<u>Spofford School – Feasibility and Design HVAC Electrification</u>

In the Town's 5-Year Capital Improvement Program, from fiscal years 2024 through 2008, are the replacement of the HVAC systems at Cole and Spofford Schools, including boilers and controls. In advance of those projects, the School Committee is working collaboratively with the Sustainability Committee and Permanent Building Committee on the feasibility of replacing these systems through electrification. The Town completed an Electrification Scoping Audit through National Grid, which demonstrated that the electrification of these systems would reduce the carbon footprint for the elementary school buildings significantly. Current grants and incentives through National Grid and the state's Green Communities program could cover a significant portion of the installation costs, potentially making electrification more cost effective than replacing with traditional fossil-fuel-burning systems. The next step in the process is to appropriate money to fund a more detailed study with firmer cost estimates, starting with Spofford Pond Elementary, since it has the oldest heating system.

This Warrant Article would fund Feasibility Study & Schematic Design for Spofford School. The Town would work with a consultant team and further explore options and generate schematic information and cost estimate specific for Spofford. The Sustainability Committee received a $75,000 order of magnitude estimate for the Feasibility Study & Schematic Design from an architectural firm that specializes in school construction and building systems. The Feasibility & Schematic Design would provide a plan for next steps, including funding full design and construction plans for bidding.

Spofford Pond School

31 Spofford Road

Boxford, MA 01921

Prepared by

B2Q Associates
100 Burtt Rd Suite 212
Andover, MA 01810

Revision Date

8/17/2022

Electrification Scoping Study

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Introduction & Background

B2Q Associates (B2Q) has been retained by National Grid to provide engineering consulting services through a high-level scoping study to evaluate the potential for electrifying Spofford Pond School in Boxford, MA.

The objective of this study is to identify a suggested electrification approach and to perform a high-level evaluation to determine the likely budget impacts, in pursuit of the Town of Boxford's longer term carbon reduction goals. This report includes a summary of existing equipment and operations observed in the scoping phase of the study, as well as our recommended equipment options for starting the process of phasing out fossil fuels in the school. We have included associated estimates of energy and cost savings, opinions of probable implementation cost, and estimated utility rebates. This report is also intended to serve as an introduction to the electrification process that can be used as a model for future evaluations of other town properties.

As part of the study, B2Q conducted site visits to collect nameplate and operational data from each building's major equipment. Available drawings and utility data were reviewed to document existing equipment, controls, and sequences of operation.

EXECUTIVE SUMMARY

The table below summarizes annual energy and cost savings for the suggested electrification approaches. In reviewing the table below, please note the following:

1. Total cost savings in the Executive Summary Table are based upon average blended utility rates of $0.13/kWh for electricity and $1.50/therm for natural gas. The electric rate was provided by the Town. The natural gas rate is calculated from utility data provided by National Grid. Note that the natural gas supply rate was not provided and therefore is estimated. Note that the relative net energy cost difference of the electrification options would improve if natural gas prices rose or electricity prices fell and vice versa.
2. Potential utility incentives are estimated in the Executive Summary Table. Incentives are estimated based on heat pump rebates published on the Mass Save website at the time of this report; however, these will be subject to further analysis and rebate amounts are solely determined by the utilities. MassSave does not currently include air-to-water heat pumps in the rebate table; therefore, it is unclear at this time what the available incentive may be for that option, but the approximate scale of incentive is likely to be comparable to other heat pump technologies on a $/ton basis. Refer to the MassSave website for more information.
3. The opinions of probable construction cost **do not include an estimate of the cost to upgrade the building's electrical service** capacity and primary electrical infrastructure. This scope and cost would be required to implement the electrification options below, but the electrical infrastructure upgrade costs cannot be estimated at this time, as more detailed engineering is required, but is outside the scope of this study. Refer to the Electrical Infrastructure section below for more information.
4. CO_2 emissions savings estimates are based on 0.633 lb CO_2/kWh from ISO New England's 2019 Air Emissions Report and 11.023 lb CO_2/therm from the US Energy Information Administration. Note that CO_2 emissions savings will continue to improve over time if New England continues to make progress toward its goal of decreasing carbon intensity on the electric grid.
5. Total energy use in the Executive Summary Table only accounts for heating energy use as there is no mechanical cooling in the base case and we wanted to provide a more direct comparison with current operations in the project economics. The proposed systems could be capable of proving cooling, as well, which would further increase the proposed case electricity use considerably.

Table 1: Executive Summary of proposed equipment electrification options.[1]

Existing Equipment	Proposed Electrification Option	Estimated Annual Electric Savings	Estimated Annual Gas Savings	Estimated Annual Energy Cost Reduction	Estimated Annual CO_2 Emissions Savings$_1$	Opinion of Probable Cost	Estimated Potential Utility Incentive	Estimated Net Cost
		kWh	*therms*	*$*	*lbs*	*$*	*$*	*$*
Gas-Fired Rooftop Units	Heat Pump RTU Retrofit	-67,205	7,644	$2,729	46,622	$353,420	$157,500	$195,920
Hot Water End Uses	Option A: VRF	-191,977	24,834	$12,294	168,167	$732,350	$597,917	$134,433
	Option B: Central Air-to-Water Heat Pump	-263,444	24,834	$3,003	122,928	$2,280,900	TBD	$2,280,900
	Total Electrification Savings (with Option A)	**-259,182**	**32,478**	**$15,023**	**214,789**	**$1,085,770**	**$755,417**	**$330,353**
	Total Electrification Savings (with Option B)	**-330,649**	**32,478**	**$5,732**	**169,550**	**$2,634,320**	**$157,500**	**$2,476,820**
	Percent of Baseline Usage (Option A)	*-100%*	*70%*		*30%*			
	Percent of Baseline Usage (Option B)	*-128%*	*70%*		*24%*			

[1] For estimated annual CO_2 emissions savings, 0.633 lbs/kWh and 11.665 lb/therm were assumed. Note that CO_2 savings would continue to improve over time as New England decreases carbon intensity on the electric grid.

Facility Description

General

The Spofford Pond School is approximately 75,000 ft^2 and was originally constructed in 1963. It is located at 31 Spofford Road in Boxford, MA and is comprised of a one-story brick building that surrounds a central courtyard. The school accommodates students in third through sixth grades. Since the initial construction, the Spofford School has undergone several renovations and additions. The original 1963 building comprised solely of the southwest wing of today's construction, with several classrooms, administrative offices, library, and cafeteria. In 1967, an addition created what is today's southeast wing, adding more classrooms. The northeast and northwest wings of classrooms were constructed in 1990 and 1995, respectively.

Mechanical Systems

The mechanical room is located between the gymnasium and the kitchen along the southeast side of the building. There are (2) hot water boilers, one Weil-McLain and one HB Smith, which are fueled by natural gas. They have input capacities of 2,216 and 3,668 MBH, respectively. The heating hot water is circulated by (4) distribution pumps that operate as pairs in lead/lag fashion. The ceiling-hung inline pumps are 1-hp each. The base-mounted pumps are 3-hp and 5-hp. The boilers and pumps are controlled via a Johnson Controls Metasys building automation system (BAS).

Hot water is distributed by the pumps to various end devices throughout the school, including unit ventilators (UVs), fin tube radiation (FTR), and unit heaters (UHs). The classrooms are heated by approximately (35) UVs. Among those UVs, the (12) that service the northeast wing of classrooms were replaced in 2012 and feature electronic dampers and valve actuators which are controlled by the Metasys BAS. The other UVs all continue to utilize pneumatic controls. Based on available drawings and conversations with facilities staff, HW piping runs behind the UVs along the outside perimeter wall through piping chases.

The domestic hot water heater, also located in the mechanical room, is a direct gas-fired Bradford White D75T. The DHW heater has an input capacity of 125 MBH and volume of 75 gallons.

There are (5) rooftop units (RTUs) which provide gas-fired heating and direct expansion (DX) cooling throughout the building. The areas serviced by the RTUs include the library, computer room, conference room, and administrative areas. The units are programmed by their factory controllers, but are integrated with the Metasys BAS. The occupied runtime schedule for the RTUs is generally 6 AM- 6 PM Monday – Friday based on discussions with facilities staff.

There is (1) 100% outside air makeup-air unit (MAU) that provides heating via a gas-fired furnace to a portion of the corridors. Several ceiling and wall mounted cabinet UHs also serve the corridors.

There are (2) interior air handling units (AHUs) which provide heating via hot water (HW) coils to the kitchen and gym. These units are located in the ceiling of the boiler room and a storage closet next to the gym, respectively. B2Q observed the units during our site walkthrough but they are not included in the available documentation, so their heating capacities are unknown at the time of this report.

There is (1) 100% outside air heating recovery unit (HRU) serving the cafeteria. The unit features a heat recovery wheel, gas-fired heating, and DX cooling.

There is (1) dehumidifier, H-1, made by Desert Aire which serves the water treatment plant, though limited information was available about this unit at the time of our study.

UTILITY INFORMATION

UTILITIES

Electricity Delivery: National Grid
Natural Gas Delivery: National Grid

The graphs and discussion on the following pages are based on utility data provided by National Grid from January 2018 – December 2021.

ANNUAL SUMMARY

A summary of the monthly electricity and gas consumption is shown in the table and graphs below. Both the facility's gas use and electricity use are highly dependent on school operations, with energy usage dropping in the summer when school is out of session. Figure 1 illustrates the electric loads that contribute to the site's 258,600 kWh average yearly electricity use. Major contributors to the load are HVAC fans (supply fans, exhaust fans, burner fans, unit ventilators, and unit heaters) and the HW pumps. Figure 2 illustrates the gas loads that contribute to the site's 46,543 therm average yearly gas use. Gas consumption is primarily due to heating loads, as well as some domestic hot water heating and cooking equipment. Note that electricity usage was considerably lower in 2020 as a result of reduced occupancy from the Covid-19 pandemic, although 2019 was also relatively low. Natural gas use in 2019 and 2020 was lower than other years, but 2019's number appears to be influenced by an unreasonably low January usage that may have been a result of a meter error or a data discrepancy.

Table 2: Annual electric and gas data for 2018-2021.

	Electricity Use (kWh)				Natural Gas Use (therms)			
Month	2018	2019	2020	2021	2018	2019	2020	2021
January	25,200	23,280	21,960	26,520	11,005	1,365	7,407	10,035
February	23,520	23,040	23,280	24,360	7,438	8,564	6,893	12,056
March	19,560	22,320	22,680	27,840	6,207	8,441	6,528	8,613
April	25,680	23,400	12,720	29,520	5,933	3,760	2,864	7,046
May	21,360	20,760	10,560	23,880	2,501	3,518	556	3,543
June	23,880	20,640	14,160	13,200	154	144	494	391
July	18,360	14,280	13,200	36,720	103	82	93	422
August	16,800	14,880	14,520	19,680	-103	72	51	412
September	21,960	18,720	20,760	24,600	175	19	299	340
October	21,840	19,920	19,560	24,000	1,101	204	710	268
November	22,080	21,960	25,800	23,400	5,932	3,782	3,988	3,546
December	22,800	22,800	25,800	26,640	13,108	6,516	8,773	6,784
Total	**263,040**	**246,000**	**225,000**	**300,360**	**55,572**	**38,486**	**38,656**	**53,456**

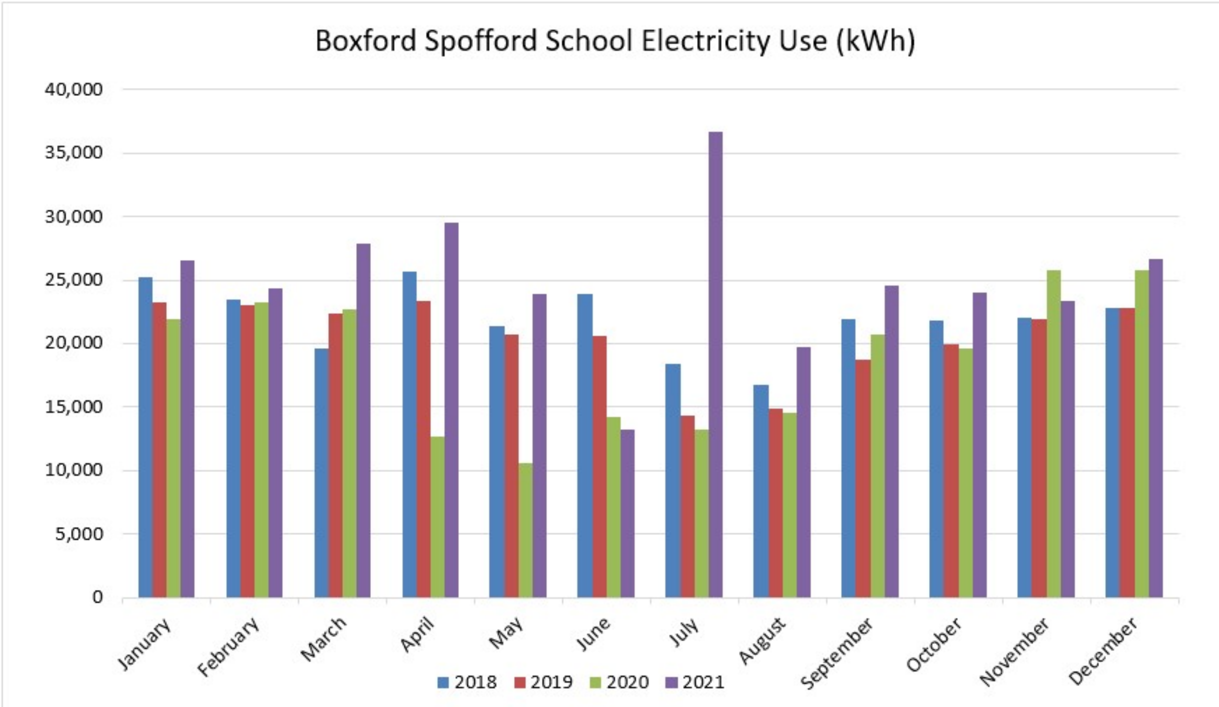

Figure 1: Monthly electric use at Spofford Pond School

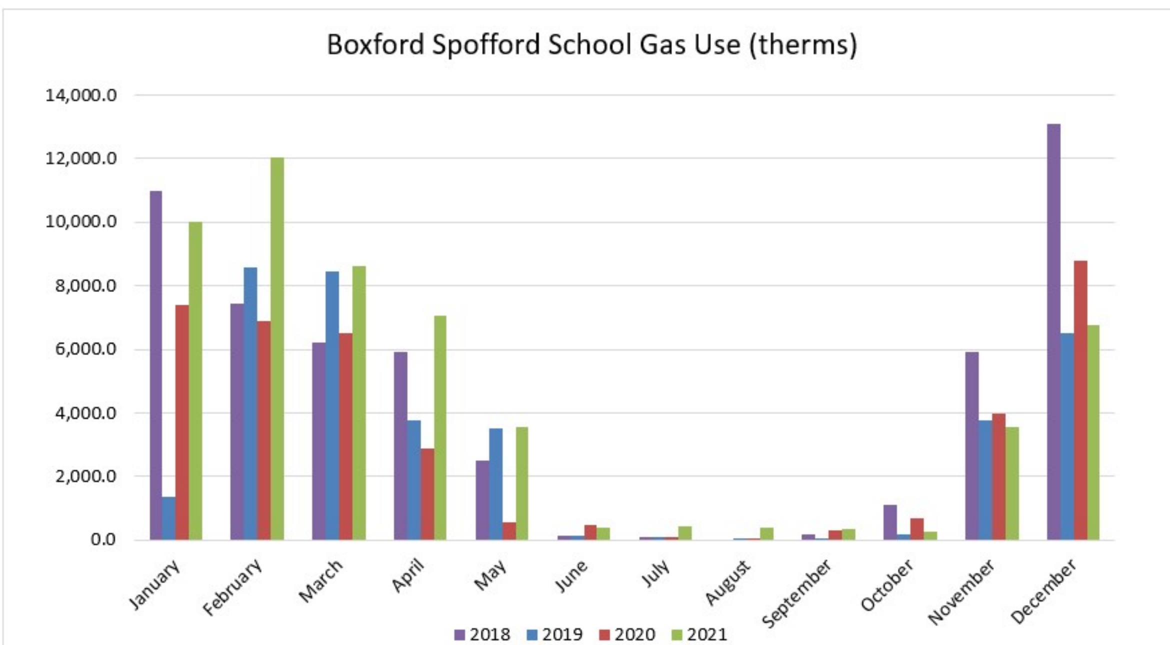

Figure 2: Monthly gas use at Spofford Pond School.

BENCHMARKING

The table below summarized the building's energy use intensity (EUI) for each year. Note that the energy use intensity (EUI) presented in Table 3 is based on an estimated building square footage of 75,000 ft^2 from the floorplans provided by Boxford. The Spofford School's average total EUI of 74 is slightly higher than the average EUI of 69.7 for education buildings in the New England area.[2]

Table 3: Facility benchmarking metrics for 2018-2021.

Year	Total Electric	Total Gas	Electric EUI	Gas EUI	Total EUI
-	kWh	Therms	kBtu/sf	kBtu/sf	kBtu/sf
2018	263,040	55,572	12.0	74.1	86.1
2019	246,000	38,486	11.2	51.3	62.5
2020	225,000	38,656	10.2	51.5	61.8
2021	300,360	53,456	13.7	71.3	84.9
Avg	258,600	46,543	12	62	74

[2] US Energy Information Administration Commercial Buildings Energy Consumption Survey

SUGGESTED HVAC ELECTRIFICATION OPTIONS

The following section provides suggestions for potential retrofit and/or replacement options to electrify the HVAC equipment in the school. Note that the options analyzed and presented below may not be the only option, therefore each section includes a list of other potential options which could be considered, as applicable. Given the preliminary and high-level nature of this study, additional study and/or design would provide a more detailed assessment of the scope and assumptions used in this report and may alter the recommend approach for each system type.

Table 4: HVAC electrification cost and energy comparison.

Existing Equipment	Proposed Electrification Option	Base Case Heating Energy		Proposed Case Heating Energy		Base Case Heating Energy Cost		Proposed Case Heating Energy Cost	
-	-	kWh	therms	kWh	therms	$ kWh	$ therms	$ kWh	$ therms
Gas-Fired RTUs	Heat Pump RTU Retrofit	0	9,925	67,205	2,282	$0	$14,888	$8,737	$3,423
HW End Uses	Option A: VRF	0	24,834	191,977	0	$0	$37,251	$24,957	$0
	Option B: Central Air-to-Water Heat Pump	0	24,834	263,444	0	$0	$37,251	$34,248	$0
	Total MMBtu (Option A)	**3,476**		**1,112**		**$52,139**		**$37,116**	
	Total MMBtu (Option B)	**3,476**		**1,356**		**$52,139**		**$46,407**	

EXISTING GAS-FIRED RTUS

ELECTRIFICATION OPTION SUMMARY

The table below compares the estimated base and proposed energy use and cost for the suggested electrification option.

Table 5: Rooftop, makeup air, and heat recovery unit electrification option summary.

Estimated Annual Electric Savings	Estimated Annual Gas Savings	Estimated Annual Energy Cost Reduction	Opinion of Probable Cost	Estimated Potential Utility Incentive	Net Project Cost	Estimated CO_2 Emissions Reduction
kWh	therms	$	$	$	$	lbs
-67,205	7,644	$2,729	$353,420	$157,500	$195,920	46,622

BASE CASE

The existing rooftop units (RTUs 1-5), heat recovery unit (HRU-1), and makeup-air unit (MAU-1) provide gas-fired heating and electric DX cooling (RTUs 1-5 and HRU-1 only) to various spaces throughout the school. All of the units were replaced around 2017. The existing equipment specifications are summarized in the table below.

Table 6: Existing equipment list.

Equipment	Service	Model	Supply Airflow	Cooling Capacity	Heating Capacity
-	-	-	cfm	tons	MBH
RTU-1	Library	Daikin DPS010	4,000	9.9	240
RTU-2	Computer Room	Daikin DPS05	2,000	5.0	96
RTU-3	Conference Room	Lennox KGB024	640	2.1	52
RTU-4	Admin Interior	Lennox KGB024	650	2.1	52
RTU-5	Admin Exterior	Lennox KGB024	850	2.1	52
HRU-1	Cafeteria	Daikin DPS018	6,000	29.5	600
MAU-1	Corridors	Daikin DAHA03	1,200	N/A	128

PROPOSED CASE

The suggested electrification option for these units is to retrofit them with a new refrigeration circuit to enable the rooftop units to operate as a heat pump. The retrofit would include a new evaporator coil, compressor, expansion valve, and possibly a remote condensing unit (rather than reusing the existing packaged condenser section that may be too small), as well as a reversing valve to enable heat pump operation. Note that B2Q utilized the equivalent heat pump heating capacity that the manufacturer indicates if the heat pump cooling capacity matched the existing RTU DX cooling capacity, where applicable, to increase the likelihood that the new heat pump components would fit in the same place as the demolished DX. This results in the new heat pump coil having less heating capacity than the existing natural gas furnaces, so it is recommended that the existing gas-fired furnace remain in place for backup and supplementary heating on the coldest days of the year. It is also likely that a new controller would be needed for each RTU, as the existing OEM controller likely does not have built-in functions available for heat pump operation instead of traditional DX.

Table 7: Proposed rooftop unit heating retrofit.

Equipment	Service	Existing Gas Furnace Heating Capacity	Heat Pump Heating Capacity Average Conditions	Heat Pump Heating Capacity Peak Conditions	Remaining Load on Gas Furnace at Peak Conditions	Proposed Heat Pump Heating Annual Usage	Proposed Gas Furnace Annual Usage
-	-	MBH	MBH	MBH	MBH	kWh	therms
RTU-1	Library	240	105	62	179	12,823	582
RTU-2	Computer Room	96	54	33	63	6,939	195
RTU-3	Conference Room	52	24	13	39	4,419	128
RTU-4	Admin Interior	52	24	13	39	5,311	128
RTU-5	Admin Exterior	52	24	13	39	6,283	128
HRU-1	Cafeteria	600	172	104	496	19,691	875
MAU-1	Corridors	128	102	60	68	11,740	246
Total		**1,220**	**505**	**298**	**923**	**67,205**	**2,282**

Another potential option could be to replace the existing rooftop units with new packaged heat pump rooftop units. The advantage of this solution would be that the replacement unit would come fully packaged, meaning the condensing section would be built into the unit and the controller would be preconfigured to work as a heat pump, rather than requiring a customized controller retrofit. Also, there would be more flexibility to increase the size of the unit so that the heat pump could handle 100% of the heating load in the winter and therefore displace 100% of the gas use. The disadvantage of this approach is that it would be more costly and would involve demolishing the rest of the RTU components, such as the fans, dampers, controls, and casing that are only 5 years into a 20+ year life.

Note if a full building VRF system is pursued, then these RTUs could be tied in with that system instead of utilizing their own standalone condensing units.

Opinion of Probable Cost

The opinion of probable cost assumes that each of the units would receive new refrigeration circuits, including standalone condensing units.

Table 8: Opinion of probable construction cost.

Opinion of Probable Construction Cost
Retrofit RTUs with Heat Pump System

B2Q Associates, Inc. 100 Burtt Rd. Ste. 212 Andover, MA 01810 (978) 208 - 0609	Customer: National Grid Address: Spofford Pond School 31 Spofford Rd Boxford, MA	Date: 7/18/2022 Estimated By: GC Checked By: JAB

General			Materials				Labor				
Number	Source	Item	Type	Quantity	Unit Cost	Total Cost	Unit Rate	Workers	Hours Each	Labor Cost	Total Cost
1	3	New equipment for HRU heat pump retrofit (refrigeration circuit, including coil, compressor, condenser, refrigerant charge)	ea	1	$12,000	$12,000	$175	2	24	$8,400	$20,400
2	3	New equipment for RTU-1 heat pump retrofit (refrigeration circuit, including coil, compressor, condenser, refrigerant charge)	ea	1	$4,800	$4,800	$175	2	24	$8,400	$13,200
3	3	New equipment for RTU-2 heat pump retrofit (refrigeration circuit, including coil, compressor, condenser, refrigerant charge)	ea	1	$2,320	$2,320	$175	2	24	$8,400	$10,720
4	3	New equipment for RTU-3-5 heat pump retrofit (refrigeration circuit, including coil, compressor, condenser, refrigerant charge)	ea	3	$1,400	$4,200	$175	2	24	$25,200	$29,400
5	3	New equipment for MAU heat pump retrofit (refrigeration circuit, including coil, compressor, condenser, refrigerant charge)	ea	1	$4,000	$4,000	$175	2	24	$8,400	$12,400
6	3	Submittals, As-Built Documentation, Project Management	ea	1		$0	$200	1	80	$16,000	$16,000
7	3	New Controllers, Programming, Control Wiring	ea	7	$2,500	$17,500	$200	1	20	$28,000	$45,500
8	3	Contractor Commissioning, Training	ea	7		$0	$175	1	8	$9,800	$9,800
9	3	Startup	ea	7		$0	$175	1	8	$9,800	$9,800
10	3	Allowance for Electrical - Breakers, disconnects, wiring, conduit	ea	7	$2,500	$17,500	$175	2	8	$19,600	$37,100
11	3	Allowance for Shipping & Rigging	ea	7	$1,000	$7,000	$150	2	4	$8,400	$15,400

Sources	
1	Means
2	Vendor Quote
3	Other
4	Vendor Allowance

Subtotal		$219,720
Contingency	15%	$33,000
Engineering	10%	$25,300
Construction Administration	5%	$12,700
Commissioning	10%	$25,300
Construction Observation	0%	$0
Contract General Conditions	10%	$25,300
Contractor O&P	10%	$7,000
Project Closeout & Expenses	2%	$5,100
Total		$353,420

Notes

B2Q's construction cost estimates are opinions of probable cost and are based upon traditional sources such as the Means Cost Estimating guide, previous experience, or budget quotes from vendors (pre-design). Due to the volatile nature of labor and material pricing and unforeseeable factors affecting the construction industry, B2Q does not expressly or implicitly warrant or represent that B2Q cost estimates will be the actual cost of equipment and/or installation.

EXISTING HOT WATER SYSTEM (OPTION A)

ELECTRIFICATION OPTION A SUMMARY

The table below compares the estimated base and proposed energy use and cost for the variable refrigerant flow (VRF) system replacement electrification option.

Table 9: Hot water system electrification option A summary.

Estimated Annual Electric Savings	Estimated Annual Gas Savings	Estimated Annual Energy Cost Reduction	Opinion of Probable Cost	Estimated Potential Utility Incentive	Net Project Cost	Estimated CO_2 Emissions Reduction
kWh	therms	$	$	$	$	lbs
-191,977	24,834	$12,294	$732,350	$597,917	$134,433	168,167

BASE CASE

The unit ventilators, indoor AHUs, unit heaters, cabinet unit heaters, and fin tube radiation throughout the school are served by the building's hot water system. The hot water system is served by (2) natural gas-fired boilers, which are summarized in the table below. Hot water is distributed throughout the building by (4) distribution pumps that operate as pairs in lead/lag fashion. The hot water system is controlled by the Metasys BAS for boiler start/stop, boiler staging, pump start/stop, and hot water temperature setpoint control.

Table 10: Spofford existing HW boilers.

Equipment	Model Number	Input Capacity	Estimated Average Efficiency
-	-	MBH	%
Boiler 1	Weil-McLain HR-40-11	2,216	74%
Boiler 2	HB Smith Series 350 Mills	3,668	73%

PROPOSED CASE

One electrification option considered for the hot water system is to install a new air-source VRF replacement system. This system would comprise of ceiling cassette or wall-mounted indoor units in spaces which currently have HW UVs or FTR. This measure also proposes to retrofit the (2) indoor AHUs serving the gym and the kitchen with heat pump coils tied into the same VRF refrigeration circuit to provide heating instead of the existing hot water coils. Condensing unit(s) for the building VRF system would be installed outdoors on the roof or at grade.

This option would also involve installing new energy recovery ventilators (ERVs), which would be equipped with heat pump coils, to provide the required ventilation to each space conditioned by an indoor VRF unit.

The advantage of a VRF system is that it constitutes an entirely separate system from what currently exists and is therefore not dependent on reusing any existing parts of the heating system. The VRF system may also be more cost-effective, and the existing HW equipment– the UVs, FTR, boilers, and distribution piping – could be retired in place.

A potential disadvantage of a VRF system approach is that there may be a significant amount of exposed equipment and piping (including wall and floor penetrations) that would need to be fit into an existing older building that was not designed for VRF.

Note that the proposed case energy use presented only accounts for heating energy use as there is no mechanical cooling in the base case and we wanted to provide a more direct comparison with current operations in the project economics. However, the proposed VRF system would be capable of providing cooling, as well, which would further increase the proposed case electricity use considerably.

The capacity of each new indoor unit and outdoor unit would be determined during a more detailed study based on the heating loads, and potentially cooling loads, of each space.

Opinion of Probable Cost

The opinion of probable cost for Option A is summarized in the table below. The cost estimate assumes that new refrigeration and condensate piping would be required. It also assumes that a building automation system would be installed in the building separate from this project. Therefore, we have estimated the cost of a new equipment controller, controls wiring, and programming for the new equipment only. This cost estimate excludes the cost of demolishing the existing HW system and assumes all existing HW equipment will be retired in place.

Table 11: Opinion of probable construction cost for Option A.

Opinion of Probable Construction Cost											
New VRF System to serve HW End Uses											
B2Q Associates, Inc. 100 Burtt Rd. Ste. 212 Andover, MA 01810 (978) 208 - 0609			Customer: National Grid Address: Spofford Pond School 31 Spofford Rd Boxford, MA					Date: 8/11/2022 Estimated By: GC Checked By: JAB			
General			Materials				Labor				
Number	Source	Item	Type	Quantity	32	Total Cost	Unit Rate	Workers	Hours Each	Labor Cost	Total Cost
1	3	New equipment for indoor VRF units	ea	40	$500	$20,000	$175	2	4	$56,000	$76,000
2	3	New equipment for outdoor heat pump condensing unit	ea	5	$10,000	$50,000	$175	2	8	$14,000	$64,000
3	3	New equipment for energy recovery ventilators	ea	2	$3,000	$6,000	$175	2	8	$5,600	$11,600
4	3	New LEV coil for (2) existing AHUs	ea	2	$1,500	$3,000	$175	2	16	$11,200	$14,200
5	3	Allowance for ductwork, insulation	lf	800	$75	$60,000	$150	1	0.125	$15,000	$75,000
6	3	Allowance for fittings, supply diffusers, return grilles, dampers	%	0		$0	$150	included		$0	$18,750
7	3	Allowance for ERV roof penetrations, roof curb, structural	ea	2	$5,000	$10,000	$150	included		$0	$10,000
8	3	New concrete pad outside	ea	5	$1,000	$5,000	$150	2	4	$6,000	$11,000
9	3	Allowance for refrigeration piping, condensate piping, branch control boxes, insulation	ea	5	$10,000	$50,000	$175	2	16	$28,000	$78,000
10	3	New equipment for electric baseboard heating	ea	10	$500	$5,000	$150	1	4	$6,000	$11,000
11	3	Allowance for electrical	ea	1	$30,000	$30,000	$175	2	40	$14,000	$44,000
12	3	Allowance for shipping & rigging	ea	7	$1,000	$7,000	$150	2	4	$8,400	$15,400
13	3	Demolition	ea	1		$0	$150			$0	$0
14	3	Startup	ea	4		$0	$175	1	8	$5,600	$5,600
15	3	Contractor Commissioning, Training	ea	1		$0	$175	2	40	$14,000	$14,000
16	3	Programming	ea	1		$0	$200	1	24	$4,800	$4,800
17	3	Submittals, As-Built Documentation, Project Management	ea	1		$0	$200	1	80	$16,000	$16,000

Sources	
1	Means
2	Vendor Quote
3	Other
4	Vendor Allowance

Subtotal		$469,350
Contingency	10%	$47,000
Engineering	10%	$51,700
Construction Administration	5%	$25,900
Commissioning	10%	$51,700
Construction Observation	0%	$0
Contract General Conditions	10%	$51,700
Contractor O&P	10%	$24,600
Project Closeout & Expenses	2%	$10,400
Total		$732,350

Notes

B2Q's construction cost estimates are opinions of probable cost and are based upon traditional sources such as the Means Cost Estimating guide, previous experience, or budget quotes from vendors (pre-design). Due to the volatile nature of labor and material pricing and unforeseeable factors affecting the construction industry, B2Q does not expressly or implicitly warrant or represent that B2Q cost estimates will be the actual cost of equipment and/or installation.

EXISTING HOT WATER SYSTEM (OPTION B)

ELECTRIFICATION OPTION SUMMARY

The table below compares the estimated base and proposed energy use and cost for the central air-to-water heat pump electrification option.

Table 12: Hot water system electrification option B summary.

Estimated Annual Electric Savings	Estimated Annual Gas Savings	Estimated Annual Energy Cost Reduction	Opinion of Probable Cost	Estimated Potential Utility Incentive	Net Project Cost	Estimated CO_2 Emissions Reduction
kWh	therms	$	$	$	$	lbs
-263,444	32,478	$3,003	$2,280,900	TBD	$2,280,900	122,928

BASE CASE

The unit ventilators, unit heaters, cabinet unit heaters, and fin tube radiation throughout the school are served by the building's hot water system. The hot water system is served by (2) natural gas-fired boilers, which are summarized in the table below. Hot water is distributed throughout the building by (4) distribution pumps that operate as pairs in lead/lag fashion. The hot water system is controlled by the Metasys BAS for boiler start/stop, boiler staging, pump start/stop, and hot water temperature setpoint control.

Table 13: Spofford Existing HW Boilers.

Equipment	Model Number	Input Capacity	Estimated Average Efficiency
-	-	MBH	%
Boiler 1	Weil-McLain HR-40-11	2,216	74%
Boiler 2	HB Smith Series 350 Mills	3,668	73%

PROPOSED CASE

The second electrification option considered in this study for the hot water system is to install a new central air-to-water heat pump to provide hot water to the building. For the purposes of this study, we assumed the heat pump would operate seasonally and vary its output to match the heating demand in the school. If this option were pursued, the Town would have the option to also run the heat pump in cooling mode to provide new air conditioning to the classrooms and support spaces; however, it is likely that the existing hot water loop distribution is not sized sufficiently to support full air conditioning and piping insulation repair/addition may be required to prevent condensation and associated water damage.

As part of this option, we included a new set of hot water pumps sized to meet the flow requirements of the heat pump. The new hot water pumps would be equipped with variable frequency drives (VFDs). The existing HW boilers could be retired in place, or used to provide backup heat, if needed.

For the purposes of this study, B2Q estimated a heat pump capacity of 2,400 MBH based on the size of the existing system and the connected hot water end uses, though detailed engineering is required to size the system properly.

A significant challenge of a hydronic heat pump retrofit is that the existing piping and hot water coils were selected based on 180°F entering hot water temperature, whereas heat pumps are typically able to provide 120 – 160°F hot water. Further evaluation is required to determine if the size of the existing piping and coils would be sufficient to meet the heating demands of the building with the reduced hot water temperature from the heat pump. For the purposes of the opinion of probable construction cost in this study, we estimated the existing piping and coils could be reused because our estimated required heat pump capacity was significantly less than the current boiler capacity, suggesting that the existing hot water system may already be over-sized.

Opinion of Probable Cost

The opinion of probable cost for Option B is summarized in the table below. The cost estimate assumes that the existing piping and hot water coils would be reused and that the existing boilers would be left in place.

Table 14: Opinion of probable construction cost.

Opinion of Probable Construction Cost

HW System Electrification

B2Q Associates, Inc. 100 Burtt Rd. Ste. 212 Andover, MA 01810 (978) 208 - 0609	Customer: National Grid Address: Spofford Pond School 31 Spofford Rd Boxford, MA	Date: 7/18/2022 Estimated By: GC Checked By: JAB

General			Materials				Labor				
Number	Source	Item	Type	Quantity	Unit Cost	Total Cost	Unit Rate	Workers	Hours Each	Labor Cost	Total Cost
1	3	New Air-to-Water Heat Pump	ea	1	$1,200,000	$1,200,000	$175	2	40	$14,000	$1,214,000
2	3	Allowance for Demolition	ea	1		$0	$150			$0	$0
3	3	Allowance for Shipping & Rigging	ea	1	$15,000	$15,000	$150	4	8	$4,800	$19,800
4	3	Allowance for Electrical - Breakers to new heat pump, disconnects, wiring, conduit	ea	1	$100,000	$100,000	$175	2	80	$28,000	$128,000
5	3	Allowance for New Piping	lf	200	$100	$20,000	$175	included		$0	$20,000
6	3	Allowance for new HW Pumps	ea	2	$2,500	$5,000	$175	2	8	$5,600	$10,600
7	3	Allowance for new HW Pump VFDs	ea	2	$2,350	$4,700	$175	2	8	$5,600	$10,300
8		Allowance for New Valves, Insulation, Fittings	ea	1	$10,000	$10,000	$175	included		$0	$10,000
9	3	Controls	ea	1	$5,000	$5,000	$200	2	40	$16,000	$21,000
10	3	TAB	ea	1		$0	$175	1	32	$5,600	$5,600
11	3	Concrete Pads	ea	1	$20,000	$20,000	$150	2	40	$12,000	$32,000
12	3	Existing Conditions Survey	ea	1		$0	$175	2	12	$4,200	$4,200
13	3	Startup	ea	3		$0	$175	1	8	$4,200	$4,200
14	3	Submittals, As-Built Documentation, Project Management	ea	1		$0	$200	1	160	$32,000	$32,000
15	3	Programming & Graphics	ea	1		$0	$200	1	40	$8,000	$8,000
16	3	Contractor Commissioning, Training	ea	1		$0	$175	2	40	$14,000	$14,000

Sources	
1	Means
2	Vendor Quote
3	Other
4	Vendor Allowance

Subtotal		$1,533,700
Contingency	10%	$153,400
Engineering	5%	$84,400
Construction Administration	2%	$33,800
Commissioning	8%	$135,000
Construction Observation	0%	$0
Contract General Conditions	10%	$168,800
Contractor O&P	10%	$138,000
Project Closeout & Expenses	2%	$33,800
Total		$2,280,900

Notes

B2Q's construction cost estimates are opinions of probable cost and are based upon traditional sources such as the Means Cost Estimating guide, previous experience, or budget quotes from vendors (pre-design). Due to the volatile nature of labor and material pricing and unforeseeable factors affecting the construction industry, B2Q does not expressly or implicitly warrant or represent that B2Q cost estimates will be the actual cost of equipment and/or installation.

OTHER OPTIONS CONSIDERED FOR THE EXISTING HW SYSTEM

Another potential electrification option that was considered is a geothermal heat pump system. Geothermal systems are more efficient than the proposed air-to-water heat pump because the ground source can maintain warmer temperatures in the winter (e.g., 45 °F ground vs 0 °F air) and cooler temperatures in the summer (e.g., 60 °F ground vs 90 °F air), making the heat pump itself more efficient. The downside of a geothermal system is its significant upfront cost, likely more than $1M above the air-to-water or VRF options, with limited offsetting cost reductions for other aspects of the project.

Electrical Infrastructure

The existing main switchboard in the building is rated for 1,200 A at 208 V and electrical codes indicate that new load should not cause the peak demand to exceed 80% of the rated amperage capacity (960 A). The building's peak monthly demand over the past several years was approximately 110 kW, which equates to approximately 400 A. The refrigeration circuit retrofit for the existing RTUs could add anywhere from 100 to several hundred Amps to the peak demand and the air-to-water heat pump could add at least 1,000 A. Therefore, the building's electric service from National Grid, as well the existing electrical switchboard, transformer, main distribution panel(s), and other infrastructure would need to be upsized or augmented to accommodate the new electric loads. The scope and cost of electrical upgrades are contingent on numerous factors inside and outside of the building that cannot be estimated at this time without detailed engineering and input from National Grid. The opinions of probable cost presented above are limited to the electrical distribution panels and branch circuits and do not include any cost allocations for electrical infrastructure. The electrical infrastructure cost could add on the order of several hundred thousand to millions of dollars depending on the final scope and design.

Other Potential ECMs

During our site walkthrough and conversations with facilities staff, we noted several potential energy conservations measures (ECMs) which could be considered during a future project. Some of these opportunities should be vetted in more detail via a follow up study, while others could proceed to implementation as soon as resources are made available.

1. **Upgrade remaining pneumatic to direct digital controls (DDC).** As noted above, only certain sections of the building are controlled by the JCI Metasys system. This measure would include retrofitting all remaining equipment, primarily unit ventilators, to be digitally controlled, while also implementing controls optimization and integration measures for equipment already on the BAS. These actions would enable advanced control features, such as the following, which could save significant energy.
    a. Equipment scheduling
    b. Optimal start/stop
    c. Demand controlled ventilation
    d. Improved economizer controls
    e. Discharge air temperature reset
    f. Hot water temperature reset
2. **Install VFDs on supply and exhaust fans.** Most existing fans in the facility have constant speed motors. Any with motors over 3 hp could be considered for a VFD retrofit. Smaller motors could be considered for electronically commutated (EC) motor retrofits. Note that controls modifications would also be required to implement a proper sequence of

operation to reduce fan speed, while also maintaining necessary conditions for the existing DX, gas-fired, or future heat pump equipment.

3. **Install VFDs on hot water pumps.** Similarly, the existing hot water pumps in the facility do not have VFDs and could be considered for retrofits. Note that retrofits of some or all hot water control valves from 3-way to 2-way valves may be required to maximize the effectiveness of this ECM.