

**Town of Plymouth Municipal Office and Garage  
Energy Analysis Report for Net Zero Ready, Net Zero, and Hybrid Options**

August 2, 2021

**SECTION 1.0 Recommendations and Findings**

The following analysis examined the existing building, net zero ready all electric, net zero with solar, and a hybrid electric and propane building for the Town of Plymouth's Municipal Office Building.

Building options examined in this analysis:

- Option A: Existing Building with solar photovoltaics to offset electric use
- Option B: All electric Air Source Heat Pumps, Net Zero Ready Building  
B: w/ Solar Photovoltaics
- Option C: All electric Air to Water Heat Pumps, Net Zero Ready Building  
C: w/ Solar Photovoltaics
- Option D: Hybrid, Office w/ ASHP, garage with propane  
D: w/ Solar Photovoltaics to offset electric use

Initial findings:

- The net zero ready building is estimated to use 85% less energy (21 kBtu/sf-yr) than the existing building (100 kBtu/sf-yr)
- The net zero building with air source heat pumps if not financed is a similar cost to operating the existing building over 30 years.
- Adding solar to any of the options will reduce the 30-year capital and operating costs.
- Pursuing the net zero building instead of the existing building is projected to achieve 220,000 lb reduction in annual carbon dioxide equivalent emissions. This is equivalent to the amount of carbon sequestered in 120 acres of US forests in one year, charging nearly 12 million smart phones, or the carbon emitted by driving a passenger car over 246,000 miles (nearly 10 times around the world)<sup>1</sup> every year!



*Annual net savings of the net zero ready building above the existing*

<sup>1</sup> The net annual energy use was used for the CO2 calculation. Greenhouse Gas Equivalencies Calculator used on the US EPA website. <https://www.epa.gov/energy/greenhouse-gas-equivalencies-calculator>

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### SECTION 2.0 Energy Usage Intensity Comparisons

The following table summarizes the Energy Usage Intensity (EUI) <sup>2</sup> of each of the options.

Energy Usage Intensity Comparison							
		Existing	Existing w/ Solar	Net Zero Ready w/ ASHP	Net Zero w/ ASHP	Net Zero Ready w/ A2WHP	Net Zero w/ A2WHP
Electricity	kBtu/yr	140,000	140000	184,000	184,000	184000	184000
Fossil Fuels	kBtu/yr	1,105,000	1105000	-	-	0	0
Solar Photovoltaic	kBtu/yr	-	(140,000)	-	(184,000)	-	(184,000)
Total	kBtu/yr	1,245,000	1105000	184,000	-	184000	0
Total BuildingEUI	kBtu/sf-yr	100	89	15	0	15	0
% Better than Base		N/A	11%	85%	100%	85%	100%

Energy Usage Intensity Comparison			
		Hybrid Propane garage w/ ASHP office	Hybrid Propane garage w/ ASHP office and Solar for office
Electricity	kBtu/yr	87,000	87,000
Fossil Fuels	kBtu/yr	550,000	550,000
Solar Photovoltaics	kBtu/yr	-	(87,000)
Total	kBtu/yr	640,000	553,000
Total BuildingEUI	kBtu/sf-yr	51	44
% Better than Existing		49%	56%

### SECTION 3.0 Costs

The following cost chart shows cost categories broken into 4 parts:

1. Deferred Maintenance
2. Energy Envelope improvements
3. Energy Mechanical options
4. Solar Photovoltaics (PV)

Within the deferred maintenance is a code level new insulated roof, extended overhangs to protect the building from future degradation, additional steel reinforcing to make those improvements, and new insulated overhead commercial doors.

The remaining envelope improvements are categorized as energy envelope improvements and include new windows, a new wall air barrier of taped plywood sheathing, and new insulated metal wall panels throughout. This category also includes slab edge insulation around the office portions of the building only.

The Energy Mechanical options include four options:

- A) HVAC deferred maintenance – replacing the existing propane boilers in kind with new efficient units, the existing are at the end of their useful life.
- B) Air Source Heat Pumps

<sup>2</sup> Energy Usage Intensity (EUI) is a term that refers to the amount of energy a building uses related to its size. A building's EUI is expressed as kBtu/sf and is akin to a car's fuel mileage.

- C) Air to water Heat Pumps, including 3 phase power and a new radiant slab for distribution in the garage
- D) Hybrid approach with air source heat pumps in the office, and replacing the garage heaters with new efficient propane boilers.

The air source heat pump option for the whole building can be net zero, and this system is ideal for the office area due to its relatively low implementation cost, and the ability to provide heating and cooling with the same efficient system. However, there are some concerns with implementing this type of system in the two garage areas, including:

- Shorter than typical lifecycle expectancy of ASHP units due to air contaminants in the vehicle exhaust (approximately  $\frac{1}{2}$  the life expectancy due to the products of combustion corroding the aluminum fins)
- Higher frequency of maintenance due to air contaminants in the vehicle exhaust
- Slower recovery time for garage area heat in winter months due to longer lag time after garage doors are open.
- Lower temperatures the garage area in winter months due to uninsulated, cold slab.

See the updated Energy Audit Report from July 1, 2021 for additional discussion on the ASHP or A2WHP systems.

The Hybrid option includes ASHP in the office and replacing the propane furnaces with new efficient propane units. This options also assumes the full envelope upgrades would occur including air sealing and insulation. We have assumed the propane use would be reduced in half from current annual use, the air source heat pump loads would be  $\frac{1}{3}$  those projected for the full ASHP option, and the total envelope savings would be  $\frac{3}{4}$  those projected to be conservative. If this option is to remain as a part of the possible direction additional modeling should be performed to determine the total loads beyond this conceptual estimate.

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			Individual Costs	Category Cost	Category Cost w/ 2 significant digits
1. Deferred Maintenance	Demolition	Selective demolition of roofing and brick (Div. 02 and 04)	\$28,146	\$398,990	\$400,000
	Structural steel upgrades	Structural steel reinforcing for new roof insulation (Div. 05)	\$97,110		
	Overhead Doors	New overhead commercial doors (Div08)	\$70,086		
	New Roof and code insulation	New framing for overhangs, roof sheathing (Div 06)	\$42,855		
		Roof insulation 8" polyiso, new roofing, (Div 07)	\$160,793		
2. Energy Envelope	Windows	triple glazed argon filled R5 windows	\$35,727	\$184,248	\$180,000
	Air/Vapor Barrier	Infiltration: New air control layer, taped plywood or equivalent, prior to insulated metal panel installation	\$17,536		
	Insulation	Walls: R 40. Existing walls plus 5" insulated metal panels (R28) Existing R10 walls	\$115,723		
		Slab edge around office: R 16 4" continuous rigid insulation down 4 ft below grade (1/3 cost of Alt 2)	\$15,262		
3. Energy Mech Options A-D	A) HVAC deferred Maintenance	Four new replacement Propane boilers (JH estimate)	\$28,000	\$28,000	\$28,000
	B)HVAC ASHP	Air Source Heat Pump (ASHP), HRV, new 80 gallon ASHP water heaters	\$427,971	\$427,971	\$430,000
	C) HVAC A2WHP	Air to Water Heat Pump (A2WHP), HRV, new 80 gallon ASHP water heaters	\$578,441	\$770,076	\$770,000
		4" sub slab insulation and new slab	\$118,484		
		3 Phase power extended to building for A2Whp	\$73,150		
	D) Hybrid HVAC ASHP in office, propane in garage	Four new replacement Propane boilers for garage, new ASHP for office (must be included with 2. Energy Envelope upgrades)	\$186,200	\$186,200	\$190,000
4. PV	A) Solar PV	Solar PV to cover existing electrical load	\$86,000	\$86,000	\$86,000
	B) or C) Solar PV	Solar PV to cover full ASHP or A2WHP system	\$110,000	\$110,000	\$110,000
	D)Hybrid Solar PV office only	Solar PV to cover ASHP for offices only (\$38,000-\$64,000)	\$53,000	\$53,000	\$53,000

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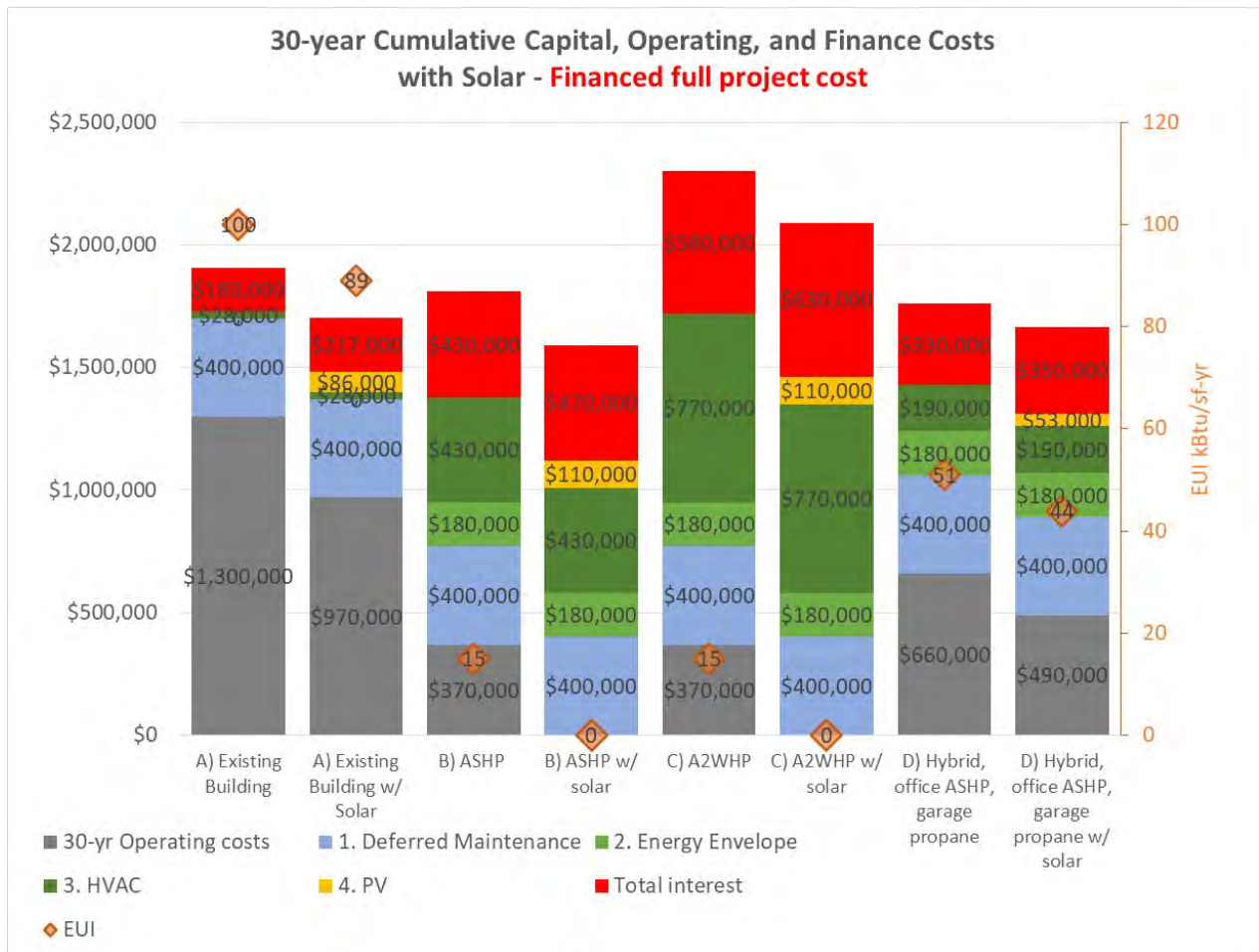
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	A) Existing Building	A) Existing Building w/ Solar	B) ASHP	B) ASHP w/ solar	C) A2WHP	C) A2WHP w/ solar	D) Hybrid, office ASHP, garage propane	D) Hybrid, office ASHP, garage propane w/ solar
1. Deferred Maintenance	\$400,000	\$400,000	\$400,000	\$400,000	\$400,000	\$400,000	\$400,000	\$400,000
2. Energy Envelope	0	0	\$180,000	\$180,000	\$180,000	\$180,000	\$180,000	\$180,000
3. HVAC	\$28,000	\$28,000	\$430,000	\$430,000	\$770,000	\$770,000	\$190,000	\$190,000
4. PV		\$86,000		\$110,000		\$110,000		\$53,000
Total Capital Costs	\$428,000	\$514,000	\$1,010,000	\$1,120,000	\$1,350,000	\$1,460,000	\$770,000	\$823,000
Total interest	\$180,000	\$217,000	\$430,000	\$470,000	\$580,000	\$630,000	\$330,000	\$350,000
30-yr Operating costs	\$1,300,000	\$970,000	\$370,000		\$370,000		\$660,000	\$490,000

### SECTION 4.0 Capital vs. Operating Cost Analysis

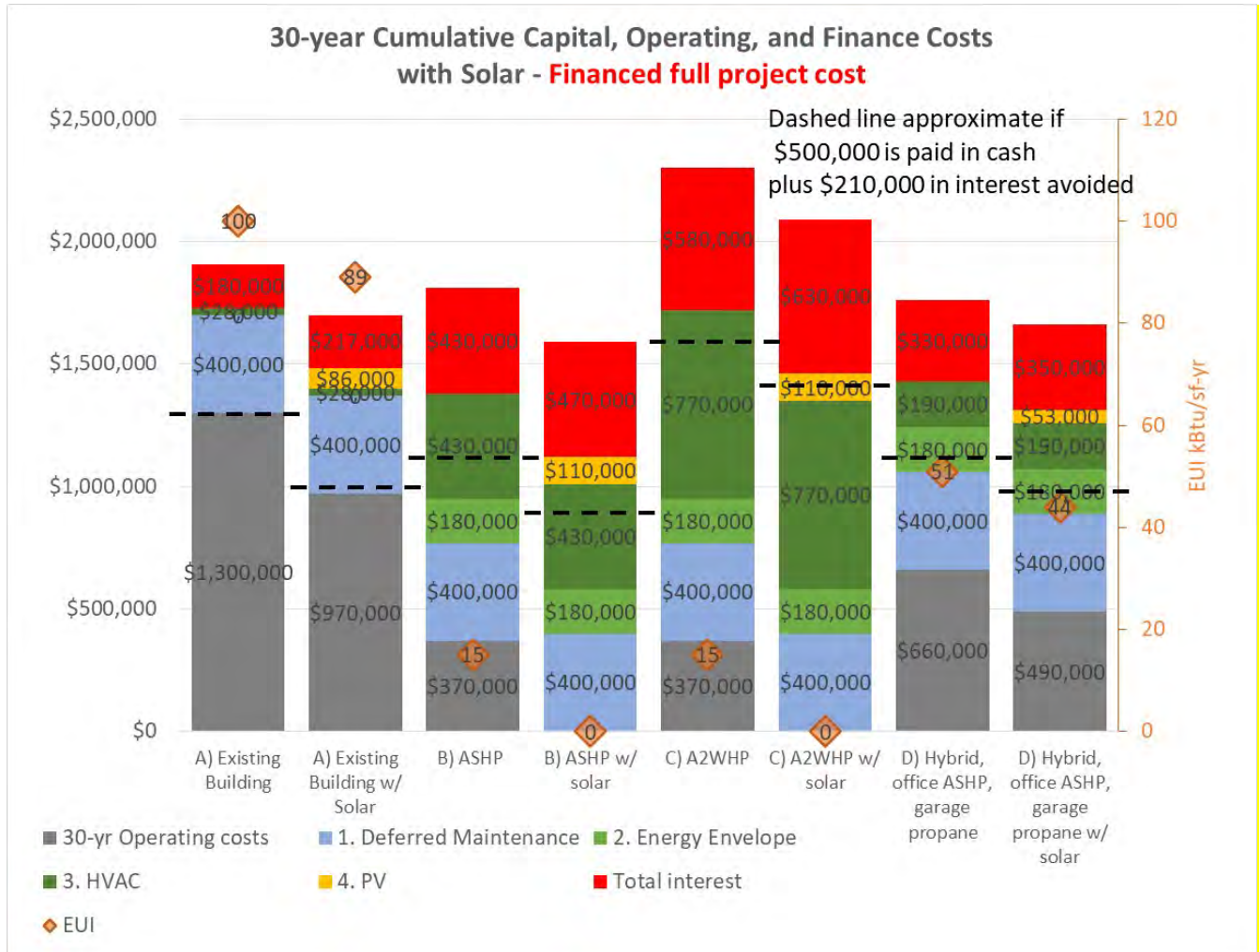
The following graphs summarize capital costs for 30-year operating costs (gray), deferred maintenance (blue), energy upgrades to the envelope and mechanical system savings (green), solar photovoltaic cost (yellow), and the financing interest (red).

With subsequent design phases, we can include further financial analysis to reflect changes as the project evolves.



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## CHOICES IN SUSTAINABILITY





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### APPENDIX Introduction and Approach

The following document summarizes the Financial Energy Analysis which was performed for building options:

Building options examined in this analysis:

- Option A: Existing Building with solar photovoltaics to offset electric use
- Option B: All electric Air Source Heat Pumps, Net Zero Ready Building  
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The steps to arrive at our results included the following:

- Conceptual energy modeling to estimate operating costs for 30-years from John Haenel.
- Determining the capital costs to reach a net zero ready envelope and net zero building.
- Consideration of the capital and operating costs for the options over a 30-year timeline.

Our assumptions are included below.

### Building Assumptions

The following assumptions were used to estimate the energy use of each building.

Building Square footage:	12,437 sf existing building size
Existing energy use:	Average from 2019-2020 41,118 kWh/yr and 12,058 gallons of propane/yr
Financing:	2.5% fixed 30-year bond for additional capital costs and solar photovoltaics

### Energy Assumptions:

- Starting fuel costs:
  - Electric: \$0.129/kWh per average from 2019-2020
  - Propane: \$1.45/gallon per average from 2019-2020
- Fuel Escalation: 4% until the solar plateau<sup>3</sup> is reached in year 30, at which point 0% is assumed.
- Inflation rate and the discount rate are assumed to be equal and therefore 0, the analysis is in 2021 dollars.
- Solar costs: \$2.50/watt installed cost. This excludes any tax credits or other incentives that may be available.
- Net Metering: Assumes a 1 for 1 accounting of kWh on an annual basis, and metering charges are equal for all options and therefore we exclude those costs from the analysis.

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<sup>3</sup> We have assumed a solar plateau where renewable energy production will become grid parity with fossil fuel energy and that the transition to renewable energy production would occur after a certain "pain factor" is reached. We assume this transition to occur after the cost of fossil fuel energy is two times the price for the renewable energy. At that point there is no longer any fuel escalation in our analysis since the market would move to renewable energy sources. (Additional explanation available on page 447 of *The New Net Zero*)

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### Cost Estimate/Additional Capital Costs

The conceptual cost estimate by Erickson Consulting broke out the additional cost for the net zero ready envelope and mechanical system options. The price per line item includes the following contingencies, general conditions, and fees.

All costs include the following:

Prime Contractors General Conditions	12%
Prime Contractors Fee	4%
Design/Trade Contingencies	10%
Bonds and Insurance	0.85%
Escalation	5%

Net Zero Cost:

Solar systems were estimated to cover the electric portion of each building option, and in the ASHP and A2WHP would make it net zero energy. The cost for solar was assumed at a conservative \$3/watt with 1.2 kWh/yr per installed watt.

### Attached:

Historic Fuel Rate Trends and Escalation Rate Justification

Updated BVH Energy Audit Report dated July 1, 2021

Detailed Cost Estimates dated July 27, 2021

Outline Specifications dated July 7, 2021

Structural Evaluation Report

Existing Drawings dated June 11, 2021

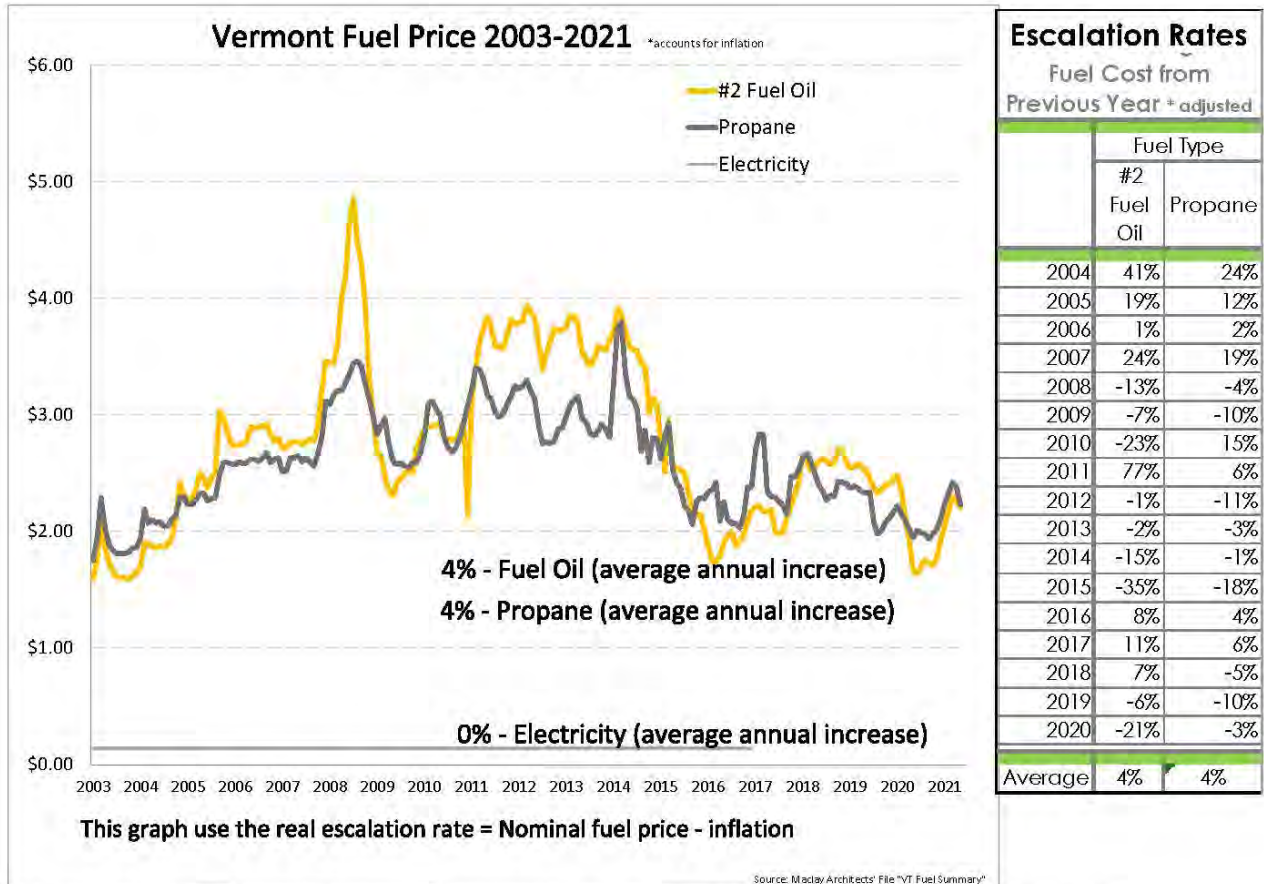


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### Historic Fuel Rate Trends and Escalation Rate Justification

The following graph summarizes actual fuel prices per gallon for three types of fuel from 2003 to June 2021 in Vermont. The data in the graph is from the Vermont Department of Public Service Retail Prices of Heating Fuels and represents the real escalation rate of each fuel where inflation has been omitted. We utilized this data to formulate reasonable assumptions related to probable fuel escalation rates in the coming years.



The annual rates of escalation vary immensely as you can see with the spikes and dips in the graph above. The average annual fuel escalation rate over this period was 4% for propane, 4% for fuel oil #2, and 0% for electricity.

<sup>1</sup> We also assumed that when fuel prices reach 2.5 times the current cost of energy from renewable fuels, either conventional fuel prices will level off and/or one would switch to a renewable fuel source. At that point, we do not escalate fuel prices further in our analysis.

# Energy Audit Report

206 West Newberry Road  
Bloomfield, CT 06002  
Tel: (860) 286-9171  
Fax: (860) 242-0236  
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July 1, 2021

To: Alex King and Bill Maclay, Maclay Architects  
From: Jon Haehnel, BVH Integrated Services, P.C.

## ***RE: Updates to Energy Audit Conducted September 24, 2010 on the Plymouth Town Offices and Garage***

The following report is an update to the original energy audit conducted September 24, 2010. Changes in building occupancy and improvements to the building since the audit have been accounted for but no site work or testing was completed as part of this update. The energy rates and estimated costs have been updated and the measures have been reevaluated in the energy model with the goal of Net Zero Ready.

### ***Summary of Analyzed Measures***

Measure	LPG Saved (Gal)	LPG Saved (\$)	Elec. Saved (kWh)	Elec. Saved (\$)	Total Savings	Approx. Cost of Measure	Lifecycle (Years)	Simple Payback (Years)	SIR
ECM #1 - Upgrade Heating System (Option 1 – AWHP)	12058	\$17,485	-60,048	(\$7,750)	\$9,734	\$433,832	20	44.6	0.4
ECM #1 - Upgrade Heating System (Option 2 – ducted ASHP)	12058	\$17,485	-60,048	(\$7,750)	\$9,734	\$122,257	20	12.6	1.6
ECM #2 - Upgrade Envelope	0	\$0	47,350	\$6,108	\$6,108	\$334,227	30	54.7	0.5
ECM #3 - Replace Water Heaters	270	\$392	59	\$8	\$401	\$400	15	1.0	15.0
ECM #4 - Improve Interior Lighting	0	\$0	4,631	\$745	\$744	\$15,952	15	21.4	0.7
ECM #5 - Improve Exterior Lighting	0	\$0	2,279	\$312	\$312	\$3,950	15	12.7	1.2

*O&M - Operation & Maintenance measure*

*ECM - Energy Conservation Measure*

*Simple Payback – The number of years the energy improvement will take to pay back the investment.*

*SIR - Savings to investment ratio, is the present value of savings divided by the cost. It can be viewed as the number of times the investment will pay for itself over its lifetime. The higher the SIR the better the return on investment.*

### ***Notes for Understanding this Report***

1. Cost estimates in this report typically include the cost for materials and labor to implement the energy efficiency measure. There can be many hidden costs associated with any building improvement that are beyond the scope of this energy audit report. The following costs may apply to the energy efficiency measures listed but have not been specifically accounted for in this report: design, demolition, temporary staging or masking beyond the normal measures of the installation crew, temporary storage or moving costs, increased maintenance costs, historic preservation

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review, permitting, state and federal regulations for lead, asbestos, radon, and the like. There may also be salvage value for old equipment or reduced maintenance that could reduce the cost of an energy improvement. Salvage values and reduced maintenance are not accounted for in the cost estimates in this report. Cost predictions in this report are not estimates or fixed quotes. They only indicate the approximate cost for the recommended upgrade assuming that you hire an outside contractor for the upgrade and are meant to aid in making preliminary decisions. ***We recommend a professional estimator review these cost estimates before making final decisions.***

2. There are several “wild cards” in predicting energy savings. Among them, the weather from year to year, occupant behavior, changes in levels of occupancy and environmental factors that are difficult to quantify. For these reasons, predicted savings are guidelines and not guarantees.
3. When viewing thermographs, lighter colors indicate higher surface temperatures than darker colors. What is considered “heat loss” is dependent upon the perspective from which it is viewed.
4. Some infrared images are taken under depressurization. Depressurization causes all outdoor air to flow inward and is not the normal operating state of the building. It is done to reveal conditions that would not normally be detected or to enhance thermographic images. Depressurization is also used to mimic the environment a building would be under in conditions of high wind or very cold temperatures. The building was depressurized to about –20 Pascals during the last part of the imaging.
5. Air leaks are detected by the infrared camera when cooler air “washes” across a surface. The pattern of air leakage is typically dark wispy lines emanating from the air leakage site.
6. I used \$0.129/kWh and \$1.45/gallon of propane to predict cost savings. These are taken from the 2018-2021 energy consumption information provided. The energy model also includes demand rates and administrative charges. Energy prices are volatile and difficult to predict year to year but the long-term trend is that energy prices will continue to rise. The electricity prices in 2010 were \$0.124/kWh and \$2.62/gallon of propane.
7. Rebates, incentives, and tax credits may apply. Look for programs at <http://www.dsireusa.org/>.

## ***Health and Safety Recommendations (from 2010, not updated)***

All building systems interrelate and occasionally improvements to one building system can create problems in another. Measures to improve energy efficiency should be regarded in the context of the health and safety of occupants and in the long-term durability of a building. Careful consideration of the following and testing before and after efficiency improvements will help to prevent conditions that could have a negative impact on the building.

1. There are no CO detectors in the building. At least 1 should be installed per floor in the offices, fire department, and town garage.
2. Have the boiler and hot water heater tuned to reduce CO levels (See “Combustion testing” below).

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3. There is no provision to remove exhaust fumes from the building while a motor vehicle is going. A tube that can be attached to the exhaust pipe and vented outside should be installed. Also, an exhaust fan that can be run only when the bay doors are partially open (to avoid back drafting the furnaces) should be considered.
4. According to Building Performance Institute (BPI) protocols, the present natural ventilation is NOT sufficient for the building and the occupants (see "Building Ventilation" below). Continuous mechanical ventilation equal to 182 CFM must be included in any insulation or air sealing scope for the building in order to meet BPI standards. Note: The BPI protocols that define the ventilation requirements are specifically designed for residential type structures and may not be applicable to this building. This building is very leaky at present and may not need mechanical ventilation. Consult with a HVAC engineer for the proper sizing of mechanical ventilation when planning improvements that will increase the air tightness of the building.

## ***Energy Plan - Energy Efficiency Measure Descriptions***

The following measures with predicted savings, predicted costs, and implementation notes can be used as the foundation for a long-term energy plan for these buildings. The energy plan has the potential to save the most energy at the least cost if consulted at least once a year and before every renovation, addition, and equipment or building upgrade.

### **ECM #1- Upgrade Heating System**

**Finding:** The building uses about twice as much heating fuel as similar buildings in the northeast. The existing boiler and 4 modine type furnaces are approximately 35 years old. The boiler has a steady state efficiency of 82% and the modine furnaces have rated efficiencies of 75-77%. Circulating fans are installed in both garage bays to improve the circulation of heated air. Distribution for the boiler seems adequate with the exception of some heat pipes that are in the slab and run very close to the outside wall. There is no insulation on the perimeter of the slab.

**Recommendation:** Replace the boiler and modine-style furnaces with an air source heat pump (ASHP) system. For the office areas, this will be a ducted ASHP system. For the garage bays it can be either an air to water heat pump with distribution through a new radiant slab topping the original slab (option 1) or a ducted ASHP (option 2). The efficiencies and energy consumption of the 2 possible systems would be the same but they have distinct differences in implementation.

An air to water heat pump system in the garage bays will require less maintenance because the distribution system is encapsulated in the radiant slab. It will also have a faster recovery time (return to set temperature) after bay doors are opened in the winter because the slab has significant mass and once up to temperature it rebounds quickly after an air change. The only downside to this system is that it requires installation of radiant tubing in a new slab, which is a substantial first cost.

A ducted ASHP is ideal for the office space but would have drawbacks in the garage bays. It's recovery time would be noticeably longer than the current modine system after the bays doors are opened. This could

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be mitigated by adding curtains between bays so that all the heated air is not drawn out when bay doors are opened. However, the system would need more frequent and careful maintenance than an air to water system. The filters would have to be well fit and cleaned often in order to maximize the lifespan of the system. The major advantage of this system is that it would not include the cost of radiant tubing. R15 insulation over the existing slab, a new topping slab with integral drains, and height adjustments to the bay doors are still included in our cost estimate for this option to mitigate heat loss through the floor.

One of the major advantages of an ASHP system over the existing boiler and furnaces is the ability to cool the building as well as heat it. Currently, the office areas are cooled using window AC units. These could be removed permanently. In summer, just switch the ASHP from heating to cooling mode in the office areas. Cooling the garage bays would be an option too, although it would increase the total electricity load. Since this has not been an option previously it could overload the current service you have to the building. Verify the existing service can handle the new load and consider putting a lockout and override in the controls of the garage-based ASHP to prevent excessive use of the AC.

Also included in our energy model and estimate for the HVAC systems is the cost for heat recovery ventilation in the offices and a new ventilation system in the garage bays. With the building envelope retrofits proposed below, the building will need ventilation air, carbon monoxide protection, and an automatic system to exhaust moist air from the building when the trucks return laden with snow.

You may consider keeping the existing boiler and furnaces as a back-up system to your primary ASHP system but this will take up space and increase maintenance costs in the future.

**Implementation and timing:** The boiler and 4 modine-style furnaces are near the end of life and will need to be replaced soon. Now is the ideal time to make this switch. We estimate the replacement cost for this equipment at \$28,000 so that amount has been subtracted from our estimate for the 2 upgrade options shown below.

Measure	LPG Saved (Gal)	LPG Saved (\$)	Elec. Saved (kWh)	Elec. Saved (\$)	Total Savings	Approx. Cost of Measure	Lifecycle (Years)	Simple Payback (Years)	SIR
ECM #1 - Upgrade Heating System (Option 1 – AWHP)	12058	\$17,485	-60,048	(\$7,750)	\$9,734	\$433,832	20	44.6	0.4
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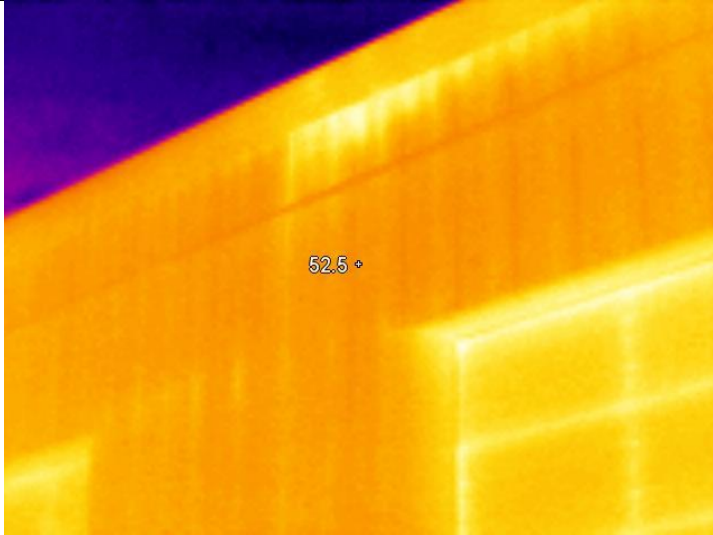


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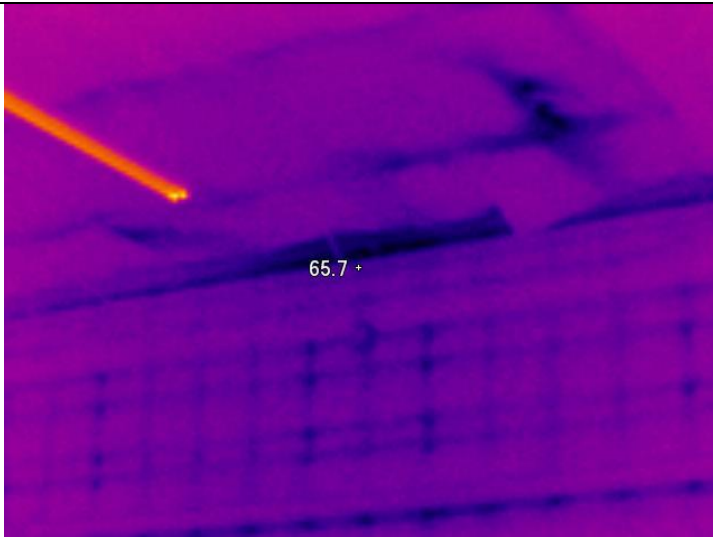
## ECM #2- Upgrade Envelope



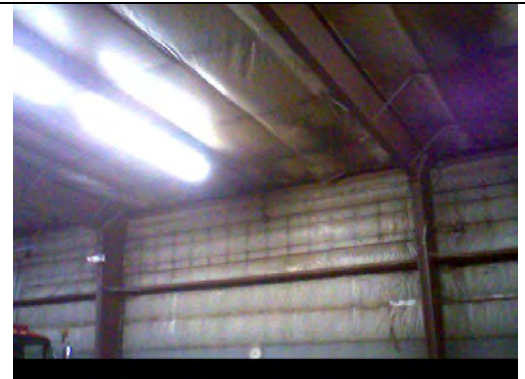
Heat loss at the wall to roof connection as seen from outside.



Visual reference for the IR picture



More heat loss at the wall to roof connection as seen from inside.



Visual reference for the IR picture

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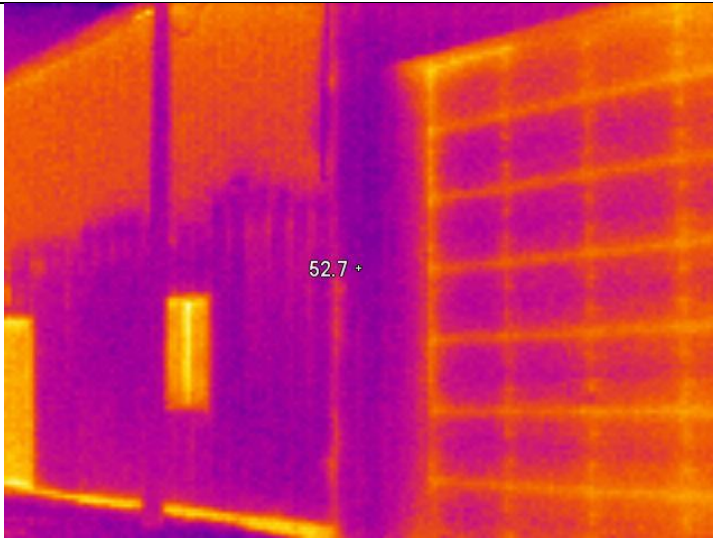
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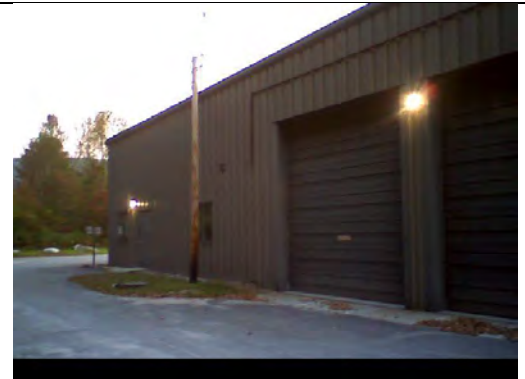
Air leakage around the bay doors.



Visual reference for the IR picture



The office wall, note the insulation stops halfway up the wall. Also note the warm slab edge that has heat pipes in it.



Visual reference for the IR picture

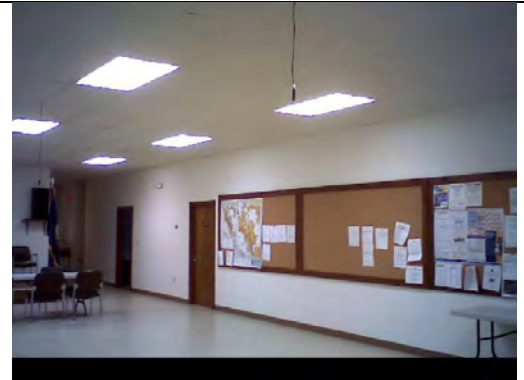


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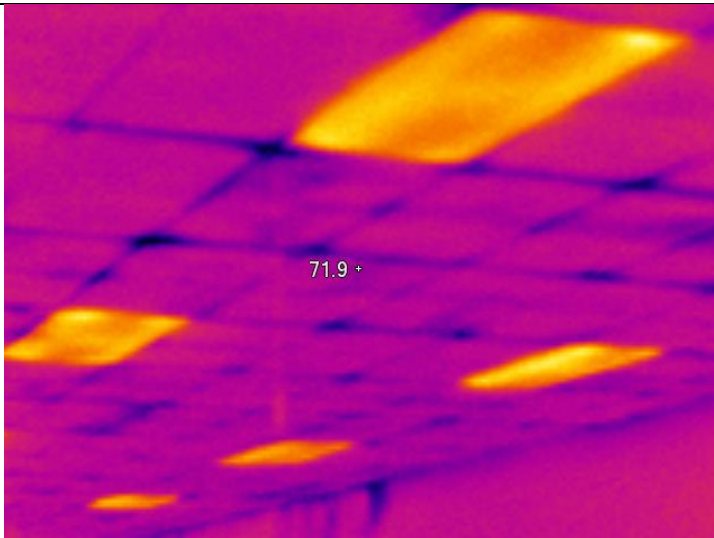
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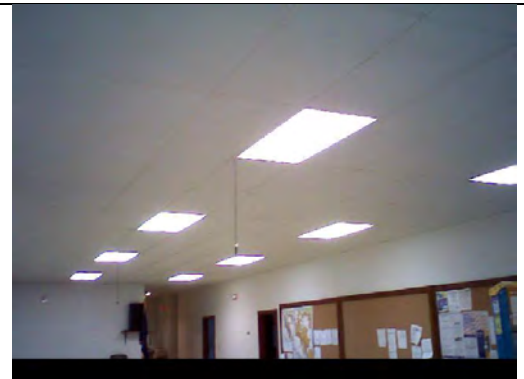
The ceiling before depressurization.



Visual reference for the IR picture



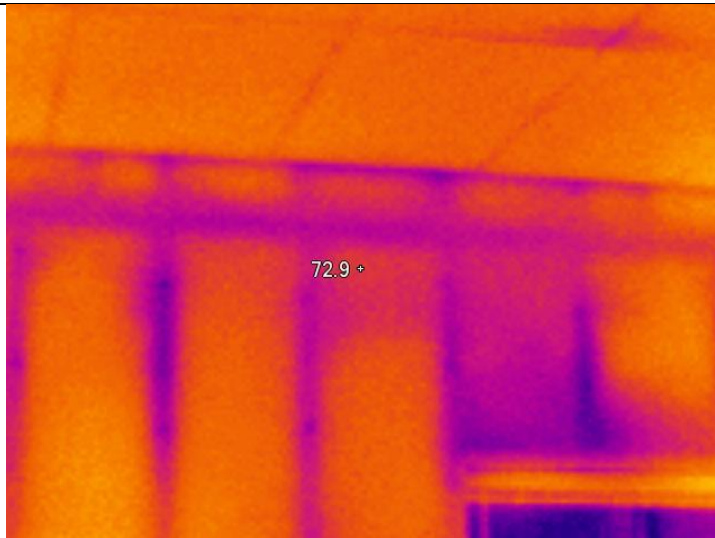
The ceiling after depressurization, the dark spots are air leaks.



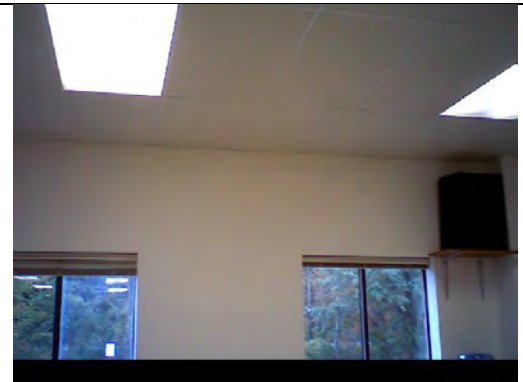
Visual reference for the IR picture

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The office walls are under performing because they are open into the attic above. The steel light gauge framing in the walls is also very distinct in this image.



Visual reference for the IR picture



The exposed stack and lights heats the attic both by radiant heat loss and through air leakage.



The ceiling changes plane and creates step walls which are harder to insulate effectively than if the ceiling was all one plane.

**Finding:** The building uses about twice as much heating fuel as similar buildings in the northeast. Part of this is because of the low efficiency heating system but I believe the bulk of the fuel consumption is because the envelope is under insulated and air leaky. The blower door test showed that the building is higher than average air leakage. The major air leakage sites are the large bay doors on both sides of the bays, the wall to roof connections, and through the walls and dropped ceiling over the town offices. Typical of steel framed structures, the building is insulated with vinyl wrapped fiberglass about 5.5" thick

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on the roof and 3.5" to 5.5" on the walls. The effective R-value of the walls is about R10 and the roof about R12. The ceiling over the town offices has an additional 6" of fiberglass insulation but it is not a continuous thermal layer, it is broken up by step walls, lights, and other penetrations. The slab edge and short foundation walls are uninsulated.

The attic above the town offices is in limbo. The roof above is insulated but the walls are not, it has no clear definition as indoor or outdoor space. In addition, this space has heat sources, like the boiler stack, the top of the lights, and warm air through the office ceilings and walls. These heat sources and the lack of winter sun probably contribute to the ice dam problems on the north side of the roof that require the use of heat cable to manage. Our understanding is that most winters, the ice dams cause widespread roof leaks and can cost up to \$5,000 per year for clearing the ice.

The exterior walls of the offices are underperforming because air is able to move around and through the insulation. The tops of the walls are open into the attic space above.

## **Recommendation:**

Replace the R8 bay doors with doors that have thick insulated panels so you get a higher total R-value out of the door, target R26 or better. Depending on the height of the new slab, some bay doors will have to be cut and reframed at the head. Given the number and size of the doors in this building, the upcharge for a high R-value door vs. a conventional door will be paid off quickly in energy savings. Adjust the bay door closers so the top of the door meets the weather-stripping when closed. Check the weather-stripping on all sides of each door to make sure it is in close contact with the door. When the door is closed, and with the lights off, look at the door from all sides for daylight. If you see daylight the weather stripping needs to be adjusted. Given the number of large doors on this building, it will be worth it in energy savings to check the doors each year for optimal air tightness.

Air seal the roof to the walls. Add insulation to the whole roof from above and outside to bring the total R-value to 62. Install a cover board and fully adhered membrane roof over the additional insulation. The existing fiberglass may need the vinyl slashed with a knife to avoid having more than one vapor barrier and trapping moisture between the 2 layers of insulation.

Wrap the existing metal walls from the exterior with 5" insulated metal panels (IMPs) for an additional R28 to the existing R10 walls. This will require the removal of some exterior brick but the IMPs have an integral finish system so once installed no other finishes will be required on the exterior.

Insulate the foundation walls above and below grade with R15 rigid insulation and a protective finish for the above grade application. As mentioned above, the garage slab should be insulated with R15 insulation and protected with a topping slab 4-5" thick.

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Replace the windows with R5 glazing, warm edge spacers, and low conductivity frames.

Through this comprehensive retrofit of the building envelope, air sealing at the wall and roof, the doors, the windows, and at the foundation will be paramount. The building leaks nearly 1 CFM/sf at 50 pa. which is far above average. With air sealing detailed for each transition of the building envelope, a target of 0.15 CFM50/sf is achievable.

**Implementation and timing:** Implement the envelope measures concurrent with the HVAC measures or, if the work must be phased, implement the envelope measures first. With a high performance envelope, the total heating load goes down and a smaller mechanical system can be sized appropriate to the load.

Measure	LPG Saved (Gal)	LPG Saved (\$)	Elec. Saved (kWh)	Elec. Saved (\$)	Total Savings	Approx. Cost of Measure	Lifecycle (Years)	Simple Payback (Years)	SIR
ECM #2 - Upgrade Envelope	0	\$0	47,350	\$6,108	\$6,108	\$334,227	30	54.7	0.5

## ECM #3- Replace Water Heaters

**Finding:** There are 2 water heaters in the building: a propane 40 gallon water heater and an electric 30 gallon water heater. The propane heater has a steady state efficiency of 78%. There is a low demand for hot water, mostly for hand washing and limited cleaning.

**Recommendation:** Replace both hot water heaters with an 80-gallon ASHP water heater located in the garage bays. One of the benefits of an ASHP water heater is that it dehumidifies the space that it is in so that could be helpful in keeping the air of the garage bays dry. All hot water lines from the heater must be insulated.

**Implementation and timing:** The propane water heater is near the end of life and will need to be replaced soon. The cost of a propane replacement is nearly the same as that of installing a new ASHP water heater so only the cost of rerouting and insulating piping has been included in our estimate.

Measure	LPG Saved (Gal)	LPG Saved (\$)	Elec. Saved (kWh)	Elec. Saved (\$)	Total Savings	Approx. Cost of Measure	Lifecycle (Years)	Simple Payback (Years)	SIR
ECM #3 - Replace Water Heaters	270	\$392	59	\$8	\$401	\$400	15	1.0	15.0



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## ECM #4- Improve Interior Lighting

**Finding:** Most of the lighting in the building is T12 fluorescent lighting. There are a few incandescent bulbs in regular use throughout the building, especially in the bathrooms and in recessed ceiling fixtures. The T12 lighting in the fire dept. and public works bays has been replaced with high bay LED lights but lighting in other areas has not been improved.

**Recommendation:** Replace all the remaining T12 fluorescent lighting with LED lighting. Replace all incandescent bulbs with LED bulbs.

**Implementation and timing:** Replace the fluorescent lights now and replace the incandescent bulbs with LED replacements as old bulbs burn out. Replace the bathroom light fixtures with LED lights of comparable light quality.

Measure	LPG Saved (Gal)	LPG Saved (\$)	Elec. Saved (kWh)	Elec. Saved (\$)	Total Savings	Approx. Cost of Measure	Lifecycle (Years)	Simple Payback (Years)	SIR
ECM #4 - Improve Interior Lighting	0	\$0	4,631	\$745	\$744	\$15,952	15	21.4	0.7

## ECM #5- Improve Exterior Lighting



A typical metal halide wall pack.



Photosensor for the flood light in the back.

**Finding:** There are eight 70W metal halide wall packs, and a halogen flood light on photo sensor controls. These lights are on all night, every night. Other outside lights are one 190W parking lot light, and two 190W metal halide lights used infrequently.

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**Recommendation:** For lights that must always be on for security reasons, replace them with equivalent LED lights. They can remain on photo sensor controls. For lights that are only needed periodically for spot lighting, add motion sensor controls.

**Implementation and timing:** Replace the wall pack lights and flood light with equivalent low wattage LED lights immediately. Replace the infrequent use lights with LED equivalents as they wear out. Work with an electrical supply house like Needham Electric to get the best equivalent lights to the ones you have.

Measure	LPG Saved (Gal)	LPG Saved (\$)	Elec. Saved (kWh)	Elec. Saved (\$)	Total Savings	Approx. Cost of Measure	Lifecycle (Years)	Simple Payback (Years)	SIR
ECM #5 - Improve Exterior Lighting	0	\$0	2,279	\$312	\$312	\$3,950	15	12.7	1.2

## Existing Energy Use

Below is a summary of the energy use for the building in recent years. When possible, the total loads are divided into base load (energy loads that are consistent month to month) and seasonal load (energy loads that spike seasonally). The designation "NA" indicates data that was not available for this study.

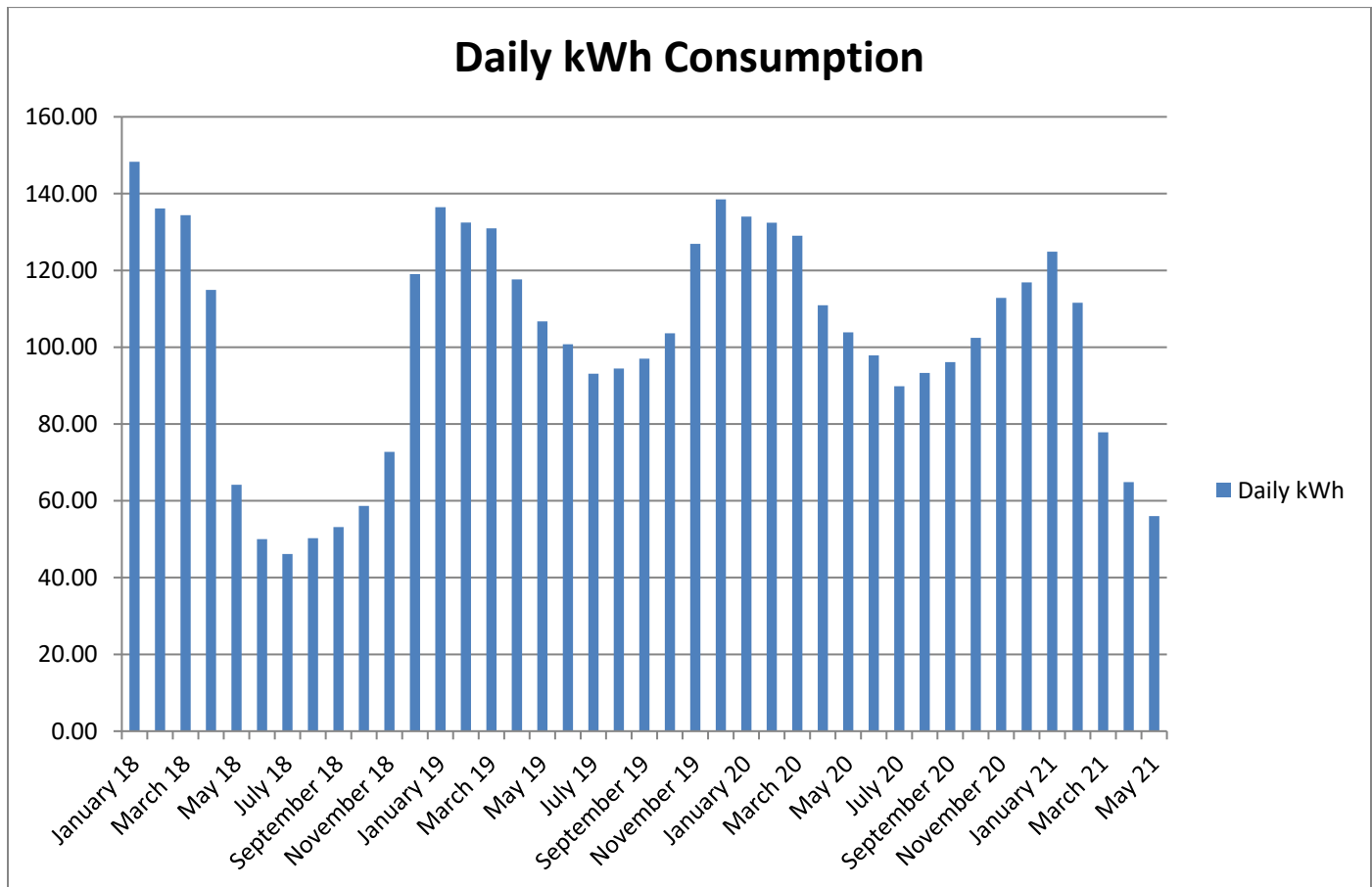
Energy Use Summary for Plymouth Town Office and Garage							
Energy type	Unit	Total 2020	Total 2019	Total 2018	Average	Annual Base load	Annual Seasonal load
Electricity	kWh	40,347	41,889	31,726	37987	33,598	4,389
Propane	Gallons	12981	13266	11830	12692	N/A	12,692

The average electricity use has gone down about 20% since 2010 not including the unusual drop in energy use in 2018. This is attributed to fewer operating hours for the town offices and new LED lighting being installed in the fire dept. and public works equipment bays. Propane use is 7% higher than in 2010.

Below is the average daily electrical consumption in kWh for each month.

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As can be seen in the chart above, the daily electrical load was significantly lower from May 2018 to November 2018. Talking with the town, we have not found an explanation for this significant change in consumption. Overall, electric energy use has decreased about 20%. In 2010, nearly every month the daily consumption was over 120 kWh, now it only crosses that line seasonally.

Energy intensity is energy consumption per square foot of floor area. The table below compares the energy intensity of this building with buildings of similar size and type in the North East (NE). Energy intensity per square foot of floor area does not account for differences in building volume or shell surface area so comparisons cannot be precise.

Energy Intensity Benchmarks				
Building Name	Floor Area sq. ft.	Electricity kWh/sf	Heat Energy kBtu/sf	Total Energy kBtu/sf
Plymouth Town Office and Garage	12,437	3.1	93.6	104.0
Similar TYPE Buildings in NE		5.9	40.0	41.6
Similar SIZE buildings in NE		9.6	45.2	75.3



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As can be seen, electricity use is well below other buildings, but fuel consumption is way above average for buildings of similar type and similar size in the North East (NE). As noted above, propane use has increased since 2010.

## **Combustion Testing (from 2010, not updated)**

The table below summarizes the testing on the boiler and furnaces. Cells in red indicate failure to draft or carbon monoxide (CO) levels above 25ppm which is an indicator of incomplete combustion and a possible health risk if the chimney was not properly drafting. The N/A designation indicates that the test was not applicable to this combustion appliance either because the test data could not be obtained in a safe manner or testing could not be done in accordance with Building Performance Institute (BPI) protocols. The tests show that the boiler and hot water heater should be serviced to insure it they are venting properly and burning safely.

*CAZ- combustion appliance zone, the area where a combustion appliance is and where pressure readings are taken to determine if conditions for back drafting may occur.*

*Worst case – turning on all fans and appliances that can make the building negatively pressurized to see if the potential for back drafting exists.*

Combustion Testing- Boiler #1, Propane		
Baseline CAZ pressure	-1	Pascals
Worst case CAZ pressure	-0.3	Pascals
Worst Case Spillage	Failed to draft within 1 minute	
Steady State Stack Temperature	459	° F
Steady State Efficiency	82.4	%
Flue CO	35	ppm
Outside temp	60	° F
Minimum Acceptable draft	-1.25	Pascals
Draft	-4	Pascals
Ambiant CO	0	ppm

Combustion Testing- Hot water heater #1 , Propane		
Baseline CAZ pressure	-1	Pascals
Worst case CAZ pressure	-0.2	Pascals
Worst Case Spillage	Passed, draft within 1 minute	

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Steady State Stack Temperature	619 ° F
Steady State Efficiency	78 %
Flue CO	30 ppm
Outside temp	60 ° F
Acceptable draft	-1.25 Pascals
Draft	-3.4 Pascals
Ambiant CO	0 ppm

Combustion Testing- Furnace #1 -Fire Dept , Propane	
Baseline CAZ pressure	-1 Pascals
Worst case CAZ pressure	0 Pascals
Worst Case Spillage	NA
Steady State Stack Temperature	NA ° F
Steady State Efficiency	NA %
Flue CO	NA ppm
Outside temp	60 ° F
Acceptable draft	-1.25 Pascals
Draft	NA Pascals
Ambiant CO	0 ppm

Combustion Testing- Furnace #2 - Fire Dept , Propane	
Baseline CAZ pressure	-1 Pascals
Worst case CAZ pressure	0 Pascals
Worst Case Spillage	NA
Steady State Stack Temperature	NA ° F
Steady State Efficiency	NA %
Flue CO	NA ppm
Outside temp	60 ° F
Acceptable draft	-1.25 Pascals
Draft	NA Pascals
Ambiant CO	0 ppm

Combustion Testing- Furnace #3 - Garage , Propane	
Baseline CAZ pressure	0.8 Pascals
Worst case CAZ pressure	0 Pascals
Worst Case Spillage	NA
Steady State Stack Temperature	NA ° F
Steady State Efficiency	NA %

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Flue CO	NA	ppm
Outside temp	60	° F
Acceptable draft	-1.25	Pascals
Draft	NA	Pascals
Ambiant CO	0	ppm

Combustion Testing- Furnace #4 - Garage , Propane		
Baseline CAZ pressure	0.8	Pascals
Worst case CAZ pressure	0	Pascals
Worst Case Spillage	NA	
Steady State Stack Temperature	NA	° F
Steady State Efficiency	NA	%
Flue CO	NA	ppm
Outside temp	60	° F
Acceptable draft	-1.25	Pascals
Draft	NA	Pascals
Ambiant CO	0	ppm

Combustion Testing- Stove #1 - Crew Kitchen, Propane		
Baseline CAZ pressure	-1	Pascals
Worst case CAZ pressure	-0.5	Pascals
Worst Case Spillage	NA	
Steady State Stack Temperature	NA	° F
Steady State Efficiency	NA	%
Flue CO	29	ppm
Outside temp	60	° F
Acceptable draft	-1.25	Pascals
Draft	NA	Pascals
Ambiant CO	4	ppm

## **Building Ventilation (from 2010, not updated)**

The table below is a summary of the calculations to determine the minimum ventilation required for the building compared to the ventilation rate determined by blower door testing. Based on our testing the building is not sufficiently ventilated by natural ventilation and will need mechanical ventilation or review by a HVAC engineer to determine the proper ventilation rate for the building.

Minimum Building Airflow Standard (ASHRAE 62-89)		
Conditioned space floor area	12437	square feet

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Excluded areas	none	
Total conditioned volume	214487	cubic feet
# of regular occupants	6	people
# of stories above grade	1	stories
Zone and Location	2	Plymouth, VT
N- factor and Adj. N- factor	18	18.0
Required Building ventilation	1251	CFM
Required Occupant ventilation	90	CFM
Minimum airflow standard	22521	CFM50
Blower door test result	19241	CFM50
Minimum airflow standard met?	No	

## **Blower Door Test Results (from 2010, not updated)**

### Ambient conditions 9-24-10:

Outside temperature: 60 °F

Inside temperature: 68 °F

Wind conditions: calm

Time of day: 9:00 am

### Notes:

1. All interior doors were open except the vault door was closed.
2. All exterior doors and windows were closed and latched.
3. Heaters were turned off.

### Results:

Most buildings in the United States are tested at 50 Pascals (0.2" w.c. or 1.04 lbs./sq. ft) as a means of comparison. 50 Pascals is about 5 times the pressure a building might experience on a cold winter day. Temperature adjusted CFM50 accounts for the change in air density as it is drawn in through gaps and cracks from outside and is a more accurate measure of air flow under test conditions.

Temperature adjusted CFM @ 50Pa.	Cubic feet of Building Volume	Air changes per hour @ 50Pa.	Square Feet of Building Shell	CFM50/sf of shell
19,241	214,487	5.38	19,452	0.95

### Air Leakage Comparison to Other Buildings:

Building	Air Leakage Rate (CFM50/sf of exposed shell)
----------	--

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Ultra tight construction	<0.10
High performance construction	<0.25
Typical modern construction	0.60 to 0.90
<b>Plymouth Town Offices and Garage</b>	<b>0.95</b>
Leaky construction	> 0.60



Item	Description	Takeoff Qty	Unit Cost	Total	
					Amount
<b>1 Deferred Maintenance</b>					
<b>02 SITEWORK</b>					
<i>02-41-13.00 Selective Site Demolition</i>					
<i>02-41-13.33 Minor Site Demolition</i>					
5600	Site demo, for disposal on site, to 5 mis, add <i>Minor Site Demolition</i>	9.259 cy	22.601 /cy		209
					209
	0.975 Labor hours				
	1.949 Equipment hours				
	<i>Selective Site Demolition</i>				209
	0.975 Labor hours				
	1.949 Equipment hours				
<i>02-41-19.00 Selective Demolition</i>					
<i>02-41-19.16 Selective Demolition, Cutout</i>					
----	Removal for structural reinforcing Allowance <i>Selective Demolition, Cutout</i>	12,360.00 sf	1.357 /sf		16,778
					16,778
<i>02-41-19.23 Selective Demolition, Rubbish Handling</i>					
n 0840	Selective demolition, rubbish handling, dumpster, 40 c.y., 13 ton capacity, weekly rental, includes one dump per week, cost added to demolition cost. <i>Selective Demolition, Rubbish Handling</i>	5.00 each	1,153.842 /each		5,769
					5,769
	<i>Selective Demolition</i>				22,547
	<b>02 SITEWORK &amp; DEMOLITION</b>				<b>22,757</b>
	0.975 Labor hours				
	1.949 Equipment hours				
<b>04 STONE &amp; M</b>					
<i>04-05-00.00 Common Work Results For Masonry</i>					
<i>04-05-05.10 Selective Demolition</i>					
5020	Selective demolition, masonry, veneers, brick, hard mortar, remove <i>Selective Demolition</i>	1,000.00 sf	5.389 /sf		5,389
					5,389
	64.00 Labor hours				
	<i>Common Work Results For Masonry</i>				5,389
	64.00 Labor hours				
	<b>04 STONE &amp; MASONRY</b>				<b>5,389</b>
	64.00 Labor hours				
<b>05 METALS</b>					
<i>05-12-23.00 Structural Steel For Buildings</i>					
<i>05-12-23.75 Structural Steel Members</i>					
----	Strural steel reinforcing	9.18 tons	6,923.044 /tons		63,554



Item	Description	Takeoff Qty	Unit Cost	Total	
				Unit Cost	Amount
	Structural Steel Members				63,554
	Structural Steel For Buildings				63,554
<b>13-34-19.00 Metal Building Systems</b>					
<b>13-34-19.50 Pre-Engineered Steel Buildings</b>					
----	Add purlins between existing 10X3X.7z	2,060.00	lf	16.29 /lf	33,556
	Pre-Engineered Steel Buildings				33,556
	Metal Building Systems				33,556
	<b>05 METALS</b>				<b>97,110</b>
<b>06 WOOD &amp; PLASTICS</b>					
<b>06-11-00.00 Wood Framing</b>					
<b>06-11-10.02 Blocking</b>					
2620	2" x 4" miscellaneous wood blocking, to wood construction, per M.B.F.	0.207	mbf	5,938.90 /mbf	1,227
8050	Framing, miscellaneous wood blocking/backing for sheet metal	1.80	mbf	4,208.106 /mbf	7,575
	Blocking				8,802
	67.325 Labor hours				
	Wood Framing				8,802
	67.325 Labor hours				
<b>06-16-36.00 Wood Panel Product Sheathing</b>					
<b>06-16-36.10 Sheathing</b>					
0100	Sheathing, plywood on roof, CDX, 1/2" thick	12,767.00	sf	2.158 /sf	27,556
	Sheathing				27,556
	145.909 Labor hours				
	Wood Panel Product Sheathing				27,556
	145.909 Labor hours				
<b>06-18-00.00 Glued-Laminated Construction</b>					
<b>06-18-13.20 Laminated Framing</b>					
6050	Laminated framing, laminated veneer members, southern pine or western species, 1-3/4" wide x 5-1/2" deep	742.00	lf	8.756 /lf	6,497
	Laminated Framing				6,497
	24.733 Labor hours				
	Glued-Laminated Construction				6,497
	24.733 Labor hours				
	<b>06 WOOD &amp; PLASTICS</b>				<b>42,855</b>
	237.968 Labor hours				
<b>07 THERMAL INSULATION</b>					

				Total	
Item	Description	Takeoff Qty		Unit Cost	Amount
07-22-00.00 Roof And Deck Insulation					
07-22-16.10 Roof Deck Insulation					
1755	Roof deck insulation, polyisocyanurate, 4" thick, 2#/CF density	12,355.00	sf	4.41 /sf	54,484
1755	Roof deck insulation, polyisocyanurate, 4" thick, 2#/CF density	12,355.00	sf	4.41 /sf	54,484
	Roof Deck Insulation				108,967
	222.39 Labor hours				
	Roof And Deck Insulation				108,967
	222.39 Labor hours				
07-53-23.00 Ethylene-Propylene-Diene-Monomer Roofing					
07-53-23.20 Ethylene-Propylene-Diene-Monomer Roofing (EPDM)					
4800	Ethylene-propylene-diene-monomer roofing, (EPDM), 0.40 psf, fully adhered with adhesive, 60 mils	127.67	sq	344.795 /sq	44,020
	Ethylene-Propylene-Diene-Monomer Roofing (EPDM)				44,020
	196.415 Labor hours				
	39.283 Equipment hours				
	Ethylene-Propylene-Diene-Monomer Roofing				44,020
	196.415 Labor hours				
	39.283 Equipment hours				
07-71-19.00 Manufactured Gravel Stops And Fasciae					
07-71-19.10 Gravel Stop					
1360	Gravel stop, galvanized steel, plain, with continuous cleat, 4" leg, 6" face height, 24 gauge	460.00	lf	16.968 /lf	7,805
	Gravel Stop				7,805
	25.379 Labor hours				
	Manufactured Gravel Stops And Fasciae				7,805
	25.379 Labor hours				
07 THERMAL PROTECTION					160,793
	444.185 Labor hours				
	39.283 Equipment hours				

**08 Openings***08-36-13.00 Sectional Doors**08-36-13.10 Overhead Commercial Doors*

2800	Doors, overhead, commercial, stock, steel, heavy duty, sectional, chain hoist, 15' x 15' high	8.00	ea	7,035.02 /ea	56,280
2860	Doors, overhead, commercial, stock, steel, heavy duty, sectional, for 1-1/4" rigid insulation and 26 gauge galvanized back panel, add	1,800.00	sf	7.67 /sf	13,805
	<i>Overhead Commercial Doors</i>				<u>70,086</u>
	182.857 Labor hours				

Item	Description	Takeoff Qty	Unit Cost	Total	
				Unit Cost	Amount
	<i>Sectional Doors</i>				70,086
	182.857 Labor hours				
	<b>08 Openings</b>				<b>70,086</b>
	182.857 Labor hours				
	<b>1 Deferred Maintenance</b>				<b>398,988</b>
	929.984 Labor hours				
	41.232 Equipment hours				
	<b>2 Energy Envelope</b>				
	<b>06 WOOD &amp; PL</b>				
	<i>06-16-36.00 Wood Panel Product Sheathing</i>				
	<i>06-16-36.10 Sheathing</i>				
0500	Sheathing, plywood on walls, CDX, 3/8" thick	6,500.00	sf	2.698 /sf	17,536
	<i>Sheathing</i>				17,536
	110.500 Labor hours				
	<i>Wood Panel Product Sheathing</i>				17,536
	110.500 Labor hours				
	<b>06 WOOD &amp; PLASTICS</b>				<b>17,536</b>
	110.500 Labor hours				
	<b>07 THERMAL I</b>				
	<i>07-42-13.00 Metal Wall Panels</i>				
	<i>07-42-13.20 Aluminum Siding Panels</i>				
----	Aluminum sandwich panel system, 5"	5,500.00	sf	21.041 /sf	115,723
	<i>Aluminum Siding Panels</i>				115,723
	<i>Metal Wall Panels</i>				115,723
	<b>07 THERMAL PROTECTION</b>				<b>115,723</b>
	<b>08 Openings</b>				
	<i>08-05-00.00 Common Work Results For Openings</i>				
	<i>08-05-05.10 Selective Demolition Doors</i>				
0200	Door demolition, exterior door, single, 3' x 7' high, 1-3/4" thick, remove	6.00	ea	42.08 /ea	252
3440	Door demolition, special doors, overhead, commercial, 15' x 15' high, remove, includes frames	8.00	ea	563.351 /ea	4,507
	<i>Selective Demolition Doors</i>				4,759
	45.667 Labor hours				
	<i>08-05-05.20 Selective Demolition Of Windows</i>				
0200	Window demolition, aluminum, to 12 S.F.	11.00	ea	42.081 /ea	463

Item	Description	Takeoff Qty	Unit Cost	Total	
				Unit Cost	Amount
	<i>Selective Demolition Of Windows</i>				463
	5.50 Labor hours				
08-05-05.30	<i>Doors Complete</i>				
0250	Exterior door/frame/hardware (wd or hm) complete	6.00	leaf	2,714.918 /leaf	16,290
	<i>Doors Complete</i>				16,290
08-05-05.40	<i>Windows</i>				
100	Fiberglass insulated windows	154.00	sf	92.307 /sf	14,215
	<i>Windows</i>				14,215
	<i>Common Work Results For Openings</i>				35,727
	51.167 Labor hours				
<b>08</b>	<b>Openings</b>				<b>35,727</b>
	51.167 Labor hours				
<b>2</b>	<b>Energy Envelope</b>				<b>168,987</b>
	161.667 Labor hours				
<b>3</b>	<b>Energy Mech Opt A-D</b>				
<b>23 HVAC</b>					
23-05-00.00	<i>Common Work Results For HVAC</i>				
23-05-00.10					
0200	HVAC & Electrical OPTION 2 - ESV	1.00	ls	455,970.59 /ls	455,971
	CONCEPTIAL ESTIMATE				
23-05-00.10					455,971
	<i>Common Work Results For HVAC</i>				455,971
<b>23</b>	<b>HVAC</b>				<b>455,971</b>
<b>3</b>	<b>Energy Mech Opt A-D</b>				<b>455,971</b>

Estimate Totals

Description	Amount	Totals	Rate
Labor	111,250		
Material	209,384		
Subcontract	701,872		
Equipment	1,440		
Other			
	1,023,946	1,023,946	
Total		1,023,946	



#####





				Total	
Item	Description	Takeoff Qty	Unit Cost	Amount	
<div>* <i>unassigned</i> *</div>					
<div>03 CONCRETE</div>					
<div>03-11-13.00 Structural Cast-In-Place Concrete Forming</div>					
<div>03-11-13.65 Forms In Place, Slab On Grade</div>					
3000	C.I.P. concrete forms, slab on grade, edge, wood, to 6" high, 4 use, includes erecting, bracing, stripping and cleaning	572.00	lf	4.29 /lf	2,454
	Forms In Place, Slab On Grade				2,454
	30.507 Labor hours				
	Structural Cast-In-Place Concrete Forming				2,454
	30.507 Labor hours				
<div>03-15-05.00 Concrete Forming Accessories</div>					
<div>03-15-05.25 Expansion Joints</div>					
5500	Sawcut control joints, slab on grade	824.00	lf	1.012 /lf	834
	Expansion Joints				834
	8.24 Labor hours				
	12.36 Equipment hours				
	Concrete Forming Accessories				834
	8.24 Labor hours				
	12.36 Equipment hours				
<div>03-21-05.00 Reinforcing Steel Accessories</div>					
<div>03-21-10.60 Reinforcing In Place</div>					
0600	Reinforcing Steel, in place, slab on grade, #3 to #7, A615, grade 60, incl labor for accessories, excl material for accessories	3.815	ton	2,275.007 /ton	8,679
0605	Reinforcing, a615 60, sog, thickened edge, allow 28 lbs/cy, #3 to #7	0.055	ton	2,200.00 /ton	121
2005	Reinforcing in place, unloading & sorting, add to above - slabs	3.87	ton	54.00 /ton	209
	Reinforcing In Place				9,009
	56.011 Labor hours				
	0.310 Equipment hours				
	Reinforcing Steel Accessories				9,009
	56.011 Labor hours				
	0.310 Equipment hours				
<div>03-31-05.00 Normal Weight Structural Concrete</div>					
<div>03-31-05.35 Normal Weight Concrete, Ready Mix</div>					
0405	Concrete, ready mix, regular weight, slabs/mats, 5000 psi	137.667	cy	144.00 /cy	19,824
	Normal Weight Concrete, Ready Mix				19,824
<div>03-31-05.70 Placing Concrete</div>					
4300	Structural concrete, placing, slab on grade, direct chute, up to 6" thick, includes strike off & consolidation, excludes material	137.667	cy	28.50 /cy	3,924

Item	Description	Takeoff Qty	Unit Cost	Total	
				Amount	
	Placing Concrete				3,924
	60.073 Labor hours				
	20.024 Equipment hours				
	Normal Weight Structural Concrete				23,748
	60.073 Labor hours				
	20.024 Equipment hours				
03-35-29.00 Tooled Concrete Finishing					
03-35-29.30 Finishing Floors, Tooled					
n	0250 Cfnsh,flrs,for spcf rndm accs flrs aci cls 1,2,3 and 4,achv a crmps ovrl flr fltn&l/vln val f35/25,bull flt,mchn flt&stl trwl (wlk-bhn),excl plcn,strkn	8,240.00	sf	0.99 /sf	8,158
	2350 Concrete finishing, floor, hardener, non-metallic, medium service, 0.75 psf, add	8,240.00	sf	1.04 /sf	8,570
	Finishing Floors, Tooled				16,727
	203.206 Labor hours				
	38.437 Equipment hours				
	Tooled Concrete Finishing				16,727
	203.206 Labor hours				
	38.437 Equipment hours				
03-39-00.00 Concrete Curing					
03-39-13.50 Water Curing					
	0300 Curing, sprayed membrane curing compound	82.40	csf	24.50 /csf	2,019
	Water Curing				2,019
	13.878 Labor hours				
	Concrete Curing				2,019
	13.878 Labor hours				
	03 CONCRETE				54,790
	371.914 Labor hours				
	71.131 Equipment hours				
05 METALS					
05-05-00.00 Common Work Results For Metals					
05-05-05.05 Misc. structural					
----	Reframe 3-0 x 7-0 exterior door openings	3.00	each	500.00 /each	1,500
----	Reframe OH door openings	4.00	each	1,500.00 /each	6,000
	Misc. structural				7,500
	Common Work Results For Metals				7,500
	05 METALS				7,500
07 THERMAL I					
07-21-13.00 Board Insulation					
07-21-13.13 Foam Board Insulation					
	0700 Foam board insulation, polystyrene, expanded, 2" thick, R8	16,480.00	sf	1.626 /sf	26,796

Item	Description	Takeoff Qty	Unit Cost	Total	
				Unit Cost	Amount
	<i>Foam Board Insulation</i>				26,796
	195.319 Labor hours				
	<i>Board Insulation</i>				26,796
	195.319 Labor hours				
	<b>07 THERMAL PROTECTION</b>				<b>26,796</b>
	195.319 Labor hours				
<b>23 HVAC</b>					
<i>23-05-00.00 Common Work Results For HVAC</i>					
<i>23-05-00.10 HVAC Systems Cost</i>					
0200	HVAC & Electrical OPTION 1 - ESV CONCEPTIAL ESTIMATE	1.00	Is	440,400.00 /Is	440,400
0200	Three phase primary elctrical to building	1.00	Is	75,000.00 /Is	75,000
0200	HVAC & Electrical OPTION 2 - ESV CONCEPTIAL ESTIMATE	0.00	Is		
	<i>HVAC Systems Cost</i>				515,400
	<i>Common Work Results For HVAC</i>				515,400
	<b>23 HVAC</b>				<b>515,400</b>
	<b>* unassigned *</b>				<b>604,487</b>
	567.233 Labor hours				
	71.131 Equipment hours				

Estimate Totals

Description	Amount	Totals	Rate
Labor	41,516		
Material	39,593		
Subcontract	522,900		
Equipment	477		
Other			
	604,486	604,486	
Prime Contractor's G.C.'s	72,538		12.000 %
	72,538	677,024	
Prime Contractor's Fee	27,081		4.000 %
	27,081	704,105	
Design/Trade Contingency	70,411		10.000 %
	70,411	774,516	
Bonds and Insurance	6,975		0.850 %
	6,975	781,491	
Escalation	39,075		5.000 %
	39,075	820,566	
Total		820,566	





				Total	
Item	Description	Takeoff Qty	Unit Cost	Amount	
<div>* <i>unassigned</i> *</div>					
<div>02 SITEWORK</div>					
<div>02-41-13.00 Selective Site Demolition</div>					
<div>02-41-13.17 Demolish, Remove Pavement And Curb</div>					
5010	Demolish, remove pavement & curb, remove bituminous pavement, up to, 3" thick	111.111 sy	10.475 /sy	1,164	
	Demolish, Remove Pavement And Curb				1,164
	11.111 Labor hours				
	10.000 Equipment hours				
	Selective Site Demolition				1,164
	11.111 Labor hours				
	10.000 Equipment hours				
<div>02-41-19.00 Selective Demolition</div>					
<div>02-41-19.23 Selective Demolition, Rubbish Handling</div>					
n 0840	Selective demolition, rubbish handling, dumpster, 40 c.y., 13 ton capacity, weekly rental, includes one dump per week, cost added to demolition cost.	3.00 each	850.00 /each	2,550	
	Selective Demolition, Rubbish Handling				2,550
<div>02-41-19.25 Selective Demolition, Saw Cutting</div>					
0015	Selective demolition, saw cutting, asphalt, up to 3" deep	270.00 lf	1.80 /lf	486	
	Selective Demolition, Saw Cutting				486
	4.114 Labor hours				
	6.171 Equipment hours				
	Selective Demolition				3,036
	4.114 Labor hours				
	6.171 Equipment hours				
	02 SITEWORK & DEMOLITION				4,200
	15.225 Labor hours				
	16.171 Equipment hours				
<div>07 THERMAL I</div>					
<div>07-21-13.00 Board Insulation</div>					
<div>07-21-13.13 Foam Board Insulation</div>					
0700	Foam board insulation, polystyrene, expanded, 2" thick, R8	4,500.00 sf	1.52 /sf	6,840	
	Foam Board Insulation				6,840
	53.334 Labor hours				
	Board Insulation				6,840
	53.334 Labor hours				
<div>09-28-00.00 Backing Boards And Underlayments</div>					
<div>09-28-13.10 Cementitious Backerboard</div>					

Item	Description	Takeoff Qty	Unit Cost	Total	
					Amount
09-28-13.10 Cementitious Backerboard					
0090	Cementitious protection board 3' x 6' x 1/2" sheet fnd't rigid insulation	1,350.00	sf	3.25 /sf	4,388
	Cementitious Backerboard				4,388
	41.143 Labor hours				
	Backing Boards And Underlayments				4,388
	41.143 Labor hours				
	07 THERMAL PROTECTION				11,228
	94.476 Labor hours				
31 EARTHWOI					
31-23-16.00 Excavation					
31-23-16.13 Excavating, Trench					
0100	Excavating, trench or continuous footing, common earth, 5/8 C.Y. excavator, 4' to 6' deep, excludes sheeting or dewatering	453.704	bcy	14.104 /bcy	6,399
	Excavating, Trench				6,399
	54.444 Labor hours				
	29.037 Equipment hours				
	Excavation				6,399
	54.444 Labor hours				
	29.037 Equipment hours				
	31 EARTHWORK				6,399
	54.444 Labor hours				
	29.037 Equipment hours				
32 EXTERIOR					
32-12-16.00 Asphalt Paving					
32-12-16.13 Plant-Mix Asphalt Paving					
1050	Pavement replacement over trench, 4" thick, Plant-Mix Asphalt Paving	112.00	sy	78.143 /sy	8,752
					8,752
	85.000 Labor hours				
	18.000 Equipment hours				
	Asphalt Paving				8,752
	85.000 Labor hours				
	18.000 Equipment hours				
32-91-19.00 Landscape Grading					
32-91-19.13 Topsoil Placement And Grading					
----	Repair distrubed areas at foundation lawn exca Topsoil Placement And Grading	1,050.00	sf	3.00 /sf	3,150
					3,150
	Landscape Grading				3,150
	32 EXTERIOR IMPROVEMENTS				11,902
	85.000 Labor hours				
	18.000 Equipment hours				

Item	Description	Takeoff Qty	Total	
			Unit Cost	Amount
	* <i>unassigned</i> *			33,729
	249.146 Labor hours			
	63.208 Equipment hours			

Estimate Totals

Description	Amount	Totals	Rate
Labor	18,024		
Material	9,320		
Subcontract	3,150		
Equipment	3,235		
Other			
	33,729	33,729	
Prime Contractor's G.C.'s	4,047		12.000 %
	4,047	37,776	
Prime Contractor's Fee	1,511		4.000 %
	1,511	39,287	
Design/Trade Contingency	3,929		10.000 %
	3,929	43,216	
Bonds and Insurance	389		0.850 %
	389	43,605	
Escalation	2,180		5.000 %
	2,180	45,785	
Total		45,785	



## COST ESTIMATE SPECIFICATION

Town of Plymouth Municipal Building  
Plymouth, VT  
07.06.2021

### DEMOLITION

- Remove existing brick veneer, complete to wall sheathing
- Remove all existing windows, doors and garage doors complete to rough opening
- Remove (4) existing modine furnaces
- Remove existing Propane + Electric boilers

### BELOW ARE TWO OPTIONS FOR

#### CODE COMPLIANT

- Replace existing boiler
- Replace existing hot water heater
- Extend overhang on office side of building

#### NET ZERO READY

- Slab / Foundation:
  - Excavate around perimeter of entire building
  - Install 4" EPS rigid insulation (R-16) continuous at perimeter of building from top of foundation wall to 4' below grade.
  - Install coverboard over EPS insulation where exposed above grade.
  - Backfill around perimeter and patch in pavement as required.
- Slab (Fire Department and Town Garage bays only, WITH Radiant heat):
  - Install new 4" EPS rigid insulation (R-16) continuous on top of existing slab
  - Install new **TBD** reinforced concrete slab w/ radiant tubing.
- Exterior Walls (Metal Panel) (R-36 Ci, R-10 Cavity):
  - Install new plywood over existing metal siding. Tape seams for continuous air barrier.
  - Install new Insulated Metal Panels (R-36) Kingspan Shadowline, 5" PIR, air sealed with mfg. panel sealant. Finish to be selected from mfg. standard color range.
  - Slash vinyl wrapping on existing R-10 fiberglass wall insulation to avoid double vapor barrier.
- Exterior Walls (Brick) (R-36 Ci, R-10 Cavity):
  - Demolish existing brick façade back to wall sheathing.
  - Apply new plywood over exg. Sheathing, and tape seams for air barrier.
  - Install new Insulated Metal Panels (R-36) Kingspan Shadowline, 5" PIR, air sealed with mfg. panel sealant. Finish to be selected from mfg. standard color range.
  - Slash vinyl wrapping on existing R-10 fiberglass wall insulation to avoid double vapor barrier.
- Roof (R-48 Ci, R-12 Cavity):



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## CHOICES IN SUSTAINABILITY

- 8" Polyiso insulation (~R-48). Cut first layer into strips to fit tightly between standing seam metal roof. Stagger all seams. Tape joints at second layer of foam for air barrier.
- ½" Cementitious coverboard.
- Self-adhered membrane roofing, color TBD.
- Provide 2x4 blocking at \_\_\_\_ O.C. for installation of solar panels.
- \_\_\_\_ kW solar array on roof
- Slash vinyl wrapping on existing R-12 fiberglass roof insulation to avoid double vapor barrier.
- Windows:
  - Provide new plywood buck for windows.
  - Air seal plywood buck to new plywood sheathing.
  - Install new R-5 triple glazed windows in existing openings.
- Garage Doors:
  - Remove existing doors and hardware.
  - Reframe existing door openings (only in option where new slab is selected)
  - Install new R-26 doors – Thermacore AP 850 or similar.

## TYPICAL INTERIORS

- Interior Wall, typical: unchanged
- Interior Demising Wall, typical: unchanged
- Interior Floor, office: unchanged
- Interior drop ceiling at office: Existing suspended ceiling to remain, reinstall existing batt insulation for acoustics.

## ROOM DESCRIPTION

1. Fire Department
  - a. Radiant Slab
  - b. Raise Doors (#)
2. Town Garage
  - a. Radiant Slab
  - b. Raise Doors (#)
3. Town Offices
  - a. Ducted ASHP

## STRUCTURAL

- See EV Description

## MEP

- See ESVT Description



9 Washington Street  
Rutland, Vermont 05701  
Tel: 802-855-8091  
[www.engineeringvermont.com](http://www.engineeringvermont.com)

## Plymouth Municipal Garage and Offices

Plymouth, Vermont

### Mechanical and Plumbing Design Concept

June 23, 2021

### DIVISION 22- PLUMBING SYSTEMS

#### 1. Scope of Work:

- a. Remove existing gas fired water heater serving the Office, replace with heat pump water heater with back-up electric water heater equal to Rheem.
- b. Provide thermostatic mixing valve.
- c. Modify existing drains in garage to accommodate raising the garage finished floor elevation by 8".

#### 2. Domestic Water System:

- a. Domestic Water Distribution piping shall be Type "L" hard temper copper tubing, ASTM B-88. Fittings shall be wrought copper solder joint type. Use "Silverbrite" lead free solder with suitable flux for joining pipe and fittings. Pro-press shall be approved as an alternate. Copper pipe fitting shall be wrought copper solder joints, ANSI B-16.22, streamlined pattern joints and shall be made with "Silverbrite" lead free solder with non-corrosive flux.
- b. Branch Run outs: Domestic water branch piping and run outs 3/4" and smaller, located within the units or truss spaces and not above corridors, shall be PEX tubing. Alternate PEX tubing shall be plumbed using Watts WaterPEX® cross-linked polyethylene pipe or approved equal, and all joints shall be made using Watts brass CrimpRing™ and/or poly-alloy CrimpRing™ fittings using either the Watts copper CrimpRing™ or stainless steel CinchClamp™ crimping methods as outlined in the Watts WaterPEX® Installation Guidelines. Tubing shall be rated 160psi @ 73.4°F. Tubing shall be color coded blue for cold water and red for hot water.
- c. Valves: shall be equal to Apollo, Milwaukee or Watts.
- d. Domestic Water Piping Specialties: Provide the following piping specialties for installation in piping systems at locations shown or as required by installation requirements.
  - i. Provide a thermostatic mixing valves for all domestic water heaters.

#### 3. Sanitary Waste and Vent Systems:

- a. Waste piping for trench drains: All new soil, waste and vent piping shall be ASTM D-1785, and ASTM D-2665 schedule 40, PVC-DWV pipe. Fittings shall conform to ASTM D-2665 and shall be PVC-DWV fittings.
  - b. Provide schedule 40 PVC condensate drainage piping from all air conditioning condensate drains.
4. Drainage Specialties:
- a. Line cleanouts: Zurn No. Z-1440, with raised hex head plug, DCCI.
  - b. Wall cleanouts: Zurn No. Z-1447, bronze square access panel with vandal proof secured top, min. size 8" x 8" or as required for equipment. Provide raised hex plug behind cover.
  - c. Cleanouts in waste piping 2" and under shall be screwed plugs to suit type of piping, i.e. copper, galvanized, etc.
  - d. Floor cleanouts: Zurn Model Z-1400, "Level-trol" adjustable floor cleanout with polished bronze top.
  - e. Floor Drains: Zurn Z-415, bronze type "B" strainer, 6" diameter with dura-coated cast iron body.
  - f. Garage Drains shall be replaced in kind at the new elevation.
5. Pipe Hangers
- a. All piping shall be rigidly supported from the building structure by means of approved hangers and supports.
  - b. Provide spring isolator hangers for all pipe hangers.
6. Pipe Sleeves and Fire Stopping
- a. Furnish and set sleeves to accommodate pipes passing through foundations, walls, floors, furring and ceilings. Cooperate with other Contractors in setting all sleeves. Sleeves shall be full thickness of construction. Fill annular space between pipe and sleeve with U. L. approved fire retarding packing, rated for 1 hour minimum. For PVC pipe provide approved fire stop collars.
  - b. Sleeves through exterior walls below grade, through foundation walls, shall be watertight construction. Use "Link-seal", compression type neoprene link seals installed in sleeve or core drilled hole.
7. Insulation:
- a. All new copper hot and cold water; hot water recirculating piping shall be insulated with Armaflex closed cell pipe insulation. Thickness to be as follows:  
  
Cold Water: (Domestic)  
All sizes: (With Vapor Barrier)                      1/2"

Hot Water: (Domestic)	
1 1/2" and smaller:	1 1/2"
2" and larger:	2"
Recirculating Hot Water: (Domestic)	
All sizes:	1 1/2"
Condensate Drainage Piping:	
All sizes:	1/2"
Above Slab Roof Drainage Piping:	
All sizes:	1/2"

8. Access Panels:

- a. Provide access panels in ceilings and in walls to permit access to concealed valves, etc. Panels for shall be of sufficient size to permit access to concealed equipment. Valve access panels shall be 12" by 12" minimum and shall be fire rated where required.

9. Water Heater:

- a. Provide Rheem Platinum 80 gallon hybrid heat pump water heater to replace Office gas heater.
  - i. Efficiency: 3.70 UEF, ENERGY STAR® rated.
  - ii. Performance: First-hour delivery 89 gallons per hour, Ambient operating range: 37-145° F is widest in class, offering more days of HP operation annually; designed to meet Northern Climate Spec (Tier 3).
  - iii. Integration: LCD Screen with built-in water sensor alert with audible alarm, provide EcoNet® WiFi-connected technology and free mobile app to give control over water systems, allowing for customizable temperature, vacation settings, energy savings and system monitoring at home or away.
- b. Provide thermostatic mixing valve, thermostatic expansion tank, pressure and temperature relief valve.

**DIVISION 23 MECHANICAL SYSTEMS**

## 1. General Scope of Work:

- a. Offices HVAC: Provide a ducted air source heat pump system to replace existing system, ventilation would be provided by an air to air heat recovery unit.
- c. Garage Heating: Two options shall be priced, as follows:
  - i. Option 1 - Air to Water heat pump:
    - 1. Provide cold climate air to water heat pump capable of providing hot water down to -4 deg. F. Include a buffer tank and back-up supplemental electric boiler. Provide in-floor radiant heating system installed in new slab, include pumps, radiant tubing, reset controls, mixing valves, outdoor sensor, slab sensors and controls. System shall have capacity for 30 BTUH/SF.
  - ii. Option 2 - Ducted Air Source heat pump:
    - 1. Provide a ducted air source heat pump system to replace existing system, ventilation would be provided by an air to air heat recovery unit. System shall have capacity for 30 BTUH/SF.
- d. Garage Ventilation:
  - 1. Provide exhaust and intake system sized to provide 1.00 CFM/SF when gas levels reach threshold required by code, the system shall include controls as follows:
    - a. CO, NO2 and combustible gas detection system when gas levels exceed code minimums.
    - b. Provide manual timer switch to allow for manual operation,
    - c. System shall also be triggered to operate for 15 minutes after doors open.
    - d. Also provide humidistat to automatically start ventilation system if room humidity levels exceed 45%.

## 2. Heating Pipe And Fittings

- a. General: Provide pipe and fittings of the type grade, size and weight indicated for each piping system as shown on the Drawings and specified here herein.
- b. Hydronic heating system piping 2" and smaller shall be type "L" hard copper tubing with wrought copper fittings for solder fitting assembly.
- c. Heating distribution piping for runouts to individual sections of baseboard and located in ceiling spaces, less than 3/4" in size shall be Watts Radiant PEX-AL. All connections shall be made using Watts Radiant Press or Compression fittings and in accordance

with all corresponding installation guidelines. Radiant PEX-AL must be installed in accordance with all Watts Radiant installation procedures, including information.

- d. Gas Piping 2" and Smaller: Shall be schedule 40 black steel pipe with malleable iron screwed fittings, cast iron fittings not allowed. Piping 2" and larger shall be schedule 40 black steel piping with welded fittings.
- e. Hydronic Heating System Piping 2 1/2" and Larger: Shall be black steel pipe ASTM A-120 grade A or B Schedule 10. Pipe ends shall be roll grooved for mechanical grooved fitting assembly.
- f. Dielectric unions: To prevent corrosion caused by dissimilar materials provide dielectric unions equal to Watts Series 3000, with materials to match piping system. Flanged dielectric fittings shall be equal to Watts Series 3100 with materials to match piping system.

### 3. Valves

- a. Ball Valves: Ball valves for heating service shall be equal to Watts No. B-6000-SS, bronze body, 600 lb. W.O.G., stainless steel ball and stem, extended handle to accommodate insulation thickness, PTFE seat and seals, screwed ends or B-6001-SS sweat ends, virgin PTFE seats and seals. For gas service provide U.L. Approved model.
- b. Butterfly Valves: Watts lug style BF-03 ANSI 125 flanges, cast iron body, stainless steel disc, 416 stainless steel stem, Buna-N-Seat and standard handle.
- c. Check Valves: Watts series CVS, solder ends, series CV screwed ends, bronze body, 200 lb. W.O.G.
- d. Drain Valves: Watts No. B-6000-SS, bronze body, stainless steel ball and stem, screwed ends, No. B-6001 sweat ends. Provide cap and chain, with 1/2" I.P.S. to 3/4" hose.
- e. Balancing Valves: Tour and Anderson Model STAS with temperature/pressure readout ports, valve to be sized based on terminal flow rate. Handle shall be lockable type with memory stop.

### 4. Piping Specialties

- a. Thermometers shall be H.O. Trerice Catalog No. A40507 or approved equal, with 9" scale, adjustable angle, and separable socket.
- b. Thermometers shall be installed so as to be easily read while standing on the floor.
- c. Pressure gauges shall be Trerice No. 450B with 4-1/2" dial, range as shown or approved equal to U.S. Gage or Crosby-Ashton. Each gauge shall be provided with a 1/4" ball valve gauge isolation valve. Gauges shall be installed so as to be easily read while standing on the floor. Provide pulsation dampener.



## 5. Access Panels

- a. Access panels shall be provided in ceilings, except in removable tile, and in walls to permit access to concealed valves, automatic damper operators, etc. Panels for fire dampers shall be of sufficient size to permit opening of the fire damper duct access door. Valve panels shall be 12" by 12" minimum.

## 6. Electric Boiler

- a. Cemline or approved equal, vertical electric hot water boiler.
- b. Boiler shall be constructed according to the ASME Code and National Board stamped for 150 psi design pressure. Boiler shall be Underwriter's Laboratories listed and include ASME Code pressure relief safety valve set at 30 psi.
- c. Boiler shall be of the vertical type and designed with a minimum of 4" of mud space below the heating elements. Boiler shall be insulated with 3" thick 6 pound density therma-fibre felt and covered with a metal jacket. Metal jacket shall be electro-galvanized and phosphate coat bonderized for protection against corrosion and to provide maximum paint adhesion. Boiler shall be painted with two coats of high temperature silicon enamel paint.
- d. Electrical control panel shall be mounted with 1" air gap between panel and boiler to ensure minimum heat build-up. Magnetic contactors shall be furnished in the number required (see chart), shall be UL listed for 100,000 cycles, shall break all ungrounded conductors, and shall be assembled and factory pre-wired to heating elements and source connection terminals. All ungrounded circuits shall be fused between contactors and source terminals with dual element fuses rated for 200,000 RMS interrupting capacity. The boiler ON/OFF switch shall include an ON indicating lamp.
- e. Immersion heaters shall be of the resistance type with U-bent tubular heating blades silver soldered or welded to a steel flange. Solid bus type connections shall be used between heater blades and shall be silver soldered to terminals to eliminate heat build-up possible with small threaded terminal connections. Heating elements shall be flange mounted with bolted steel flanges for easy removal and inspection. Flanges shall be bolt and nut type, not threaded into pressure vessel, eliminating need for stainless steel bolts. Watt density shall not exceed 68.5 watts per square inch.
- f. Sequence controls shall be equipped with step controller with pilot lights with the number of steps limited to the number of contactors in the boiler.
- g. Hot water boilers shall be furnished with boiler ON/OFF switch, operating and manual reset high limit temperature controls, pressure/temperature gauge, manual reset probe type low water cut-off, pressure relief valve, and drain valve.

## 7. Hydronic Specialties

- a. Expansion Tank: Taco model CA, fabricated steel shell, ASME rated and labeled per Section VII, Div. 1 for 125 psig, replaceable bladder.

- b. Air Separator: Spiro Vent size 4". Provide high capacity vent.
- c. Manual air vents shall be coin style vents with manual shut-off.

#### 8. Hot Water In-line Pumps

- a. In-line circulator pumps for the hydronic system shall be ECM type equal to Grundfos or Wilo Stratus, flanged wet rotor circulator with ECM motor and automatic capacity adjustment with on-board control electronics for variable speed pumping.
- b. Boiler Injection circulators shall be Wilo model Top-S, single stage wet rotor pump, PSC motor with flanged connection. Pre-selectable speed stages for capacity adjustment.

#### 9. Heating Pipe Insulation

- a. All hydronic heating system piping shall be insulated with Manville fiberglass pipe insulation, Owens-Corning fiberglass, or approved equal. The insulation shall have an average thermal conductivity not to exceed .25 BTU in. per sq. ft. per F. per hour at a mean temperature of 75 degrees F. Thickness of the insulation shall be as scheduled below. Jacket shall be ASJ. Longitudinal jacket laps and the butt strips shall be smoothly secured with self-sealing longitudinal lap joints.
- b. Thickness shall meet the 2020 Commercial energy standard.

#### 10. Ducted Air Source VRF Heat Pump Systems:

- a. Provide a variable refrigerant flow ducted multi-zone air cooled refrigerant based heat pump system capable of providing heat output down to -22 deg. F. Provide fan coil indoor units, outdoor heat pump units, refrigerant piping, condensate drainage piping, ducted indoor evaporator units, filters, controls and accessories for a complete system.
- b. Provide the following:
  - i. Centralized controller, with wiring, with controls and sensors installed for a complete and operational system.
  - ii. Insulate all refrigerant piping using 1" thick Armaflex insulation.
  - iii. Provide PVC schedule 40 condensate drain piping for all condensate drainage piping. Provide cleanout plugs at all elbows and bends to allow for cleanout and flushing.
  - iv. Insulate condensate drainage piping with 1/2" thick Armaflex closed cell insulation.
  - v. Provide MERV 13 filters on all fan coil units.

#### 11. Packaged Air To Water Heat Pump

- a. Description: Factory-assembled and performance-tested water heat pump complete with base and frame, condenser casing, compressors, compressor motors and motor controllers, evaporator, condenser coils, condenser fans and motors, electrical power, controls, and accessories. AERMEC or approved equal.
- b. Cabinet:

- i. Base: Galvanized-steel base extending the perimeter of water chiller. Secure frame, compressors, and evaporator to base to provide a single-piece unit.
  - ii. Frame: Rigid galvanized-steel frame secured to base and designed to support cabinet, condenser, control panel, and other chiller components not directly supported from base.
  - iii. Casing: Galvanized steel.
  - iv. Finish: Coat base, frame, and casing with rustproof polyester paint.
- c. Compressors:
- i. Description: Positive-displacement direct drive with hermetically sealed casing.
  - ii. Enhanced Vapor Injection
  - iii. Each compressor provided with, crankcase oil heater, and suction strainer.
  - iv. Operating Speed: Nominal 3,600 rpm for 60-Hz applications.
  - v. Capacity Control: On-off compressor cycling
  - vi. Oil Lubrication System: Automatic pump with strainer, sight glass, filling connection, filter with magnetic plug, and initial oil charge.
  - vii. Vibration Isolation: Mount individual compressors on vibration isolators.
  - viii. Compressors must be enclosed in acoustically insulated and weatherproof compartment.
- d. Refrigeration:
- i. Refrigerant: R-410A. Classified as Safety Group A1 according to ASHRAE 34.
  - ii. Refrigerant Compatibility: Parts exposed to refrigerants shall be fully compatible with refrigerants, and pressure components shall be rated for refrigerant pressures.
  - iii. Refrigerant Circuit: Each circuit shall include a thermal-expansion valve, refrigerant charging connections, a hot-gas muffler, a liquid-line shutoff valve, a replaceable-core filter-dryer, a sight glass with moisture indicator, a liquid-line solenoid valve, and an insulated suction line.
  - iv. Each unit shall have two refrigeration circuits.
- e. Evaporator:
- i. Brazed Plate:
    - a. Direct-expansion, single-pass, brazed-plate design.
    - b. Type 316 stainless-steel construction.
    - c. Heat exchanger shall have two independent refrigerant circuits, one cooling water circuit
  - ii. Heater: Factory installed and wired electric heater with integral controls designed to protect the evaporator.
  - iii. Evaporator shall be provided with a factory installed inlet strainer.
  - iv. Air-Cooled Condenser:
    - a. Condenser shall be made of copper tubes and aluminum fins.
    - b. Fans: Direct-drive propeller type with statically and dynamically balanced fan blades, arranged for vertical air discharge.
    - c. Fan Motors: Inverter driven totally enclosed non-ventilating (TENV) or totally enclosed air over (TEAO) enclosure, with permanently lubricated

bearings, and having built-in overcurrent- and thermal-overload protection.

f. Noise level:

- i. Sound Power level from the chiller, in accordance with EN ISO 9614-2, shall be less than 87.8 dB (A).
- ii. Sound pressure level from the chiller, in accordance with EN ISO 9614-2, shall be less than 55.7 dB (A).

g. Defrost

- i. The unit must include intelligent defrost. This allows the unit to go in defrost only when is needed, avoiding unnecessary defrost cycles. This shall be achieved by monitoring the suction pressure decay and the OAT.
- ii. Timed defrost is not allowed.
- iii. Heat pumps performance and efficiency should take into consideration of defrost cycles.
- iv. Defrost cycle should not usually be less than 2 minutes and not more than 6 minutes.
- v. During defrost cycle, condenser fan should be off.
- vi. Defrost will start only when external air temperature is less than 50F .
- vii. Low pressure threshold on the coil should be less than 5.2 bar/75.42 Psi.
- viii. When the pressure variations between clean and uncleaned coil is 0.6 bar/8.70 psi, defrost will start automatically.
- ix. Minimum time between two defrost should be greater than 15 minutes.

h. Electrical Power:

- i. Factory-installed and wired switches, motor controllers, transformers, and other electrical devices necessary shall provide a single-point field power connection to each Unit.
- ii. House in a unit-mounted, NEMA 250, Type 3R enclosure with hinged access door with lock and key or padlock and key.
- iii. Wiring shall be numbered and color-coded to match wiring diagram.
- iv. Install factory wiring outside of an enclosure in a raceway.
- v. Field power interface shall be heavy-duty, non-fused disconnect switch.
- vi. Provide each motor with overcurrent protection.
- vii. Overload relay sized according to UL 1995, or an integral component of water chiller control microprocessor.
- viii. Phase-Failure and Under voltage: Solid-state sensing with adjustable settings.
- ix. Transformer: Unit-mounted transformer with primary and secondary fuses and sized with enough capacity to operate controls
- x. Control Relays: Auxiliary and adjustable time-delay relays.

i. Controls:

- i. Unit shall be provided with a microprocessor based standalone controls.
- ii. Enclosure: Share enclosure with electrical power devices or provide a separate enclosure of matching construction.

- j. Operator Interface: Keypad or pressure-sensitive touch screen. Multiple-character, backlit, liquid-crystal display or light-emitting diodes. Display the following:
  - i. Date and time.
  - ii. Operating or alarm status.
  - iii. Operating hours.
  - iv. Outside-air temperature if required for chilled-water reset.
  - v. Temperature and pressure of operating set points.
  - vi. Entering and leaving temperatures of chilled water.
  - vii. Refrigerant pressures in evaporator and condenser.
  - viii. Saturation temperature in evaporator and condenser.
  - ix. No cooling load condition.
  - x. Elapsed time meter (compressor run status).
  - xi. Anti recycling timer status.
  - xii. Percent of maximum motor amperage.
  - xiii. Current-limit set point.
  - xiv. Number of compressor starts.
- k. Control Functions:
  - i. Manual or automatic startup and shutdown time schedule.
  - ii. Entering and leaving chilled-water temperatures, control set points, and motor load limit. Chilled-water leaving temperature shall be reset based on [return-water] [outside-air] temperature.
  - iii. Current limit and demand limit.
  - iv. External water chiller emergency stop.
  - v. Anti recycling timer.
  - vi. Automatic lead-lag switching.
- l. Manual-Reset Safety Controls: The following conditions shall shut down water chiller and require manual reset:
  - i. Low evaporator pressure or high condenser pressure.
  - ii. Low chilled-water temperature.
  - iii. Loss of chilled-water flow.
  - iv. Control device failure.
- m. Insulation:
  - i. Material: Closed-cell, flexible elastomeric, thermal insulation
  - ii. Thickness: 1/3 Inch
  - iii. Factory-applied insulation over cold surfaces of water chiller components.
    - a. Adhesive: As recommended by insulation manufacturer and applied to 100 percent of insulation contact surface. Seal seams and joints.
  - iv. Apply protective coating to exposed surfaces of insulation.

## 12. Heat Recovery Units:

- a. Units shall be air-to-air energy recovery ventilator as manufactured by BROAN, RENEW-AIRE, Inc., LIFE BREATH, ZENDER or approved equal. Units to include static plate heat

and humidity transfer exchanger, supply air and exhaust air blowers, motors with starters and relays, outside air filters, adjustable defrost control, recirculation defrost controls.

- b. Units shall be designed for indoor installation and shall include motorized close-off damper, factory controls and disconnect switch.
- c. Unit housings shall be of formed heavy gauge galvanized steel supports (20 gauge min). Panels to be 20 gauge galvanized steel with closed cell 1" thick insulation with galvanized lining secured and sealed to provide a complete vapor barrier and non-contaminating surface to all air streams. Framing and panels of dissimilar metals that could create a galvanic effect are not allowed.
- d. All exchanger surfaces, blowers, motors, filters, through double wall gasketed access doors held closed by adjustable cam-lock latches. Continuous hollow rubber gasket shall be applied to all access openings to provide water and air-tight seals. Access door hinges shall be hot dipped galvanized for maximum protection from corrosion.
- e. The units shall be capable of transferring both sensible and latent energy between airstreams. Latent energy transfer shall be accomplished by direct water vapor transfer from one airstream to the other, without exposing transfer media in succeeding cycles directly to the exhaust air and then to the fresh air.
- f. Blowers shall be forward curved DWDI class I for quiet efficient operation arranged in a draw through configuration relative to exchanger. Direct drive motors shall be efficient multi-speed ECM type with internal thermal overload protection. Motor and blower to be mounted on common frame and isolated from unit case with RIS isolators and flexible duct connections. Motors and blowers shall have V-belt drives with variable pitch sheaves. Belt drive fans shall have a hollow rubber gasket around the fan discharge to provide an air tight seal while allowing for easy removal and replacement of the fan without screws or permanent fasteners. The discharge gasket shall isolate the fan from the unit casing and eliminate the requirement for an expansion duct fitting.
- g. Electrical controls include motor starters with overloads, fuses, control transformer for low voltage controls, service switch and terminal points.
- h. Outdoor air and/or return air filters shall be MERV 13 filters. Filters shall be mounted within unit in galvanized holding frames upstream of exchanger and accessible through access panels. Provide one spare set of filters for each unit; replace filters prior to final inspection.

### 13. Air Distribution Ductwork:

- i. Duct construction shall be in accordance with best practices and latest SMACNA requirements for metal gauges, joints, reinforcing, and supports except where specified otherwise in these specifications. All exposed ductwork shall be constructed and hung to provide a neat, smooth, finished appearance. Cadmium plated sheet metal screws shall be used on all exposed ductwork. Ducts shall be free from thumping or rattling

when fans are turned on or off. All ductwork shall be air sealed. No ductwork shall be run in unconditioned attics.

#### 14. Ductwork Insulation

- a. All heat pump and HRU Supply and Fresh Air intake ductwork, shall be insulated with 1 1/2" thick one pound density duct wrap with factory applied reinforced aluminum jacket, insulation shall be equal to Knauf Duct Wrap with FSK facing. Product shall not exceed 25 flame spread, and 50 smoke development. Apply with 3" wide pressure sensitive tape and sealing tool, for ducts over 18" wide secure insulation to duct with mechanical fasteners spaced on 18" centers. Limit average compression to 25% or less. All ductwork carrying exhaust air to the outdoors or outdoor intake air shall be insulated with 3" of duct wrap or with Insulation equivalent to the thermal insulation of the building.

#### 15. Controls:

- a. The control contractor shall provide required controllers, software and programming for a complete control system. Provide all programming for controls to allow for sequences specified.
- b. General System Description:
  - i. Option 1 Garage Heating System: provided with a Cold Climate heat pump system with back-up electric resistant heat.
  - ii. Option 2 Garage Heating System: Air to Water Heat Pump with back-up electric boiler to provide heating of domestic water and for heating the Garage.
  - iii. The Office Area is provided with a Cold Climate heat pump system with back-up electric resistant heat.
  - iv. Ventilation in garage area is provided by air to air heat recovery unit.
  - v. The garage area exhaust and intake controlled by a gas detection system, humidistat and manual timer
  - vi. Office heat recovery unit controlled by a schedule.
- c. Option 1 Garage Air to Air Heat Pump System:
  - i. Air source heat pump units shall be provided with thermostat controllers capable of controlling space heating set points.
  - ii. Each thermostat shall be programmed with an occupied/unoccupied set point. Fan coil units shall cycle and provide heating as required to maintain the zone set point, cooling shall be locked-out.
  - iii. System shall be programmed to operate in a heating mode at the central controller, this shall be easily adjustable and accessible to the building operator for adjustment.
  - iv. The indoor units shall be set to auto mode during both occupied and unoccupied times, with the set point automatically adjusted and scheduled using the factory control system. Temperature setting and schedules shall be visible and programmable from the factory control system. The system shall limit commands to the local controls to prevent on-off and local schedule override

of schedules and temperature set point ranges. The System shall monitor room temperatures. Provide for controls supplemental electric heating for each space.

d. Option 2 Garage Air to Water Heat Pump:

- i. The control system shall start the pumps, which shall operate in a lead-lag sequence of operation.
- ii. Once the controls verify that flow has been established the controls shall enable this unit. Once enabled the unit control start compressor if flow switch closed and if there is load demand, the second compressor will come ON if needed 60 seconds after first one, the minimum run time for each compressor is 2 minutes, at no load and all compressors will shut-off.
- iii. Defrost sequence:
  - a. When unit's defrost starts, all compressors except for one shutdown
  - b. Reversing valve moves for 30 seconds
  - c. Actual defrost time is 2-6 minutes
  - d. Reverse cycle valve moves again for 30 seconds
  - e. 30 second delay before compressor starts in heating mode.
- iv. Back-up Electric Boiler:
  - a. The electric boiler shall be used to supplement the air to water heat pump and water heater. The heat pump shall act as the primary heat generator for the building, if the supply water temperature drops to 135 Deg. F. the electric boiler and injection pump shall be energized to maintain the target temperature of 140 Deg. F Minimum . The electric boiler shall also be energized to provide supplemental heating if the domestic water heating system requires supplemental heat.
- v. Radiant Heat Controls:
  - a. For each radiant zone provide a space sensor and the monitor outdoor air ambient temperature. When outdoor air temperature is below 65 deg. F. pump shall run continuously. Provide controls to vary the injection pump which shall be utilized to reset the radiant system water temperature to meet the space heating load. Whenever there is no call for heat in any zone the respective zone control valve shall shutdown to the heating zone. The pump shall include a factory constant pressure designed to maintain a constant system pressure differential

e. Heat Recovery Unit:

- i. The Heat Recovery Unit provide fresh air and exhaust for the each zone and shall run when commanded to run by the controls specified. Provide start-stop, status and alarm control of the factory supplied fan VFD's.
- ii. Unit supply and exhaust fans shall be provided with factory installed VFD's for fan balancing, provide status, alarm and fan capacity controls for each fan.
- iii. Provide a hot water heating coil. Whenever the discharge temperature drops below the required set point the three way control valve shall be modulated maintain minimum discharge air at the set point. The discharge air temperature for the HRU unit system shall be maintained at 60 deg. F, the reset schedule



shall be adjustable and shall be customized to the building through the control system.

f. Garage Exhaust System:

- i. Exhaust and Intake damper shall be controlled by a wall timer switch, space humidistat, carbon monoxide detectors, and nitrogen dioxide detectors. All of these controls shall be capable of starting the exhaust fan and opening the intake damper. Upon activation of any of these controls the outdoor air damper shall open and the end switch on the damper shall start the Exhaust Fan.

g. Office Air to Air Heat Pump System:

- i. Air source heat pump units shall be provided with thermostat controllers capable of controlling space heating and cooling set points. The heat pump systems shall be furnished with factory controls to operate the heat pump system.
- ii. Each thermostat shall be programmed with an occupied/unoccupied set point. Fan coil units shall cycle and provide heating or cooling as required to maintain the zone set point.
- iii. System shall be programmed to operate in either a heating or cooling mode at the central controller, this shall be easily adjustable and accessible to the building operator for adjustment.
- iv. The indoor units shall be set to auto mode during both occupied and unoccupied times, with the set point automatically adjusted and scheduled using the control system. Temperature setting and schedules shall be visible and programmable from the control system. The system shall limit commands to the local controls to prevent on-off and local schedule override of schedules and temperature set point ranges. The control system shall monitor room temperatures. Provide for controls supplemental electric heating for each space.

## FACILITY EVALUATION REPORT

### PLYMOUTH TOWN BUILDING

### PLYMOUTH, VERMONT



#### OVERVIEW

The following is a preliminary structural assessment of the existing Plymouth Municipal Building on Rt 100 in Plymouth Vermont. All information used for this evaluation has been provided to us by the owner and we have not visited the site. The field notes used are provided as Attachment 1. This evaluation has been performed to determine the suitability of the structure to be modified, primarily for, thermal improvements including insulation on the roof, walls and slab on grade. Based on International Existing Building Code (IEBC), certain work can, and certain work cannot, be performed without confirmation that the existing building is capable of resisting the current IBC design loading (either 'as is' or through reinforcing). Thus, it is the primary goal of this report to determine if the existing structure can support current IBC design loading.

#### STRUCTURE

- The Plymouth Municipal Building can generally be described as a one-story, low-slope roof, "prefabricated" steel framed structure with poured concrete foundation walls and footings. Light Gauge Metal Frame (LGMF) roof and wall purlins support the steel roof deck and span between welded steel 'frames'. Lateral stability is provided by rod bracing in the North/South direction and moment frames in the East/West direction. There are three distinct 'bays' separated by CMU walls in the North/South direction that likely also resist some of lateral force. It is assumed that there exist concrete foundation walls at the building's perimeter and shallow foundations supporting the interior masonry walls and columns. Exterior walls are clad with brick and metal panels. Historically, "prefabricated" steel structures are designed with no additional capacity and are based on proprietary design tables which often do not meet the requirements of the American Institute of Steel Construction (AISC) that our evaluation is based upon.
- One drawing, including the roof framing, wall layout and brace location has been provided, see Attachment 1.

## ANALYSIS

- We have based our analysis on the current 2015 Vermont Fire and Safety Building Code which references the International Building Code – 2015 (IBC), which in turn used the loading provided by ASCE 7-10. IBC-2015 also references both the American Institute of Steel Construction (AISC) for hot rolled steel framing and the American Iron and Steel Institute (AISI) for cold formed steel framing.
- Based on IBC-2015, the loads are as follows:
  - Live Load at Slab on Grade: 54,000# Truck with 3 total axles.
    - Max Axle Load: 25,000#
    - This design truck provided by the owner
  - Dead Load at Roof: 10psf + Steel Frame
    - Purlins included in 10psf
  - Ground Snow Load: 70psf
    - Roof Snow Load: 49psf
    - No drifting
  - Basic Wind Speed: 115mph
    - Main Wind Force, Windward Side only: 12psf
    - Main Wind Force, Total: 20psf
  - Seismic Loading: By observation Earthquake loading does not control
    - There are many distributed lateral force resisting elements
    - The building is extremely light, yet broad, which results in wind loading as the controlling force
- We used computer modeling to analyze the steel frames including lateral loading and investigated the roof purlin at several locations for gravity and uplift forces.

## RESULTS

- Roof Purlins: Based on the provided field measurements, we approximated the roof purling to be an 8ZS2.75x105 Z purlin that is 8" tall with 3" flanges and .1" thick. The steel grade is unknown.
  - Assuming 33ksi material, with 10psf DL + 49psf SL, at a spacing of 5'; the purlin is 2.4 times over-stressed and deflects 2.6"
  - Assuming 50ksi material, with 10psf DL + 49psf SL, at a spacing of 5'; the purlin is 1.6 times over-stressed and deflects 2.6"
- Bay 1 Frame: We modeled a 3-leg frame consisting of tapered steel framing as provided and measuring 18' tall and 40' wide and spaced at 20' on center.
  - The columns were measured at 9" deep the base and 24" deep at the eave. The flanges were measured at 1/4"x6" and we assume they are continuous.
  - The controlling load combination for the columns is Dead Load + Snow Load:
    - The columns fail in bending and are 1.5 times over-stressed, we assumed the columns were braced from lateral buckling by the wall girts at mid height.
  - The beam was measured at 24" deep at the eave and we assume 26" deep at the ridge. The flanges were measured at 1/4"x6" and we assume they are continuous.

- The controlling load combination for the beam is Dead Load + Snow Load:
  - The beam fails in bending and is 1.4 times over-stressed, we assumed the beams are braced from lateral buckling by the roof purlins at 5'oc.
- Bays 2 and 3: The field measurements indicated substantially smaller beam and column sizes for Bays 2 and 3. So, based on the results of our Bay 1 study, we know they will need substantial reinforcing and the stress ratios presented above will be substantially exceeded in all beams and columns in Bays 2 and 3.
- The Lateral Force Resisting System (LFRS) is apparent, and by observation appears adequate to resist the minimal lateral load from wind in this sheltered location. We have applied a lateral force to the Bay 1 steel frame, and based on the applicable load combination (DL + .75SL + .45WL), did not overstress the column while overstressing the beam minimally (1.13). Thus, lateral forces do not control the design of the frames.

## DISCUSSION

The IEBC groups "Alterations" in to 3 Levels as well as Change of Occupancy, Historic Buildings and Relocated Buildings.

- Level 1 alterations include the removal and replacement or the covering of existing materials, elements, equipment, or fixtures using new materials, elements, equipment, or fixtures that serve the same purpose.
- Level 2 alterations include the reconfiguration of space, the addition or elimination of any door or window, the reconfiguration or extension of any system, or the installation of any additional equipment.
- Level 3 alterations apply where the work area exceeds 50 percent of the building area.

It is our opinion that insulating the shell of the structure constitutes a work area exceeding 50 percent of the building. We also believe insulating the roof will increase the true (real world) loading based by reducing the R value and allowing less heat loss which now melts and removes snow and ice. IEBC Section 807.4 'Existing Structural Elements Carrying Gravity Loads' states that 'existing structural elements supporting any additional gravity loads as a result of the alterations shall comply with the International Building Code'. This section is applicable to Level 3 Alterations. Furthermore, as the framing is substantially overstressed, we cannot recommend any 'Alterations' without reinforcing.

It is clear from our analysis and the IEBC that reinforcing is required, based on exceeding the 50% work area and based on our calculations which shows that the framing does not meet current design loading.

## REINFORCING RECOMMENDATIONS

Reinforcing of the steel frames will require significant field welding. The following charts tabulate our estimate of the reinforcing at each of the three frame types. Purlins will be required at each space, except as noted below in overhang discussion, doubling the number of purlins. For estimating purposes, the purlins should be 10"x3"x.1" Z purlins (similar but deeper than the existing) with coped flanges at each end for connection to the steel frames. Assume a seat will be required to stiffen the coped ends and provide positive bearing at the steel frames. For all reinforcing prescribed here including field welding and fit up; removal of electrical conduit, bat insulation, lighting and sprinklers systems will very likely be required.

Frame 1	Element	Location	Reinforcing
	Column Interior Flange	Top 2/3 of column	PL 3/8"x7" A36
	Column Exterior Flange	Top 2/3 of column	(2) PL 3/8"x3.5" A36
	Beam Bottom Flange	Continuous	PL 3/8"x7" A36
	Beam Top Flange	Continuous	(2) PL 3/8"x3.5" A36

Frame 2	Element	Location	Reinforcing
	Column Interior Flange	Top 2/3 of column	WT6x20 with part-pen weld to flange
	Column Exterior Flange	Top 2/3 of column	(2) PL 1/2"x3" A36
	Beam Bottom Flange	Continuous	WT6x20 with part-pen weld to flange
	Beam Top Flange	Continuous	(2) PL 1/2"x3" A36

Frame 3	Element	Location	Reinforcing
	Column Interior Flange	Top 2/3 of column	WT6x20 with part-pen weld to flange
	Column Exterior Flange	Top 2/3 of column	(2) PL 1/2"x3" A36
	Beam Bottom Flange	Continuous	WT6x20 with part-pen weld to flange
	Beam Top Flange	Continuous	(2) PL 1/2"x3" A36

Notes:

Top flange and exterior flange reinforcing is to be located on inboard face of flange and welded at both edges.

Plate and WT reinforcing to be full-pen welded at ridge and at eaves.

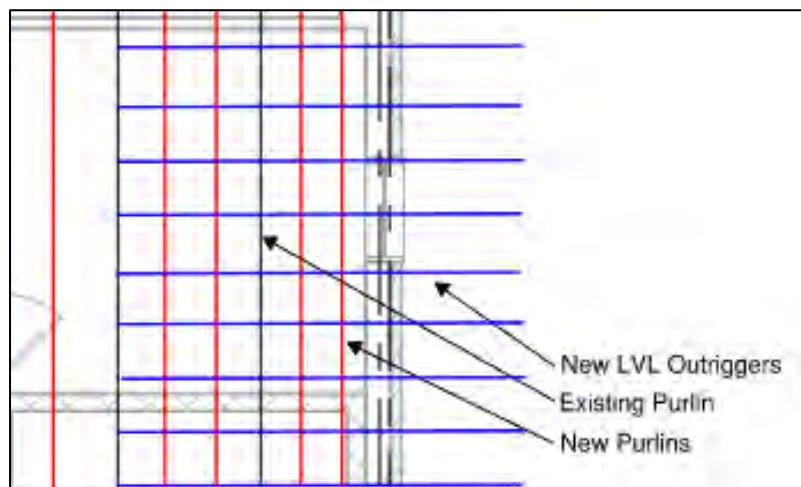
## SLAB-ON-GRADE RECOMMENDATIONS

It is our understanding that in addition to the shell insulation and re-finishing, the slab is to be insulated as well. We understand the town uses vehicles with weights ranging between 40,000# and 50,000#. We estimate the resulting contact pressure under vehicle tires is approximately 75psi. We recommend topping the existing slab with 3" to 4" of 80psi (or greater) rigid insulation. On top of the insulation we recommend a topping slab of 5" of 4,500psi concrete reinforced with #4 bars at 12"oc each way at mid-height of the slab. Control joists must be provided with spacing between joints of no more than 20ft.

## GRID 10 ROOF EXTENSION

It is our understanding that a roof extension is planned along grid 10 to provide some additional protection from weather. The extension will project out approximately 4ft from the building edge.

To achieve this condition, we recommend adding two additional lines of purlins between each existing purlin within 10ft of grid 10. Perpendicular 1.75"x5.25" LVL's at 24" (can be adjusted based on final insulation thickness, etc) frame new edge. The LVLs extend out 4ft and have a back span of 10ft. See Figure 1 below for a conceptual partial layout. Outriggers should be blocked at ends and at edge of building and will be fastened down to purlins below with clips and screws.



*Figure 1: Overhang concept*

## CONCLUSION

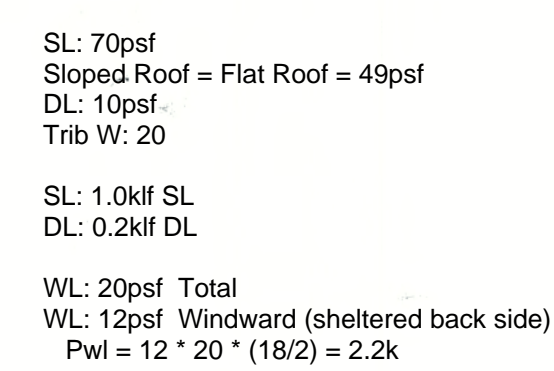
Generally, the building framing was found to generally not meet current code. The one significant exception is the lateral force resisting system which does appear to be adequate and appropriate. Per the IEBC the building is acceptable for current use as is. If additional loads (insulation, appendages, etc) are added reinforcements will be required per the preliminary recommendations above.

Please be in touch if there is any need for clarification or further discussion regarding any of the requirements, concepts or conclusions provided here.

Respectfully,  
Engineering Ventures, PC

Paul A. Hobbs, PE





## S1.1

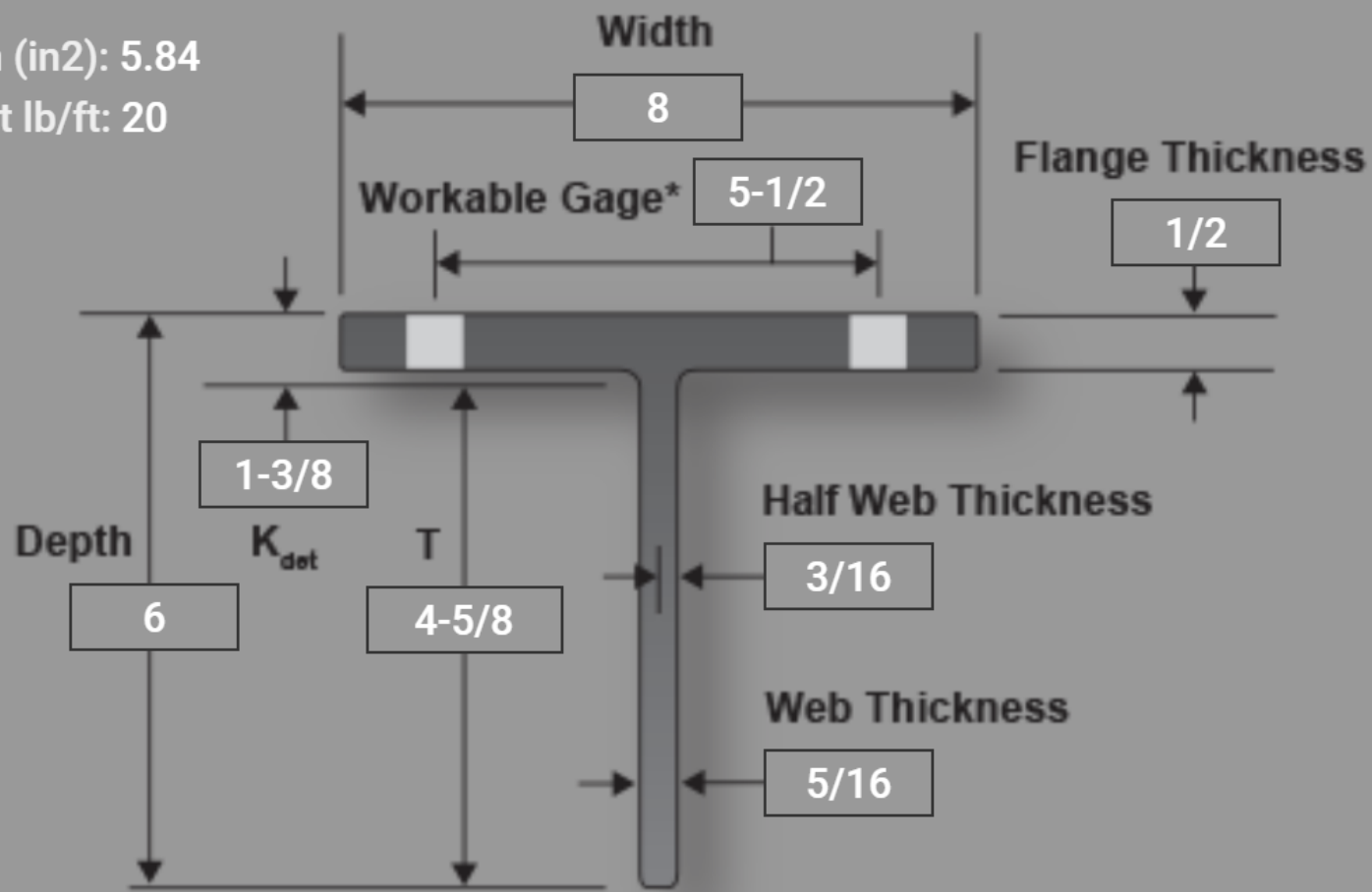


WT6x20

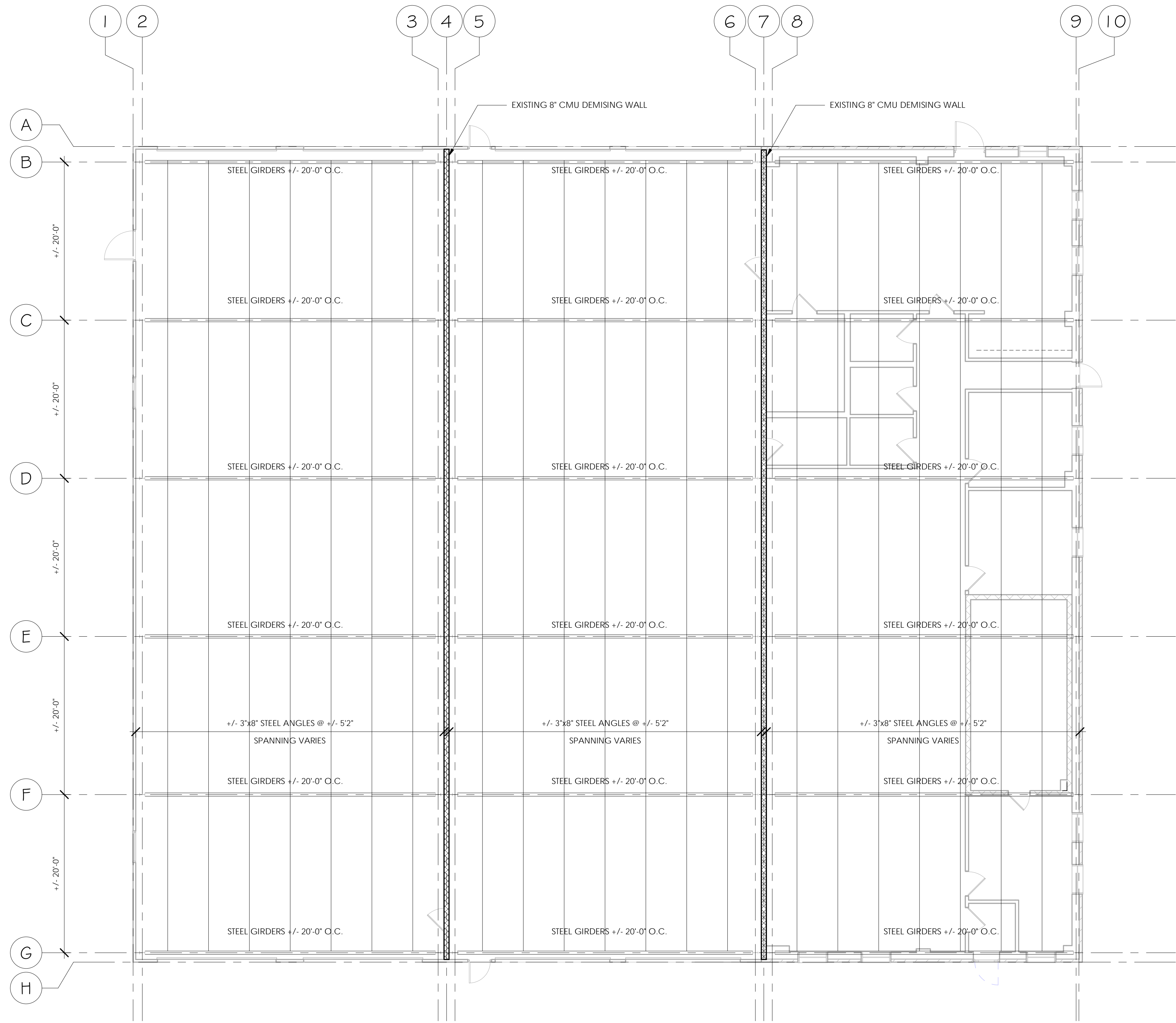
All dimensions in inches

Area of Section (in2): 5.84

Nominal Weight lb/ft: 20







① EXISTING STRUCTURE  
1/8" = 1'-0"

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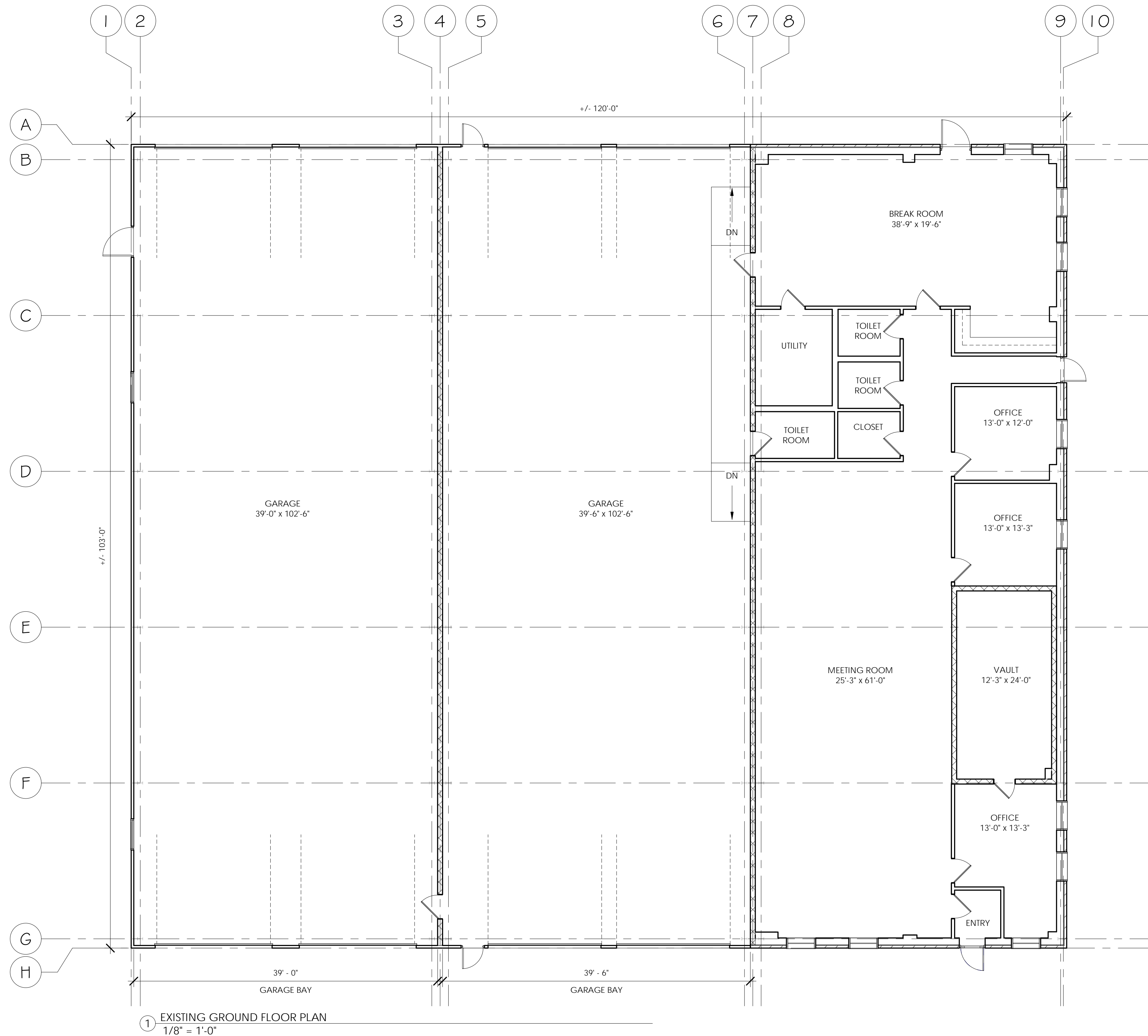
NO. DATE REVISED REMARKS

PROJECT#	2109
DRAWN	TJT
CHECKED	AK
SCALE	1/8" = 1'-0"
DATE	06/11/21

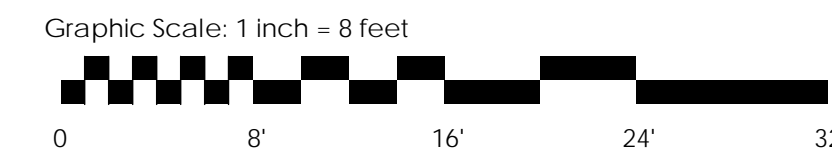
PROJECT TITLE	PLYMOUTH MUNICIPAL BUILDING
SHEET TITLE	EXISTING STRUCTURE

SHEET NO.

S1.1



1 EXISTING GROUND FLOOR PLAN  
1/8" = 1'-0"



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NO. DATE REVISED REMARKS

PROJECT#	2109
DRAWN	TJT
CHECKED	AK
SCALE	1/8" = 1'-0"
DATE	06/11/21

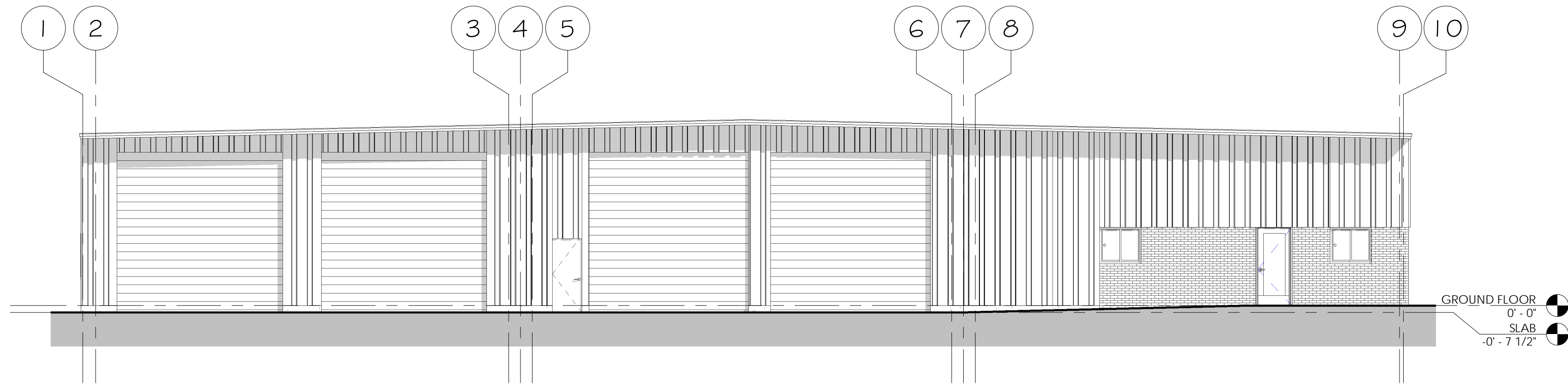
Plymouth, Vermont

PROJECT TITLE  
PLYMOUTH MUNICIPAL BUILDING

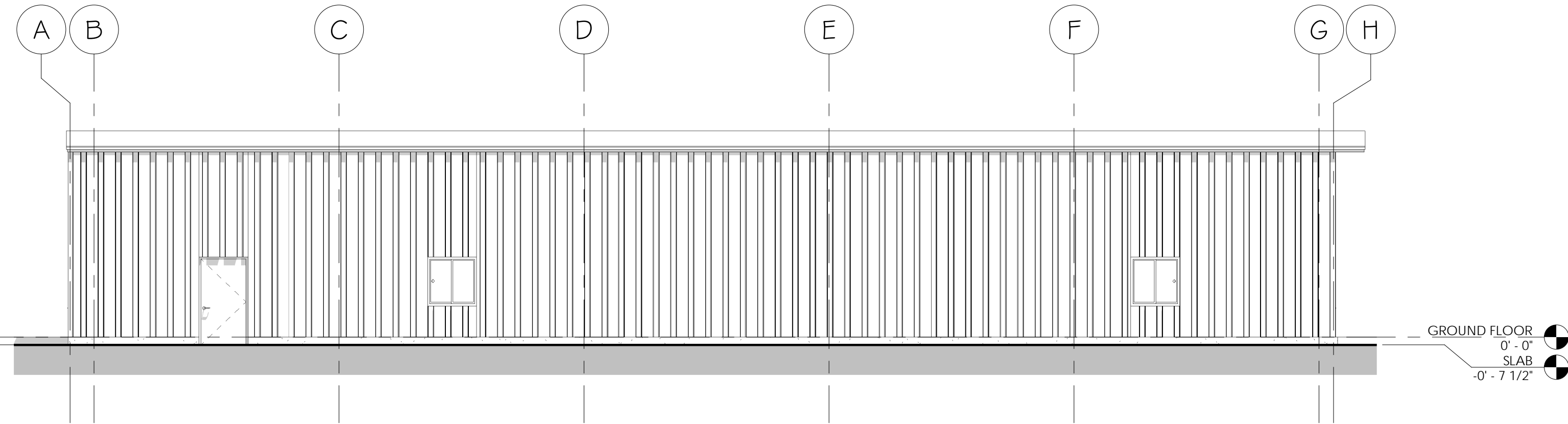
SHEET TITLE  
EXISTING GROUND FLOOR PLANS

SHEET NO.

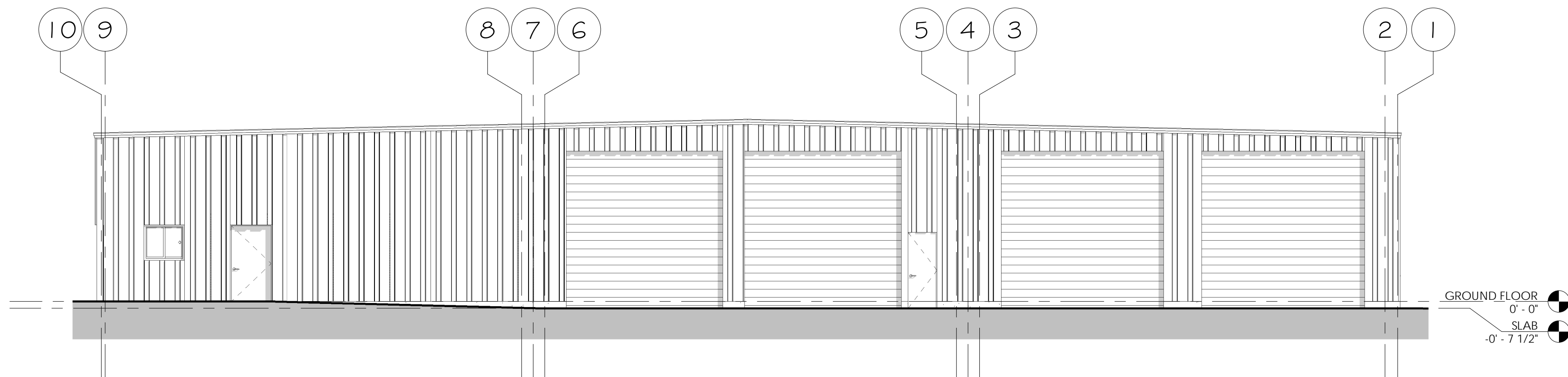
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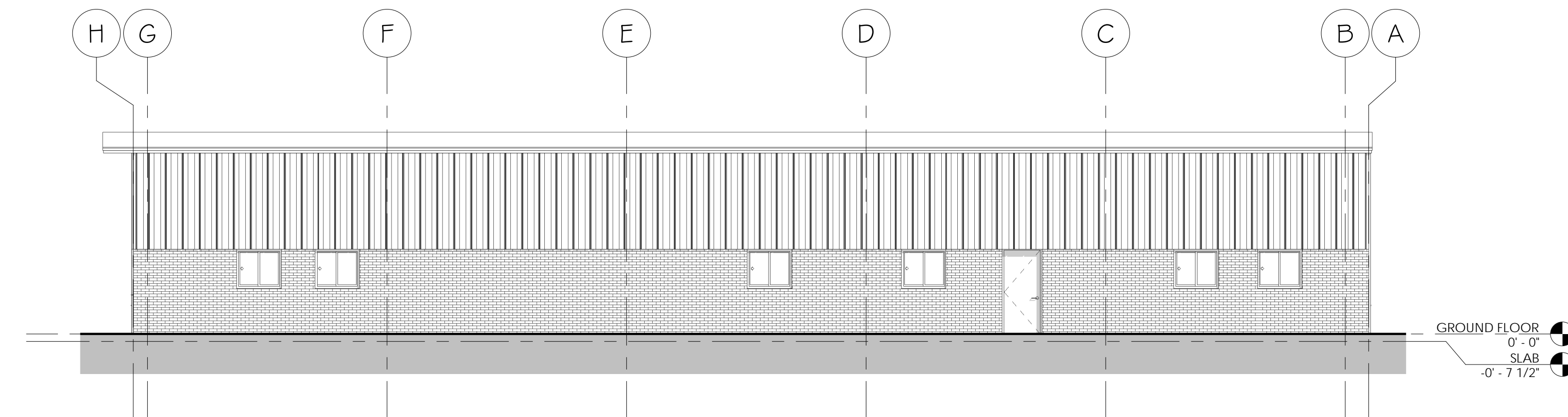
① EXISTING FRONT ELEVATION  
1/8" = 1'-0"



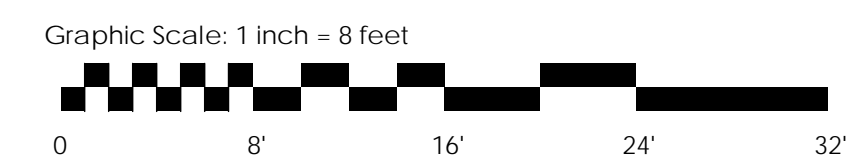
② EXISTING LEFT SIDE ELEVATION  
1/8" = 1'-0"



③ EXISTING REAR ELEVATION  
1/8" = 1'-0"



④ EXISTING RIGHT SIDE ELEVATION  
1/8" = 1'-0"



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NO. DATE REVISED REMARKS

PROJECT# 2109

DRAWN TJT

CHECKED AK

SCALE 1/8" = 1'-0"

DATE 06/11/21

PROJECT TITLE  
PLYMOUTH MUNICIPAL BUILDING  
Plymouth, Vermont

SHEET TITLE  
EXISTING ELEVATIONS

SHEET NO.

A2.1