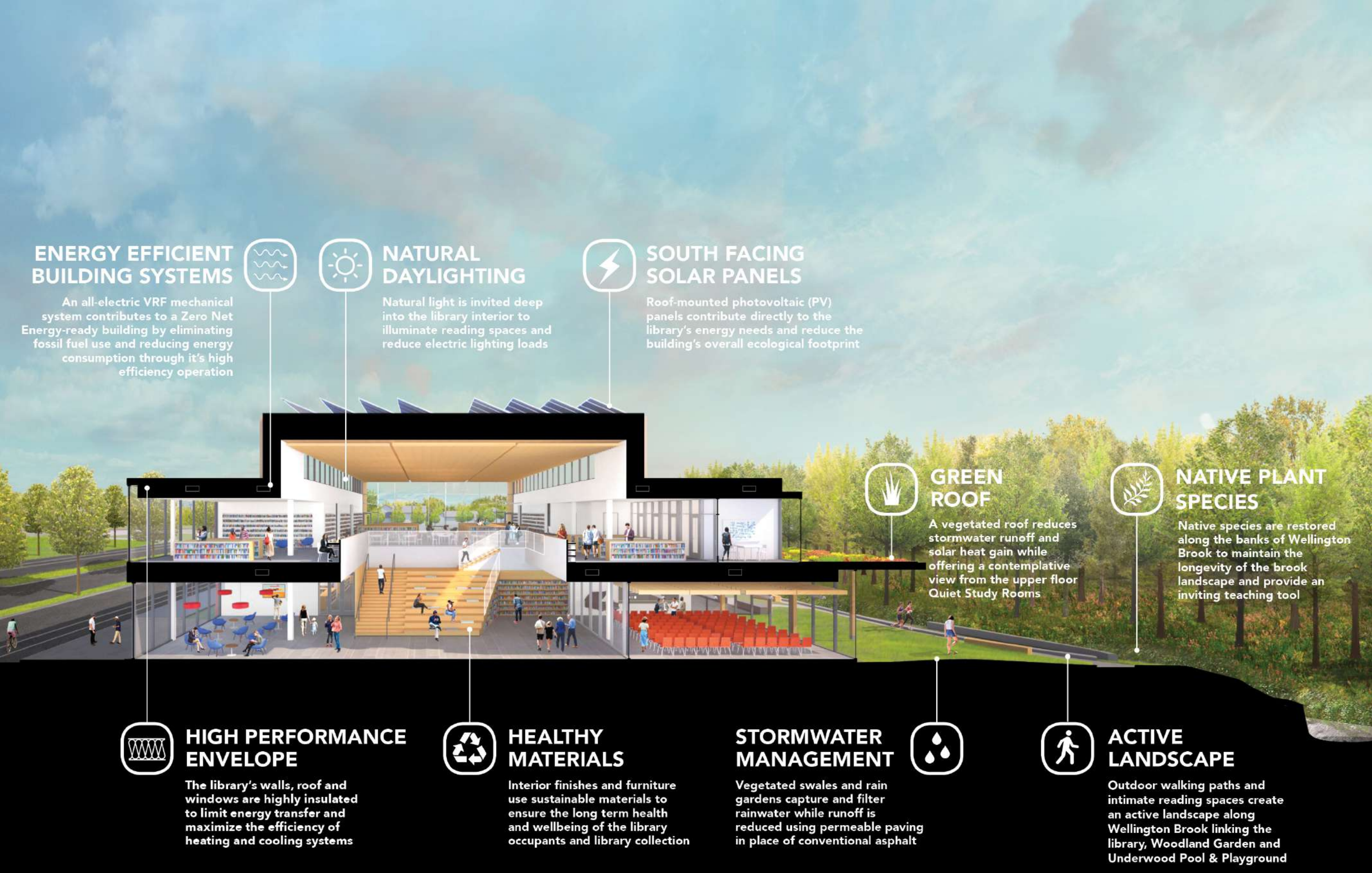

Building Section Sustainability Features

The Green Engineer
Sustainable Design Consulting

Conceptual Design Belmont Public Library
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CONCEPT PHASE - ZERO NET ENERGY ANALYSIS

BELMONT PUBLIC LIBRARY

JUNE 17, 2019

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Zero Net Energy Analysis


Project Goal Setting: Exercise 2
What is unique about this location and program that could contribute to the sustainable design features of project?
What is unique about the project that could contribute to the sustainable development of the neighborhood / Town / greater Boston?
SITE DESIGN
QUALITY OF SPACE/LIGHT
ENERGY
WATER/BROOK
STORY FOR FUNDRAISING

II. Preliminary Energy Analysis

A. Design Options

Energy Use Intensity (EUI) is a measure of how much energy a building uses. EUI is expressed as energy use per square foot per year. It is calculated by dividing the total energy consumed by the building in one year (often measured in kBtu) by the total gross floor area of the building. A lower EUI signifies better energy performance. EUI of 0 signifies a Net Zero building, often achieved through a combination of load reduction, energy efficient systems and renewable energy systems.

Discussions were held to identify the potential for improvements beyond a standard library building and to create a list of Energy Conservation Measures (ECMs) for the preliminary energy analysis. In addition, it was recognized that the project will potentially be built under the new MA energy code that goes into effect in January 2020. The new MA energy code is more stringent and requires several additional efficiency options to be included in the design. Based on these discussions, six different design options pertaining to envelope, lighting and HVAC improvements were shortlisted for further analysis. Figure 2 below summarizes the shortlisted ECMs.

- Option 1A: New MA energy code building with conventional HVAC - DX VAV and condensing boilers (VAV)
- Option 1B: Super-insulated envelope with conventional HVAC - DX VAV and condensing boilers (VAV)
- Option 2A: New MA energy code building with all electric HVAC - Variable Refrigerant Flow system (VRF)
- Option 2B: Super-insulated envelope with all electric HVAC - Variable Refrigerant Flow system (VRF)
- Option 3A: MA energy code building with all electric HVAC - Ground Source Heat Pump system (GSHP)
- Option 3B: Super-insulated envelope with all electric HVAC - Ground Source Heat Pump system (GSHP)

Figure 2: Summary of ECMs discussed for preliminary energy analysis

		Envelope Options		LPD Options		HVAC Systems		Renewable Energy	
		New MA Code 20% Better Envelope (*Roofs R-39.2 Walls R-22.7 Glazing R-3. 2*)	Super-insulated Envelope (*Roof R-60 Walls R-40 Glazing R-5*)	New MA Code Improved Lighting & Controls (*LPD - 0.62 W/SF*)	40% Better Than MA Code Lighting (*LPD - 0.47 W/SF*)	Conventional System DX VAV Condensing Boilers	All Electric HVAC Sytems	On-site PV on roof	Off-site PV
Convention System DX VAV unit w/ Condensing Boilers	Option 1A	X		X		X		X	
	Option 1B		X		X	X		X	
All Electric VRF Systems	Option 2A	X		X			X	X	X
	Option 2B		X		X		X	X	X
Ground Source Heat Pump	Option 3A	X		X			X	X	X
	Option 3B		X		X		X	X	X

B. Energy Use Analysis

Preliminary energy analysis was performed to estimate annual site energy use, source energy use, greenhouse gas (GHG) emissions, annual energy cost, and site EUI for the six options identified for the project. The results of the energy analysis indicate that:

- **Option 1A** uses fossil fuels, has the highest EUI, and high greenhouse gas emissions.
- **Option 2A** is an all electric design option. It reduces site energy use and greenhouse gas emissions significantly, both important descriptors for ZNE building. This option has an EUI at the upper limit of the target EUI range.
- **Option 2B** option is all electric and has a more stringent envelope and lower lighting power density. It reduces site energy use by 50% and GHG emissions by 41% when compared to option 1A.
- **Options 3B** (all electric GHSP) has the lowest site EUI, site energy use, annual energy cost, and greenhouse gas emissions. This option reduces site energy use by 53% and GHG emissions by 45% when compared to option 1A.
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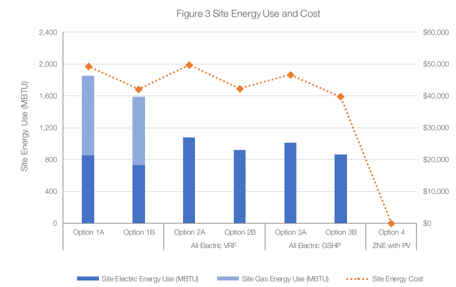

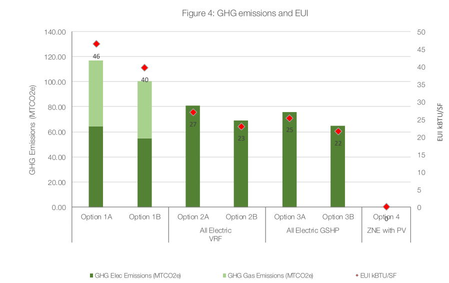

Figure 3 above presents the annual site energy use and annual energy costs for each of the options analyzed. Site energy consumption for Option 2A is 42% lower than Option 1A compliant option. Annual energy costs for Option 1A vs Option 2A are comparable. The annual energy costs are driven by changes to the utility pricing structure.

Figure 4 above presents the GHG emissions and site EUIs for each of the options analyzed. Site energy consumption for Option 2A has 31% lower GHG emissions when compared to Option 1A compliant option. Options 2A, 2B, 3A, and 3B can all enable the design to meet the target EUI but all have capital cost, utility pricing, and other implications.

D. On-site Solar PV Potential

Based on the early discussions with the design team, under current library design the available area for a rooftop PV installation is estimated to be approximately 10,000 SF (Figure 6). This would accommodate a 100 kW(p) PV system on-site. A 100 kW(p) system offsets between 23% to 49% of the project's energy use for the six design options. The remainder of the renewable energy required to achieve ZNE design would need to be procured through off-site PV, community solar, renewable energy credits (REC's) or carbon offsets.

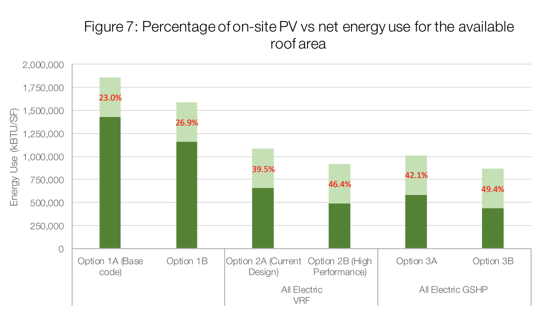

Figure 6: Potential available roof area for PV array

For a 100 kW(p) PV array system on-site, the maximum offset of site energy used is for Option 3B, where this system offsets about 49.4% of total site energy consumption. In comparison, for Option 1A, the on-site PV only offsets 23% of the site energy consumption.

As the design progresses there is an opportunity to alter the design to add potential roof area suitable for on-site solar PV system, thus increasing the overall capacity of on-site renewable energy generation. In addition, design team will also investigate high efficiency solar panels to maximize the solar generation within the available roof area.

E. VRF vs GSHP energy comparison and path to zero net energy

The four all electric options (Options 2A, 2B, 3A, and 3B) require significantly smaller renewable energy generation systems when compared to the fossil fuel options (Option 1A and 1B). Of these, the lowest EUI options are Option 2B and Option 3B. Option 3B requires the least amount of renewable energy generation to get to ZNE as it has the lowest site energy consumption (Figure 8 below). Option 2B and 3B can achieve a site EUI of 23 kBTU/SF and 22 kBTU/SF respectively, which meets the lower threshold for the target EUI range. Additionally, Option 3B saves about $2,568 in site energy cost per year over Option 2B since GSHPs are more efficient than the VRF systems.

Figure 8 : Summary - VRF vs GSHP options

Options	Site EUI (kBTU/SF)	Site Energy Use (kWh)	Site Energy Cost ($)	Energy Cost Savings ($)	Source Energy (MBTU)	GHG Emissions (MTCO2e)
Option 2B - All Electric VRF	23	269,334	$42,285		2,573	68.87
Option 3B - All Electric GSHP	22	252,980	$39,718	$2,568	2,417	64.69

As indicated above, all electric options require renewable energy generation to get to the goal of ZNE building. Figure 9 below compares the amount of installed PV that will be required to get to ZNE for Option 2B and Option 3B. The associated installed PV costs are lower for Option 3B since it requires smaller installed PV capacity. However, this option has additional cost associated with the ground wells that are required to implement the GSHP option. Adding the cost of ground wells to the installed PV cost to achieve ZNE, option 2B turns out to be a lower first cost option when comparing the two.

Figure 9 : Option 2B vs Option 3B - path to net zero

Options	Estimated PV Output to off-set site energy use (kWH)	Estimated installed PV Capacity (kWp)	Approximate Installed PV SF	Approximate Installed PV Cost per Watt ($)	Approximate Total PV Cost ($)	Total Cost to achieve Net Zero	Notes
Option 2B - All Electric VRF	269,334	215	21,547	$3	$646,401	$646,401	No additional well cost
Option 3B - All Electric GSHP	252,980	202	20,238	$3	$607,152	$847,152	Additional GSHP cost, @ $10,000 per well for 18 wells and $60,000 for the system.

Zero Net Energy Analysis