Town of Brookline

Interim Report and Recommendations

of the Net Zero Ninth School Subcommittee

of the Selectmen's Climate Action Committee

September 25, 2017

Contents

Introduction

Over the course of the last several years, the Brookline Selectmen's Climate Action Committee (SCAC) received comments from members of the public and had its own discussions concerning whether the Town's already energy-efficient school building projects—particularly the Runkle School and Devotion School expansions—could be made even better by focusing specifically on the need to address climate change through state-of-the-art design.

The decision to construct a ninth elementary school and expand the high school were recognized as prime opportunities to explore this issue and, in response, the SCAC created the Net Zero Ninth School Subcommittee (NZNS Subcommittee) in late summer 2016, and asked it to research the objective of a Net Zero Energy building.

The subcommittee has met regularly—about every other week beginning in September 2016. During that time, the subcommittee has worked with representatives from the School, Building, and Planning departments, as well as with the state Department of Energy Resources, and other municipalities and individuals—including site visits—to research Net Zero Energy concepts and the practical opportunities and obstacles to making them a reality in Brookline.

The NZNS Subcommittee is issuing this interim report to share what it has learned during the past year and to make recommendations on how to proceed. While we believe it is important to share what we have learned so far, the subcommittee plans to continue working and to issue a full report detailing our findings in 2018. It is the subcommittee's hope that its ongoing practical research will inform best practices for the Town's building projects, as well for its evolving energy and sustainability policies.

Executive Summary

Goals – The NZNS Subcommittee identified several goals as it met over the year:

1. **To gather information on Net Zero Energy (NZE).** What is Net Zero? How is it measured? Is it the best measure of energy efficiency? Is it the best way to reduce carbon emissions?
2. **To learn from the experiences of other communities.** What were the important lessons shared by other communities that implemented NZE? How were the economics of the NZE projects evaluated?
3. **To share information about NZE with all stakeholders.** This includes the Brookline Building Department staff, appointed and elected Brookline officials, and the public.
4. **To create an environment that ensures NZE is integrated into the design of Brookline public schools.**

Topics – This interim report includes:

- A review of various definitions of NZE and related concepts.
- A review of previous efforts in Brookline, that is, energy-efficient design at the Runkle and Devotion Schools, and the recent passage by Town Meeting of a resolution in support of NZE schools.
- A review of NZE efforts in other communities, specifically the MLK and King Open Schools in Cambridge, the new school in Lexington, and the Pell School in Newport, RI.
- A summary of different design methodologies or standards related to NZE, that is, LEED, Architecture 2030, Passive House, and the New Building Institute.
- Consideration of the advantages and disadvantages of different methodologies for doing cost-benefit analysis with regard to NZE.

Recommendations

The subcommittee identified several issues for further study based on these goals, as well as uncovering additional issues as it carried out its research. These issues are described briefly below, along with our recommendations for next steps.

1. **Issue:** The concept of Net Zero Energy buildings, while a worthy goal, does not necessarily minimize or eliminate greenhouse-gas emissions in their operations, that is, result in buildings that use no fossil fuel.
   Recommendation: That the subcommittee continue to evaluate other standards, in particular the possibility of eliminating the use of on-site fossil fuels. A Fossil Fuel Free approach to building design is likely to best address the Town's goals of energy efficiency and reduction of greenhouse-gas emissions. (See the sections on *Standards for Minimizing Energy Consumption and Greenhouse-Gas Emissions* for details.)

2. **Issue:** Our study of other community efforts to achieve energy efficiency and zero greenhouse gas emissions has found that to be successful the design process must be based on a documented policy of Net Zero Energy building design, development, construction, and building operation processes. Brookline does not currently have such a policy. It is difficult for staff to allocate funds on or fully adhere to Net Zero Energy principles without the authorization that such a policy would provide.
   Recommendation: That the subcommittee work with appropriate stakeholders to recommend adjustments to the design, project management, and cost-benefit analysis processes to take advantage of all opportunities to achieve Net Zero Energy or Fossil Fuel Free buildings.

3. **Issue:** Our study of other community efforts to achieve energy efficiency and zero greenhouse gas emissions also found that success is enhanced when there is an individual dedicated to integrating energy efficiency and the goal of zero greenhouse gas emissions. Despite widespread community, political, and staff support in Brookline for Net Zero Energy, currently no specific individual is designated in the decision-making process to articulate these concerns.
   Recommendation: That Net Zero Energy principles be incorporated in the Town's construction process for schools in a formal manner, either by creating a staff function with such responsibility or by some other mechanism such as including a citizen representative on each building committee with such responsibility.

4. **Issue:** The Town uses a simple payback-period method for cost-benefit analysis. However, simple payback period does not account for long-term costs, which in the case of energy-efficiency features will typically be lower than a conventional alternative over the life of a building. Because it provides a more accurate projection of actual costs, businesses, project developers, and investors typically prefer the net present value method.
   Recommendation: That the Town's methodology for cost-benefit analysis be strengthened to include the net present value method. (See the section on *"Financing Energy Efficiency and Cost-Benefit Analysis"* for details.)

Net Zero and Related Concepts

Brookline's Climate Action Plan, adopted in 2012 and updated in 2015, establishes a target of reducing climate-changing greenhouse gas (GHG) emissions by 25% below 1990 levels by 2020. Buildings annually consume nearly 40% of fossil-fuel-produced energy in the United States and, according to the Massachusetts Department of Energy and Environment Affairs, 54% of energy used in Massachusetts. Although energy efficiency is a fundamental strategy in reducing our carbon footprint, we cannot meet our GHG emissions reductions target without decreasing our reliance on carbon-producing fossil fuels.

The subcommittee believes that Brookline should strive toward the goal of net zero energy buildings as part of a larger effort to reduce Brookline's greenhouse gas emissions. It reviewed a number of complex technical definitions of NZE that capture different nuances of energy consumption, the greenhouse-gas emissions, or the cost of energy consumed. [1]

A simple working definition of Net Zero Energy is: a building that produces as much energy as it uses over the course of a year.[2]

Greenhouse Gas Emissions Basis

The sub-committee has learned that accounting for energy usage on a greenhouse gas emissions basis is the preferred method if a community's goal is to measure and reduce greenhouse gas emissions to address climate change. This is consistent with an approach used by the US Department of Energy's National Renewable Energy Laboratory: "*A net zero emissions building produces (or purchases) enough emissions-free renewable energy to offset emissions from all energy used in the building annually*."

Reporting Energy Usage - Energy Use Intensity (EUI)

As the subcommittee has learned, quantifying building energy performance depends on how one reports a building's energy usage. Energy usage is typically reported using the Energy Use Intensity (EUI). The lower the EUI, the more energy efficient the building.

EUI is reported as energy in BTU used per square foot per year. It is calculated by dividing the total energy consumed by the building in one year by the total gross floor area of the building. The total energy annual usage is the sum of the annual consumption of electricity, natural gas, and heating oil, normalized by converting these to British Thermal Units (BTU) from kilowatt-hours, therms, and gallons, respectively.[3]

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1. For instance, one common definition of a Net Zero Energy building is, "An energy-efficient building where, on a source energy basis, the actual annual delivered energy is less than or equal to the on-site renewable exported energy." "A Common Definition for Zero Energy Buildings" (prepared for the U.S. Department of Energy by the National Institute of Building Sciences, September 2015) p. 4; https://energy.gov/sites/prod/files/2015/09/f26/bto_common_definition_zero_energy_buildings_093015.pdf. Also see "Zero Energy Buidlings: A Critical Look at the Definition," by P. Torcellini, S. Pless, and M. Deru (National Renewable Energy Laboratory) and D. Crawley (U.S. Department of Energy) (Conference Paper NREL/CP-550-39833 June 2006); http://www.nrel.gov/docs/fy06osti/39833.pdf.

2. "Net Zero Energy Buildings," by Steven Winter Associates, Inc. (publ. on Whole Building Design Guide website, a program of the National Institute of Building Sciences, updated 8/2/16), para. 2; https://www.wbdg.org/resources/net-zero-energy-buildings.

3. Warrant Article 21, approved at the Spring 2017 Town Meeting, sets a goal of at least an EUI of 30, with the goal of achieving an EUI of 25.

Achieving Net Zero

A useful explanation of the difficulties of achieving Net Zero Energy has been provided with regard to a NZE school in Cambridge, Massachusetts:

> *"[…it is] a very ambitious goal. Most projects have constraints related to available space for renewable energy systems or limited funds to purchase these systems. Therefore, achieving net zero energy operation requires that first a building be designed, constructed and operated to use as little energy as possible so that it can operate within the renewable energy resources available. Achieving this goal requires the full engagement and active participation of the owner, design team, construction team and the building occupants and users*."[4]

Previous Efforts in Brookline

Runkle School and Devotion School

Brookline completed a major renovation and expansion of the Runkle School in 2012, and is nearing completion of an even more ambitious renovation and expansion of the Devotion School. Both are highly energy efficient. These excellent results, however, did not come from specific, articulated goals or standards used in approaching energy-efficiency design. They came instead from the overall commitment from Town staff and consultants to good design.

Both projects received reimbursement from the Massachusetts School Building Authority (MSBA), which provides incentives for compliance with Collaborative for High Performance Schools (CHPS) or Leadership in Energy and Environmental Design (LEED) standards. But those standards do not represent particularly ambitious goals. For instance, the LEED goal for 2% additional reimbursement is at the LEED Silver level,[5] and the Devotion School is projected to greatly exceed that—falling only one point short of the LEED Gold level. Similarly, although the Town's own Building Commission bylaw requires the development of sustainability goals, it sets no specific standards.[6]

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4. King Open and Cambridge Street Upper Schools and Community Complex (KOCSUS) Feasibility Study, Vol. 3: Appendices (Feb. 15, 2016), p. 655, (section entitled "Net Zero Feasibility Report" by In Posse, IP Project No. G150002-000 (rev'd Feb. 5, 2016)); https://www.cambridgema.gov/~/media/Files/publicworksdepartment/Engineering/cityprojects/kingopenconstruction/Volume_3.pdf.

5. See MSBA Certificate of Sustainable School Achievement (for Projects pursuing MA CHPS or LEED designation). *http://www.massschoolbuildings.org/guidelines.*

6. The bylaw states, "The Using Agency shall formulate a program in writing … [including] environmental and sustainability goals and objectives…. Environmental and sustainability goals and objectives include design and construction practices that explicitly consider Green technologies, site selection, waste minimization, energy efficiency, water conservation, indoor environmental quality, and other environmental and health factors that may provide financial, environmental, and occupant health and productivity benefits. … The work of the consultant [architect] shall consider the investigation, cost-benefit analysis, and recommendation of appropriate options that address the environmental and sustainability goals and objectives…." Brookline Bylaws (Building Commission; Procedure for the Construction and Alteration of Town Buildings and Structures), § 3.7.2(a), (b).

Throughout the process of selecting architects and reviewing designs, however, Town staff have emphasized energy efficiency.[7] This was the case with the Runkle and Devotion projects, and has continued with the 9th Elementary School and BHS Expansion projects. In addition, in preparing its educational program for the ninth elementary school, the School Committee took a significant step forward in articulating its own general, if not technical, objectives with regard to environmental sustainability.[8]

Warrant Article 21

In early 2017, three Town Meeting members began to explore whether the Town's commitment to energy efficiency and renewable energy could be strengthened by placing a warrant article before Town Meeting.[9] The warrant article took the form of a non-binding resolution for two reasons. First, the petitioners recognized that NZE principles are not easily reduced to actual design standards. Second, a resolution provided more flexibility, particularly in addressing possible cost increase that might result from a fully NZE building. Third, even though not binding, a strong resolution concerning NZE schools would articulate and confirm NZE as a community value which was likely to be respected and observed by both Town staff and decision makers in the design process.

The final language of Warrant Article 21, which addressed both the new ninth elementary school and high school expansion, included modifications requested by the Town Building Department, and set goals and minimum standards calculated so that the new schools

7. Since the passage of Warrant Article 21 (see below) by November 2017 Town Meeting, a specific reference to NZE has been incorporated into the Request for Qualifications for the feasibility study of the BHS Expansion.

8. The educational program states, "Building a new school in the early 21st century when our community and society are more conscious than ever of the delicate balance between environmental sustainability and ongoing development provides an opportunity to have the physical plant itself play a significant role in the culture, educational approach and daily lives of students and teachers. Whether it's through monitoring waste water, understanding the science behind passive and active solar power, or studying conservation measures built into the new building, the physical plant can be used to help students learn about science, sustainability, and taking care of the environment. For example, signs and working exhibitions created by students could identify design elements that demonstrate architectural, structural, mechanical, and green building strategies. Student tour guides could be trained to introduce visitors to the building's features. Back-of the-house spaces could be used as instructional spaces for students and staff, and could be used by town building and maintenance staff for hands-on training. Brookline's new elementary school could stand as a physical demonstration of environmental stewardship and innovation, providing a local case study for sustainable school construction." 9th Elementary School Educational Program (11/29/16 draft), p. 13.
http://www.brookline.k12.ma.us/cms/lib8/MA01907509/Centricity/Domain/722/Draft%209th%20School%20Ed%20Plan%20-%2011.29.2016.pdf

9. The three members were Werner Lohe, Kathleen Scanlon, and Alan Christ.

would be a significant advance toward NZE buildings. [10] The resolution a.) set a goal of certification at the LEED Platinum level, with a minimum of LEED Silver certification, b.) prioritized the achieving of LEED performance points in the Optimize Energy Performance category with the goal of achieving 16 of the possible 16 points and a minimum of 13 points, and c.) set a goal of achieving overall Energy Use Intensity (EUI) of 25 kBTU/sq.ft./yr. and a minimum EUI of 30 kBTU/sq.ft./yr.

This resolution received very broad support at spring 2017 Town Meeting. It was supported unanimously by the Board of Selectmen and the School Committee, by a vote of 24-1 by the Advisory Committee, and unanimously (with abstentions) by Town Meeting itself.

Other Communities in the Northeast

Cambridge, MA

Members of the NZNS Subcommittee met with the architect responsible for Cambridge's Martin Luther King School and toured that facility, and did additional research on the King Open and Cambridge Street Open School.

In 2013, the City of Cambridge established a Net Zero Task Force to "foster a deep conversation among stakeholders to advance the goal of setting Cambridge on a trajectory to becoming a "net zero community", with a focus on carbon emissions from building operations." The findings and recommendations of the Net Zero Task Force were published in 2015 in the "*The Getting to Net Zero Framework*". The report began by defining net zero:

- *The Task Force defines net zero with respect to* the city as a whole *as: A community of buildings for which, on an annual basis, all greenhouse gas emissions produced through building operations are offset by carbon-free energy production.*
- *The Task Force defines net zero with respect to* individual buildings *as: An annual balance of zero greenhouse gas emissions from building operations achieved on a building by building basis using energy efficiency, renewable energy, and if necessary carbon offsets or, potentially, credits as a temporary measure.*
- *Net zero for new construction does not include embodied emissions generated from the manufacture of building materials, building construction activities, occupant transportation or waste.*

Target dates to achieve net zero were established for different building types:

Type:	Municipal	Residential	Multi-Family	Commercial	Institutional	Labs
Target Year:	2020	2022	2025	2025	2025	2030

10. The critical portions of the resolution entitled "A Resolution Regarding a Net Zero Energy Ninth Elementary School and the Expansion of Brookline High School" are, "*… Resolved that* in order for the Ninth Elementary School to be a significant advance toward a net zero energy school and consistent with the projected energy efficiency results at the new Devotion School, it shall seek a minimum of LEED v4 certification at the Silver rating level, with a goal of achieving the Platinum rating level; and in addition it shall prioritize achieving points in the Optimize Energy Performance category and shall seek to achieve a minimum of 13 of the possible 16 points available in that category, with the goal of achieving 16 of the possible 16 points available in that category; and, finally, it shall seek to achieve at least an EUI of 30 kBTU/sq.ft./yr., with the goal of achieving an EUI of 25 kBTU/sq.ft./yr.,

"And, be it further Resolved that while overall net zero energy is unlikely to be achieved for Brookline High School and even the degree to which the as-of-yet-undefined, expanded portion of the school can approach net zero energy design is currently uncertain, nevertheless, net zero energy principles shall be appropriately applied, to the extent feasible, during all design phases of Brookline High School."

Martin Luther King School, Cambridge

This project began in 2012. The school has been open since 2015. The 187,000-square-foot building features:

- Geothermal wells which extract heat from the ground, helping keep energy costs low
- Daylight harvesting, including glass and other design elements that allow natural light to pass through the building
- Automatic lighting dimmer system, which helps conserve energy use, and a gray water storage system that helps conserve water use"
- Solar PV panels on the roof, which take up about half of the total area of the school site and produce about 45% of the energy used by the school annually.

The EUI is 31.7 kBTU/ft^2/year; Cambridge expects the school will be certified as a LEED platinum building.

King Open and Cambridge Street Upper Schools and Community Complex, Cambridge

For the King Open and Cambridge Street Upper Schools and Community Complex (KOCSUS), a project that is currently underway and expected to open in 2019, the City of Cambridge set more ambitious goals. The following excerpts are from The King Open and Cambridge Street Upper Schools and Community Complex Feasibility Report, which was written by In Posse, an engineering consulting firm that specializes in net zero energy buildings. The goals established show an evolution in Cambridge net zero policy toward a more ambitious zero-emissions or fossil fuel free approach.

> *"[Cambridge] has indicated that the King Open project should meet the [city's] net zero energy goal for Municipal buildings. This goal as defined by the policy means a net zero energy building without the use of fossil fuels on site if possible, or by ending any use of on-site fossil fuels within 10 years*.
>
> "…*The Cambridge Net Zero Energy Action Plan is based on emissions and therefore in order to comply, the project will need to account for energy on the basis of net zero greenhouse gas emissions. If the project proceeds* without the use of on-site fossil fuels *the energy use and renewable energy generation will be all electric in which case net zero energy as metered at the site should equate to net zero energy emissions as well*.
>
> **"…***The preferred renewable energy system for the project is a photovoltaic system (PV). The amount of renewable energy that can be harvested on site depends on the efficiency of the PV panel used and the way the panels are mounted. A typical mounting for PV is to be mounted directly on roof surfaces. While this is a cost effective way to install PV systems, it will not generate enough energy to realize the NZE goal for this project. Mounting the PV panels in contiguous arrays with panels butted together and supported on an independent structure that is above the building roof or on-site will generate the most energy for the available area and will be the required mounting arrangement for the project to achieve the NZE goal.*
>
> *"In order to achieve the NZE goal, the most efficient PV panel available will need to be utilized. Based on existing available efficiencies, an independently supported contiguous array of 118,400 square feet will be required if the administrative spaces are not included in the project and a contiguous array of 130,390 square feet will be required if administrative areas are included in the project.*
>
> "…*Achievement of the net zero energy goal will require a combination of several strategies including the following:*

- *"Reduce annual energy requirements of the project through continued optimization of the building design*
- *"Engagement with occupants and building users to reduce their energy needs without sacrificing on building programs and mission.*
- *"Strategies for purchasing the most efficient photovoltaic (PV) panels available for the project.*
- *"Larger areas of PV supported on structures independent of building roof areas, either above the building or on site.*
- *"Redefinition of the net zero energy goal for the project."*[11]

Lexington, MA

Members of the NZNS Subcommittee spoke with the chair of Sustainable Lexington.

- Lexington, MA is in the preliminary design stages of a new school for 645 students, targeted for completion in 2020. The town has representative town meeting form of government, similar to that of Brookline.
- Sustainable Lexington, a Town committee appointed by the Board of Selectmen to enhance Lexington's long-term sustainability and resilience in response to environmental resource and energy challenges, has had significant involvement in the design process.
- The project architect for the school advocated for natural gas heating. Based on a Harvard School of Public Health study that CO_2 levels have a detrimental effect on learning and on measurements at existing schools, the School Committee recommended against natural gas heating.
- Sustainable Lexington advocated for zero emission heat pump solutions as being critical to reducing emissions from the building. Both air-sourced heat pumps (cost less up front) and ground-sourced heat pumps (up-front costs are higher, but use less energy so lower costs over the long run) would have lower energy costs and maintenance costs than natural gas.
- The Lexington Board of Selectmen made the final decision to install ground-sourced heat pumps based on the following:
    - The recommendation of the School Committee against natural gas heating based upon possible health concerns
    - The recommendation of the town's Dept. of Public Facilities against air sourced heat pumps due to maintenance issues
    - The fact that the ground-sourced heat pumps would have lower energy costs and lower maintenance costs, as well as leaving optimal room for solar panels

11. King Open and Cambridge Street Upper Schools and Community Complex (KOCSUS) Feasibility Study, Vol. 3: Appendices (Feb. 15, 2016), pp. 655, 656, 654, (section entitled "Net Zero Feasibility Report" by In Posse, IP Project No. G150002-000 (rev'd Feb. 5, 2016)); https://www.cambridgema.gov/~/media/Files/publicworksdepartment/Engineering/cityprojects/kingopenconstruction/Volume_3.pdf.

Newport, RI - The Pell School

Members of the NZNS Subcommittee met with the architect and mechanical, electrical, and plumbing engineer for the Claiborne Pell School in Newport, RI.

The Pell School project was of special interest to the subcommittee due to the construction cost parity achieved incorporating net zero features. The school is designed for 880 students, 105,000 sf, PreK-4th grade. There is a dehumidification system in lieu of an air conditioning system, a full scratch kitchen, and the building is used for nine months out of the year. The school opened in 2013 with a $238/ sf budget. Reimbursement was through the state building program and additional rebates were acquired as the project hit tiers of reduction. The architect and engineer presented a number of recommendations for further consideration and implementation for projects pursuing a net zero goal:

- Use an integrated approach to design.
    - Orientation is important. Classrooms can be 50% of the total floor area and ideally should be north/ south facing.
    - Energy will be saved through maximized daylight harvesting and reduced cooling loads.
- Budget for energy modeling early in schematic design phase.
- Invest in capital costs for the life of the building.
    - Light shelves and sloped ceilings will bounce light into the classroom.
    - Tall windows will maximize daylight.
    - Aim for triple glazed windows with argon film and a tight envelope.
- Determine how and where energy will be used, benchmarking against the ASHRAE (American Society of Heating, Refrigerating and Air-Conditioning Engineers) regional baseline. This could lead to creative improvements such as providing centralized teacher workrooms or scheduling an electrical outlet shutdown at night.
- Choose the best HVAC system. Aim for increased ventilation effectiveness for the displacement ventilation rate.
- Keep the building and systems as simple as possible. Maximize use of daylight. Consider geothermal heating and cooling, which may be less expensive than photovoltaics.
- Consider year-round use since it typically makes the economics of geothermal heating and cooling more attractive. Move summer activities from older town buildings to the new school.
- Set an aggressive goal for EUI. DO not accept a base EUI of less than 30, which is achievable without exceptional features.

Standards for Minimizing Energy Consumption and Greenhouse Gas Emissions

Various standards and rating systems used to evaluate building performance with respect to minimizing energy consumption and greenhouse gas emissions. Four prominent examples are described below.

LEED Energy Performance Criteria

LEED (Leadership in Energy and Environmental Design) measures energy performance by comparing the on-site annual energy usage of a proposed building to that of a baseline less energy-efficient building. The American Society of Heating, Refrigerating and Air- Conditioning Engineers (ASHRAE) defines the characteristics of the baseline building in Standard ASHRAE 90.1, which also serves as the basis for building energy codes in most states including Massachusetts.

Computer models are used to estimate the annual energy usage for both the new building design and the baseline building. Performance is based on percentage reduction in energy cost. A new building must have an annual energy cost at least 5% less than the baseline to meet minimum LEED requirements. School buildings are awarded LEED points if they exceed baseline performance by more than 5%. Up to 16 points are awarded, corresponding to outperforming the baseline by 42%.

It is possible to be awarded all 16 points while only achieving an EUI of around 35 kBTU/ft2/Year. This falls short of the objective of Warrant Article 21 (May 2017): "*to achieve at least an EUI of 30 kBTU/ft2/Year, with the goal of achieving an EUI of 25 kBTU/ft2/Year*".

LEED also awards up to an additional 3 points (above the 16) corresponding to 10% of the annual site energy being produced with on-site renewable energy. This is only a small fraction of the way to Net Zero, in which case on-site renewable energy produces 100% of annual consumption.

Architecture 2030

The American Institute of Architects has adopted the Architecture 2030 program, which calls for "carbon-neutral" buildings by 2030. A carbon-neutral building is defined as "*a building that is designed and constructed to require a greatly reduced quantity of energy to operate, meeting the balance of its energy needs from sources that do not produce CO_2 emissions and therefore result in zero net CO_2 emissions.*"[1] This is different from Net Zero Energy buildings that can offset consumption of fossil fuel with production or purchase of renewable energy.

"*Site EUI (building energy consumed at the building site in Btu/ft^2/year) reduction targets for new buildings and renovations are accomplished by implementing low- cost/no-cost efficiency and sustainable design strategies and practices, and by generating on-site renewable power and/or by importing non-CO_2 emitting energy*."

"All new buildings, developments and major renovations shall be designed to meet a fossil fuel, GHG-emitting, energy consumption performance standard [based on EUI] of 70% below the regional (or country) average/median for that building type. The fossil fuel reduction standard for all new buildings and major renovations shall be increased to:

- *80% in 2020*
- *90% in 2025*
- *Carbon-neutral in 2030 (using no fossil fuel GHG emitting energy to operate).*

"These targets may be accomplished by implementing innovative sustainable design strategies, generating on-site renewable power and/or purchasing (20% maximum) renewable energy."

Passive House

The Passive House Institute (US) sets standards for energy efficient homes based on design occupancy, which is defined as the number of bedrooms plus one. For example, a four-bedroom house has a design occupancy of 5 persons.

The current standard is 6,200 kWh/Person/Year which, for a 2000 ft^2 four-bedroom house, translates to an EUI of 52.9 kBTU/ft^2/year. Primary energy consumption can be offset with renewable energy systems such as solar PV. The intent is to reduce this to 4,200 kWh/Person/Year in "a few short years". This corresponds to an EUI of 35.8 kBTU/ft^2/year.

According to the Passive House Institute: "The approach can be successfully applied to any type of building, including skyscrapers." However, the published standards are directed towards small residential buildings.

New Building Institute (NBI)

The NBI maintains an on-line Getting to Zero Database to track net zero and near net zero buildings in North America. The New Buildings Institute (NBI) uses Net Energy Use Intensity (NEUI = EUI - RPI), which is similar to site EUI but gives credit for renewable energy produced at the building (RPI). RPI is the total renewable energy generated by the building annually divided by the total floor area.

Financing Energy Efficiency and Cost-Benefit Analysis

The Town's Building Commission Bylaw addresses environmental and sustainability cost considerations as follows (Brookline Bylaws, § 3.7.2):

> *"The [Building] Commission shall notify the Using Agency of its decision to engage a consultant…. The work of the consultant shall consider the investigation, cost-benefit analysis, and recommendation of appropriate options that address the environmental and sustainability goals and objectives...."*

In practice, the Town uses a simple payback-period method for the cost-benefit analysis prescribed in § 3.7.2. Because it provides a more accurate projection of actual costs, businesses, project developers, and investors typically use the net present value method. There is often a tradeoff between capital cost and operating cost of energy-efficiency features so that over the lifetime of the building, the total costs of an energy-efficient feature may be less than those of a conventional alternative. These costs are more accurately accounted for with a net present value analysis, also sometimes referred to as internal rate of return, levelized energy, or discounted cash flow analysis incorporating projected energy prices and the cost of capital. An additional advantage of this approach is that it allows consideration of hedge value. That is, capital costs are fixed and known in advance, while future energy costs are uncertain. Energy-efficient design that shifts operating costs to capital costs exposes the Town to less financial risk in the future. Such an approach might permit the Town to consider other long-term costs as well, such as the social costs of carbon.[12]

12. See "Technical Support Document: Technical Update of the Social Cost of Carbon for Regulatory Impact Analysis Under Executive Order 12866" published by the Interagency Working Group on Social Cost of Carbon, United States Government, in May 2013, and revised in November 2013 and July 2015.

Problems with Payback Period

Payback Period Ignores the Time Value of Money.

> *"…the payback period does not account for time value of money (TVM). Simply calculating the PB provides a metric which places the same emphasis on payments received in year one and year two. Such an error violates one of the basic fundamental principles of finance. [This] problem can easily be amended by implementing a discounted payback period model."*[13]

Payback Period Ignores Any Benefits That Occur After the Payback Period.

> *"…[This] problem is more serious. Both payback periods and discounted payback periods ignore the cash flows that occur towards the end of a project's life."*

Massachusetts Uses an Updated Cost Analysis Methodology

The US Department of Energy Report "*Cost-Effectiveness of ASHRAE Standard 90.1-2013 for the State of Massachusetts (PNNL-25045)*" compares the cost effectiveness of 90.1-2013 to 90.1-2010. Massachusetts transitioned from 90.1-2010 to 90.1-2013 in January 2017. The report states:

> "*Simple payback is not used as a measure of cost-effectiveness as it does not account for the time value of money, the value of energy cost savings that occur after payback is achieved, or any replacement costs that occur after the initial investment.*"[2]
>
> "*DOE uses standard economic LCC cost-effectiveness analysis methods in comparing Standard 90.1-2013 and Standard 90.1-2010.* "*Under this methodology, two metrics are used:*
>
> *"**LCC Savings**: LCC is the calculation of the present value of costs over a 30-year period including initial equipment and construction costs, energy savings, maintenance and replacement costs, and residual value of components at the end of the 30-year period. A separate LCC is determined for Standard 90.1-2010 and for Standard 90.1-2013. The LCC savings is the Standard 90.1-2010 LCC minus the Standard 90.1-2013 LCC.*
>
> "***Simple Payback**: While not a true cost effectiveness metric, simple payback is also calculated. Simple payback is the number of years required for accumulated annual energy cost savings to exceed the incremental first costs of a new code.*"[14]

The value of using a more sophisticated methodology for cost-benefit analysis was also described during the debate on Warrant Article 21 at Spring 2017 Town Meeting. See Appendix C, below. Based on these considerations, the Sub-Committee recommends that the Town use the Net Present Value method to evaluate options as part of the cost-benefit analysis prescribed in Paragraph 3.7.2 in the Brookline Bylaws.

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13. http://www.investopedia.com/walkthrough/corporate-finance/4/npv-irr/payback-rule.aspx

14. "Cost-Effectiveness of ASHRAE Standard 90.1-2013 for the State of Massachusetts (PNNL-25045)". Also see *Financing Energy Upgrades for K-12 School Districts: A Guide to Tapping into Funding for Energy Efficiency and Renewable Energy improvements*, by Marrian Goggio Borgeson and Mark Zimring (2013, U.S. Department of Energy LBNL-6133E), p. 26, http://www1.energy.gov/wip/solutionscneter/pdfs/financing_energy_upgrades_k-12.pdf

Appendices

A. Creation and Membership of the Subcommittee

During the summer of 2016, Selectman Nancy Heller, in consultation with the leadership of Climate Action Brookline, initiated the formation of a subcommittee of the Selectmen's Climate Action Committee (SCAC) to examine the feasibility of a net zero energy effort for Brookline's ninth elementary school.

The following are the members of the Net Zero Ninth School Subcommittee:

- Werner Lohe (chair) – SCAC and CAB (Climate Action Brookline)
- Michael Berger – SCAC and CAB
- Benjamin Chang – SCAC and School Committee
- Alan Leviton – SCAC and CAB
- Susan Martin – CAB
- Kathleen Scanlon – SCAC and Mothers Out Front

The following Town of Brookline staff members or officials also participated:

- Maria Morelli, Senior Planner
- Ray Masak, Building Department and Project Manager for the Ninth School
- Nancy Heller, Selectman
- Daniel Bennett, Building Commissioner
- Mary Ellen Dunn, Deputy superintendent for Administration and Finance, Brookline Public Schools

B. Meetings

The sub-committee's first meeting took place on Tuesday, September 20th. Regular meetings followed, typically once every two weeks on Thursday mornings at 8:00 am.

A listing of sub-committee meetings appears below, as well as some additional information-gathering sessions conducted outside regular sub-committee meetings.

Agendas and meeting minutes are stored under "Climate Action Committee" on http://www.brooklinema.gov/AgendaCenter

Date	**Type of Meeting**
Friday, September 16, 2016	Maria Morelli and Werner Lohe meeting with Massachusetts Department of Energy Resources (DOER)
Tuesday, September 20	First full sub-committee meeting
September	Maria Morelli meeting with Eversource
Thursday, October 6	Sub-Committee meeting
Tuesday, Nov. 15	Sub-Committee meeting
Thursday, Dec. 8	Sub-Committee meeting Guest: Philip Gray, from Jonathan Levi Architects
Saturday, Dec. 10	Tour of MLK School, Cambridge, a LEED Platinum building
Thursday, January 12, 2017	Sub-Committee meeting
Thursday, January 26	Sub-Committee meeting Guests: Carlos DeSousa and Matthew LaRue talked about their experience designing the Pell School, a net zero building in Rhode Island
Thursday, Feb. 23	Sub-Committee meeting
Thursday, March 9	Sub-Committee meeting
Thursday, March 23	Sub-Committee meeting Site Visit to Baldwin School
Thursday, April 11	Sub-Committee meeting
Thursday, May 11	Sub-Committee meeting
Thursday, June 8	Sub-Committee meeting
Friday, June 16	Sub-Committee meeting
Friday, July 7	Sub-Committee meeting

C. Methodology for Cost-Benefit Analysis

Remarks by Scott Englander
with regard to Warrant Article 21
Brookline Spring Town Meeting, May 25, 2017

Thank you, Mr. Moderator. I'm Scott Englander, Precinct 6. Professionally I've worked in the energy sector my entire career, and I began it by designing energy efficient buildings and innovations in HVAC control, and designing commercial and industrial energy efficiency programs for a major utility.

I advise project developers, investors, utilities, governments, and end users on the economics of large clean energy and renewable generation investments.

The school facility we're about to design and build, as well as any other new town facilities we build will last for many decades. The points I'm going to make have to do with the long-term nature and impact of these investments.

There are many features of a net-zero facility that, if included early enough in the design process, will add nothing or little to the capital cost, and—there is no reason not to include them.

With some energy-efficiency features, however, there is often a tradeoff between capital cost and operating cost. A feature might have a higher capital cost that the more conventional alternative, but result in a lower operating cost due to reduced energy consumption. Over the facility's lifetime, the total of the capital and the operating cost will be less than that of the conventional alternative. You spend more up front, but much less in total over time.

Project developers and investors in my world normally make financial decisions on long-term investments like this by looking at the internal rate of return or the net present value, or the levelized cost of energy — all metrics calculated using a discounted cash flow analysis, incorporating a projection of energy prices and the cost of capital. These metrics allow the comparison of alternative designs that might have very different capital and operating cost profiles.

This is the sort of analysis the town should be using to make decisions about its long-term investments in buildings. For the town to make investment decisions on some other basis—such relying only on a simple pay-back period with no further analysis—or to choose alternatives that have a less favorable NPV could be considered fiscally irresponsible.

Another factor to consider is the hedge value. Capital costs are fixed, whereas the energy prices that will determine future energy costs can be volatile. Therefore, another benefit of energy-efficient designs that shift operating costs to capital costs is that they allow the town to lock in a larger portion of the total cost, exposing the town to less financial risk going forward.

Finally, I want to remind you that while policy and regulations can always change, the greenhouse gas emissions associated with the schools and other facilities we're investing in now will become baked into the town's emissions profile for decades to come, with little recourse. Those ongoing emissions will continue to be part of the legacy we leave future generations.

As climate policy at the national level moves in the wrong direction, tangible steps at the local level are an even greater imperative. Article 21 in its current form, it could be argued, does not go far enough in this regard. But it is a step in the direction of a more sustainable legacy.

I urge you to vote in favor of Article 21. Additionally, as the town moves to evaluate the energy-efficiency design features needed to achieve environmentally-sustainable facilities, I would urge the adoption of a discounted cash flow approach that allows capital costs and operating costs to be compared on a level footing.

D. Warrant Article 21

PETITIONED ARTICLE 21 - SPRING 2017 TOWN MEETING

PETITIONERS: Werner Lohe, Alan Christ, Kathleen Scanlon

RECOMMENDATIONS: The Advisory Committee, by a vote of 24-1-0, recommended Favorable Action on its own resolution, below, which became the main motion.

A unanimous Board of Selectmen recommended Favorable Action on the motion offered by the Advisory Committee.

At its April 27, 2107 the School Committee had voted unanimously to support the Petitioner's resolution, as amended.

VOTE: On May 25, 2017, Town Meeting voted Favorable Action on the following resolution by a vote of 183-0-6.

A RESOLUTION REGARDING A NET ZERO ENERGY NINTH ELEMENTARY SCHOOL AND THE EXPANSION OF BROOKLINE HIGH SCHOOL

Whereas our town, the nation, and the world are increasingly aware of the need to address climate change and of the importance of better protection of the environment in general, and

Whereas an international standard known as LEED (Leadership in Energy and Environmental Design of the United States Green Building Council) allows for a building's environmental and energy performance to be accurately measured and provides a benchmark to assist in designing a net zero energy building, and

Whereas net zero energy LEED Platinum schools create an environment that supports student learning and health through improvements in daylighting, indoor air quality, thermal comfort, acoustics, and classroom design, all of which have an impact on a child's ability to learn and a teacher's ability to teach, while saving energy, resources, and money, and

Whereas net zero energy LEED Platinum schools increase energy efficiency, thereby reducing greenhouse gas emissions, cost less to operate, utilize durable materials, reduce water and energy use, and provide other benefits; while providing an educational experience that transcends the classroom by creating opportunities for curriculum innovation and hands-on, project-based learning in which the building itself becomes an interactive teaching tool, and

Whereas decisions made now about the design of the Ninth Elementary School and the expansion of Brookline High School will determine each school's environmental footprint, particularly greenhouse gas emissions, for decades to come, and

Whereas the technical ability to create energy-efficient, high performing buildings has increased significantly by incorporating systems thinking into design processes, and

Whereas construction of new schools in Massachusetts and around the nation during the past five years has shown the feasibility and desirability of net zero energy schools, that is, schools in which the amount of energy delivered on an annual basis is less than or equal to the amount of renewable energy exported from the site, and

Whereas the most accurate measure of energy efficiency for a building is EUI (Energy Use Intensity), calculated by dividing total energy consumed annually by the gross floor area of the building,

Now therefore be it Resolved that in order for the Ninth Elementary School to be a significant advance toward a net zero energy school and consistent with the projected energy efficiency results at the new Devotion School, it shall seek a minimum of LEED v4 certification at the Silver rating level, with a goal of achieving the Platinum rating level; and in addition it shall prioritize achieving points in the Optimize Energy Performance category and shall seek to achieve a minimum of 13 of the possible 16 points available in that category, with the goal of achieving 16 of the possible 16 points available in that category; and, finally, it shall seek to achieve at least an EUI of 30 kBTU/sq.ft./yr., with the goal of achieving an EUI of 25 kBTU/sq.ft./yr.,

And, be it further Resolved that while overall net zero energy is unlikely to be achieved for Brookline High School and even the degree to which the as-of-yet-undefined, expanded portion of the school can approach net zero energy design is currently uncertain, nevertheless, net zero energy principles shall be appropriately applied, to the extent feasible, during all design phases of Brookline High School.

PETITIONERS' EXPLANATION

Summary

Brookline was one of the first communities in Massachusetts to address climate change, adopting its first Climate Action Plan in 2002. In 2012, it accepted Massachusetts' target for greenhouse gas emissions—the reduction in emissions to 80% below 1990 levels by 2050. See "2012 Climate Action Plan," p. 9 (http://www.brooklinema.gov/DocumentCenter/View/2402). In part in response to this statement of our community's environmental values, recent school construction (i.e., the Runkle School and the Devotion School) has achieved high standards of energy efficiency. Similarly, in the Educational Plan for the Ninth Elementary School at Baldwin, the School Committee has stated its strong commitment to a state-of-the-art school.[15] Nevertheless, overall town-wide progress toward reduced emissions has been slow, not yet approaching the rate needed to reach our goal. See, generally, "Selectmen's Climate Action Committee Report to Town Meeting, Spring 2015," p. 2 (http://www.brooklinema.gov/DocumentCenter/View/8158).

New construction of any sort inevitably leads to a slight increases in emissions. Therefore, communities throughout Massachusetts and New England have begun to address that reality by designing "Net Zero Energy" (NZE) schools, that is, schools that minimize on-site energy use as much as possible, and offset that energy use with renewable energy generated on site, with the goal of equalizing, on an annual basis, energy consumed and renewable energy generated on site. (Examples of such schools are the Martin Luther King School, Cambridge, MA, the King Open School, Cambridge, MA, and the Pell Elementary School,[16] Newport, RI.) Schools such as this not only address climate change, but typically save money by reducing energy costs. See below. Brookline now has an opportunity to design its own NZE school.

About ten years ago, Brookline improved its design process for municipal buildings by including consideration of "environmental and sustainability goals and objectives, includ[ing] design and construction practices that explicitly consider Green technologies." Bylaws, § 7.3.2(a). Because of the Town's sound design practices and the Massachusetts School Building Authority's (MSBA) standards, the Runkle and Devotion projects have good energy performance, though they are not NZE. The Ninth Elementary School at Baldwin, however, is not subject to MSBA requirements, and no specific standards for energy performance have been set. This resolution provides direction to the design architects, under the supervision of the School Committee, the Building Commission, and the Board of Selectmen, by establishing Net Zero Energy as the community's goal for its new school. This goal encourages energy efficient building design, places a major focus on energy, and encourages building users to reduce their energy needs without compromising building programs or mission.

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15. " "Building a new school in the early 21st century when our community and society are more conscious than ever of the delicate balance between environmental sustainability and ongoing development provides an opportunity to have the physical plant itself play a significant role in the culture, educational approach and daily lives of students and teachers. Whether it's through monitoring waste water, understanding the science behind passive and active solar power, or studying conservation measures built into the new building, the physical plant can be used to help students learn about science, sustainability, and taking care of the environment. For example, signs and working exhibitions created by students could identify design elements that demonstrate architectural, structural, mechanical, and green building strategies. Student tour guides could be trained to introduce visitors to the building's features. Back-of the-house spaces could be used as instructional spaces for students and staff, and could be used by town building and maintenance staff for hands-on training. ***Brookline's new elementary school could stand as a physical demonstration of environmental stewardship and innovation, providing a local case study for sustainable school construction***." 9th Elementary School Educational Program (11/29/16 draft), p. 13 (emphasis added). *http://www.brookline.k12.ma.us/cms/lib8/MA01907509/Centricity/Domain/722/Draft%209th%20School%20Ed%20Plan%20-%2011.29.2016.pdf*

16. "The Pell School is… considered a net-zero-ready building. With the addition of a 1,100-kW photovoltaic system in the future, the school will be an actual net-zero building." https://webspm.com/Articles/2014/08/01/Net-Zero-in-School-Design.aspx. Binghamton, NY designed a NZE school, the MacArthur Elementary School, that is not only NZE, but also "fossil-fuel-free." Building Energy, vol. 36, no. 1 (2017), p. 12,

Mechanism for Assuring a NZE Design

The most widely used and accepted rating system in the United States and in the world for green buildings is LEED v4 (Leadership in Energy and Environmental Design, version 4). See http://www.usgbc.org/LEED. Building performance is measured by awarding up to a total of 110 checklist points in eight categories and 57 sub-categories. The single sub-category in which the most points are available—with 16 points—is Energy and Atmosphere: Optimize Energy Performance. Consultation with architects and energy efficiency consultants familiar with schools, NZE principles, and LEED indicates that the realistic goal for achieving NZE for the Ninth Elementary School at Baldwin is 16 Optimize-Energy-Performance points with certification at the Platinum rating level with Energy Use Intensity (EUI) of 25 kBTU/sq.ft.

Cost

NZE schools, in addition to addressing climate change, typically save money by reducing energy costs. See https://www.districtadministration.com/article/net-zero-schools-save-big-energy-costs. Further, the Town and its architect are committed to "integrated design," which is the most effective process for ensuring not only energy efficiency, but also cost savings. See http://www.facilitiesnet.com/facilitiesmanagement/article/When-talk-is-cheaper-Integrated-design-and-better-buildings-Facilities-Management-Facilities-Management-Feature--2138.

Integrated design relies on careful planning and goal setting early in the design process. Project costs and savings are evaluated during the schematic design phase of the project. Thus, the savings (or costs) that may be realized by designing an NZE school cannot be accurately assessed at present since schematic design has not yet been authorized by Town Meeting. But, consistent with best practices, an important provision in the Town's bylaw requires that "the consultant [(the architect) prepare] a cost estimate for the project (including life-cycle costs) [and] consider the investigation, cost-benefit analysis, and recommendation of appropriate options that address the environmental and sustainability goals and objectives…." Bylaw, § 3.7.2(b).

The bylaw does not specify the methodology to be used in the cost-benefit analysis. The Town has frequently used "simple payback period" methodology. But, because of the complexity of the design of a large project such as the Ninth Elementary School at Baldwin and the desire to achieve the goal of NZE, financial analysis of energy-related features such as geothermal HVAC, solar PV panels, triple-glazed windows, and the like should include a Discounted Cash Flow (DCF) analysis, considering Internal Rate of Return (IRR) or Net Present Value (NPV) or both, based upon the life of the features,[17] and should also consider the Social Cost of Carbon.[18]

17. Funding for the Ninth Elementary School at Baldwin will be provided by the issuance of municipal bonds. Energy-related features whose nominal rate of return, as compared to baseline conventional features, are projected to exceed the Town's cost of capital in the municipal bond market should be chosen because they are the more fiscally responsible alternative.

18. See "Technical Support Document: Technical Update of the Social Cost of Carbon for Regulatory Impact Analysis Under Executive Order 12866" published by the Interagency Working Group on Social Cost of Carbon, United States Government, in May 2013, and revised in November 2013 and July 2015.