TRANSFORMATION OF AN ICONIC 1884 SCHOOLHOUSE INTO NET-ZERO READY MUNICIPAL OFFICES

HARTFORD MUNICIPAL BUILDING
WHITE RIVER JUNCTION, VT

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TOWN OF
HARTFORD
EST. 1761
MUNICIPAL BUILDING
Serving the Villages of
HARTFORD · WEST HARTFORD
WHITE RIVER JUNCTION
WILDER · QUECHEE
Hartford Town Hall
Renovation
ARCHITECT / BUILDER:
CIVIL ENGINEER:
STRUCTURAL ENGINEER:
MECHANICAL ENGINEER:
ELECTRICAL ENGINEER:
ENERGY CONSULTANT:
We would like to thank the taxpayers of Hartford for funding this project!

LEARNING OBJECTIVES

- Challenges of Net-Zero ready on municipal budget
- Historic Considerations
- The Building Envelope
- Mechanical Systems

INTEGRATED DESIGN TEAM

Architect/Builder:
Bread Loaf Corporation

Civil Engineer:
Otter Creek Engineering, Inc.

Structural Engineer:
Engineering Ventures, Inc.

Mechanical Design/Build Engineer:
Vermont Heating and Ventilating

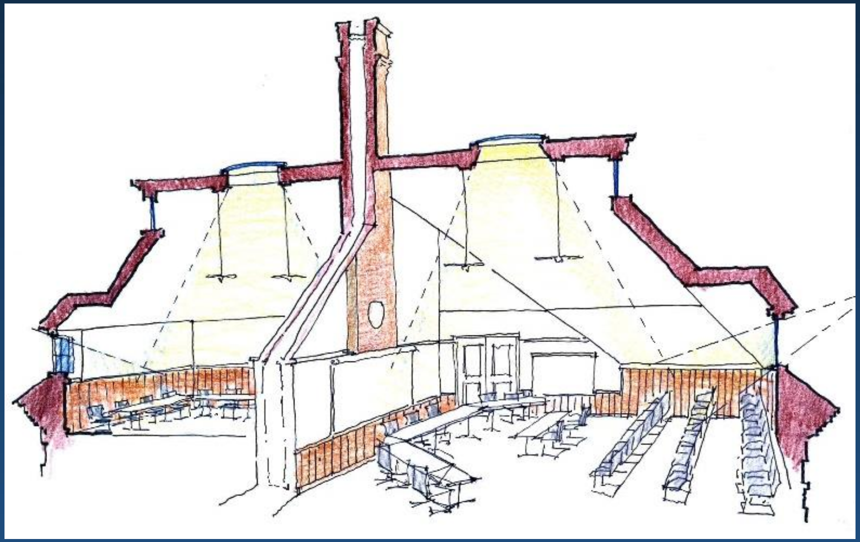
Electrical Design/Build Engineer :
Cole Electric, Inc.

Fire Protection Design/Build Engineer :
John L. Carter Sprinkler Company, Inc.

Energy Consultant:
Energy Balance, Inc.

Building Envelope Commissioning Agent:
Zero by Degrees

Flood Engineering:
Headwaters Hydrology



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WHAT IS “NET-ZERO READY” vs NET-ZERO?

Efficiency Vermont Net Zero Energy Building (NZEB) Requirements

- ENERGY EFFICIENCY
  Design and operate building to use no more than 50% of the site energy of a building built to meet 2011 VT CBES before site-produced renewables are counted

- ENERGY CHARRETTE
  Conduct a meeting that presents the challenges and possible solutions to achieving a Net-Zero building.

- ENERGY SIMULATION
  Complete a whole-building energy simulation in accordance with ASHRAE 90.1-2010 with baseline model adjusted to the 2011 VT CBES.

WHAT IS "NET-ZERO READY" vs NET-ZERO?

- ENERGY MONITORING
  Incorporate measurement devices for each energy supply source to the building, including electric and fuel, each on-site renewable energy production system and each major building electric system.

- COMMISSIONING
  Throughout the design and construction phase, as well as first year of operation, complete building commissioning including acceptance testing for mechanical systems, domestic hot water, lighting, renewable-energy, building envelope and building measurement devices.

- RENEWABLE ENERGY GENERATION
  The building will be designed, and achieve, over a one-year period, performance as a net zero site energy building. Renewable energy sources available off-site used to generate energy through on-site processes may be use.

In summary, approximate net additional cost to be in compliance with NZEB program is $51,500.

Client preferred to spend all of budget on building upgrades.

WHY RENOVATE AN ICONIC BUILDING TO NET-ZERO READY?

- *Existing buildings have significant embodied energy.*
- *Connection to the past, saving our enduring structures. A source of civic pride.*
- *A demonstration of how our buildings need to adapt over time.*
- *Many similar structures exist throughout Vermont and New England*

"PRESERVING VERMONT'S HISTORY LEAVES A NEVER-ENDING LEGACY FOR ALL FUTURE GENERATIONS…..VISION AND DEDICATION CAN MAKE A POSITIVE IMPACT IN PRESERVING OUR VALUABLE HISTORICAL INHERITANCE." - Gov. Jim Douglas

"IF YOU DON'T PRESERVE OLD BUILDINGS, YOU TEND TO LOSE A PIECE OF WHAT MAKES YOUR COMMUNITY SPECIAL. AS PEOPLE LOSE MORE AND MORE OF THE SPECIALNESS, THEY TEND TO STOP CARING …AND IT LOOKS LIKE ANY OLD PLACE."
- Alex Aldrich, Executive Director, Vermont Arts Council

BUILDING HISTORY

1884 – Built as an Elementary & High School

1895 – South end of building constructed

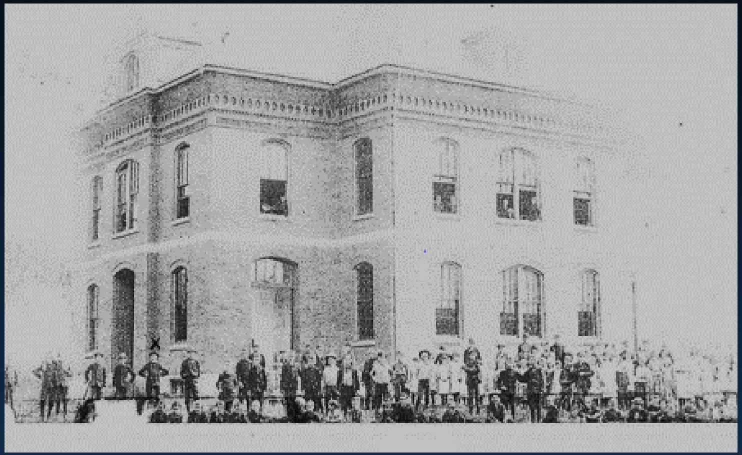
1907 – High School students removed from building

1927 & 1936 – Major Flooding

1952 – All students removed from building

1956 – Building converted into Municipal Offices

1960 – Entry porches and west dormers removed



CIRCA 1885

CIRCA 1936

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BUILDING HISTORY

CIRCA 1896

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BUILDING HISTORY

CIRCA 1936 (FLOOD)

BUILDING HISTORY

CIRCA 1961

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EXISTING CONDITIONS

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EXISTING CONDITIONS

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EXISTING CONDITIONS

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EXISTING CONDITIONS

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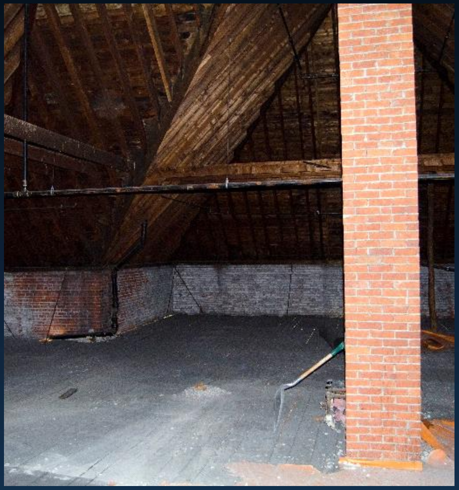

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EXISTING CONDITIONS – STRUCTURAL STABILIZATION

- DEMO PRIMARY INTERIOR BEARING WALLS AND REPLACE WITH NEW STEEL STRUCTURE
- REINFORCE EXISTING FIRST AND SECOND FLOOR FRAMING MEMBERS
- REINFORCE EXISTING ROOF FRAMING
- REINFORCE EXISTING CHIMNEYS

EXISTING CHIMNEY REINFORCEMENT

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EXISTING CONDITIONS – STRUCTURAL STABILIZATION

STRUCTURAL REINFORCEMENT MUST BE CONSIDERED DURING EARLY ESTIMATING WHEN RENOVATING OLDER, WOOD-FRAMED BUILDINGS. IT CAN BECOME A SIGNIFICANT PART OF THE OVERALL PROJECT BUDGET.

$$$$$

EXISTING CHIMNEY REINFORCEMENT

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EXISTING CONDITIONS – STRUCTURAL STABILIZATION

EXSTG FLOOR JOIST SUPPORT w/ (2) 3-PLY 18" DEEP LVL BEAMS

NEW 8-PLY 21" DEEP LVL BEAM @ PRIMARY BEARING WALL

EXISTING CONDITIONS – STRUCTURAL STABILIZATION

4-PLY 18” DEEP LVL HIP & VALLEY REINFORCING

6x6 DOUGLAS FIR REINFORCING @ CHIMNEYS

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EXISTING CONDITIONS – STRUCTURAL STABILIZATION

4-PLY 18" DEEP LVL HIP & VALLEY REINFORCING

EXISTING CONDITIONS

FIRST FLOOR PLAN

N

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EXISTING CONDITIONS

SECOND FLOOR PLAN N

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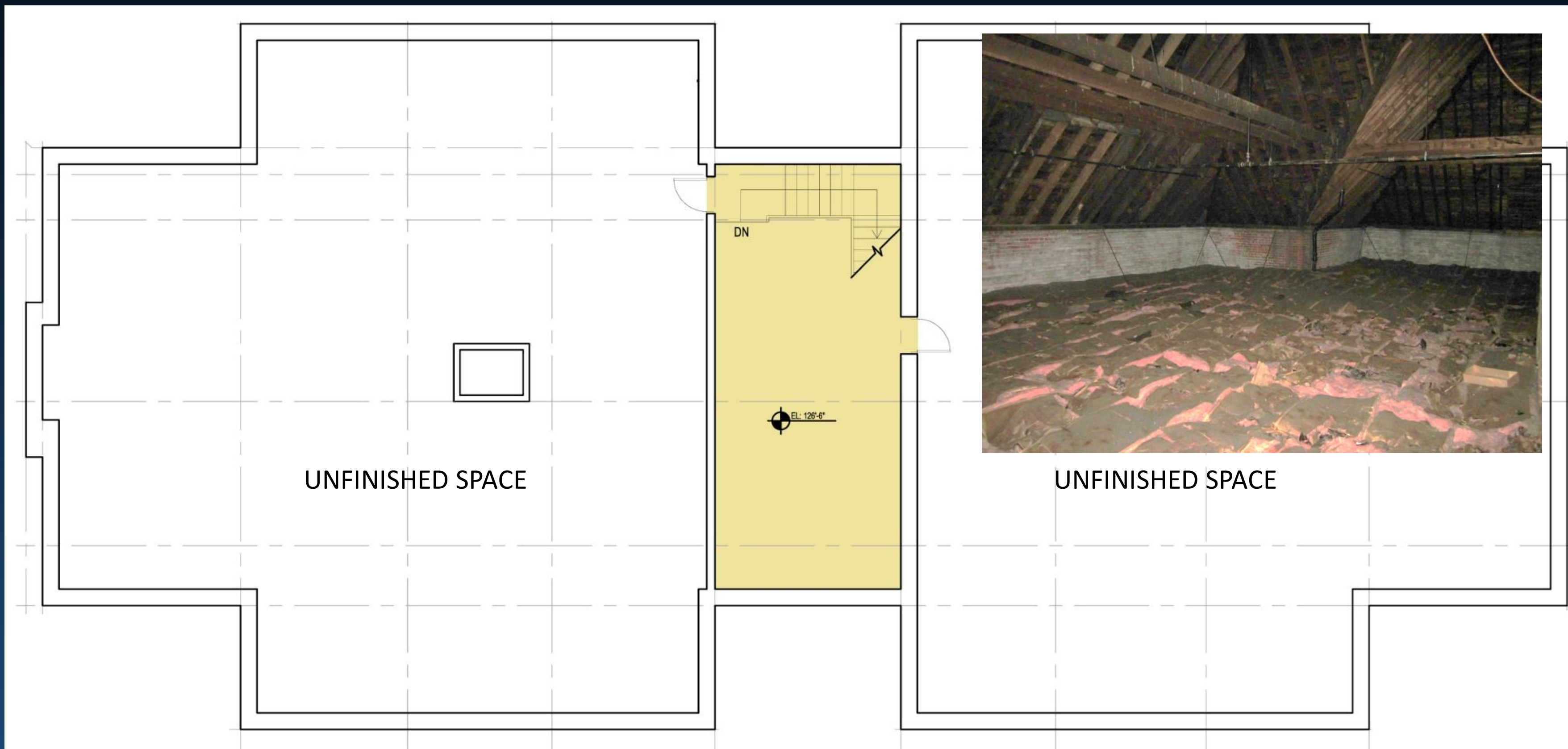
EXISTING CONDITIONS



THIRD FLOOR PLAN N

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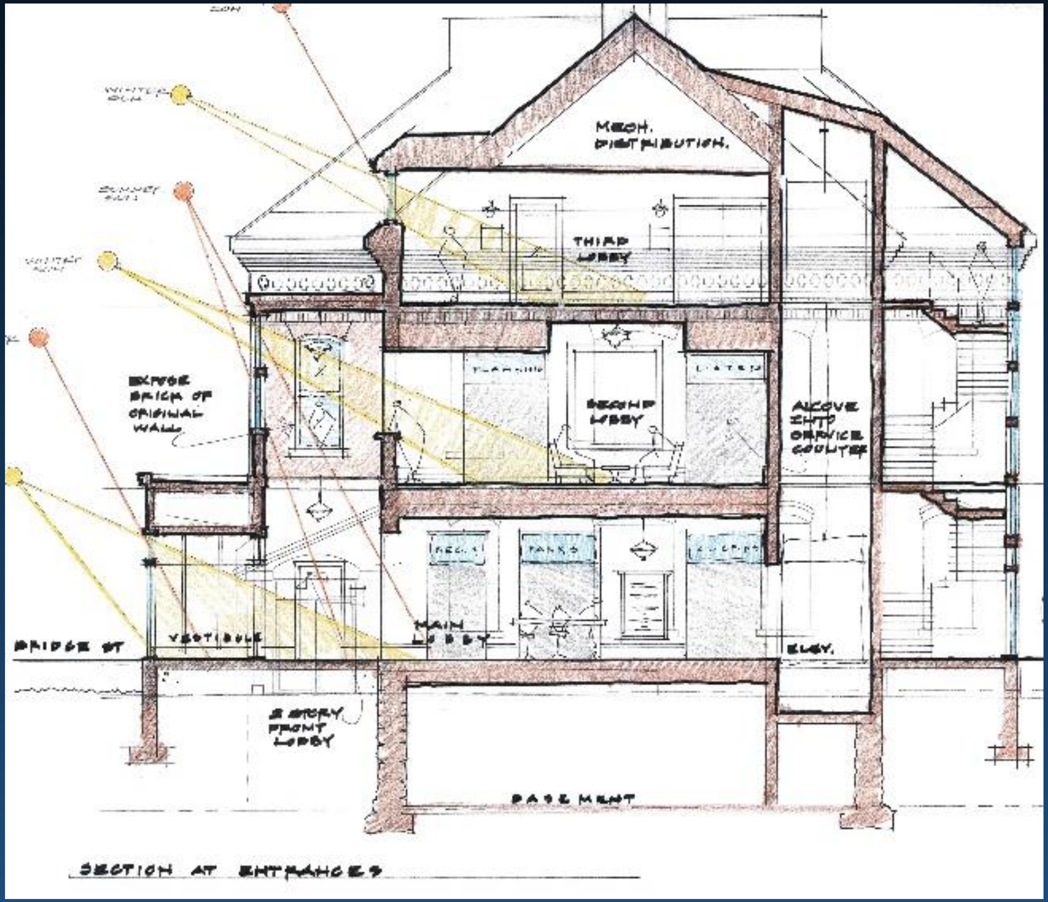
INITIAL DESIGN IDEAS – COST CONSIDERATIONS

Pre-Approved total bond $4.95 million

- *Construction Cost $4.32 million*
- *Approx. $226/SF*
- *19,065 SF First, Second, and Third Floors*
- *Does not include basement SF*

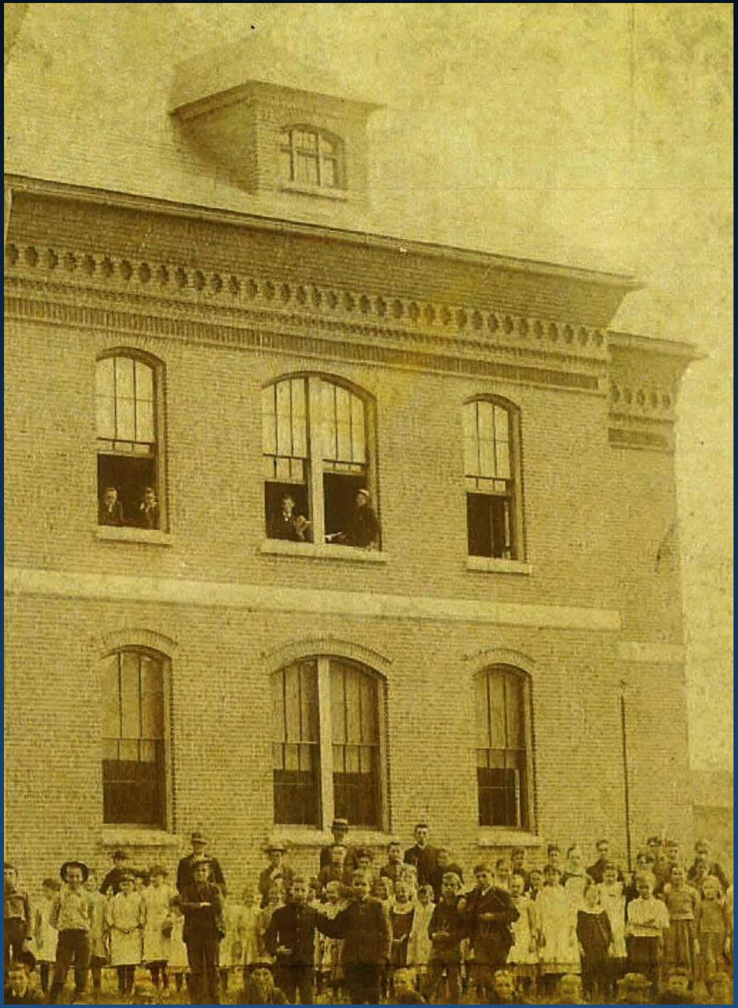


INITIAL DESIGN IDEAS – GUIDING PRINCIPLES

Building:
- Architectural restoration and repair
- Air-tight and well insulated envelope
- Durable, quality materials
- Restoring civic pride

Systems:
- Energy efficient and reliable
- Easy to zone and operate
- Comfortable for the staff
- Forward thinking (new technologies)

Net Zero Ready



INITIAL DESIGN IDEAS - SITE

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INITIAL DESIGN IDEAS - SITE

Property = 3.3 acres
(Including Lyman Park)

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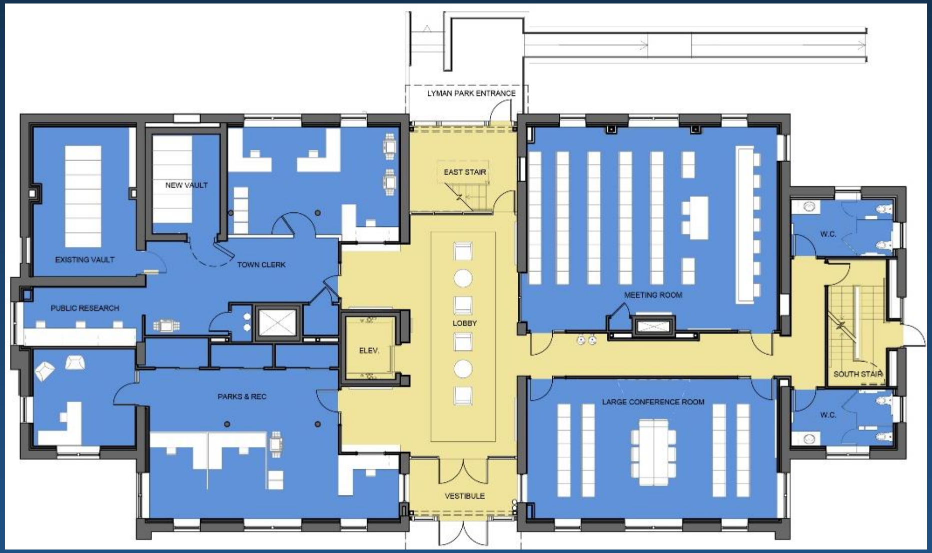
INITIAL DESIGN IDEAS – PLAN ORGANIZATION

EXISTING



NEW

- SIMPLE BUILDING OREINTATION
- ACCESS TO VIEWS / DAYLIGHT
- VISUALLY TRANSPARENT

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INITIAL DESIGN IDEAS – FLOOR PLANS

FIRST FLOOR PLAN

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INITIAL DESIGN IDEAS – FLOOR PLANS

SECOND FLOOR PLAN N

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INITIAL DESIGN IDEAS – FLOOR PLANS

THIRD FLOOR PLAN N

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INITIAL DESIGN IDEAS – BUILDING TRANSPARENCY

SECTION @ NEW CENTER LOBBIES

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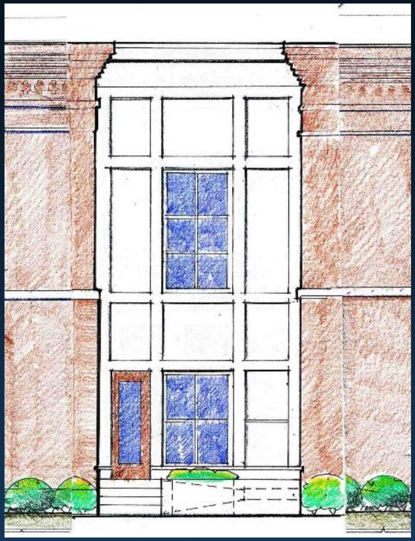
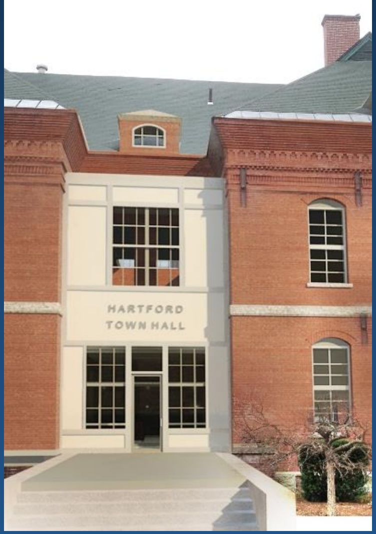
INITIAL DESIGN IDEAS – BUILDING TRANSPARENCY





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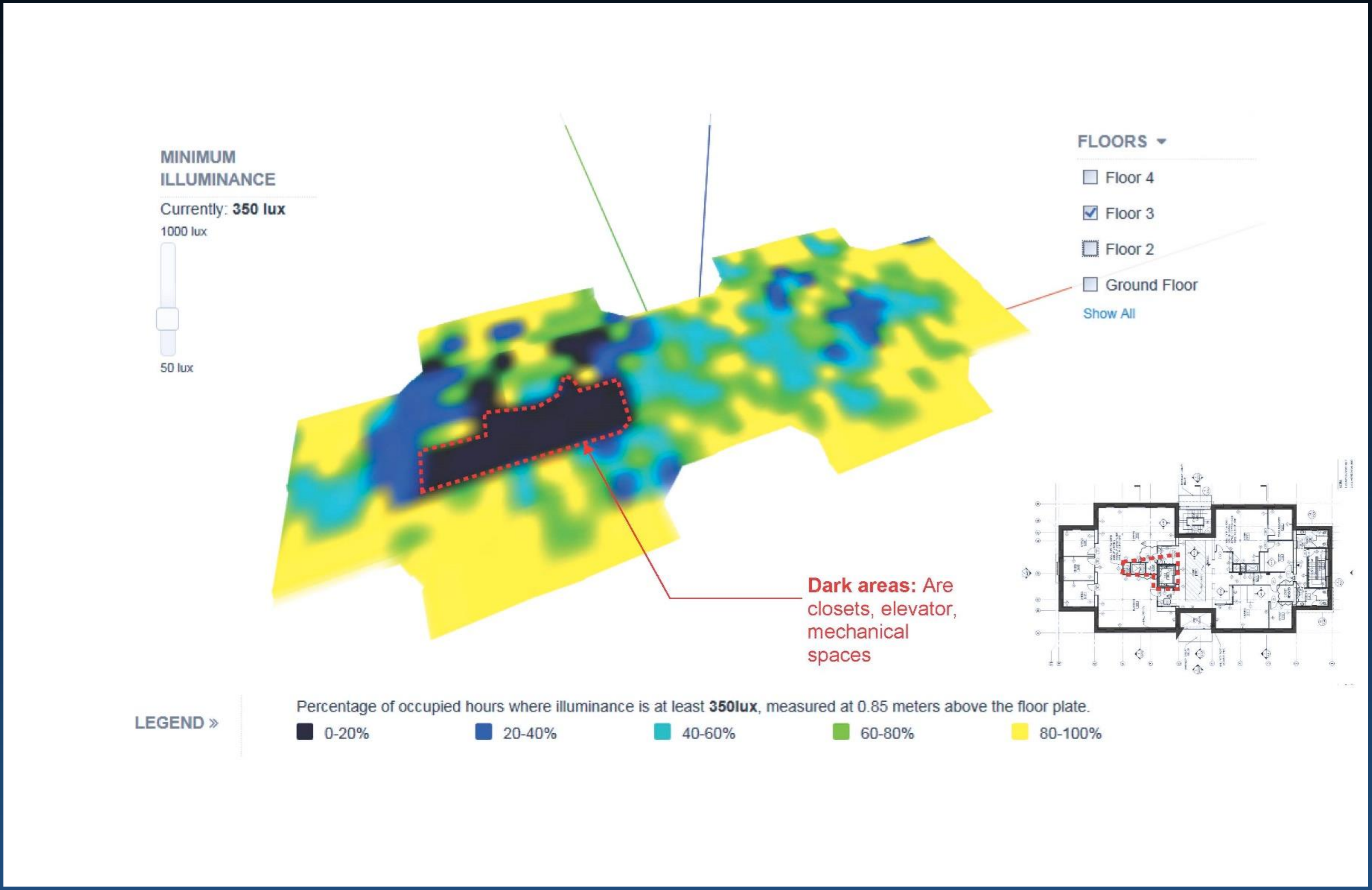
INITIAL DESIGN IDEAS – BUILDING TRANSPARENCY

INITIAL DESIGN IDEAS – DAYLIGHTING ANALYSIS



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INITIAL DESIGN IDEAS – BUILDING TRANSPARENCY

FIRST FLOOR LOBBY

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INITIAL DESIGN IDEAS – NATURAL LIGHTING

FIRST FLOOR MEETING ROOM

INITIAL DESIGN IDEAS – HISTORIC CONSIDERATIONS

- Replicate historic dormers
- New center entrance with opportunity for added glass to bring daylight into the public lobby area
- Install full height arch-top windows
- Clean existing brick veneer and granite belt course

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INITIAL DESIGN IDEAS – HISTORIC CONSIDERATIONS

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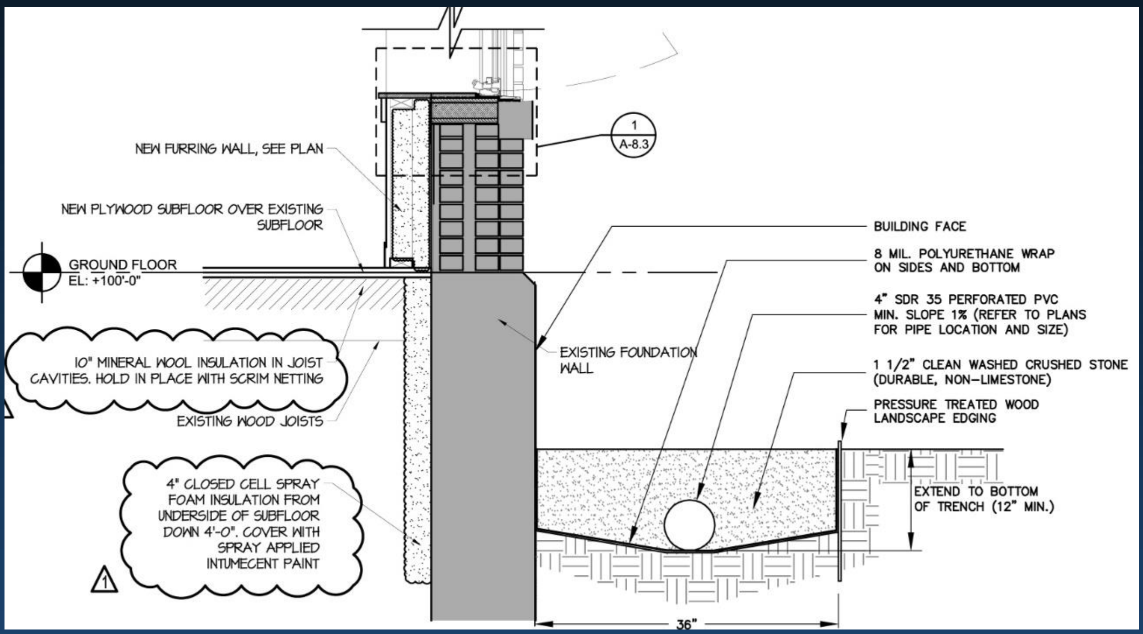
WATER MANAGEMENT

- Remove brick infill panels at grade and replace with granite panels or flood vents
- Re-grade where possible to pitch away from foundation
- Add 36” wide stone drip edge connected to an underdrain system

WATER MANAGEMENT



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WATER MANAGEMENT

BUILDING ENVELOPE – EVALUTAING/INSPECTING EXISTING BRICK

Insulation of Structural Masonry -- Process for evaluation

1. *Inspect existing conditions*
2. *Decide if brick testing is needed*
3. *Decide if wall moisture modeling analysis would be useful*
4. *If 1-3 all a go, how to insulate?*

BUILDING ENVELOPE – EVALUTAING/INSPECTING EXISTING BRICK

Inspect existing conditions

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BUILDING ENVELOPE – EVALUTAING/INSPECTING EXISTING BRICK

Inspect existing conditions

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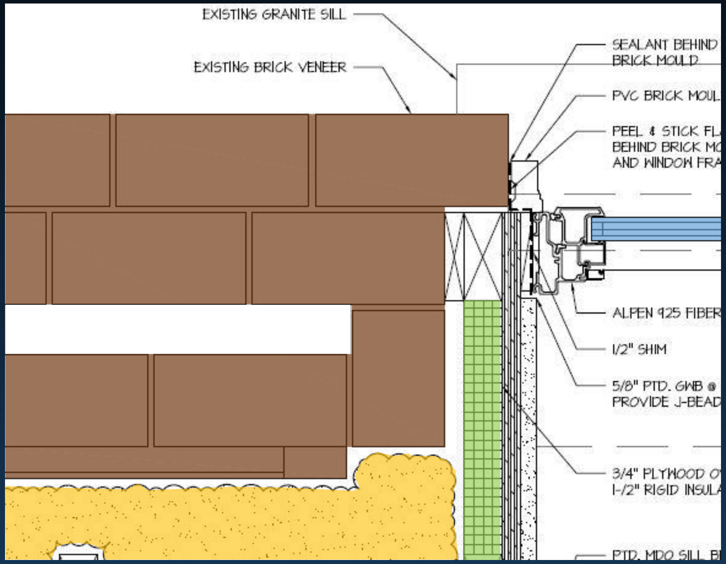
BUILDING ENVELOPE – EVALUTAING/INSPECTING EXISTING BRICK



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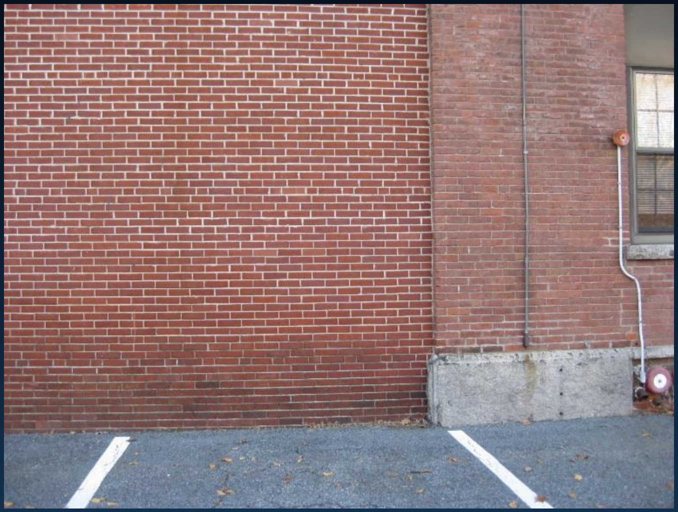
BUILDING ENVELOPE – EVALUTAING/INSPECTING EXISTING BRICK

Summary of existing conditions

1. *Brick up off the ground except one area*
2. *Brick near ground is recent addition, but in area that is to be removed*
3. *Brick condition mostly good -- hard brick with a few soft bricks*
4. *Air space between inside wythe and next wythe in wall*
5. *Many locations inside have plaster on brick with many layers of paint*
6. *Brick outside vault quite wet, but due to bad roof to be repaired*
7. *No signs of freeze/thaw spalling*



BUILDING ENVELOPE – EVALUTAING/INSPECTING EXISTING BRICK

Conclusions

Several factors lead to not decision that insulating will not significantly effect durability of the wall and that testing brick and moisture modeling are not needed

1. *Brick in good condition and of good quality – soft bricks to be replaced, so no need for brick testing*
2. *Brick is high enough up off the ground to reduce splash, and drained, crushed stone drip line to reduce further*
3. *Air space in wall helps with moisture balance in the walls*
4. *Air space in walls now connected to the outside, so outer wythes already experiencing a lot of freezing*
5. *Air space in walls and large patches of vapor impermeable inside paint would confound modeling -- modeling not useful here*

BUILDING ENVELOPE – EVALUTAING/INSPECTING EXISTING BRICK

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SO INSULATION IS A GO!

BUILDING ENVELOPE – EXISTING BRICK VENEER PROTECTION

- Repoint brick with appropriate mortar where needed
- Replace soft brick, especially within 48” of grade
- Add 36” wide drip edge to minimize splash back of water on to brick veneer
- Remove brick that is at grade and replace with granite panels or with flood vent.
- Remove one-story roof areas to eliminate splash onto the bricks in these areas

HOW TO INSULATE WALLS??

OPTIONS

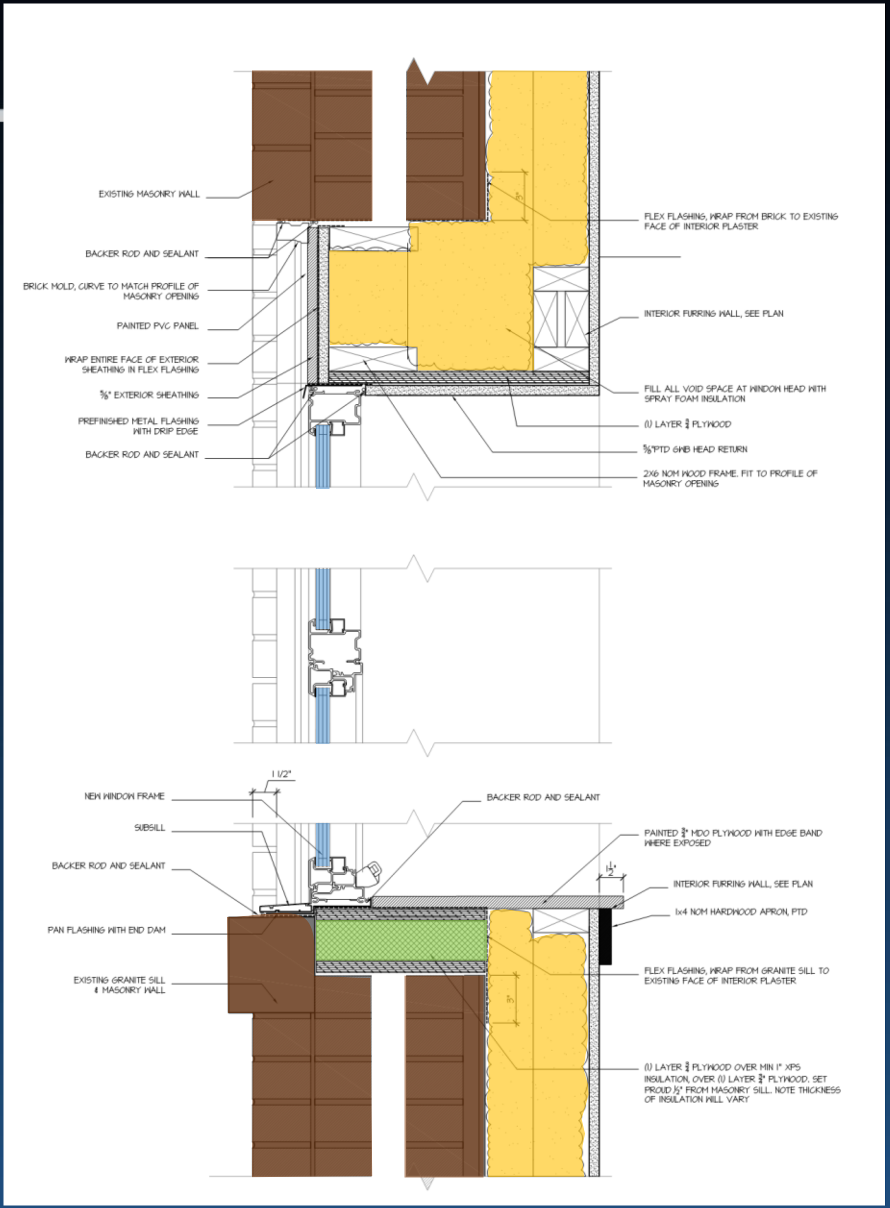
- *Closed cell spray foam*
- *Vapor managed cellulose*

Note: looking for ~R40 walls for low load, resilient structure

HOW TO INSULATE WALLS??

Closed cell spray foam system

- Wood studs with inside face ~6" inside brick
- 6" closed cell spray foam ~ half continuous
- Gypsum board



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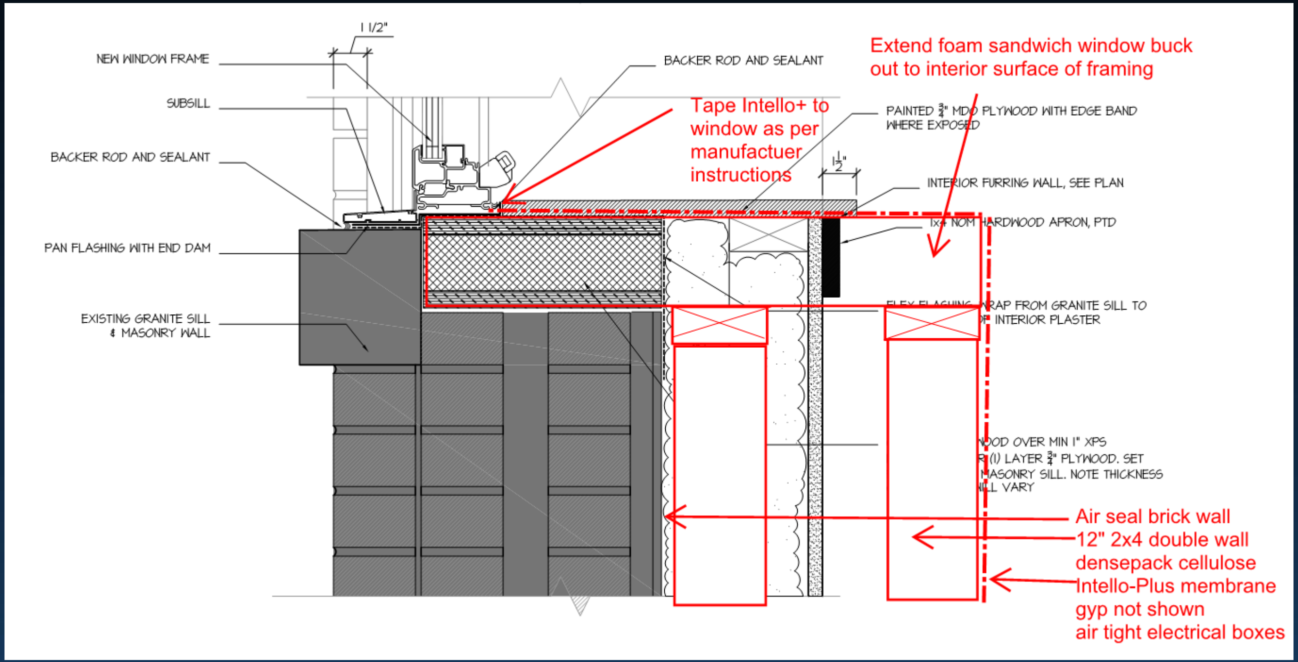
HOW TO INSULATE WALLS??



Cellulose system

- *Air seal inside of brick*
- *Double wood studs with inside face ~12" inside brick*
- *12" damp spray or dense-pack cellulose*
- *Intello Plus membrane,*
- *CAREFULLY air sealed, including electrical boxes*
- *Gypsum board*

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HOW TO COMPARE TWO INSULATION OPTIONS??

Spray foam

Pro's

- *Vapor impermeable*
- *Some of wall already impermeable*
- *Thinner wall*
- *Air seal and insulation in one operation*
- *Lower cost*

Con's

- *120 tons CO2-equivalent Global warming potential, so use 0 GWP product*
- *Not reversible for historic*

Cellulose

Pro's

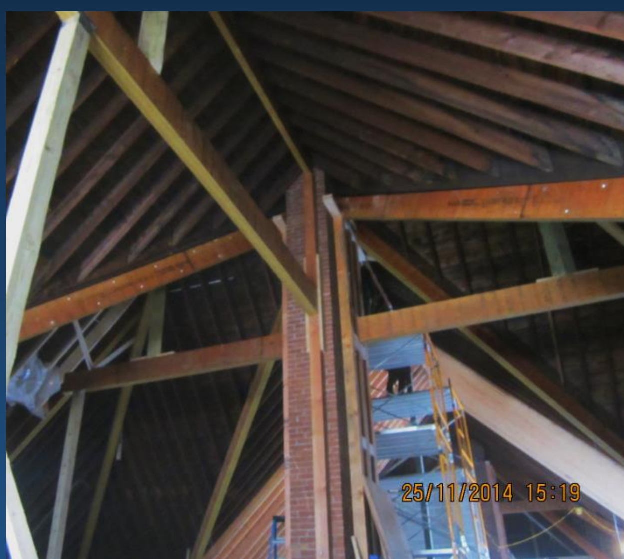
- *Vapor permeable*
- *Reversible for historic*
- *Zero GWP*
- *Recycled material*

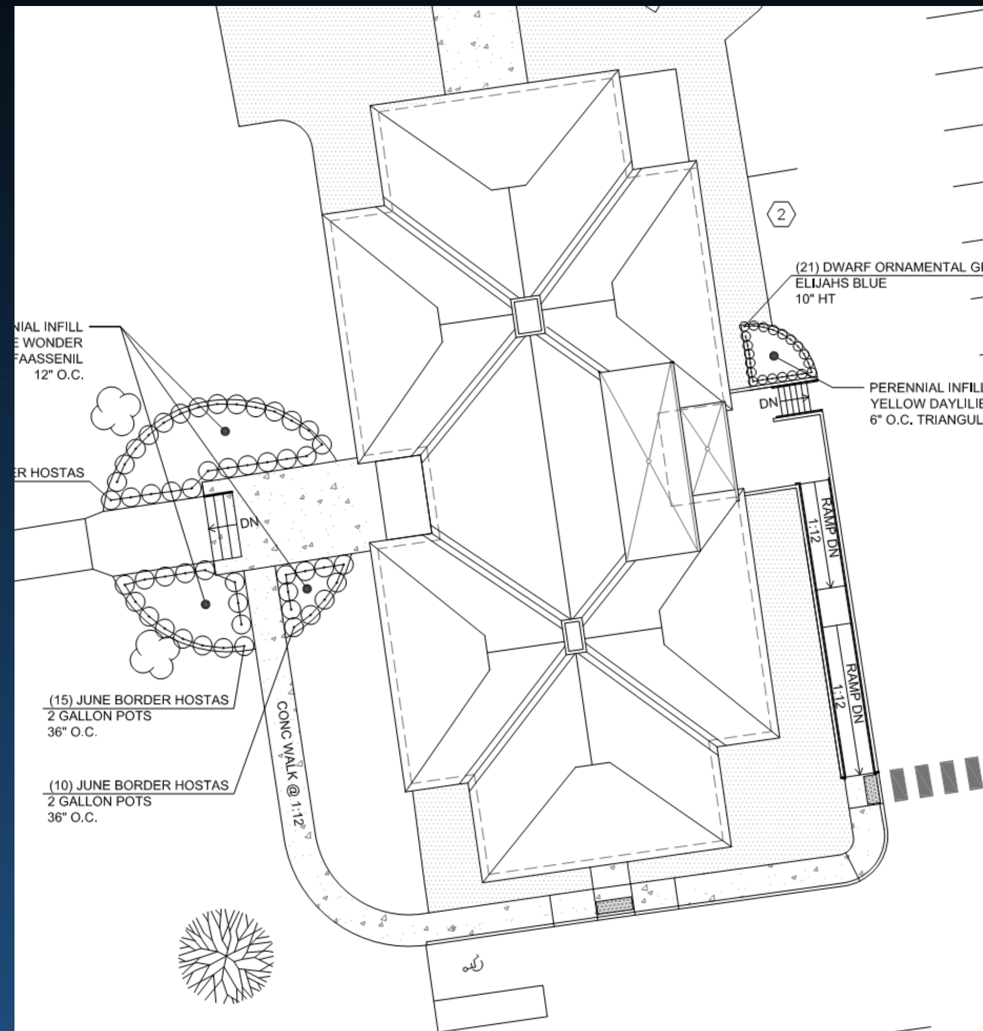
Con's

- *Higher cost*
- *Air sealing operation critical and not simple*
- *QC tougher*

ROOF INSULATION

One complex roof!!





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TWO ROOF INSULATION OPTIONS

Closed cell foam

Pro's

- *Vapor impermeable*
- *Air seal and insulation in one operation*
- *Lower cost*

Con's

- *Zero GWP spray foam**
- *Not reversible for historic*
- *Leak detection difficult*

Cellulose

Pro's

- *Vapor permeable*
- *Reversible for historic*
- *Zero GWP*
- *Recycled material*
- *Easier to find leaks*

Con's

- *Higher cost*
- *Air sealing operation critical and not simple*
- *QC tougher*

FOUNDATION INSULATION

Foundation stone has efflorescence but concentrated at areas where roof runoff not dealt with well

Considerations

- *Floodplain is just below first floor joists*
- *Permeable foundation part of flood plan*
- *Breakout panels part of flood plan*
- *Flood waters could rise above floor joists*
- *Basement to be only partially heated to above freezing, but no more boiler for heat!*

So what did we do???

The Decision for Walls and Roof was the Town's

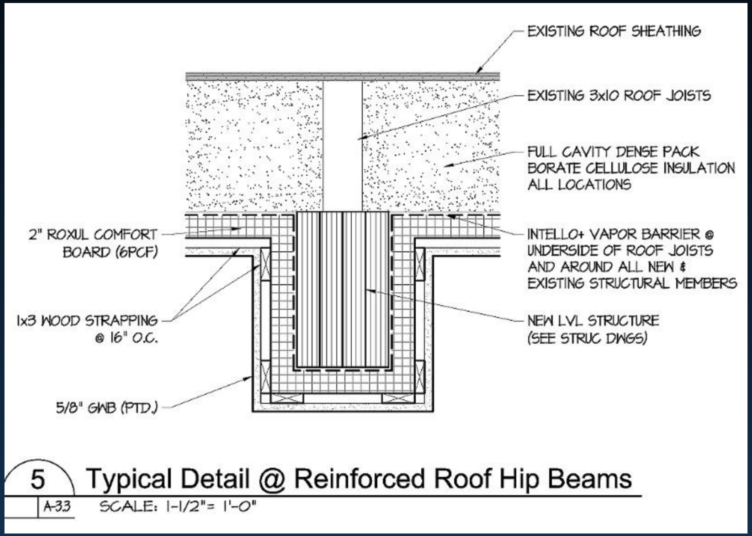
No "Right" answer

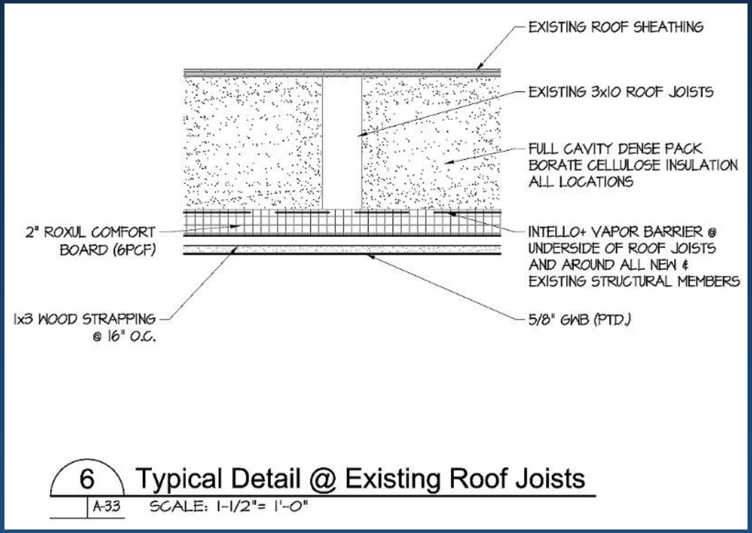
Wisdom of Solomon

Spray foam walls

Cellulose Roof

BUILDING ENVELOPE – INSULATING EXISTING ROOF





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BUILDING ENVELOPE – INSULATING EXISTING ROOF

BUILDING ENVELOPE – INSULATING FOUNDATION WALLS

SOLUTION

- Mineral fiber batts in floor with scrim underneath to contain fibers
- Top 4 feet of foundation closed cell spray foam

RATIONALE

- Allows flood water into foundation through stone wall
- Insulates basement so heat isn't a killer
- If flood water gets as high as into floor joists, water can flow in and out and insulation can be removed so that floor can be dried and insulation dried or replaced

BUILDING ENCLOSURE COMMISSIONING -- BECx

BECx extraordinaire:
Jon Haehnel
Zero by Degrees

Water-based closed cell foam woes
Selected for GWP = 0

- *New product*
- *Poor performance in sticking marginal temperature conditions*
- *Lack of independent testing*
- *Switched to typical 2 psf density for second floor with high GWP*

- *IR scan and air leakage testing critical!*

BUILDING ENCLOSURE COMMISSIONING

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BUILDING ENVELOPE – WINDOWS

- Alpen 925 Series – Fiberglass, fixed over hopper
- Marvin – Aluminum Clad Wood, single hung

Hartford Window Comparison *

		R-Value	Design Loss (BTU/hr)
Alpen 925 quad glazed	$ 270,000	7.9	16,000
Marvin Ultimate clad double glazed	$ 292,000	4.3	29,000
Marvin Ultimate clad triple glazed	$ 341,000	3	26,000

* All arch-top windows

- Marvin
  - Best historic accuracy
- Alpen
  - Best energy performance
  - Best comfort performance
    - large windows and heat pumps

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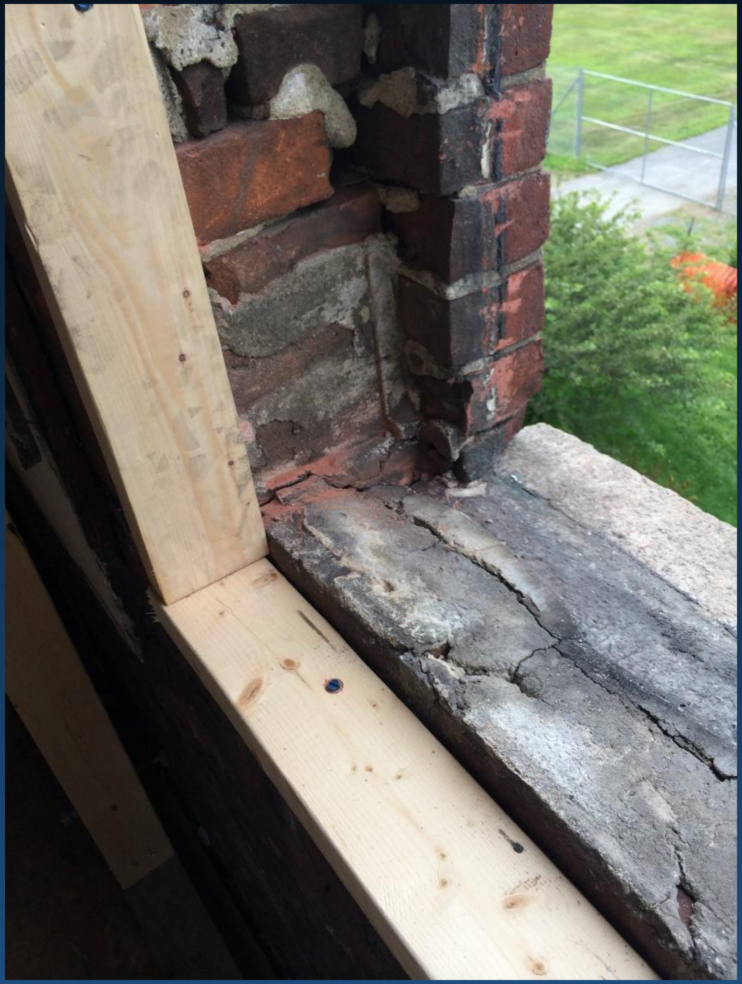
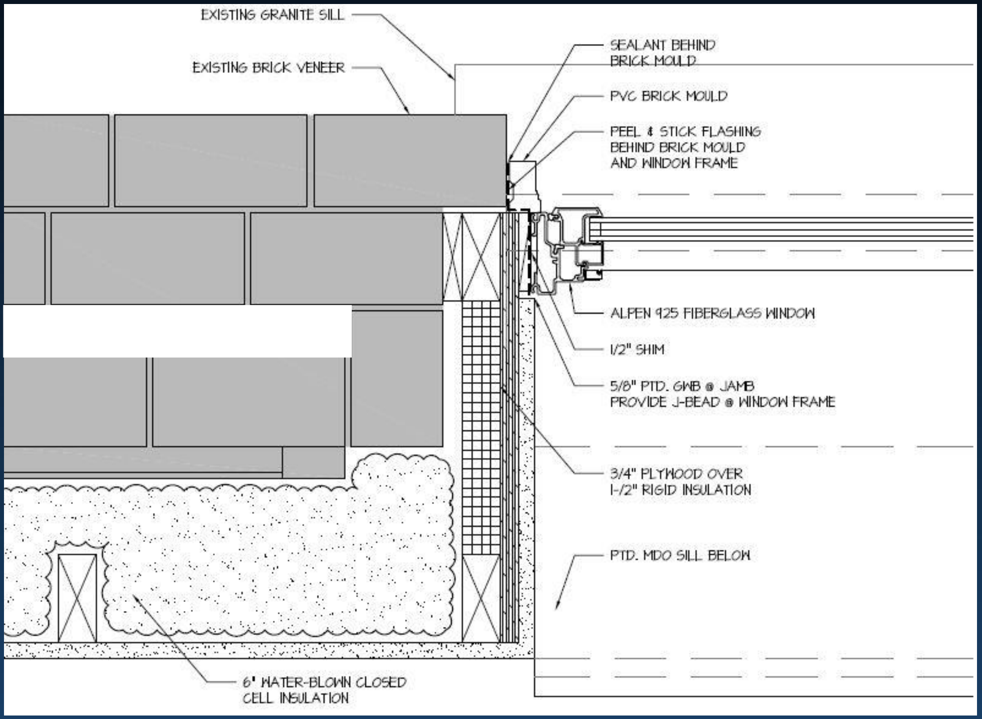
BUILDING ENVELOPE – WINDOWS

Existing

New

BUILDING ENVELOPE – WINDOWS





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BUILDING ENVELOPE – WINDOWS

BUILDING ENVELOPE – WINDOWS

BUILDING ENVELOPE – WINDOWS

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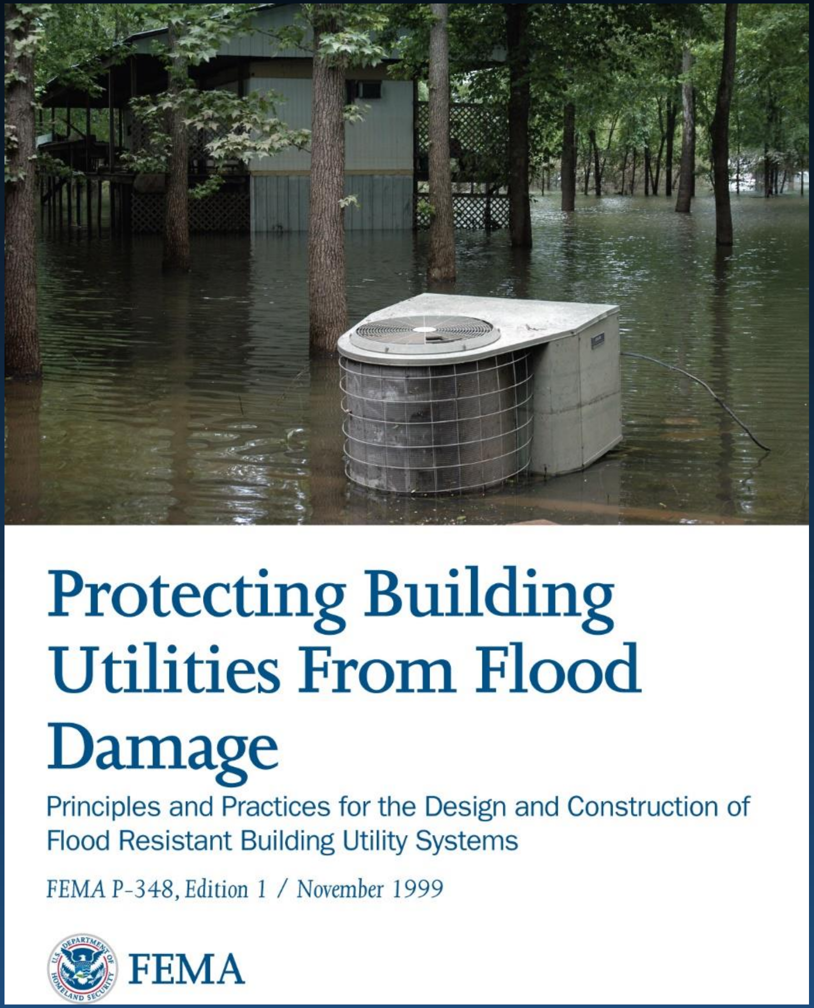
MECHANICAL SYSTEMS

Design for MEP System Goals from Building Committee

- *NET ZERO READY*
- *HISTORIC PRESERVATION*
- *NO FOSSIL FUELS IF POSSIBLE*
- *LOW CARBON EMISSIONS*
- *MINIMUM ENVIRONMENTAL IMPACT*
- *NOT JUST FIRST COST; HOWEVER <u>FIXED</u> BUDGET*

MEP BUILDING & SITE PARAMETERS

MEP BUILDING and SITE PARAMETERS



Building basement in Flood Plain

FEMA And VT ANR Zoning Review Letter
"Must be renovated / Constructed with electrical, heating , ventilation, plumbing, air conditioning equipment and other service facilities that are designed and or located as to prevent water from entering or accumulating during the conditions of flooding"

Basement is non-occupied !

No Mechanical or Electrical Equipment in Basement!

MEP BUILDING and SITE PARAMETERS

- *Limited capacity of existing structure there for no heavy equipment within building. Wood floor structure for existing attic only viable location within building*

- *Structural walls making it very difficult to cross lobby with branch ducts deeper than 10"*

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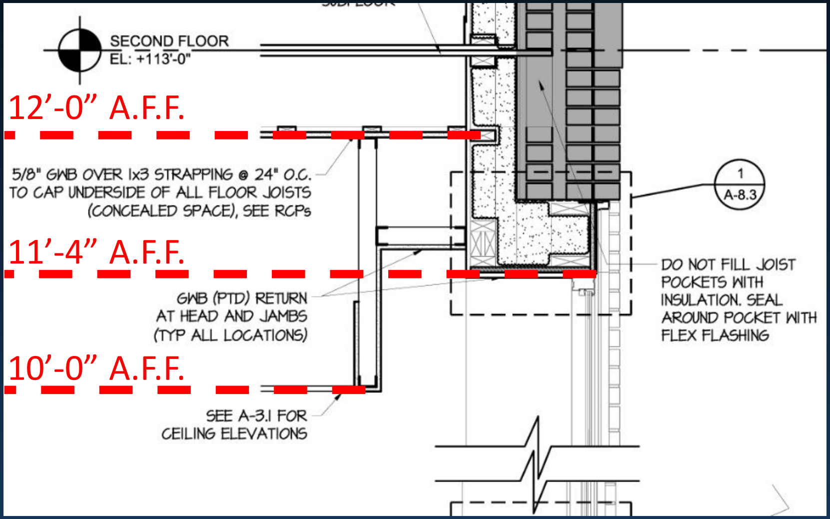
MEP BUILDING and SITE PARAMETERS

- *Limited ceiling heights and room to route duct work or house mechanical equipment*

- *Limited accessible ceiling areas due to hard soffits, perimeter window cove and deep existing structural beams with new reinforcing structural members.*



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MEP BUILDING and SITE PARAMETERS

- *Limited ceiling heights and room to route duct work or house mechanical equipment*
- *Limited accessible ceiling areas due to hard soffits, perimeter window cove and deep existing structural beams with new reinforcing structural members.*

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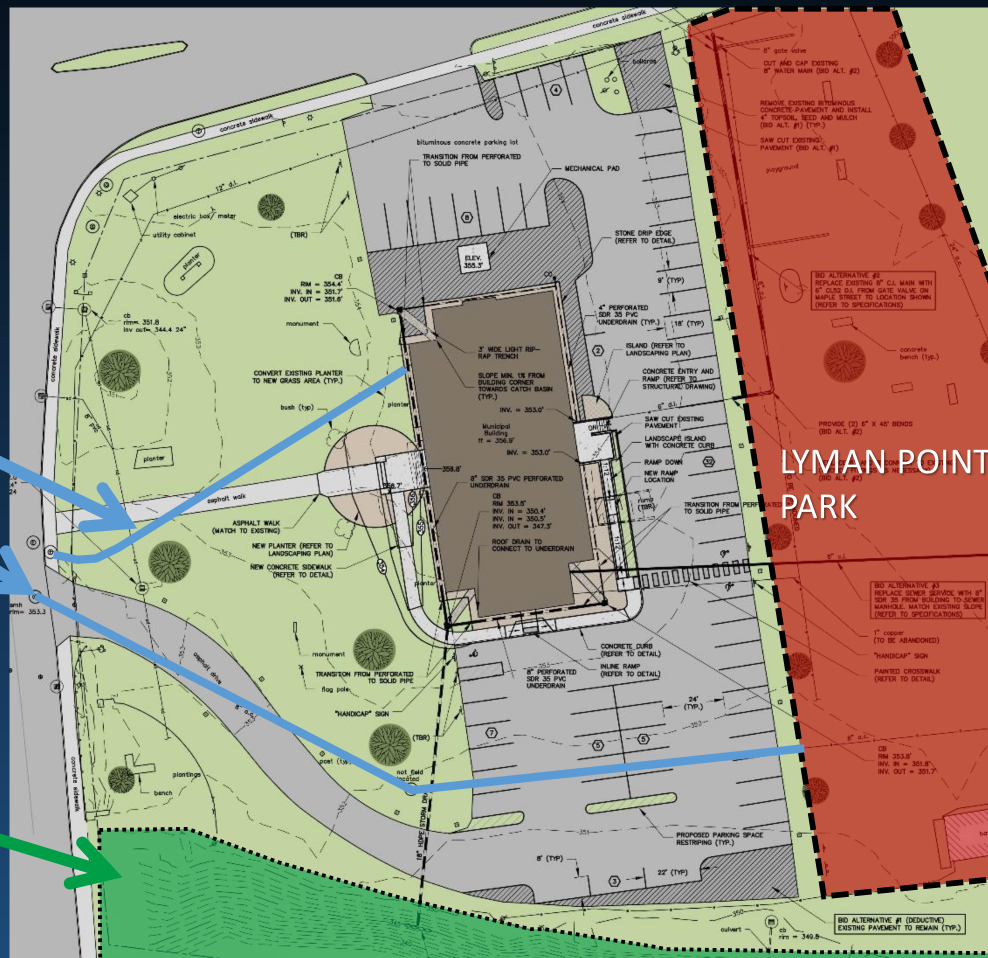
MEP BUILDING and SITE PARAMETERS



360 views of building from site, no back of house on site

MEP BUILDING and SITE PARAMETERS

No Roof Mounted Equipment

MEP BUILDING and SITE PARAMETERS

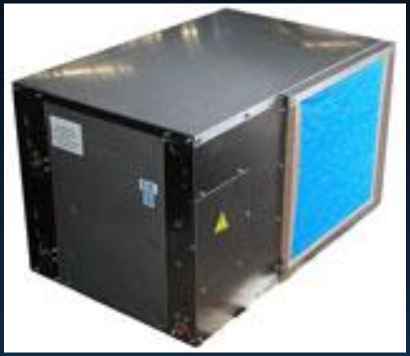
- *No Basement MEP Equipment*
- *No Roof Mounted Equipment*
- *Limited Area on Site to Locate Equipment*
- *Historical / Architectural Restraints*
- *Limited Ceiling Space to Route Utilities*
- *Extremely Limited Floor Loading Capacity*
- *No Large Building Louvers*
- *Net Zero Ready*

MECHANICAL SYSTEMS

HVAC System Options

Water Source Heat Pump

- *Individual units to deep (16” to 29”) for ceiling cavity*
- *Fluid Cooler “to large” for site*
- *Duct and water piping constraints with exiting structure*
- *Limited temperature zoning opportunities with larger WSHP units*



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MECHANICAL SYSTEMS

HVAC System Options

Package VAV RTU

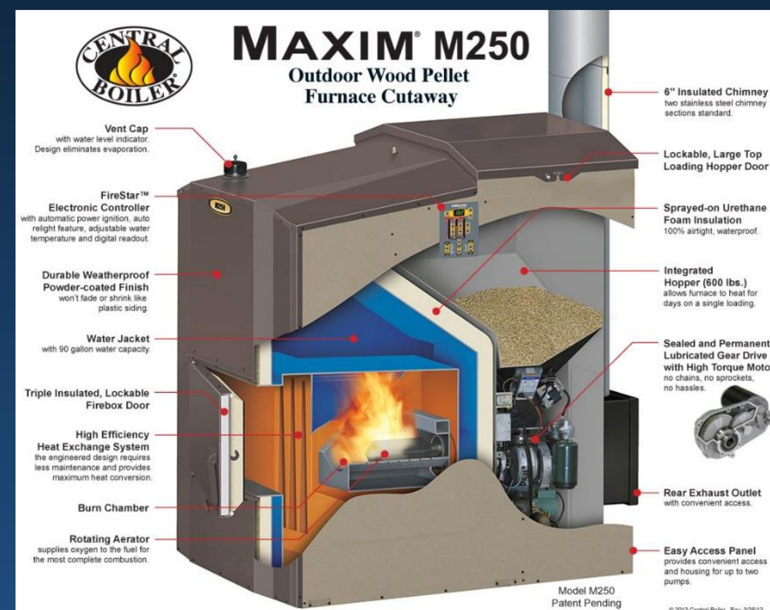
- *Large duct penetrating building envelope*
- *Not possible to get ducts across or through Lobby low beams*
- *Not acceptable for Historic Building*

MECHANICAL SYSTEMS

HVAC System Options

4 pipe fan coil system with Chiller and Boiler

- *Chiller must be located on site due to weight, size, and other restrictions*
- *Fan coil units are 16” to 29” deep*
- *All fan coil units would be ducted or floor mounted consoles*
- *Boiler location*
- *Clients desire to not use fossil fuels implies Biomass boiler*
- *Biomass boiler needs to have storage on site*



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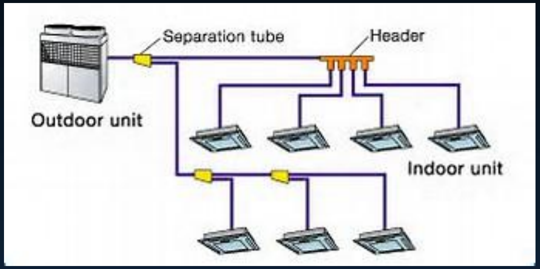
MECHANICAL SYSTEMS

HVAC System Options

Air Source Heat Pump with Dedicated OA System

- *Small easily zoned indoor units (9” deep)*
- *Heating capabilities down to –13 ºF outside air temperature*
- *Small 1.25” or less refrigerant piping and condensate piping*
- *All Electric - Net Zero ready*
- *Clean relatively small outdoor unit*
- *Simultaneous Heating and Cooling*



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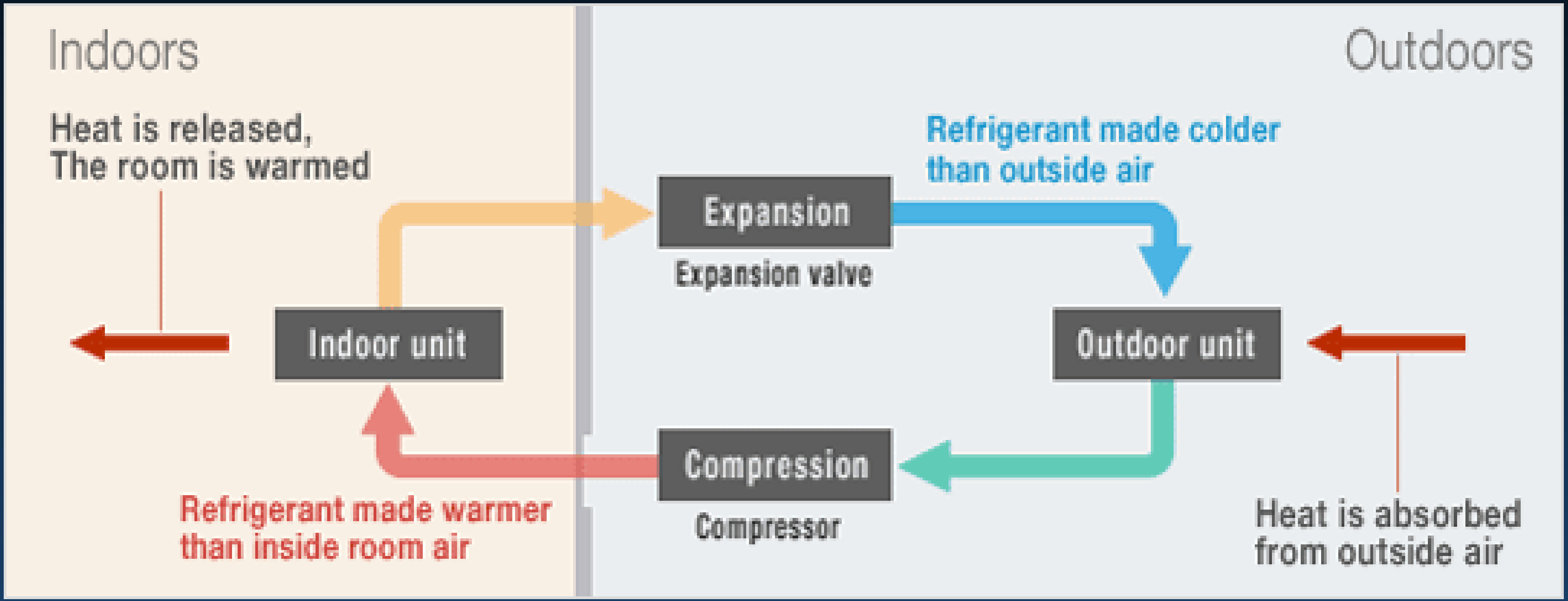
MECHANICAL SYSTEMS

Air source Heat Pump with Dedicated OA System



Questions!

- ***Ventilation Air System Location***
- ***Options for supplemental heat***

MECHANICAL SYSTEMS

Dedicated Outside Air System with Heat Recovery

Outdoor Pad Mounted :

Pros:

- *Easy to add supplemental LP heat*
- *Weight not an issue*

Cons :

- *Outdoor cabinets not well insulated reducing efficiency*
- *Need to have exterior duct which is difficult to insulate*
- *Duct needs to penetrate historic building*

Indoor :

Pros :

- *In conditioned space, higher unit efficiency*
- *Hidden*

Cons:

- *Need to supply and exhaust air louvers in historic building*
- *Need to reinforce floor structurally (if viable with existing structure)*
- *Additional cost to utilize supplemental heat*

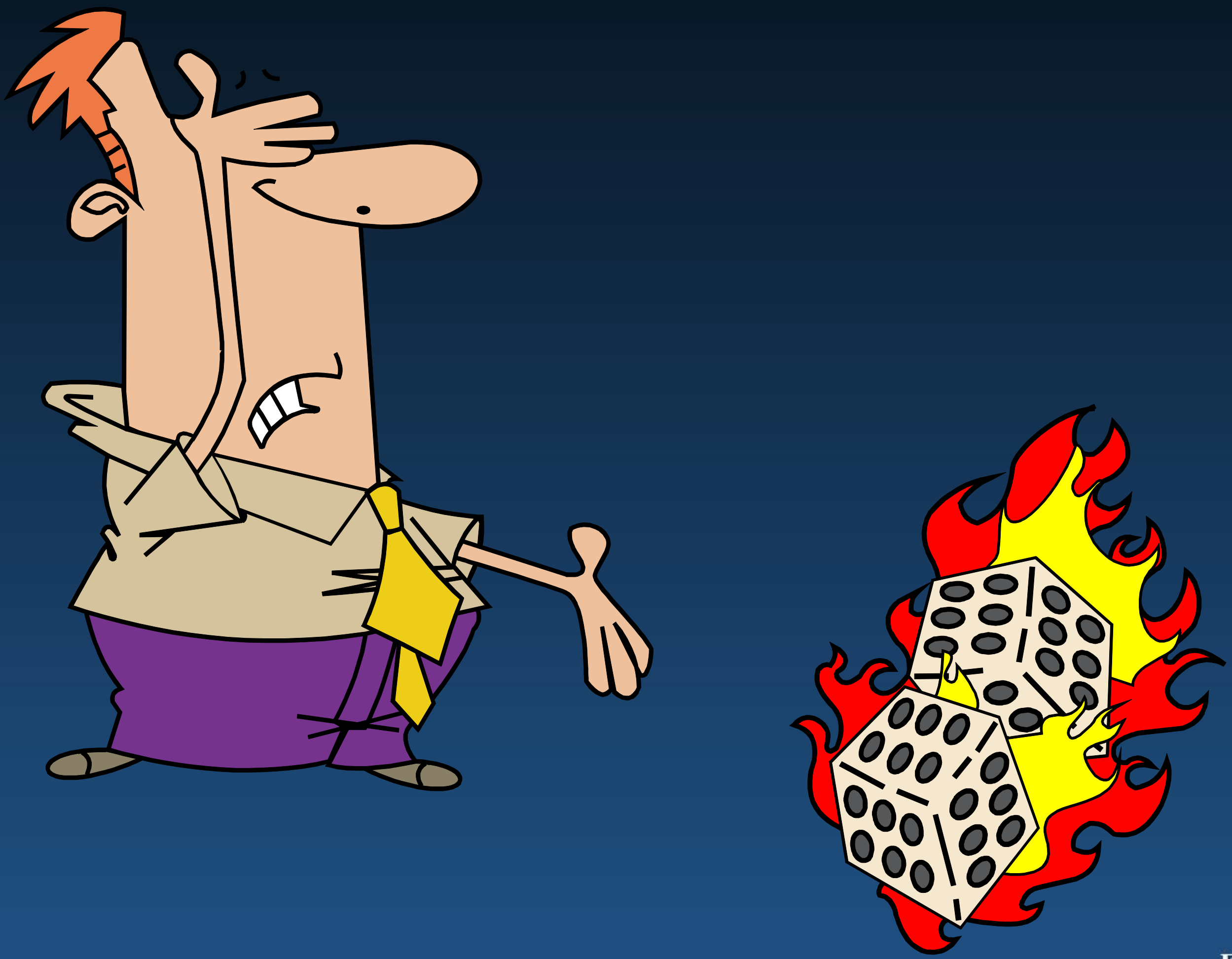
MECHANICAL SYSTEMS

Strategies for back up heating in outside air unit:

Options:

- *LP gas furnace - $ first cost, Client dead set against fossil fuels*
- *LP gas boiler - $$ first cost Client dead set against fossil fuels*
- *Pellet Boiler/ Biomass - $$$ first cost, storage silo on site*
- *Pellet stoves in building - $ first cost, high maintenance and need to be filled by staff*
- *Electric Heat – Not Vermont code compliant*
- *No back up heat? - ASHP rated to heat down to negative 13 Degrees; operates even lower…..*

Roll the dice on no back up heat?



MECHANICAL SYSTEMS

Dry-Bulb Temperature Hours For An Average Year
Period of Record = 1973 to 1996

Annual Totals

Temperature Range (°F)	Hour Group (LST) 01 To 08	Hour Group (LST) 09 To 16	Hour Group (LST) 17 To 00	Total Obs	MCWB (°F)
95 / 99		2	0	2	75.5
90 / 94		16	4	20	73.1
85 / 89		60	19	79	70.5
80 / 84	3	146	60	209	68.0
75 / 79	31	216	122	369	65.9
70 / 74	121	243	207	571	63.6
65 / 69	211	220	246	678	60.4
60 / 64	251	220	246	718	56.4
55 / 59	259	193	232	684	52.1
50 / 54	263	190	222	675	47.5
45 / 49	239	189	203	631	42.8
40 / 44	229	202	221	652	38.1
35 / 39	261	227	244	733	33.7
30 / 34	274	208	244	727	29.4
25 / 29	198	163	179	540	24.6
20 / 24	148	125	131	404	19.8
15 / 19	118	97	96	310	15.1
10 / 14	92	84	93	269	10.4
5 / 9	72	52	65	189	5.8
0 / 4	59	35	44	138	1.1
-5 / -1	33	14	21	68	-3.2
-10 / -6	34	10	15	59	-7.5
-15 / -11	14	4	5	23	-12.2
-20 / -16	8	1	2	11	-16.5
-25 / -21	2	0	1	3	-21.7
-30 / -26	1	0	0	1	-26.5
	25	5	8		38

Analysis:

- **Total hours per year less than -13 degree F = 38**
- **Business Hours less that -13 degree F = 5**
- **Envelope allows for heat interruptions**

Client Reasoning:

- **Lived in current building using hats and gloves on very cold days**
- **Already own supplemental electric heaters**
- **No back-up fossil fuel heat = net zero ready**
- **Provided space in duct system for supplemental back heating coil to added at later date if required**
- **Cited several other projects without back up heat**

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MECHANICAL SYSTEMS

Final Decision:

Alternate Costs:

MEP Alternates		
Mechanical		
Biomass Option A	$ 124,236.00	Add
Biomass Option B	$ 56,949.00	Add
Non-Simutanious Heating and Cooling	$ (55,372.00)	Deduct
Electrical		
65 kW array	$ 243,300.00	Add
Increase lumen output of Light fixtures to reduce cost	*$ (-7,500 to $1,2500)*	Deduct

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MECHANICAL SYSTEMS

Final HVAC :

- **Air Source Heat Pump**
  - **Combination of ducted and ceiling cassette type units**
- **No Supplemental or Back-up Heat**
- **Dedicated indoor 2,400 CFM Outside Air System with VAV Zone Controls, system to have override to shut down when OA is below -13 during non occupied hours.**
- **System 100% electric**
- **Town looking for site to build PV Array to offset multiple town buildings consumption**
- **Need to consider code revision to allow supplemental back up electric heat for ASHP**

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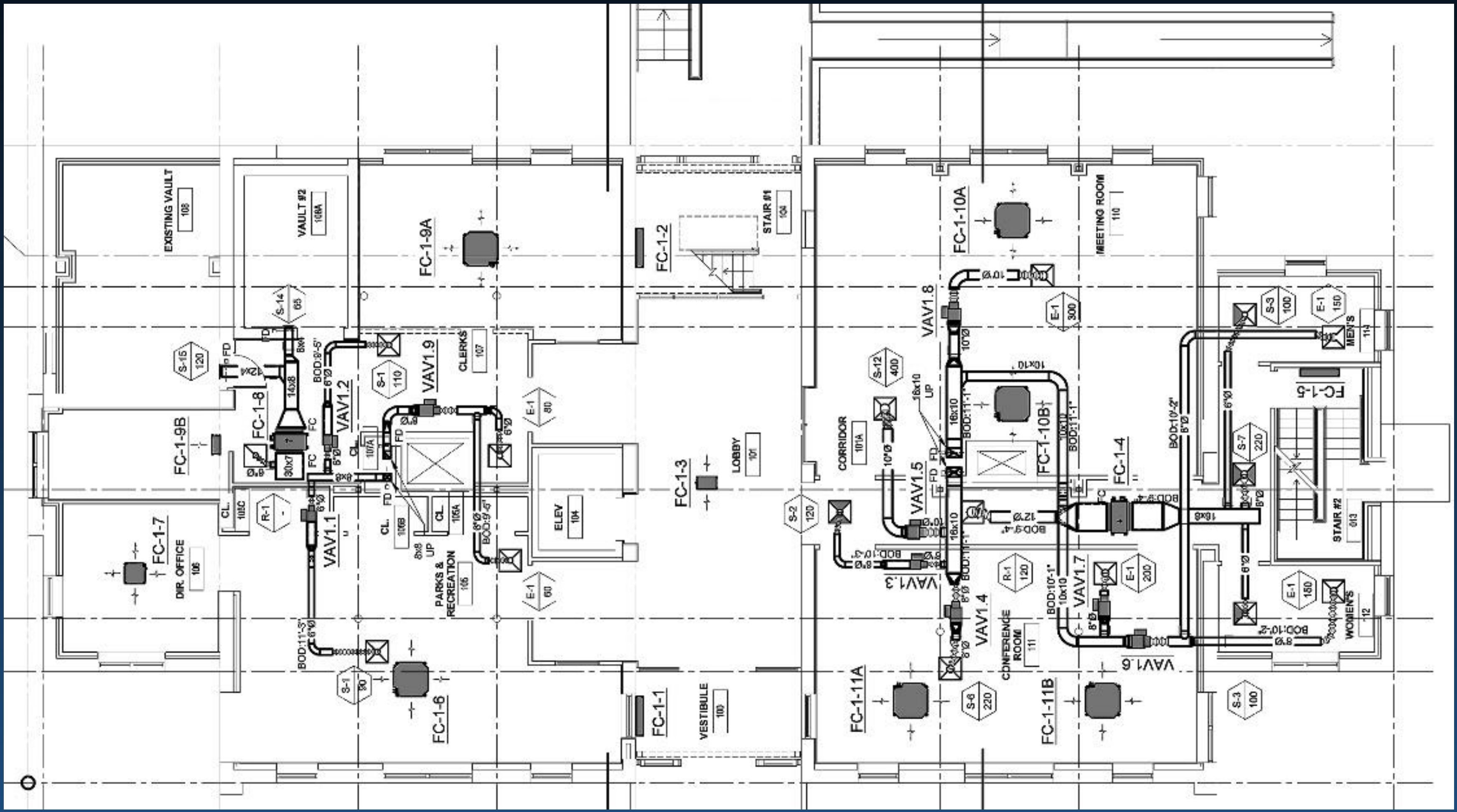
MECHANICAL SYSTEMS



HVAC DUCTWORK PLAN (FIRST FLOOR)

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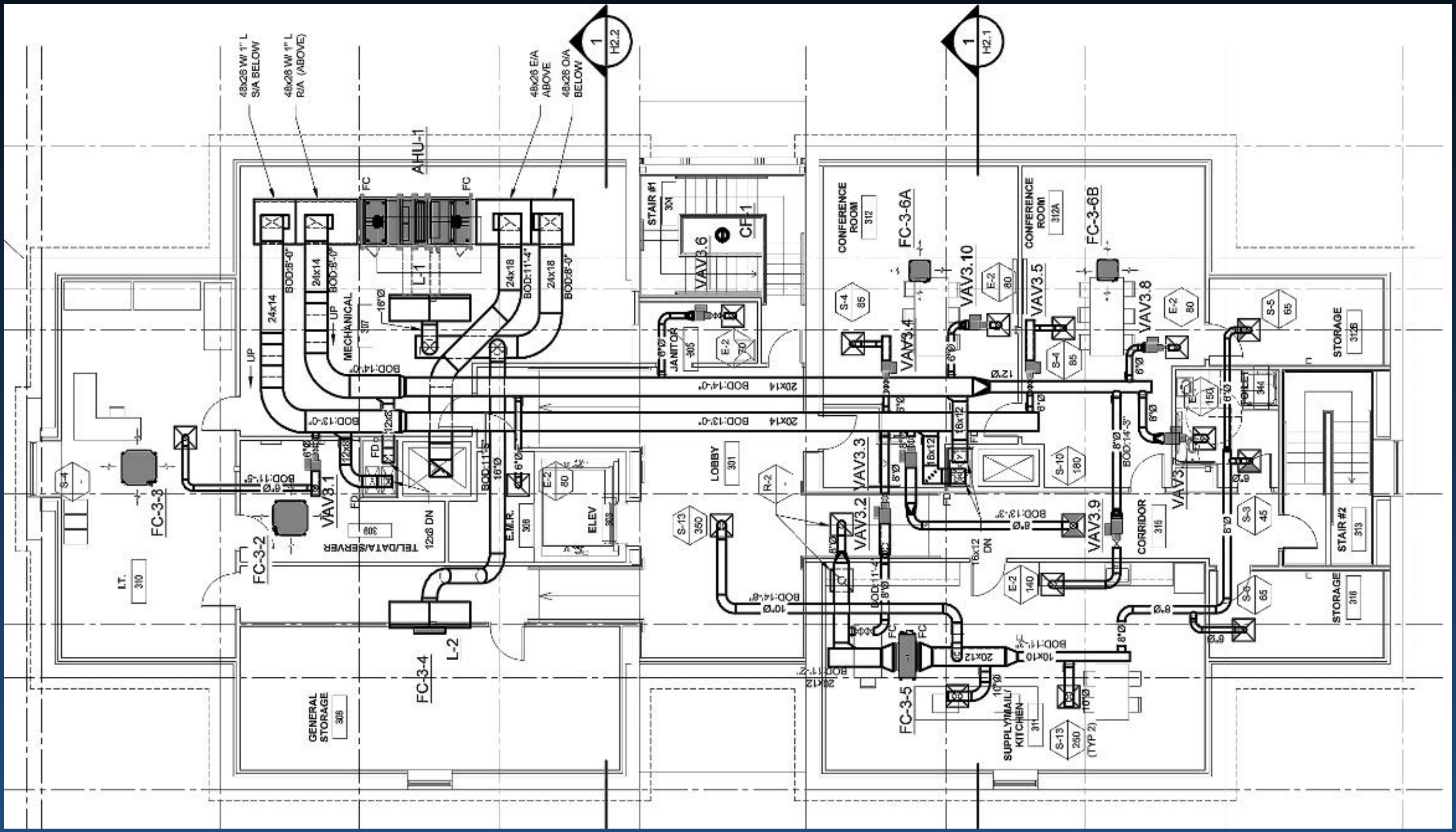
MECHANICAL SYSTEMS



HVAC DUCTWORK PLAN (THIRD FLOOR)

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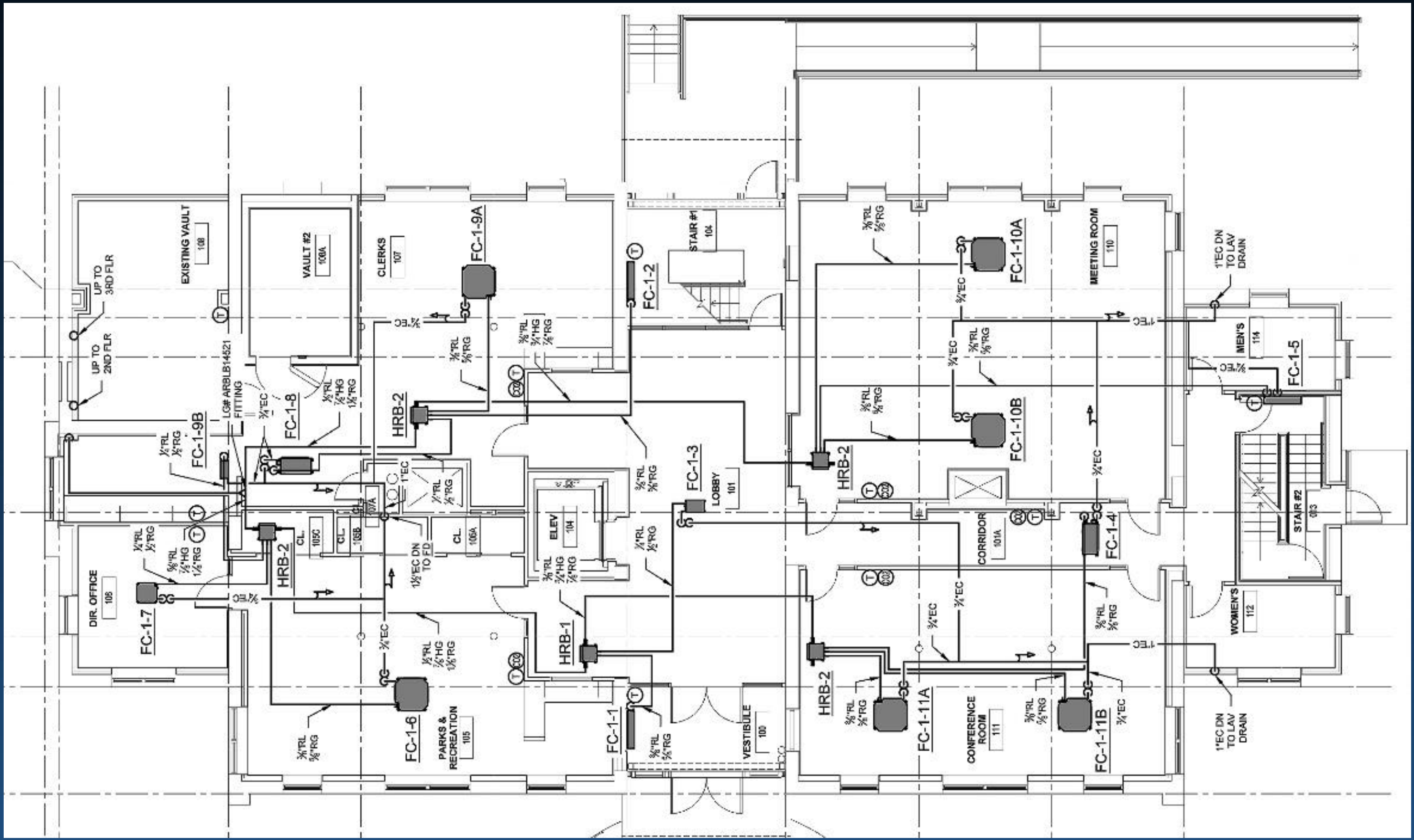
MECHANICAL SYSTEMS



MECH PIPING PLAN (FIRST FLOOR)

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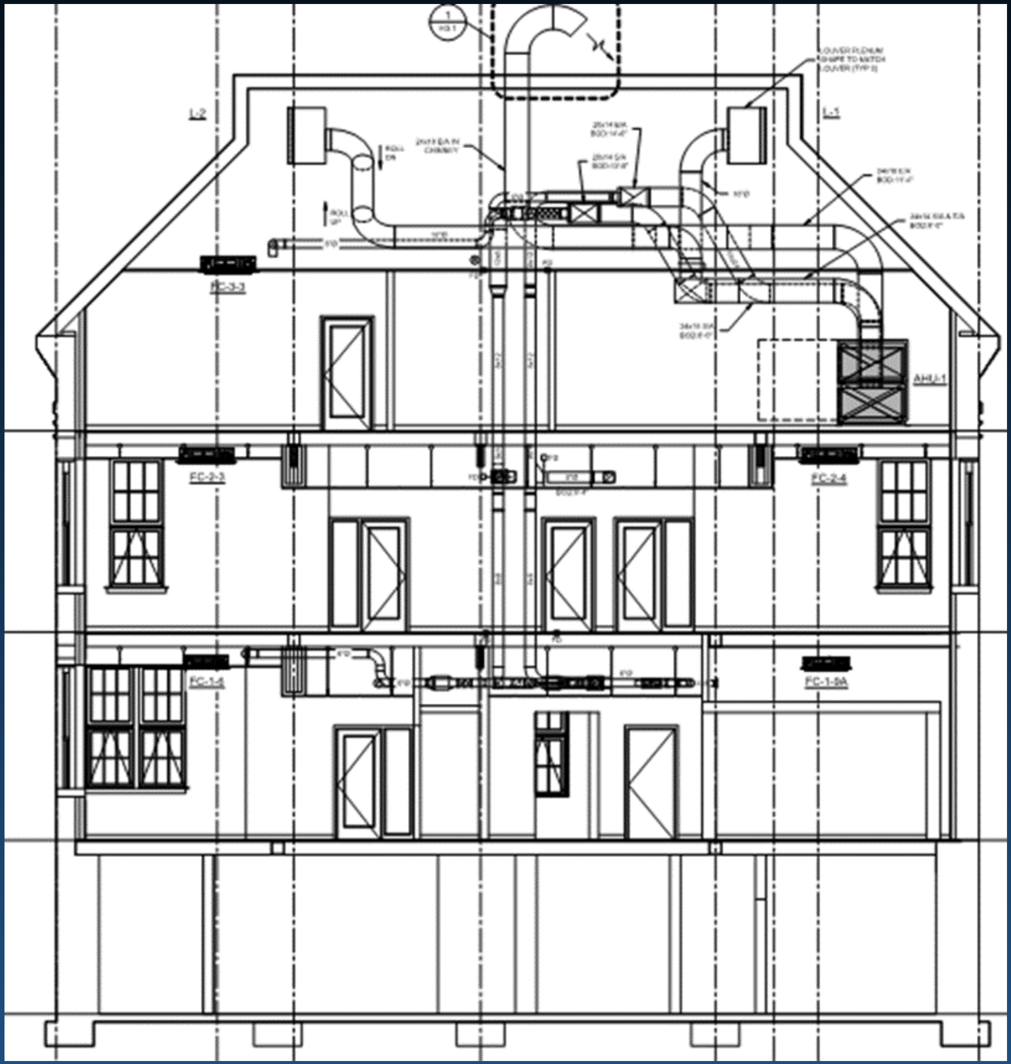
MECHANICAL SYSTEMS



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INTERIOR LIGHTING

BLC JCJ 1/14/2014

Preliminary Light Fixture Analysis *

Description	2x2 Super T8 3 lamp; standard ballast ColumbiaTRA22-3		2x2 LED Dimable Columbia LTRE 22		Units
Number of Fixtures	40		24		Qty
Utility Rebate	$	10.00	$	50.00	$
Fixture Purchase Price	$	135.00	$	193.00	$
Net Fixture Purchase Price	$	125.00	$	143.00	$
Energy					
Watts Per Fixture	42		51		W
Total kW	1.68		1.22		kW
Daily Hours	10		10		Hrs
Annual Hours	3,650		3,650		Hrs
Annual kWh	6,132		4,468		kwh
Average Cost Per kWh	$	0.14	$	0.14	$
Annual Energy Cost (Operating)	$	883.01	$	643.33	$
Annual Cost (HVAC)	$	291.39	$	212.30	$
Annual Energy Cost (Total)	**$**	**1,174.40**	**$**	**855.63**	$
5YR Energy Cost	**$**	**5,872.00**	**$**	**4,278.17**	$
5YR Energy Savings	**-**		**$**	**1,593.83**	$
Lamp Replacement Costs					
Lamp Cost (each fixture)	$	16.00	$	0.00	$
Rated Lamp Life (hrs)	24,000		75,000		Hrs
Annual Lamp Replacements	0.15		0.00		Qty
5YR Re-lamp Costs	**$**	**486.67**	**$**	**-**	$
5YR Re-lamp Savings	**-**		**$**	**486.67**	$
Total 5 Year Savings					
Energy + Relamp	**$**	**-**	**$**	**2,080.50**	$
Payback					
Payback	**(3.8)**				**Yrs**

LED vs. Fluorescent Light fixtures

Majority LED Light FIXTURES

Lighting Control Strategies

- *Full dimming for office areas*
- *No dimming for storage and non occupied spaces*
- *Occupancy sensors for all occupied spaces*

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PLUMBING FIXTURES

Plumbing Fixtures:

- Water Closets: 0.8 Gallon/Flush Ultra-High-Efficiency Water Saving Toilet; Tank Type, Floor Mounted; Niagara Stealth

- Building domestic hot water will be provided by energy efficient electric point of use water heaters located at each rest room, kitchen sink, or mop sink location. Bosch Tronic 3000T series 1,500 watt, 2.5 to 7.0 gallon tank.

JUNE 2014

FEBRUARY 2015

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THANK YOU!

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INSULATION

- TO CHANGE ROOF INSULATION FROM 8" SPRAY FOAM TO FULL CAVITY CELLULOSE WAS AN ADDED PREMIUM OF $39,000.
- TOTAL COST OF ROOF INSULATION SYSTEM IS APPROXIMATELY $108,000.

- TO CHANGE CURRENT SPRAY FOAM WALL DESIGN TO 12" CELLULOSE w/ DOUBLE 2x4 WALL w/ INTELLO MEMBRANE WAS A $51,000 PREMIUM.
- HAD THE WALL SYSTEM CHANGED, THE APPROX COST WOULD HAVE BEEN $120,000.

W INDOW SYSTEMS

Description Punched Opening Windows	Marvin Integrity Double Hung Listed R-3.33 - Not an option, cannot provide at 7'-9" H	Marvin Ultimate / Magnum Double Hung AL Clad Triple glazed krypton argon Listed (fixed or double hung) R-4.34	Double Hung Listed R-5 Alpin 725	Base Base Alpin 925 fixed over awning	Fixed Alpin 925
Listed R-Value	R-3.33	R-4.34	R-5	R-7.9	R-9
Design Loss - Btu/hr	38,071	29,211	25,356	16,048	14,086
Yearly Loss - Million Btu/yr	90.5	69.5	60.3	38.2	33.5
Fuel Cost (oil $3.50 Gallon @ 83% eff.)	$ 2,688.00	$ 2,063.00	$ 1,790.00	**$ 1,133.00**	$ 995.00
Ten Year cost (@10% inflation/year)	$ 42,822.00	$ 32,857.00	$ 28,520.00	**$ 18,050.00**	$ 15,844.00
Green House Gas (lb CO2)	15,269	12,711	10,169	6,436	5,649
Delta yearly cost from base	**$ 1,555.00**	**$ 930.00**	**$ 657.00**	**$ -**	**$ (138.00)**
Delta ten year cost from base	$ 24,772.00	$ 14,807.00	$ 10,470.00	$ -	$ (2,206.00)
Window Cost w/ fee and contigincy	**N/A**	**$ 247,679.23**	**$ 107,699.87**	**$ 119,465.88**	**TBD**

Description Curtain Wall	1" Uncoated Glazing	Base Low E Clear Glass	Alpin Glazing 9L
Listed R-Value	R-2.1	R-3.4	R-9
Design Loss - Btu/hr	29,905	18,471	6,978
Yearly Loss - Million Btu/yr	71.1	43.9	16.6
Fuel Cost (oil $3.50 Gallon @83% eff.)	$ 2,112.00	**$ 1,304.00**	$ 493.00
Ten Year cost (@10% inflation/year)	$ 33,637.00	**$ 20,776.00**	$ 7,849.00
Green House Gas (lb CO2)	11,993	7,408	2,798
Delta yearly cost from base	**$ 808.00**	**$ -**	**$ (811.00)**
Delta ten year cost from base	$ 12,861.00	$ -	$ (12,927.00)
Window Cost w/ fee and contigincy	**N/A**	**$ -**	**$ 22,520.00**

Notes:

Change Alpin to Marvin, min add of $87,000

Arch top on window is additional $ add

All Marvin are aluminum clad, Marvin cannot provide Fiberglass in 7' 9" height

MECHANICAL SYSTEMS

Manuf.	Fixture Model	Type	Warranty	Cost	Total Energy Usage watts	EFF. VT Rebate / Fixture	Expected Lamp Life (hours)	Expected Lamp Life @ 24 hrs day use (years)	Expected Lamp Life @ 10 hrs day use (years)
Finelite	HPR -A- 2x2-DCO-LED-SO-4000K LED	2x2	10	$ 233	37	$ 50.00	168,000	19.2	46.0
Finelite	HPR -A- 2x4 -DCO-LED-SO-4000K LED	2x4	10	$ 321	68	$ 60.00	168,000	19.2	46.0
Columbia	LTRE22 LED	2x2	5	$ 193	30.2	$ 50.00	75,000	8.6	20.5
Columbia	LTRE24 LED	2x4	5	$ 251	40.2	$ 60.00	75,000	8.6	20.5
Columbia	Super T8 fxture 3 lamp	2x2	1	$ 135	42	$ 10.00	24,000	2.7	6.6
Columbia	Super T8 fxture 3+ lamps	2x4	1	$ 130	70	$ 10.00	24,000	2.7	6.6
Columbia	Super T8 fxture 2 lamp dimming	2x2	1	$ 185	42	$ 40.00	24,000	2.7	6.6
Columbia	Super T8 fxture 3+ lamps dimming ballast	2x4	1	$ 175	70	$ 20.00	24,000	2.7	6.6

Hartford Municipal Offices

1/30/2014 BLC

	Existing	Windows					Curtain Wall			Insulation		
Item	Base Exisitng Building	Run # 1 New Base	Run # 2	Run # 3	Run # 4	Run # 5	Run # 6	Run # 7	Run # 8	Run # 9	Run # 10	Run # 11
Basement Walls	Masonary, No insualtion R-2	4" Foam, top 4' R-22	4" Foam, top 4' R-22	4" Foam, top 4' R-22	4" Foam, top 4' R-22	4" Foam, top 4' R-22	4" Foam, top 4' R-22	4" Foam, top 4' R-22	4" Foam, top 4' R-22	4" Foam, top 4' R-22	4" Foam, top 4' R-22	4" Foam, top 4' R-22
Basement Slab	Concrete, No insualtion R-1	Concrete no inusation R-1	Concrete no inusation R-1	Concrete no inusation R-1	Concrete no inusation R-1	Concrete no inusation R-1	Concrete no inusation R-1	Concrete no inusation R-1	Concrete no inusation R-1	Concrete no inusation R-1	Concrete no inusation R-1	Concrete no inusation R-1
First Floor	No Insulation	8" mineral fiber R-30	8" mineral fiber R-30	8" mineral fiber R-30	8" mineral fiber R-30	Concrete no insulation R-1	Concrete no inusation R-1	Concrete no inusation R-1	Concrete no insuation R-1	Concrete no inusation R-1	Concrete no inusation R-1	Concrete no inusation R-1
Walls	Brick, No insuation R-4	5"water blown spray foam R-30	5"water blown spray foam R-30	5"water blown spray foam R-30	5"water blown spray foam R-30	5"water blown spray foam R-30	6"water blown spray foam R-30	6"water blown spray foam R-30	6"water blown spray foam R-30	6"water blown spray foam R-30	5"water blown spray foam R-30	6"water blown spray foam R-30
Roof / Attic	Batts + misc. R-10 to R-30 on attic floor	8" spray foam in rafters R-40	8" spray foam in rafters R-40	8" spray foam in rafters R-40	8" spray foam in rafters R-40	8" spray foam in rafters R-40	8" spray foam in rafters R-40	8" spray foam in rafters R-40	8" spray foam in rafters R-40	8" spray foam in rafters R-40	10" spray foam in rafters R-40	10" spray foam in rafters R-40
Air Leakage	High	Very Low	Very Low	Very Low	Very Low	Very Low	Very Low	Very Low	Very Low	Very Low	Very Low	Very Low
Entry Curtain Wall	N/A	Kwaneer TriFab VG451T 2"x 4.5" w/ I" insulated glass	Kwaneer TriFab VG451T 2"x4.5" w/ I" insulated glass	Kwaneer TriFab VG451T 2"x4.5" w/ I" insulated glass	Kwaneer TriFab VG451T 2"x4.5" w/ I" insulated glass	Kwaneer TriFab VG451T 2"x4.5" w/ I" insulated glass	Kwaneer TriFab VG451T 2"x4.5" w/ I" insulated glass R-2.1	Kwaneer TriFab VG451T 2"x4.5" w/ I" insulated glass R-2.4	Kwaneer TriFab VG451T 2"x4.5" w/ I" 9L insulated glass R-9	Kwaneer TriFab VG451T 2"x4.5" w/ I" insulated glass R-2.4	Kwaneer TriFab VG451T 2"x4.5" w/ I" insulated glass R-2.4	Kwaneer TriFab VG451T 2"x4.5" w/ I" insulated glass R-2.4
Windows	Double Hung w/ storm R-1.7	Fixed over Awning Listed R-9.1/R-6.7 Alpin 925	Double Hung Listed R-5 Alpin 725	Marvin Integrity Double Hung Listed R-3.33	Marvin Ultimate / Magnum Fixed over Awning Listed R-3.57 TBV	Marvin Ultimate / Magnum Double Hung triple glazed krypton argon Listed R-4.34	Fixed over Awning Listed R-9.1/R-6.7 Alpin 925	Fixed over Awning Listed R-9.1/R-6.7 Alpin 925	Fixed over Awning Listed R-9.1/R-6.7 Alpin 925	Fixed over Awning Listed R-9.1/R-6.7 Alpin 925	Fixed over Awning Listed R-9.1/R-6.7 Alpin 925	Fixed over Awning Listed R-9.1/R-6.7 Alpin 925

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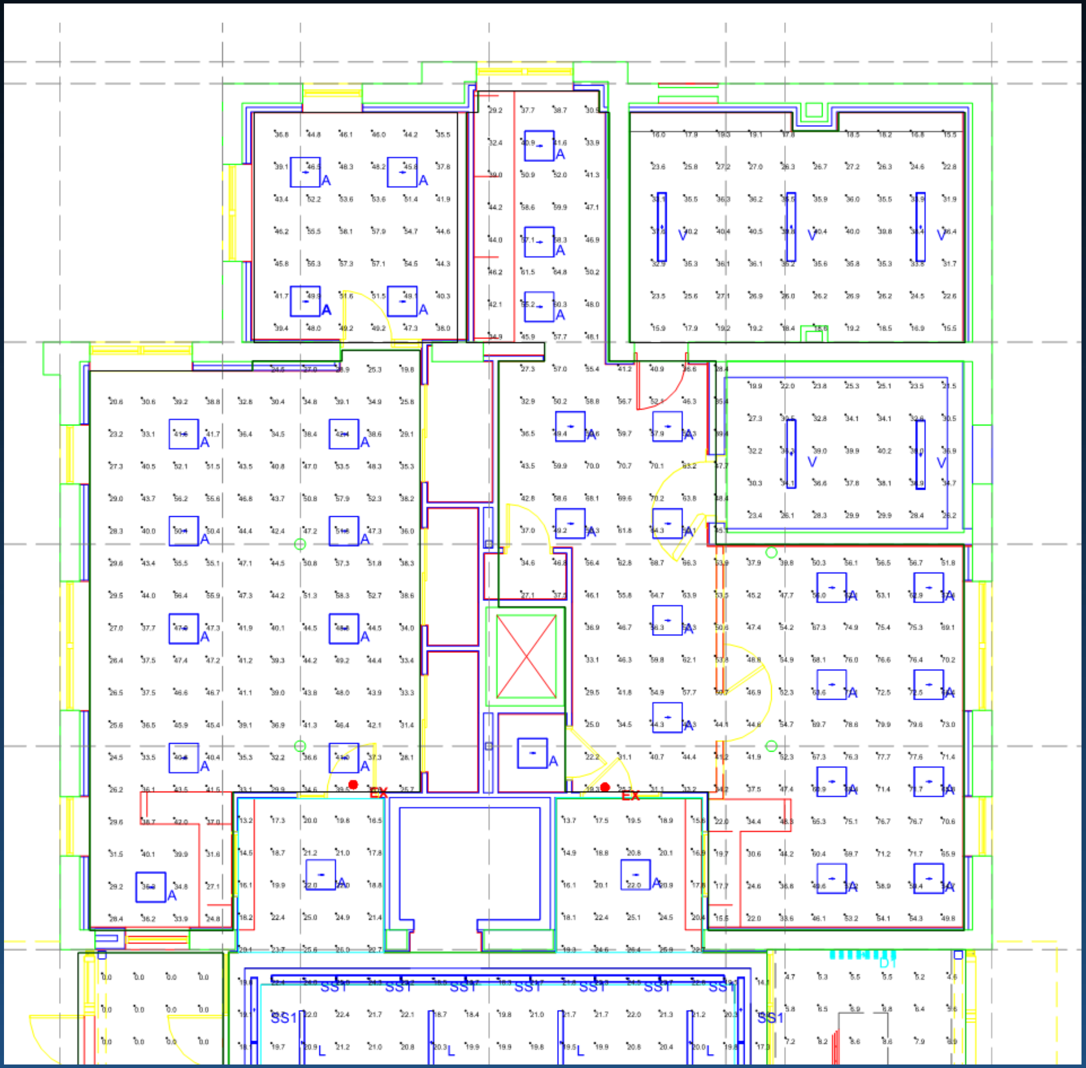
LIGHTING SYSTEMS



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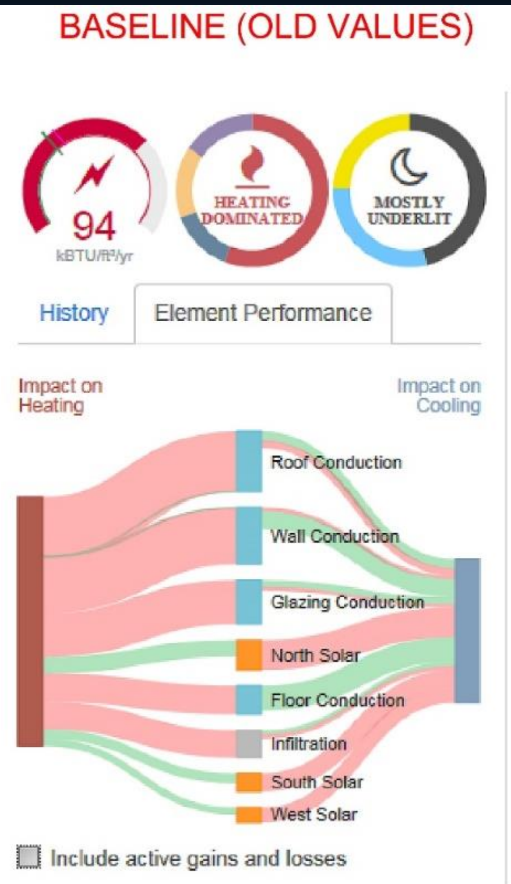
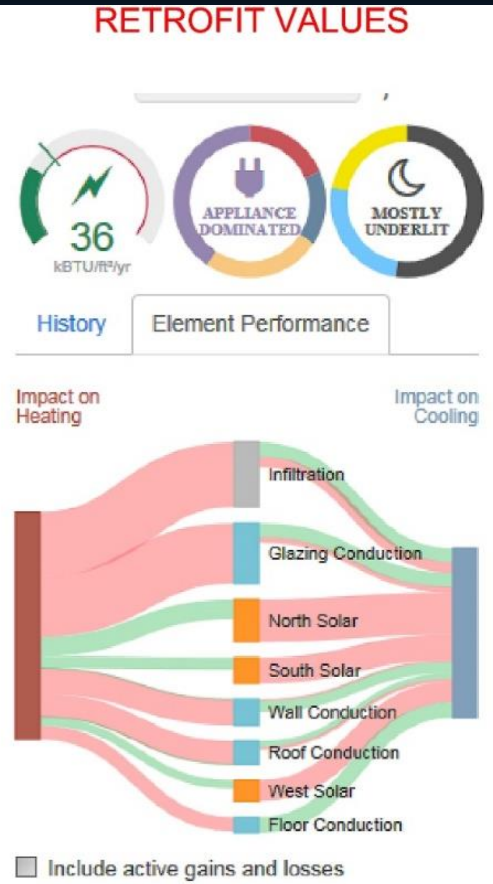
MECHANICAL SYSTEMS





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MECHANICAL SYSTEMS

sefaira

BASELINE (OLD VAULES)

RETROFIT VALUES

Typical Values | US

CONTENTS

1. Envelope Typical Values

Glazing U-Factor (BTU/h-ft²-°F)

Description	Lower	Upper
Single Glazing - including frame and sash	0.65	1.1
Standard Double Glazing - including frame and sash	0.52	0.65
Performance Double Glazing (low-e) - including frame and sash	0.37	0.52
Triple Glazing - including frame and sash	0.18	0.37
Triple Glazing (argon filled cavity) - including frame and sash	0	0.18

Glazing SHGC

Description	Lower	Upper
Clear Single Glazing	0.7	1
Clear Double Glazing	0.4	0.7
Reflective Coated Glazing	0.2	0.4
Glazing with Internal Blinds	0	0.2

Surface Reflectance

Description	Lower	Upper
Mirror Finish - highly reflective	0.9	1
Light coloured walls - reflective	0.6	0.9
Medium coloured walls	0.4	0.6
Dark coloured walls - low reflectivity	0.1	0.4
Black - very low reflectivity	0	0.1

Leakage (cfm/ft²)

Description	Lower	Upper
Leaky building	0.55	and above
Normal practice	0.27	0.55
Best practice	0.05	0.27
Extremely tight building	0	0.05

Roof Thermal Resistance R-value (ft²-h-°F/BTU)

Description	Lower	Upper
Uninsulated and single skin roofs	1.1	5
Poorly insulated (approx. 50mm/2in insulation)	5	9
Insulated (approx. 100mm/4in insulation)	9	22
Well insulated (approx. 150mm/6in insulation)	22	37
Extremely well insulated	37	60 and above

Floor Thermal Resistance R-value (ft²-h-°F/BTU)

Description	Lower	Upper
Uninsulated and single skin floors	1.1	1.4
Poorly insulated (approx. 50mm/2in insulation)	1.4	4
Insulated (approx. 100mm/4in insulation)	4	23
Well insulated (approx. 150mm/6in insulation)	23	38
Extremely well insulated	38	and above

Walls Thermal Resistance R-value (ft²-h-°F/BTU)

Description	Lower	Upper
Uninsulated and single skin walls	1.1	5
Poorly insulated (approx. 50mm/2in insulation)	5	11
Insulated (approx. 100mm/4in insulation)	11	16
Well insulated (approx. 150mm/6in insulation)	16	38
Extremely well insulated	38	and above

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2. HVAC Typical Values

Heating Efficiency or COP

Description	Lower	Upper
Above typical efficiencies of electric heating technology	3.8	10
Electric Water to Water Heat Pump	3.5	3.8
Electric Ground Source Heat Pump	2.7	3.5
Efficient Electric Air Source Heat Pump	2.3	2.7
Standard Electric Heat Pump	2	2.3
Inefficient Electric Heat Pump	1	2
Electric heating	1	1
Above typical gas heating efficiencies	0.9	0.99
New gas heating system - efficient	0.75	0.9
New gas heating system - standard	0.65	0.75
Old gas heating system - inefficient	0.55	0.65
Very inefficient gas system - much below average	0	0.55

Cooling COP

Description	Lower	Upper
Above typical efficiencies of cooling technology	4.8	and above
Efficient large scale, water cooled chiller	3.9	4.8
Efficient small scale, water cooled chiller	2.7	3.9
Efficient large scale, air cooled chiller	2.4	2.7
Efficient small scale, air cooled chiller	2	2.4
Inefficient cooling equipment	0.9	2
Absorption cycle chiller	0.5	0.9

Ventilation Rate (cfm/ft²)

Description	Lower	Upper
Swimming Pools and other spaces requiring high ventilation rates	0.47	and above
Gym	0.3	0.47
Restaurants	0.18	0.3
Library / Museums / Classrooms	0.12	0.18
Office Space	0.05	0.12
Residential	0	0.05

Design Fan Power (cfm/hp)

Description	Lower	Upper
Inefficient or complicated ventilation systems	0	718
Efficient centralised ventilation systems	718	1215
Efficient fan serving a single zone	1215	5268
Highly efficient system	5268	and above

Energy Balance, Inc.
High Performance Buildings

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