System Options for HVAC Renovations
Epping Elementary School
Epping, New Hampshire

Prepared For:
Epping School District
33 Prescott Road
Epping, NH 03042

Prepared By:
Turner Building Science & Design, LLC
26 Pinewood Lane
Harrison, ME 04040

November 10, 2017

Existing Systems

Existing Mechanical Systems
Epping Elementary School

Heating Plant

The primary heating source for the Epping Elementary School is provided by a Slant Fin Model TR-70P boiler, a Slant Fin Model LD-70-3.00 boiler, and by two Slant Fin Model L 70 P boilers. The two Model L 70 P boilers were installed in 1993 and are likely to have reached the end of their useful life. The other two boilers were installed after 2000 and likely have significant useful life remaining. All of the boilers use oil as the fuel source. The combustion air intake has low and high openings as required by mechanical code.

The hot water pumps are Taco base mounted systems with 5 horsepower motors. These pumps are constant speed, on/off type. Efficiency of operation for these pumps could be improved significantly by adding variable frequency drives (VFDs) to the motors to allow reduced speed operation during times when less heat is required in the building. Note: Adding VFDs may require installation of different valving to allow some of the hot water to be shut down and reduce pump speed.

Domestic hot water is provided by a Bock oil-fired water heater. This hot water heater appears to be in good condition and should have significant remaining useful life.

Air Handling Systems

There are five main air handling units providing ventilation to the spaces throughout the school. These units are as follows:

HV-1: Heating and ventilating unit providing air to classroom spaces on the east side of the building. This unit is located above the ceiling in the corridor on the east side of the Gymnasium.

HV-2: Heating and ventilating unit providing air to classroom spaces on the north side of the building, as well as to the former Library space in the center of the building. This unit is located suspended from the ceiling in the Boiler Room.

HV-3: Heating and ventilating unit providing air to classrooms in the south and west wings of the building. This unit is located above the ceiling in the corridor just to the south of the central open area.

HV-4: Heating, ventilating, and air conditioning unit providing air to the Gymnasium, Music Room, and Teacher's Room. This unit is located above the ceiling in the Teacher's Room.

AC-1: Air conditioning unit providing air distribution to the Administrative Office area. This unit is located above the ceiling in the main office area.

The main air handlers for the classrooms deliver 28 - 37% outside air. For a typical classroom that has 450 cubic feet per minute of supply air, this means that about 150 cfm of this is outside air. According to the current ventilation code, the outside air currently delivered to the typical classroom is enough for about 10 students.

The ten classrooms that were added in the 1999 addition are heated and ventilated by unit ventilators located in each space.

<u>Heating Terminal Equipment</u>

Most classroom spaces are heated primarily by baseboard fin tube radiators along the window walls. Entrance heating is accomplished by cabinet heaters (fan coil units) either floor mounted or ceiling mounted. Unit heaters suspended from the ceiling are used to provide heating in support spaces, like storage rooms and the kitchen.

<u>Automatic Temperature Controls</u>

The temperature controls at Epping Elementary School are for the most part local. Control is by a room thermostat. Many of the room thermostats are reportedly having issues controlling the fin tube valves or the unit ventilators. There is no central way to observe operation of the system or to troubleshoot problems with temperature control.

Goals & Issues

THE ISSUES

- Reliability – Most HVAC systems and components throughout the school are at or beyond their useful life.

- Efficiency – The school currently uses #2 fuel oil to generate hot water for distribution throughout the school. Additional ventilation and air conditioning will require additional energy use.

- Air Quality – The heating and ventilation systems were designed with less than the current code requirements for outside air ventilation.

- Maintenance – Distributed equipment, such as unit ventilators, are located throughout the school without central maintenance points.

- Controllability – The heating and ventilating controls are currently not centralized and do not allow for remote access.

OVERALL GOALS

- Provide heating, ventilating, and air conditioning systems with the longest service life and the ability to change components while maintaining operation.

- Design heating, ventilating, and cooling systems that employ the highest possible efficiency within the budget, recycling as much energy as possible in the process.

- Provide adequate ventilation and outside air distribution for all areas of the school.

- Provide centralized mechanical equipment that can be accessed and repaired/maintained by District staff.

- Provide enhanced controls and automation for the mechanical systems, including remote access of basic parameters.

- Use as little fossil fuel and electricity as possible to meet thermal needs of the occupants.

Schematic Outline Specifications

DRAFT

Outline of Specifications – Schematic Design
Epping Elementary School
HVAC Renovations

Turner Building Science & Design LLC – Project S1246
November 9, 2017

DIVISION 1 – GENERAL

- Project will be publically bid, with bids due in March 2018, construction start April 2018.
- Construction completion in mid-August 2018 in time for fall classes.
- Project is tax exempt.
- Include all required insurances and bonding.
- Assume that the City will waive building permit costs (verify).
- Include utility consumption during construction activities.

DIVISION 2 – SITEWORK

DIVISION 3 – CONCRETE

- Cast-in-place Concrete:
  - Exterior utility pads.

DIVISION 4 – MASONRY

DIVISION 5 – METALS & STRUCTURAL STEEL

  - Supports and modifications for new equipment.

DIVISION 6 – WOOD, PLASTICS AND COMPOSITES

DIVISION 7 – THERMAL AND MOISTURE PROTECTION

- Roofing:
  - Infill of removed openings.
  - New roof openings for outside air/exhaust.
- Firestopping/firesealing.

DIVISION 8 – DOORS, FRAMES & HARDWARE

DIVISION 9 – FINISHES

- Ceilings:
  - Replacement of ceiling tile where damaged during construction.
- Painting: Use paint coatings according to the following schedule. Field applied paint products shall conform to the applicable VOC limits. Surfaces shall be properly prepared, cleaned and primed with compatible primer prior to application of finish coats. Provide sealant between dissimilar materials. Provide a minimum of 2 finish coats on visible surfaces.
  - Includes painting of exposed steel and ducts.

DIVISION 10 – SPECIALTIES

DIVISION 11 – EQUIPMENT

DIVISION 12 – FURNISHINGS

DIVISION 21 – FIRE SUPPRESSION

DIVISION 22 – PLUMBING

- Condensate drain piping for new air conditioning equipment
- Piping:
  - Sanitary Drain: Type DWV PVC above slab, cast iron below slab, to match existing.
  - Vent Piping: Type DWV PVC. Paint flat black above roof.
- Insulation: As recommended in ASHRAE Standard 90.1 and applicable Codes and standards as adopted by State and local authorities.
  - Cold Piping and Equipment: Elastomeric foam.

DIVISION 23 – HVAC

- Scope:
  - Addition of central ventilation and air conditioning.
  - Complete system in accordance with the International Mechanical, Fuel Gas, and Energy Conservation Codes - 2009 Edition, NFPA 31, 54, and 90A, ASHRAE 62 and 90.1, SMACNA ductwork standards, and State and local regulations.
  - General Design:
    - Outdoor Design Temperatures: From ASHRAE Handbook weather data for Pease International Tradeport.
    - Heating: Size to maintain occupied temperature of 70°F indoors at -19°F outdoor temp., the “mean extreme annual minimum dry bulb temperature.”
    - Cooling: Maintain 75°F indoors at 90°F dry bulb / 73°F wet bulb outdoor temp., the “0.4 percent cooling dry bulb and mean coincident wet bulb.”

        - Humidification/Dehumidification: Not actively controlled (no humidifiers or dehumidifiers).
- Proposed Systems:
    - Option 1:
        - Air Conditioning (with Heating): A networked system of Daikin (or equal) variable-refrigerant-flow (VRF) ducted heat pumps. Individual units mounted above ceiling with filters located at ceiling return grilles. Zoned by room. Outdoor units mounted on grade or on exterior walls. This system also provides full space heating at 0°F outdoor temperature, and 85% of space heating capacity at -13 F. With the optional "heat recovery" accessory, the system can simultaneously provide heating to one area and cooling to another, redistributing waste heat energy from warmer rooms to where it is needed in colder rooms. Electrical typically requires 208/3/60.
        - Space Heating: Existing wall hydronic fintube, or commercial-duty baseboard, in classrooms. Other existing types of hydronic heaters for vestibules, restrooms, and boiler room. Zoned by room. Controlled to supplement the heat pump system at low outdoor temperatures.
        - Boiler: Two newer Slant Fin boilers to remain. Older boilers considered for replacement.
        - Ventilation: Central energy-recovery ventilators, mounted in locations of existing heating and ventilating units above ceiling. Supply to classrooms with unit-mounted hydronic coils served by the boiler. 100% outside air will be distributed through existing ductwork and mixed with return air with final distribution through VRF system for final heating/cooling as required. Classroom exhaust through energy recovery ventilators will use existing return air ductwork. Exhaust from restrooms and similar spaces will remain as existing.

    - System 2:
        - Air Conditioning with Conventional Direct Expansion (DX) Cooling Equipment: Replace existing heating and ventilating units above ceiling with air handlers equipped with hydronic heating coils and DX cooling coils. Zoned by wing. Unit sizes and ductwork to be replaced with larger to accommodate increased air flow requirements for cooling and ventilation.
        - Space Heating: Existing wall hydronic fintube, or commercial-duty baseboard, in classrooms. Other existing types of hydronic heaters for vestibules, restrooms, and boiler room. Zoned by room.

        - Ventilation: Energy recovery ventilators in addition to air handling units to provide code required ventilation. Supply to classrooms through ceiling mounted grilles. Exhaust from restrooms and similar spaces.

    - Automatic Temperature Controls: Complete DDC system, with remote monitoring and graphics. System will control new equipment and existing heating for classrooms (fintube radiators, boiler plant, heating pumps, etc.) to the extent possible. For equipment which comes with integral controllers (e.g. ductless heat pumps), the system will monitor the equipment to the extent practical, and provide timeclock enable/disable functions.
- Demolish Existing:
    - Four main air handling systems from supply duct exiting unit to return fan inlet. Optional: demolish two 1993 boilers and replace with new heating equipment. Explore modifications to heating pumping to provide reduced power operation via VFD during periods of less than full load.
- To Remain:
    - Two newer boilers, piping and hot water pumping systems to remain.
- Piping:
    - Heating Water: Type L copper, and Schedule 40 steel with threaded and grooved mechanical fittings.
    - Refrigerant: Type ACR copper tubing with long-radius brazed fittings.
- Variable-Frequency Drives: Toshiba, ABB, Cerus, Danfoss, or Yaskawa only. With bypass, except where separate drives serve fully-redundant equipment, such as dual lead-lag pumps.
- Pumps: Main pumps base-mounted, close-coupled type. Smaller secondary pumps inline type. Bronze fitted, with iron body and bronze impeller. Motors suitable for variable speed drives.
- Ductwork: In accordance with SMACNA HVAC Duct Construction Standards, NFPA 90A, NFPA 96, and as detailed. General ductwork shall be galvanized steel.
- Louvers: Drainable-blade aluminum, with 70-percent Kynar finish.
- Insulation: As recommended in ASHRAE Standard 90.1 and applicable Codes and standards as adopted by State and local authorities.
    - Hot Piping and Equipment: Fiberglass with white ASJ.
    - Cold Piping and Equipment: Elastomeric foam by Armacell or K-Flex USA only.
    - Ductwork: Fiberglass with foil-faced FSK for indoor ductwork, rigid board type in mechanical rooms and at louver plenums. Polyisocyanurate foam outdoors.
    - PVC jacketing on outdoor piping, and piping exposed less than 8 feet above floor.

- Testing and Balancing (TAB): Provide the services of an independent testing and balancing agency to test, adjust, and balance air, water, and plumbing systems. The Agency shall be under the supervision of a licensed Professional Engineer, or an NEBB Certified Professional.

DIVISION 26 – ELECTRICAL

- HVAC System: Provide electrical connections and wiring, panels, etc. required for new HVAC equipment. Existing panel capacity will be used for all equipment.

Cost Estimates

Draft

Epping Elementary School
HVAC Renovations
Epping School District
Epping, NH

OPTION 1 - VARIABLE REFRIGERANT FLOW SYSTEM

Section/Description	Renovation	$/sf (lf)	Budget 11/09/17
	57,763 sf		square footage of building
Construction Costs			
Concrete Pads			$8,000
Structural Steel			$8,000
Roofing			$5,000
Fire Stopping			$2,000
Ceilings			$3,000
Painting			$2,000
Condensate Piping/Insulation			$7,200
VRF Heat Pumps			$270,000
Duct Modifications			$80,000
Energy Recovery Units			$240,000
Boilers			$60,000
Pump VFDs/ Piping			$25,000
Automatic Temperature Controls			$125,000
Demolition			$5,000
Electrical Modifications			$80,000
General Conditions (15%)			$138,030
Construction Contingency (10%)			$92,020
SUBTOTAL CONSTRUCTION		**$19.91**	**$1,150,250**
Ancillary Costs			
Architectural and Engineering			$39,600
Construction Administration			$9,800
Moving and Storage			$10,000
Reimburseables			$8,000
Bidding Contingency (5%)			$61,000
Owner's Legal/Advertising/Project Admin			$6,000
SUBTOTAL ANCILLARY COSTS			**$134,400**
TOTAL PROJECT			**$1,284,650**

Draft

Epping Elementary School
HVAC Renovations
Epping School District
Epping, NH

OPTION 2 - CONVENTIONAL AIR CONDITIONING

Section/Description	Renovation	$/sf (lf)	Budget 11/09/17
	57,763 sf		square footage of building
Construction Costs			
Concrete Pads			$8,000
Structural Steel			$8,000
Roofing			$5,000
Fire Stopping			$2,000
Ceilings			$40,000
Painting			$2,000
Condensate Piping/Insulation			$1,000
Air Handling Units			$240,000
Duct Modifications			$300,000
Energy Recovery Units			$120,000
Boilers			$60,000
Pump VFDs/ Piping			$25,000
Automatic Temperature Controls			$125,000
Demolition			$5,000
Electrical Modifications			$80,000
General Conditions (15%)			$153,150
Construction Contingency (10%)			$102,100
SUBTOTAL CONSTRUCTION		**$22.09**	**$1,276,250**
Ancillary Costs			
Architectural and Engineering			$39,600
Construction Administration			$9,800
Moving and Storage			$10,000
Reimburseables			$8,000
Bidding Contingency (5%)			$67,000
Owner's Legal/Advertising/Project Admin			$7,000
SUBTOTAL ANCILLARY COSTS			**$141,400**
TOTAL PROJECT			**$1,417,650**

Life Cycle Analysis

Life Cycle Cost Analysis

The following section includes a life cycle cost analysis of the two studied options for air conditioning systems at the Epping Elementary School. Costs for utilities (oil/electric) were taken from the most recent bills available from the school. The building heating and cooling loads were calculated based on the school configuration and weather data was used from Pease International Tradeport in Portsmouth.

The operating costs and maintenance costs were generated from the Building Efficiency System Tool (BEST), a program designed to evaluate mechanical systems in the conceptual design phase. This program calculates the energy requirements for the interconnected parts of the heating and cooling systems and projects the associated O&M costs based on the seasonal variations in outdoor conditions.

The result of this life cycle analysis on the final page of this section indicates that the VRF system has approximately $600,000 in savings compared (2017 dollars) to the conventional system over a 20-year timeframe. This is largely due to the projected savings in annual energy consumption.

Project

Project: Epping Elementary
Location: Epping, NH
Engineer: SMC
Date: 09/07/17

Nearest Climatological Location

State: : NH
City: PEASE INTL TRADEPOR

Building Dimensions

Length: 962 (ft)
Width: 60 (ft)
Perimeter Width: 12 (ft)
Height: 12 (ft)
Number of Floors: 1
Total Area: 57720 (ft²)

Heat Loss

Total: 1443000 (BtuH)
Heat Loss / Area: 25.0 (BtuH/ft²)
Ventilation: 700121 (BtuH)
Envelope: 742879 (BtuH)

Heat Gain

Total: 1673880 (BtuH)
Heat Gain / Area: 29.0 (BtuH/ft²)
Ventilation Sensible: 141576 (BtuH)
Ventilation Latent: 228904 (BtuH)
People: 115440 (BtuH)
Light: 392496 (BtuH)
Equipment: 196248 (BtuH)
Envelope: 599217 (BtuH)

Energy Costs

Electricity Demand: 13.99 $/Kw
Electricity Consumption: .0941 $/KwHr
Fossil Fuel Oil: 1.66 $/Gal
Fossil Fuel Natural Gas: 1.00 $/Therm
Fossil Fuel Propane2.00 $/Gal

Life Cycle Cost

Cost of Money: 6.0 %
Inflation on Maintenance Cost: 5.0 %
Inflation on Energy Cost: 5.0 %
Project Life Cycle: 20 Years

System 1 Best Energy Analysis Nov 10, 2017
Option 1 - Variable Refrigerant Flow

Heat Source
Heat Source: Boiler
Heat Type: Oil
Heat Efficiency: 86 %

Cool Source
Cool Source: VRF Air Source
Cooling EER (EER): 12.40
Cooling IEER (EER): 12.40
Cooling IEER Adjusted (EER): 12.40
Cooling Compresser HP: 180.90 Hp
Cooling Condenser Fan HP: 16.38 Hp

Hydronic Pipe Systems
Heating Pipe System: Two Pipe Standard
Heat Pipe Flow Control: Delta T
Heat Pipe HP: 4.82 HP

Air Duct System
System : Single Duct Single Fan Ventilation Only DOAS
Heating Supply Fan Horsepower: 27.55 Hp
Cooling Supply Fan Horsepower: 21.87 Hp

System Features
Economizer

Heating Perimeter Terminals
Terminal Type: Baseboard Fintube

Heating Interior Terminals
Terminal Type: Baseboard Fintube

Cooling Perimeter Terminals
Terminal Type: Fan Coil Unit Cooling Coil
Terminal Fan Horsepower: 4.92 Hp

Cooling Interior Terminals
Terminal Type: Fan Coil Unit Cooling Coil
Terminal Fan Horsepower: 12.41 Hp

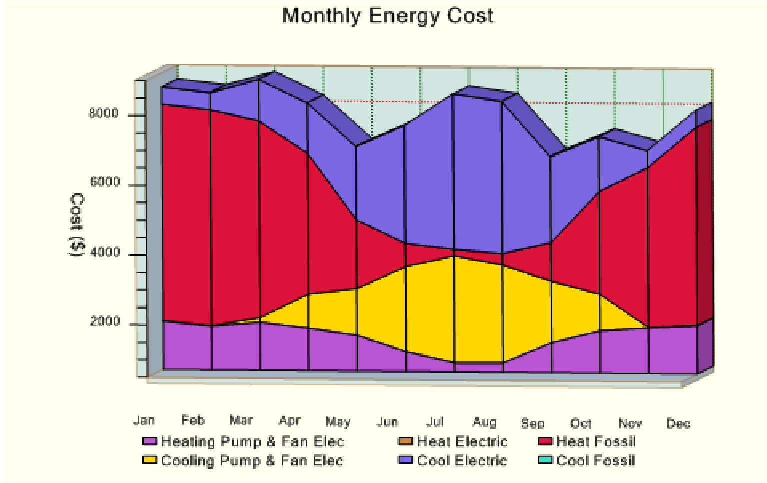
Terminal Flow Control
Pump Flow Control: Delta T
Fan Flow Control: Constant

Life Cycle Cost
First Cost:	$1141124
Annual Maintenance Cost:	$40404
Replacement Cost:	$570562
Replacement Interval:	15 Years

Annual Energy Cost
Electrical Consumption:	266812 Kw
Electrical Consumption Cost:	$25107
Electrical Demand Cost:	$29586
Fossil Consumption:	23787
Fossil Cost:	$39486
Fossil Cost:	$94179
Life Cycle Cost:	$3973197

Total Pump & Fan HP
Total Heating Pump & Fan HP: 32.37 Hp
Total Cooling Pump & Fan HP: 95.40 Hp
Cooling System COP: 8.01

System 1 Best Energy Analysis Nov 10, 2017
Option 1 - Variable Refrigerant Flow



Monthly Energy Data

	Jan	Feb	Mar	Apr	May	Jun
Heating Pump & Fan Cost($)	1879	1745	1869	1710	1522	1063
Heating Other Electical Cost($)	0	0	0	0	0	0
Heating Fossil Cost($)	6203	6185	5630	4032	1966	665
Heating Total Cost($)	8082	7931	7499	5742	3488	1728
Cooling Pump & Fan Cost($)	20	20	146	986	1342	2443
Cooling Other Electical Cost($)	492	492	1187	1443	2106	3385
Cooling Fossil Cost($)	0	0	0	0	0	0
Cooling Total Cost($)	512	512	1333	2429	3447	5828
Heating Pump & Fan Consumption (Kw)	16142	14723	16036	14517	12610	7815
Heating Other Consumption (Kw)	0	0	0	0	0	0
Heating Consumption Fossil (BtuH)	3737	3726	3392	2429	1184	401
Cooling Pump & Fan Consumption (Kw)	0	0	99	1600	5380	13562
Cooling Other Consumption (Kw)	0	0	188	2903	9948	23544
Cooling Consumption Fossil (BtuH)	0	0	0	0	0	0
Geothermal Heat Extraction (MMBTU)	0	0	0	0	0	0
Geothermal Heat Rejection (MMBTU)	0	0	0	0	0	0

	Jul	Aug	Sep	Oct	Nov	Dec
Heating Pump & Fan Cost($)	756	766	1355	1710	1804	1868
Heating Other Electical Cost($)	0	0	0	0	0	0
Heating Fossil Cost($)	190	321	1104	2940	4574	5676
Heating Total Cost($)	946	1087	2459	4650	6378	7544
Cooling Pump & Fan Cost($)	3066	2814	1769	1054	20	20
Cooling Other Electical Cost($)	4456	4365	2463	1573	492	492
Cooling Fossil Cost($)	0	0	0	0	0	0
Cooling Total Cost($)	7522	7178	4232	2627	512	512
Heating Pump & Fan Consumption (Kw)	4634	4740	10830	14515	15478	16071
Heating Other Consumption (Kw)	0	0	0	0	0	0
Heating Consumption Fossil (BtuH)	114	193	665	1771	2755	3419
Cooling Pump & Fan Consumption (Kw)	20186	18545	7441	2320	0	0
Cooling Other Consumption (Kw)	34926	33955	13749	4285	0	0
Cooling Consumption Fossil (BtuH)	0	0	0	0	0	0
Geothermal Heat Extraction (MMBTU)	0	0	0	0	0	0

System 2 Best Energy Analysis Nov 10, 2017
Otion 2 - Conventional Air Conditioning

Heat Source
Heat Source: Boiler
Heat Type: Oil
Heat Efficiency: 86 %

Cool Source
Cool Source: Condensing Unit
Cool Auxiliary Source: Air Cooled
Cool Type: Air Cooled
Cooling EER (EER): 11.00
Cooling IEER (EER): 11.00
Cooling IEER Adjusted (EER): 11.00
Cooling Compresser HP: 203.92 Hp
Cooling Condenser Fan HP: 16.83 Hp

Hydronic Pipe Systems
Heating Pipe System: Two Pipe Standard
Heat Pipe Flow Control: Constant
Heat Pipe HP: 4.82 HP

Air Duct System
System : Single Duct Single Fan
Air Flow Control: On Off
Heating Supply Fan Horsepower: 46.25 Hp
Cooling Supply Fan Horsepower: 206.64 Hp

System Features
Economizer

Heating Perimeter Terminals
Terminal Type: Baseboard Fintube

Heating Interior Terminals
Terminal Type: Baseboard Fintube

Cooling Perimeter Terminals
Terminal Type: Manual Balancing Damper

Cooling Interior Terminals
Terminal Type: Manual Balancing Damper

Terminal Flow Control
Pump Flow Control: Constant
Fan Flow Control: Constant

Life Cycle Cost

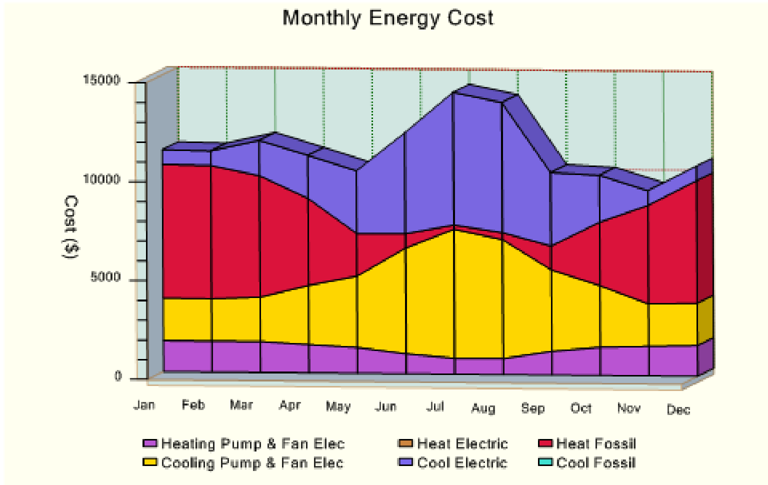
First Cost:	$1267531
Annual Maintenance Cost:	$25397
Replacement Cost:	$507012
Replacement Interval:	15 Years

Annual Energy Cost

Electrical Consumption:	372109 Kw
Electrical Consumption Cost:	$35015
Electrical Demand Cost:	$57876
Fossil Consumption:	25928
Fossil Cost:	$43041
Fossil Cost:	$135932
Life Cycle Cost:	$4569302

Total Pump & Fan HP
Total Heating Pump & Fan HP: 51.07 Hp
Total Cooling Pump & Fan HP: 267.81 Hp
Cooling System COP: 11.70

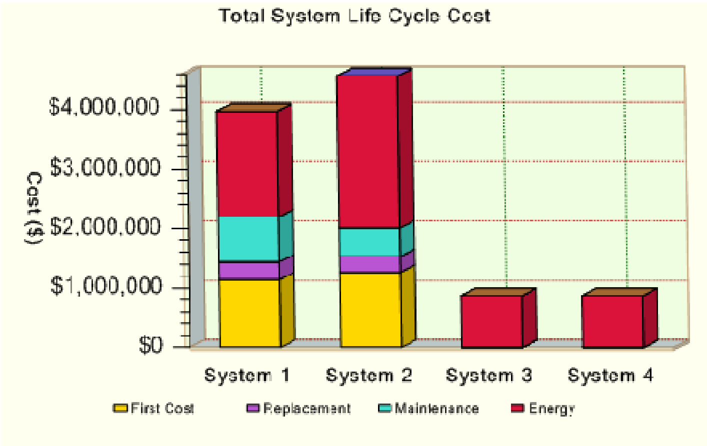
System 2   Best Energy Analysis Nov 10, 2017
Otion 2 - Conventional Air Conditioning

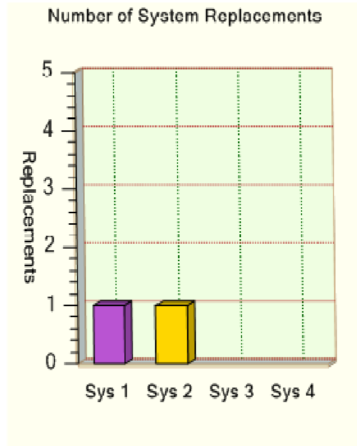


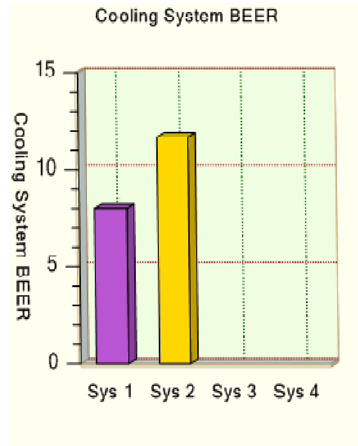
Monthly Energy Data

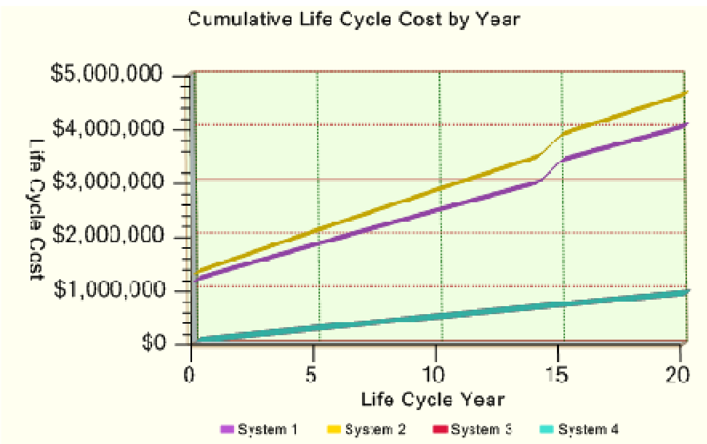
	Jan	Feb	Mar	Apr	May	Jun
Heating Pump & Fan Cost($)	1566	1546	1556	1415	1295	997
Heating Other Electical Cost($)	0	0	0	0	0	0
Heating Fossil Cost($)	6762	6742	6137	4395	2143	725
Heating Total Cost($)	8327	8288	7693	5811	3438	1721
Cooling Pump & Fan Cost($)	2157	2157	2254	3013	3624	5360
Cooling Other Electical Cost($)	742	742	1791	2176	3176	5106
Cooling Fossil Cost($)	0	0	0	0	0	0
Cooling Total Cost($)	2899	2899	4045	5189	6800	10466
Heating Pump & Fan Consumption (Kw)	10740	10528	10642	9311	8117	5035
Heating Other Consumption (Kw)	0	0	0	0	0	0
Heating Consumption Fossil (BtuH)	4073	4061	3697	2648	1291	437
Cooling Pump & Fan Consumption (Kw)	0	0	161	2946	9443	25395
Cooling Other Consumption (Kw)	0	0	284	4379	15004	35512
Cooling Consumption Fossil (BtuH)	0	0	0	0	0	0
Geothermal Heat Extraction (MMBTU)	0	0	0	0	0	0
Geothermal Heat Rejection (MMBTU)	0	0	0	0	0	0

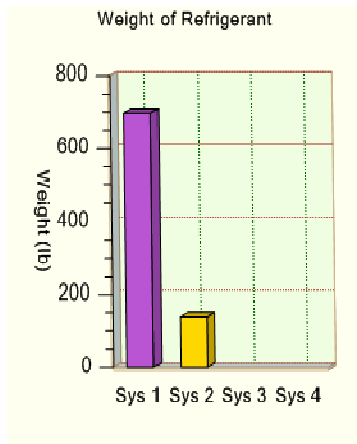
	Jul	Aug	Sep	Oct	Nov	Dec
Heating Pump & Fan Cost($)	796	802	1187	1417	1478	1538
Heating Other Electical Cost($)	0	0	0	0	0	0
Heating Fossil Cost($)	207	350	1203	3204	4986	6187
Heating Total Cost($)	1003	1152	2391	4621	6463	7725
Cooling Pump & Fan Cost($)	6533	6022	4133	3125	2157	2157
Cooling Other Electical Cost($)	6721	6583	3715	2372	742	742
Cooling Fossil Cost($)	0	0	0	0	0	0
Cooling Total Cost($)	13254	12605	7848	5497	2899	2899
Heating Pump & Fan Consumption (Kw)	2985	3054	6975	9328	9931	10490
Heating Other Consumption (Kw)	0	0	0	0	0	0
Heating Consumption Fossil (BtuH)	125	211	725	1930	3003	3727
Cooling Pump & Fan Consumption (Kw)	37861	33162	13088	4132	0	0
Cooling Other Consumption (Kw)	52679	51214	20738	6463	0	0
Cooling Consumption Fossil (BtuH)	0	0	0	0	0	0
Geothermal Heat Extraction (MMBTU)	0	0	0	0	0	0









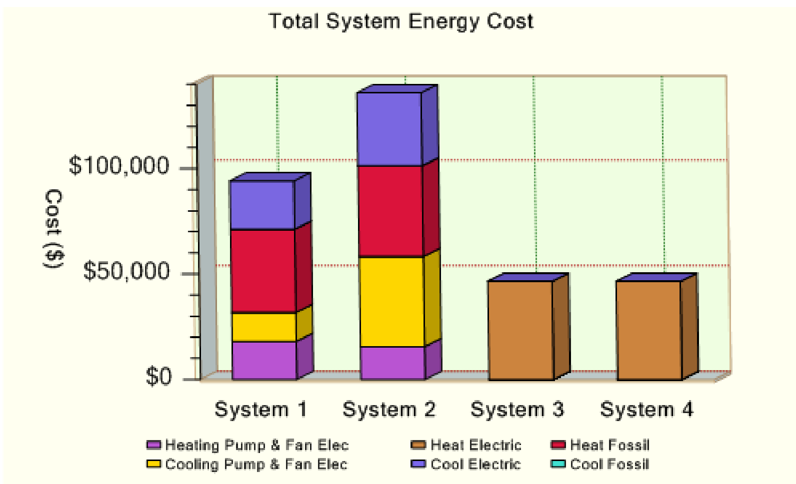


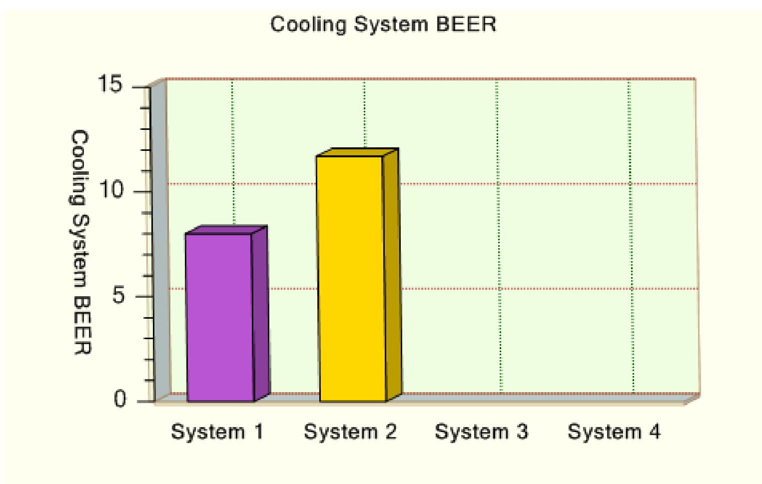
Consult ASHRAE Standard 34 Safety Classification of Refrigerants on allowable amounts of refrigerant and proper location of refrigerant sensors.

System 1: Option 1 - Variable Refrigerant Flow
System 2: Otion 2 - Conventional Air Conditioning
System 3:
System 4:

System Comparison   Best Energy Analysis   Nov 10, 2017

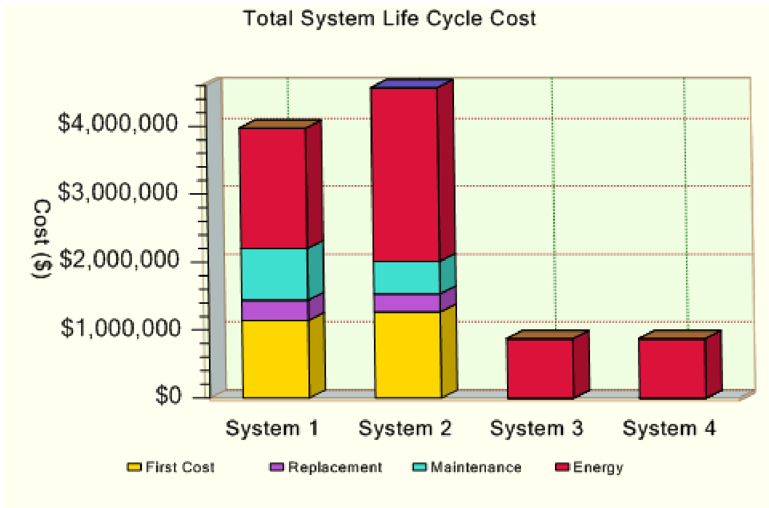
	System 1	System 2	System 3	System 4	
Heating Pump & Fan HP:	32.37	51.07	0.00	0.00	HP
Cooling Pump & Fan HP:	95.40	267.81	0.00	0.00	HP
Cooling System COP:	8.01	11.70	0.00	0.00	
Electrical Consumption:	266,812	372,109	0	0	KWHr
Electrical Consumption Cost:	25,107	35,015	0	0	$
Electrical Demand Cost:	29,586	57,876	46,511	46,511	$
Total Electrical Cost:	54,693	92,891	46,511	46,511	$
Fossil Fuel Consumption:	23,787	25,928	0	0	
Fossil Fuel Cost:	39,486	43,041	0	0	$
Total Cost:	94,179	135,932	46,511	46,511	$
Savings for System 3:	47,668	89,421		0	$

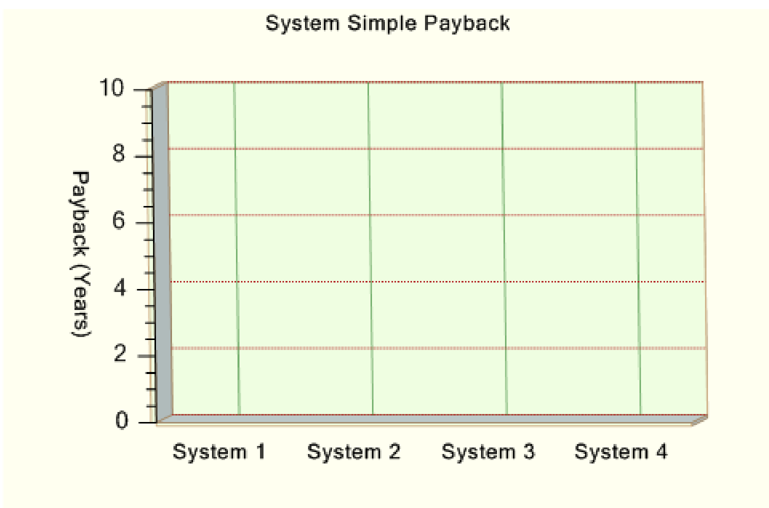




System 1: Option 1 - Variable Refrigerant Flow
System 2: Otion 2 - Conventional Air Conditioning
System 3:
System 4:

	System 1	System 2	System 3	System 4	
Life Cycle Present Worth:	3,973,197	4,569,302	874,965	874,965	$
Life Cycle Cost Savings for System 3	3,098,232	3,694,336		0	$
Annualized Life Cycle Cost:	346,401	398,373	76,283	76,283	$
Annualized Life Cycle Cost Savings for System 3	270,118	322,089		0	$
First Cost:	1,141,124	1,267,531	0	0	$
Additional First Cost Against System 1		126,407			$
Annual Energy & Maintenance Cost:	134,583	161,329	46,511	46,511	$
Annual Energy & Maintenance Cost Savings Over System 1		-26,746			$
SimplePayback:		Never			Years





System 1: Option 1 - Variable Refrigerant Flow
System 2: Otion 2 - Conventional Air Conditioning
System 3:
System 4:

Recommendation

Recommendation

The major goals of this project are to improve ventilation and provide air conditioning throughout the Epping Elementary School. While both of the system options will accomplish these basic goals, we feel that there are distinct advantages to choosing what we have labelled as Option 1 – Variable Refrigerant Flow (VRF) air conditioning.

The first advantage to the VRF option is the ability to control the cooling temperature in each space. While in both systems the heating will remain using the fin tube radiators at the window walls (with upgraded controls) and heating temperature will be adjustable in each space, the conventional air conditioning option would limit the air conditioning temperature control to a single zone per wing, as proposed. While it would be possible to zone a conventional system using variable air flow to the spaces, this would increase the cost of this option significantly.

The second advantage to the VRF system is the increased efficiency and life cycle cost advantage. While both systems will likely require additional energy to operate due to the increase in ventilation and the addition of cooling, the VRF system (Option 1) is more efficient in energy use. This leads to a significantly lower life cycle cost compared to a conventional system (Option 2). Both systems would incorporate energy recovery on the increased ventilation air, making the additional energy required for this goal relatively small. However, the electric energy required for cooling is less for a VRF system due to its higher efficiency. An added bonus is that the VRF system is capable of providing heat, as well. In the event that oil prices rose above current levels, the VRF system would likely be able to heat the building more cheaply than the current boiler system.

We recommend the installation of a VRF system as the cooling system for the Epping Elementary School. We have also included in the costs recommended modifications to other existing systems, such as replacement of boilers, pumps, and temperature controls. The heating system components have reached the end of their useful life and increased control would be advisable to enhance the energy efficiency and comfort of the building.

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