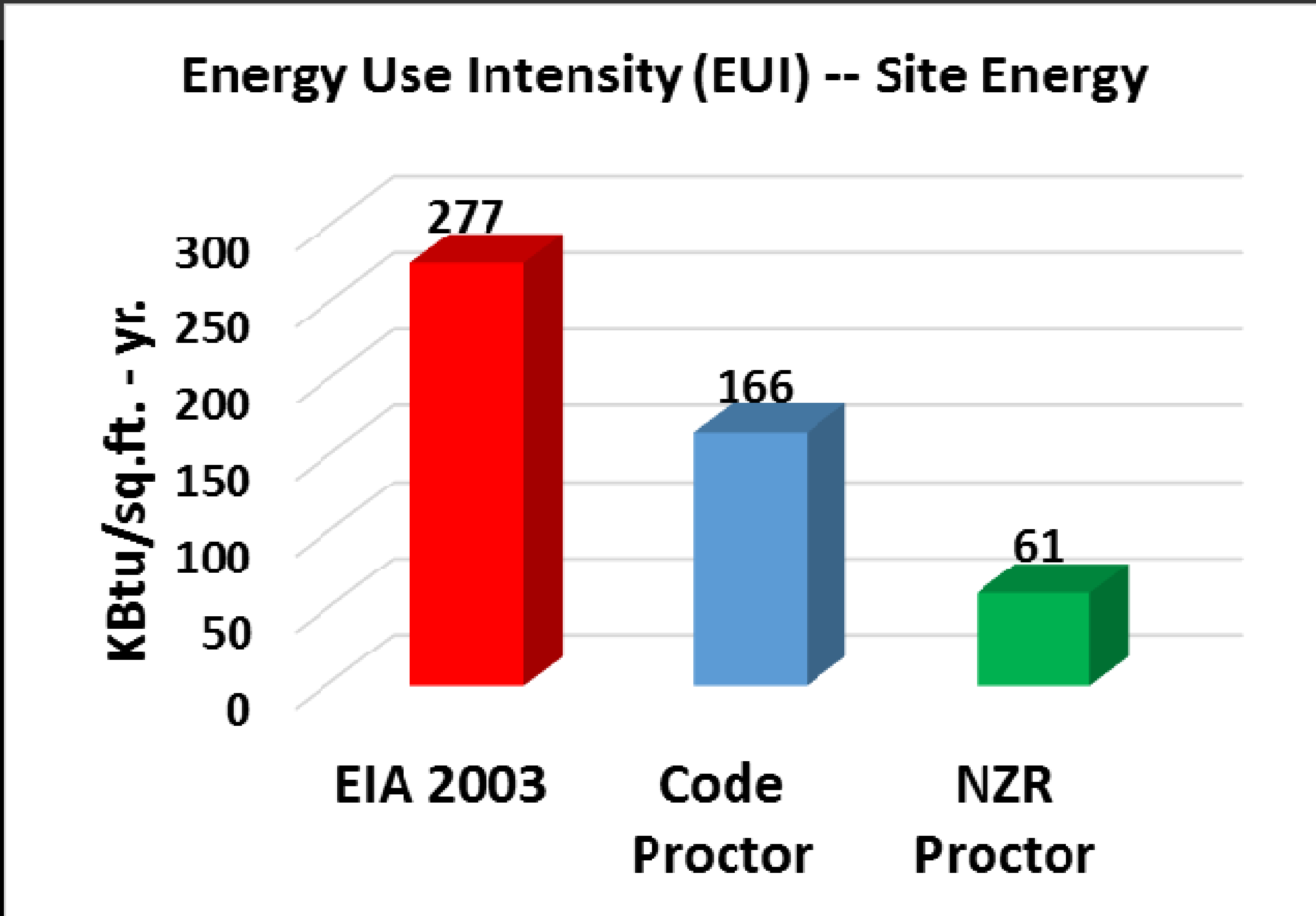
		OPTION 1	OPTION 2	OPTION 3	TYPICAL EXISTING Restaurant/ Cafeteria
Electricity	kBtu/yr	878,000	805,000	662,000	N/A
Heating	kBtu/yr	2,452,000	Included w/ Electricity	656,000	N/A
Total	kBtu/yr	3,330,000	805,000	1,318,000	N/A
EUI	kBtu/sf-yr	220	53	87	207
		Percent better than typical existing EUI:			
		-6%	74%	58%	

Source: Maclay Architects' File "BldgEnergyFinance"

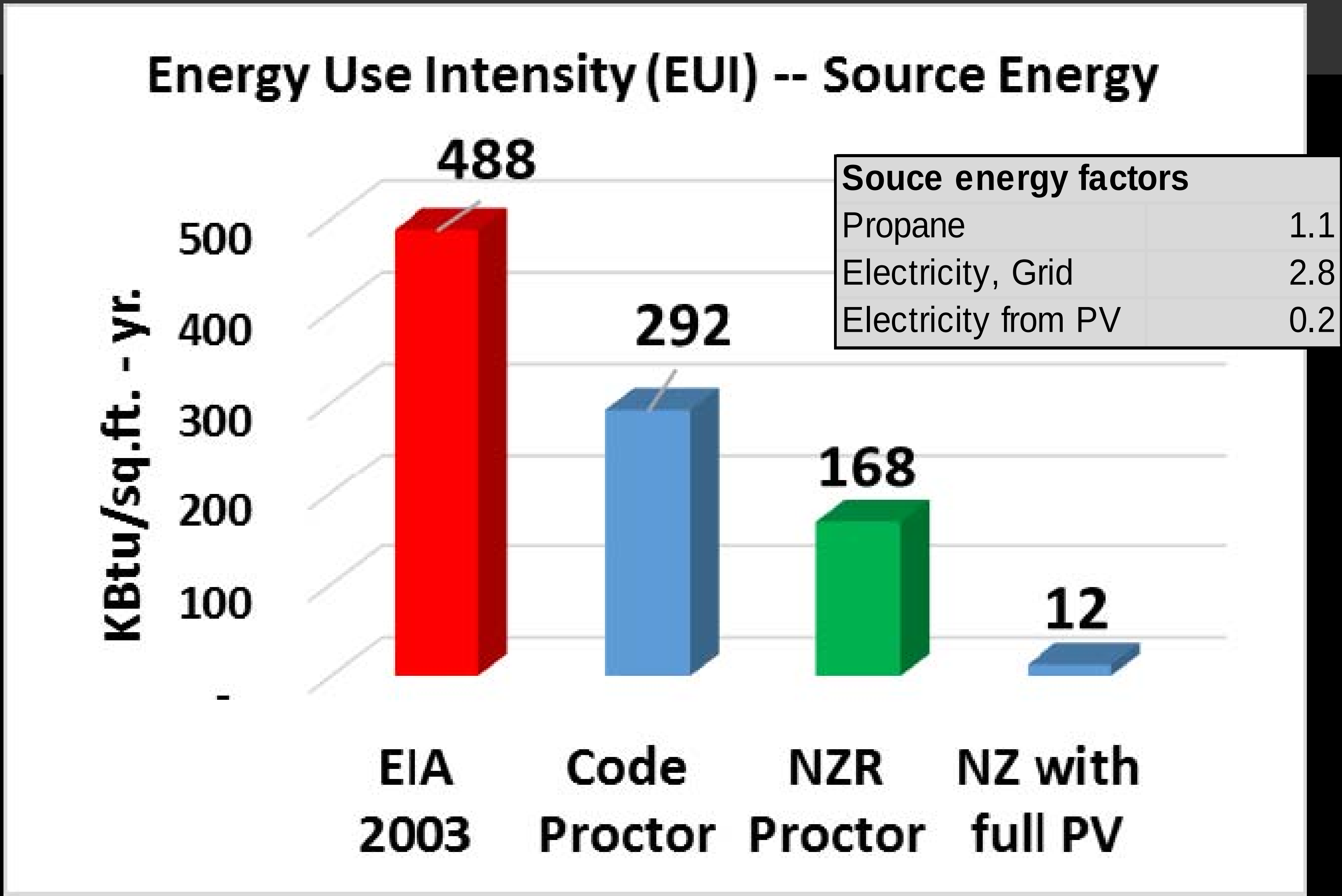
DD Energy Modeling and Optimizing Systems



DD Energy Modeling and Optimizing Systems



DD Energy Modeling and Optimizing Systems



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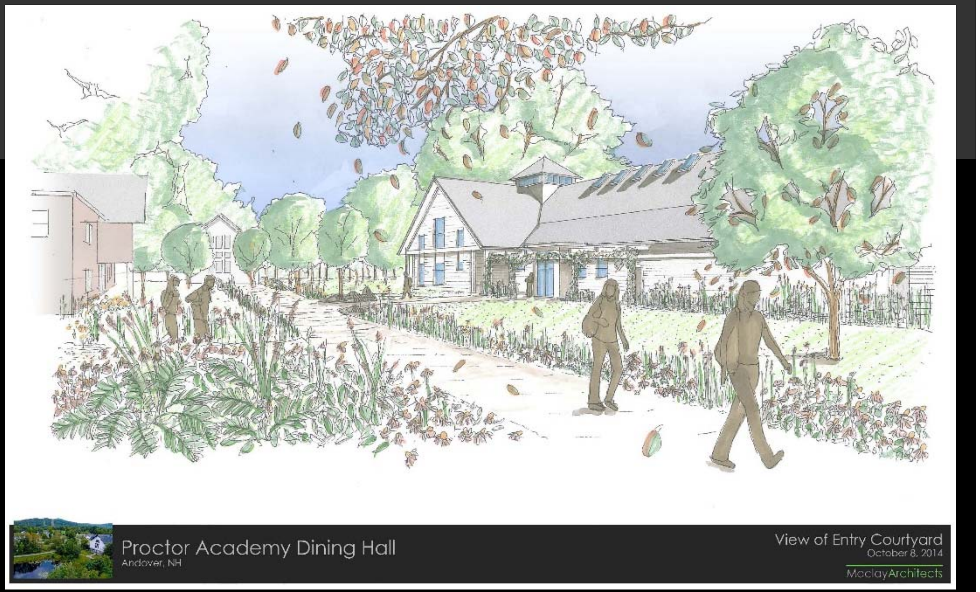
- Where are we now?

PROCTOR
Live to Learn. Learn to Live.

- Where are we now?

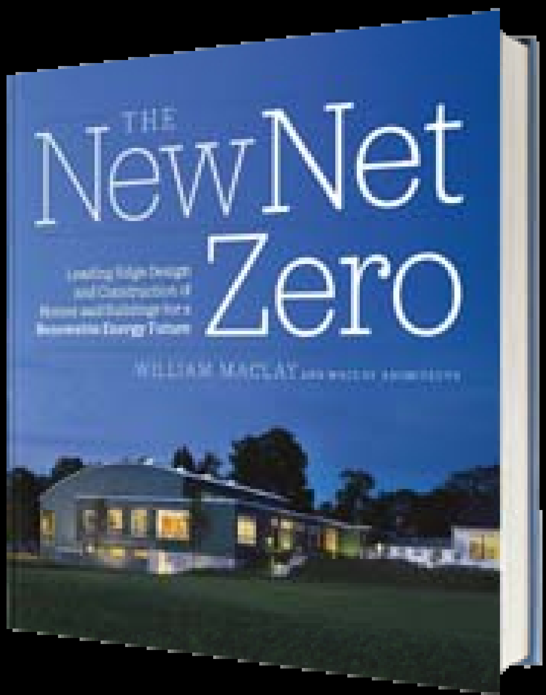
Next Steps

- Construction
- Testing and Commissioning
- Post Occupancy Monitoring
- Renewable energy on campus
  - ~275 kW PV system needed
  - ~300 kW with Pizza oven
  - ~250 kW in process



THANK YOU!

QUESTIONS?



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