Chapter 9.0

Greenhouse Gas Analysis

9.0 GREENHOUSE GAS ANALYSIS

9.1 Introduction

This section addresses greenhouse gas (GHG) emissions generated by the BCCB and 819 Beacon Street Projects and options that may reduce those emissions, in accordance with the MEPA Greenhouse Gas Emissions Policy and Protocol (Policy). The Policy requires that certain projects undergoing review by the MEPA Office quantify the project's GHG emissions and identify measures to avoid, minimize, or mitigate such emissions. In addition to quantifying project-related GHG emissions, the GHG Policy also requires proponents to quantify the impact of proposed mitigation in terms of energy savings and GHG emissions.

The analysis provided herein focuses on emissions of carbon dioxide (CO_2). As noted in the GHG Policy, there are other GHGs, but CO_2 is the predominant contributor to global warming. Furthermore, CO_2 is by far the predominant GHG emitted from the types of sources related to the Projects and CO_2 emissions can be calculated for these source types with readily available data.

9.1.1 GHG Policy Summary

The GHG Policy requires the Proponent to calculate and compare the GHG emissions in two cases, each of which incorporates both stationary source and transportation components:

Case 1 is the baseline from which progress in energy use and GHG emissions reductions are measured. The Baseline case would be a building that is designed to meet the current Massachusetts Building Code (Code) 8th edition, which incorporates the building energy provisions of the International Energy Conservation Code (IECC) 2009. However, pursuant to the Green Communities Act, the Proponent anticipates that the IECC 2012 will be incorporated into the Code shortly. In this analysis, as agreed upon with the MEPA Office and DOER on December 11, 2012, IECC 2012 is used to define the Baseline.

Offsite transportation-related emissions would be modeled for the "build condition", without improvements or mitigation measures proposed by the Project, developed using the standard methodology outlined in the EEA/EOT Guidelines for EIR/EIS Traffic Impact Assessment. However, because the TDM program and other aspects of transportation planning and mitigation are in part prescriptive by City requirements, and in part negotiated, it is not practical to determine a build-without-mitigation case. Therefore, the baseline includes all of the Projects' proposed TDM measures. The transportation analysis and details of the mitigation measures are described in Chapters 3 and 4.

Case 2 represents the proposed Project, including measures incorporated into the building shell, its mechanical, electrical and plumbing (MEP) systems, lighting design, and other factors that go above and beyond those required for Code compliance.

Boston has elected to include the state's optional Stretch (Energy) Code into its building requirements and the Proponent anticipates that a new Stretch Code (SCII) will be adopted sometime in 2013 and be effective in 2014. Although SCII has not yet been proposed by the BBRS, it is anticipated that it will require energy use of new large buildings to be 12-15% below the baseline of IECC 2012. Therefore, since both buildings are expected to seek building permits in 2014 or later, this analysis utilizes compliance with the expected SCII to be the minimum criterion for energy, and hence GHG, performance.

Transportation analysis for Case 2 is the same as for Case 1 and includes the effects all of the TDM measures proposed as part of the Projects. That is, no additional traffic mitigation measures are proposed for either building.

In addition to these two cases, the Policy requires that all feasible mitigation measures that could reduce GHG emissions be considered. The Proponent has evaluated numerous stationary source GHG mitigation techniques comprised of design parameters and applied technologies, and construction and operating parameters, which are **generally referred to herein as "technologies" for convenience**. Some have been adopted, some designated for later evaluation for possible incorporation into the Projects as design progresses, and some have been eliminated from further consideration for one or both of the Projects.

9.1.2 Mitigation Technologies

The analysis addresses two independent buildings—essentially two GHG analyses, one for the BCCB and one for the 819 Beacon Street Project.

GHG mitigation techniques are a mix of design techniques, applied technologies and operating methodologies. The Proponent has examined approximately 40 mitigation technologies for application to one or both of the Projects. Each technology has been placed in one of four categories:

- "P" - Proposed as part of the Project (included in Case 2);
- "A" - Under study for possible inclusion, and briefly analyzed herein, but not committed to at this time;
- "S" - To be studied at some time in the future as design progresses;
- "X" - Rejected or not applicable.

A matrix of the technologies and buildings, and which category a technology falls into, is presented in Table 9-1. This matrix is indicative of the extensive and detailed efforts the Proponent is using to consider, early in the design of each building, various methods to maximize energy efficiency and mitigate GHG emissions.

Technologies grouped under Energy Use Reduction and Energy Generation are the heart of GHG mitigation measures. Other Related Technologies include additional measures that may indirectly affect GHG emissions, although their primary purpose is to accomplish other goals. For these measures, the GHG emissions reduction potentials are difficult to quantify with any reasonable accuracy and are numerically expected to be a small part of the overall mitigation. They are, therefore, not quantified in this analysis.

9.1.3 GHG Analysis

GHG emissions can be categorized into two groups: emissions related to activities that are stationary on the site and emissions related to transportation. Activities on the site can be further broken down into direct sources and indirect sources: direct sources include GHG emissions from fuel combustion and indirect sources include GHG emissions associated with electricity and other forms of energy that are used on the site and are imported from off-site power plants via the regional electrical grid or local steam distribution system.

Emissions from stationary sources are discussed in Sections 9.2 (BCCB) and 9.3 (819 Beacon Street), while emissions and mitigation measures related to transportation are discussed in Section 9.4. The two are combined into a summary GHG analysis in Section 9.5, including a summary of GHG emissions mitigation commitments. Supporting technical analyses and information are presented in Appendix H.

Table 9–1 GHG Mitigation Technologies Matrix

KEY: P = Proposed (Case 2) S = to be studied at later design phase
A = Examined as alternative X = Not applicable or not feasible

Mitigation Measure/Technology	New Bldgs		Remarks
Building Use	BCCB	819	
Energy Use Reduction			
Building Orientation	X	X	
High performance building envelope	P	P	
Green roof/podium areas ▲	P	S	
Light or reflective roof	P	P	
Exterior shading devices ▲	S	S	
Under-floor air distrib./displace.	na	S	
Chilled beam	S	P	
Heat or energy recovery	P	P	
Demand-controlled Ventilation	X	S	
Room occupancy sensor, lighting	P	P	
Natural lighting / Daylighting	X	S	
Daylight harvesting	X	X	
High performance lighting. Interior	P	P	
Reduced LPD interior	P	P	
High performance lighting, exterior	S	S	
Energy-Star appliances and electronics	P	P	
Advanced elevators	S	S	
Energy Generation			
High efficiency heating equipt.	P	P	
High efficiency cooling equipment	P	P	
Cogeneration, CHP	P	X	
District heating/cooling connection	S	X	
Fuel cell	X	X	
PV - roof	S	X	
3rd Party PV	X	X	
PV-ready construction	S	X	
Solar hot water generation	X	X	
Ground source heat pumps	X	X	
Wind turbines	X	X	
Purchased Green Energy	S	S	
Other Related (not quantified)			
LEED target	cert.	cert.	cert. = certifiable
Rainwater harvest	P	S	
Low flow fixtures, water conservation	P	P	
Recycling collection areas	P	P	
Enhanced refrigerant management	S	S	
Energy management system	P	P	
Enhanced building commissioning	P	P	
Construction waste recycling	P	P	
Recycled content materials	X	P	
Regional materials	X	P	

9.2 Boston Children's Clinical Building

9.2.1 Overview

Construction of the BCCB is expected to begin in 2014. Design of the BCCB is in the schematic stage. Commissioning will occur as the design progresses.

The Proponent will utilize the nationally recognized Leadership in Energy and Environmental Design program as administered by the US Green Building Council. LEED New Construction will be utilized to quantify the Project's various metrics relating to sustainability and "green" design. In accordance with Article 37 of the City of Boston Zoning Code, the BCCB will be designed to be LEED certifiable (see Section 5.10, Sustainability).

The primary elements of the building shell and mechanical component efficiencies are presented in Appendix H.1 for both the Code building and the proposed BCCB for comparison. Case 2 represents the proposed building, including measures incorporated into the building and MEP systems above and beyond those required for Code compliance. It must be noted, however, that the BCCB is in the earliest stage of conceptual design. Many features/components may change when design efforts are undertaken in future years. This analysis presents the best thinking at this time of how the building will be configured.

9.2.1.1 Energy Use Reduction

High Performance Building Envelope

A high efficiency building shell includes, among other components, greater insulation and glazing design that combines functionality and high insulating properties. Key building design elements that relate to the energy efficiency of the building envelope are compared to minimum Code values in Appendix H.1. As indicated, proposed roof, walls, and glazing, all meet or exceed Code requirements. Glazing has been kept to a minimum consistent with the uses of the building.

Green Roof

Some areas of green roofing will be used for various levels of roofing and the podium portion for aesthetic reasons and to assist with rainstorm drainage control. The contribution to energy use reduction is considered to be minimal and green roofing was not included in the building energy modeling.

Reflective Roofs

Light colored or reflective roofing materials will be utilized, aiding in minimizing summer urban heat island effects. It has little value in reducing building energy use.

Heat Recovery

Heat recovery from the building ventilation exhaust is incorporated into the BCCB design even though outside air makeup rate is expected to be approximately 30%.

Room Occupancy Sensor

Room occupancy sensors adjust the heating/cooling set point when rooms are unoccupied, thereby reducing the energy spent on heating/cooling unoccupied or vacant rooms. Sensors also turn off the artificial lights when a space is unoccupied. Occupancy sensors are proposed for the back-of-house spaces such as conference rooms, bathrooms, offices and storage areas.

High Performance Lighting

High-performance lighting (lower wattage per square foot than the Code minimum requirement) will be utilized. A 10% reduction in average lighting power density is expected to be achieved, reducing the amount of electricity consumed by the lighting system and the corresponding energy used by the HVAC system to remove the heat generated by the lights. Lower lighting power levels will be achieved by use of fluorescent and/or LED lighting fixtures and bulbs and by focused task lighting in office areas

Low Flow Fixtures

Several features of the BCCB will reduce water consumption, in turn reducing wastewater generation. Such reductions reduce indirect GHG emissions by reducing the MWRA's water pumping and wastewater treatment energy requirements. Only credit for low-flow fixtures has been included in the energy modeling, amounting to a 5% reduction in domestic hot water use.

Energy-Star Appliances

Energy Star appliances utilize less energy than other models of the same appliances. However, some of the types of equipment utilized in a clinical building are not part of the Energy-Star rating system. The commercial and special-purpose appliances utilized in the BCCB are high efficiency equipment. Where smaller, residential- or office-type equipment are utilized, such as refrigerators in employee lounges, Energy-Star equipment will be selected. However, no credit has been taken for this energy savings in the building energy modeling reported in Section 9.2.2.

9.2.1.2 Energy Generation

High Efficiency Mechanical Equipment

High efficiency HVAC systems are a combination of energy use reduction and energy generation technologies and include use of high efficiency boilers and chillers, premium electric motors, variable frequency drive motors, and variable flow hot water pumps. Appendix H.1 indicates proposed equipment, and boilers with high thermal efficiencies, better than Code and state-of-the-art for equipment of that size and type. Condensing boilers are not used because the uses require steam more than hot water.

Air handing units in the design are Variable Air Volume (VAV) which are similar to what is required by ASHRAE 90.1 in the base case. However, the design VAVs are designed to include the following attributes to improve energy efficiency:

- Oversized fans, ducts and coils resulting in reduced air velocity and static pressure. The primary energy benefit stems from reduced fan power per cfm.
- Dual enthalpy air economizer maximizes the benefit of using outdoor air to condition the building. Rather than simply using outdoor air up to a fixed temperature (70°F in the base case), the dual enthalpy economizer selects whether to maximize outdoor air or return air based on enthalpy in either airstream. The controls will determine which airstream will consume the least amount of energy to meet the required supply conditions. This becomes important when a building such as the BCCB is also humidifying.
- The AHUs have the ability to both reset the fans static pressure and reset the supply air temperature based on space load conditions. These controls reduce fan power, chiller energy and reheat energy.

Water loops in the design have been developed to be more efficient in the following ways:

- Since the chillers in the design are variable flow, the primary chiller water loop is variable flow resulting in improved part load chilled performance and reduced primary pumping power over the base case.
- Chilled water supply temperature is reduced from 44°F (base case) to 42°F. This puts an additional burden on the very efficient chillers but reduces the demand on the less efficient pumping and fan systems.
- The condenser loop will be sized for 2 gpm/ton in lieu of the base case's 3 gpm/ton. This puts an additional burden on the very efficient chillers but reduces the demand on the less efficient condenser water pumping system.

♦ Hot water and chilled water temperature resets have an improved control strategy which resets the temperatures based on system load and not outdoor air temperature as in the base case. This offers better control and eliminates times when load may not be coincident with outdoor air temperatures.

Combined Heat and Power

CHP can satisfy some of the building's electricity and heat needs while reducing the associated GHG emissions. Standard grid-connected power plants operate at approximately 30 to 55% efficiency. Because a CHP unit will use waste heat from the engine to provide steam and/or hot water for building heating, equipment sterilization, domestic hot water, and other uses, it can generate power and heat at 60% or greater thermal efficiency. The Proponent does not consider the efficiency and reliability of absorption chillers to be adequate for utilization in the hospital environment, and so chilled water production from waste heat has not been examined.

As described in Section 2.2.2 the Proponent is considering various options for both initial development of the BCCB and future expansions to serve other properties within the LMA. This analysis includes the fundamental CHP option that will serve the BCCB only.

With moderate base loads for electricity, steam and hot water, the BCCB will include in its Central Utilities Plant (CUP) both fossil-fuel fired boilers and a CHP unit. The CHP unit will consist of a 1,200 kW natural gas-fired engine-generator and a waste heat boiler. The engine is expected to operate in electric load-following mode to maximize the economic benefits. At times, the thermal output of the CHP is greater than the BCCB can utilize and some dumping of waste heat will occur, particularly in the summers during the first few years of operation. However, as design progresses, additional uses for waste heat will be examined. Furthermore, if Children's proceeds with expansion of service to other buildings in the Children's campus by or beyond 2021, there is expected to be ample use for all of the CHP unit's waste heat.

9.2.1.3 Other Related

Other Related technologies are divided into those that are associated with the operation of the buildings and those that are associated with the construction phases of the buildings.

Rainwater Harvest – Groundwater Recharge, Irrigation

A portion of the rainwater from the BCCB will be collected and stored for various uses, including groundwater recharge and irrigation. Using rainwater for cooling tower make-up water was evaluated, but the amount of available rainwater is not sufficient to significantly reduce the cooling tower water consumption and pumping this water to the roof adds energy use.

Recycling Areas

Recycling collection staging areas will be included in the BCCB design. The initial metric used to meet this requirement will be the LEED rating system, which requires the provision of collection facilities for paper, cardboard, metal, and plastic. Detailed discussions of recycling are provided in Section 5.8.1.

Energy Management System (EMS)

An EMS does not reduce the design energy utilization, but rather insures that actual operation comes as close to design optimum as practical. An EMS allows the building manager to monitor building energy performance, which aids in identifying maintenance needs to maintain optimum performance. An EMS should, therefore, be viewed as an insurance mechanism to aid the building manager in attaining the optimum efficiency inherent in the building design.

The BCCB will be provided with Energy Management Systems which will continuously monitor building mechanical equipment control points (air handlers, fans, cooling towers, chillers, boilers, etc.), including airflows, water flows, energy consumption, etc. This will allow building operators to optimize building energy usage and will notify operators when equipment is not functioning as desired (and thereby wasting energy). The EMS in the BCCB will be capable of remote monitoring as well as monitoring from a central operator's station.

Construction Waste Management

The Proponent will work with its Construction Manager to outline, develop, and implement a comprehensive construction staging and phasing plan. Part of this plan will involve the creation of a comprehensive construction waste management plan. The Proponent is currently anticipating at least a 50% reduction in construction debris diverted to landfill (by weight).

Building Commissioning

Enhanced Building Commissioning, as defined in LEED, begins the commissioning process earlier in the design stage, and also includes a post-occupancy follow-up visit to ensure that building systems have been operating properly in both the heating and cooling season.

9.2.2 Building Energy Modeling

Building energy modeling for the BCCB was conducted by BR+A, a nationally recognized engineering firm, using the eQUEST model, version 3.64. In accordance with the Stretch Code, ASHRAE 90.1 Appendix G protocol was applied in the modeling.

Results of the Baseline and Proposed cases are summarized in Table 9-2, based on site energy. Associated GHG emissions are calculated in accordance with the Policy. The eQUEST model output tables are provided in Appendix H.2.

The CHP unit has been included in the eQUEST modeling of the Proposed case. In the eQUEST output tables, the CHP unit's fuel (heat input) is distributed to the end uses that benefit from both the electricity and thermal output rather than as direct fuel use and thermal and electricity credits. However, to avoid double-counting of the associated GHG emissions, the electrical output of the CHP is credited in Table 9-2.

The energy efficiency technologies employed in the Proposed design, including CHP, will result in a 110% increase in natural gas use (almost exclusively to run the CHP unit) which is offset by a 62% reduction in imported electricity compared to the Baseline, resulting in approximately a 1,558 ton/year, 15% decrease in GHG emissions.

Table 9-3 presents similar information as source energy, using site/source conversion factors provided by DOER. Source energy, unlike site energy, takes into consideration that a Btu of electrical energy used requires about 3 Btus to be expended at an offsite power plant due to power plant efficiency as well as transmission losses. Similarly, a Btu of natural gas requires offsite expenditure of almost 1.1 Btus due to gas processing, transmission losses and gas transmission energy (compression) requirements. These conversion factors are not New England-specific.

Energy Use Index (EUI) is calculated from these source energy data. Source energy is used for this calculation because the more common method of calculation using site energy does not adequately reflect the impact of CHP within the Project. Table 9-3 indicates that the Proposed BCCB will require approximately 26% less energy use than the Baseline building, which is much better performance than is anticipated to be required by the next Stretch Code, SCII (12-15% reduction from IECC 2012 Baseline).

Table 9-2 BCCB Modeling Results – GHG Emissions Reduction

		Site Energy		
		Case 1 Baseline	Case 2 Proposed	1–>2 Difference
DIRECT (NATURAL GAS)		MMBtu/yr	MMBtu/yr	
Space Cooling		0	6,280	
Space Heating		34,900	3,740	
Heat Rejection		0	380	
Hot Water		1,600	1,360	
Vent Fans		0	17,990	
Pumps & Auxiliaries		12,750	13,000	
Ex Usage		0	260	
Misc Equipt.		0	42,620	
Area Lights		0	18,000	
CHP Engine Fuel Use		0	distributed	
CHP Thermal Credit		0	distributed	
	subtotal	49,250	103,630	110%
INDIRECT (ELECTRICITY)		MWh/yr	MWh/yr	
Space Cooling		2,020	1,370	
Cooling Tower (Heat Reject.)		40	80	
Ventilation and Fans		4,610	3,420	
Pumps & Auxiliary		600	1,160	
Extl Usage		50	40	
Area Lighting		3,960	3,570	
Misc. Equipment		8,280	8,280	
CHP Generation Credit			-10,512	
	subtotal	19,560	7,408	-62%
GHG EMISSIONS		tons/yr	tons/yr	
Direct	Gas-burning	2,881	6,062	110%
Indirect	Imported Electricity	7,628	2,889	-62%
	Total	10,510	8,951	**-15%**
			-1,558	**ton/yr**

CO_2 Emission Factors:

Electricity [1]	780	lb/MWh
Natural Gas [2]	117	lb/MMBtu

[1] 2011 New England Electric Generator Air Emissions Report, Table 5.4, 2011 value

[2] EIA Fuel Emissions Factors, Weighted National Average (1029 Btu/scf)

Table 9-3 BCCB Modeling Results – Source Energy and EUI

	Source Energy		
	Case 1 Baseline	Case 2 Proposed	1–>2 Difference
DIRECT (NATURAL GAS)	MMBtu/yr	MMBtu/yr	
Space Cooling	0	6,845	
Space Heating	38,041	4,077	
Heat Rejection	0	414	
Hot Water	1,744	1,482	
Vent Fans	0	19,609	
Pumps & Auxiliaries	13,898	14,170	
Ex Usage	0	283	
Misc Equipt.	0	46,456	
Area Lights	0	19,620	
CHP Engine Fuel Use	0	distributed	
CHP Thermal Credit	0	distributed	
subtotal	53,683	112,957	110%
INDIRECT (ELECTRICITY)	MMBtu/yr	MMBtu/yr	
Space Cooling	20,746	14,070	
Cooling Tower (Heat Reject.)	411	822	
Ventilation and Fans	47,345	35,124	
Pumps & Auxiliary	6,162	11,913	
Extl Usage	514	411	
Area Lighting	40,670	36,664	
Misc. Equipment	85,037	85,037	
CHP Generation Credit	0	-107,960	
subtotal	200,884	76,081	-62%
ENERGY USE INDEX	569,788	gsf modeled	
	kBtu/sf/yr	kBtu/sf/yr	
	446.8	331.8	**-26%**
Source Energy Factors	Provided by DOER		
Electricity	3.01	Btu source/Btu site	
Natural Gas	1.09	Btu source/Btu site	

9.2.3 Technologies Not Currently in the Design

Orientation

The BCCB footprint is constrained by the existing street grid and adjacent buildings. In order to optimize floor plates for maximum construction efficiency, building façades will remain generally parallel to the existing street grid. The design of the exterior envelope will be evaluated on a façade-by-façade basis (each side of the building) for optimal configuration of glazing areas, opaque wall area, shading devices, overhangs, screens, balconies, operable windows, etc. However, such details will not be developed until the detailed design phase of the building.

Under-Floor Air Distribution (UFAD)

UFAD reduces energy consumption by extending the amount of time that the HVAC system can run in economizer cycle (i.e. using outside air to cool a space rather than mechanically cooled air) and by reducing the amount of air and the fan horsepower (and thus electrical energy) required to deliver the air. Implementation of UFAD requires a different architectural structure with raised floors and a different configuration and layout of air handling units compared to spaces served by conventional means. For these reasons, it is an applicable technology almost exclusively for large office and certain types of commercial buildings and is not typically applicable to the BCCB.

Daylighting

The majority of the space served by exterior windows will be patient rooms. Daylighting controls are not appropriate for this use.

Oversized Cooling Tower

Use of an over-sized cooling tower to lower return water temperature, thus increasing heat pump efficiency, may be added during subsequent design phases. However, at this stage the eQUEST model is allowed to size the cooling tower based on system loads, and so this refinement is not included in the modeling.

Advanced Elevators

Machine-roomless elevators allegedly require less energy to operate than conventional tractor-type elevators. However, their size and speed impose restrictions that may not be acceptable to the tower-type hospital environment. State of the art elevators will be examined during detailed design based upon then-current offerings in the market.

District Heating/Cooling

Currently, the Medical Area Total Energy Plant (MATEP) serves the Longwood Medical and Academic Area with steam and chilled water. In the future, the individual hospitals are planning independent, presumably more economical systems as the area continues to grow. As indicated in Section 2.2.2, the Proponent is considering either a limited or a more extensive district system development, but no decisions are expected for some time.

Fuel Cells

Fuel cells use methane (natural gas) in an electro-chemical process operating at low temperature to generate electricity. High-grade or low-grade waste heat recovery, or both, can make these units into a CHP technology.

Fuel cells have been used in limited applications for continuous power generation, but they are very expensive. Although the cost has apparently decreased considerably in recent years, it appears to remain well above $5,000 per kilowatt (kW). Even with tax incentives and the potential availability of Alternative Energy Renewable Energy Credits, the cost of fuel cells is considered to be too high for likely application to the residential building.

Ground-Source Heat Pumps (GSHP)

GSHPs take advantage of the relatively constant temperature and infinite mass of the ground to seasonally either extract or discharge heat in an efficient thermodynamic cycle. GSHP is deemed to be an infeasible technology as there is no room in a dense urban environment for the well field required to significantly compliment a large building.

Photovoltaics (PV)

The traditional PV installation on a building is an array of collectors mounted on a flat or sloped roof, angled to face south and with appropriate slope above horizontal. Given the tower structure of the BCCB, MEP equipment, emergency generators and elevator penthouses and ventilation exhausts will occupy the majority of the tower rooftop area. Additional area will be required for access ways to this equipment, and some of the remaining rooftop area will be at least partially shadowed by the equipment, penthouse, and curtain wall. Any area remaining that might be available for a PV array is expected to be very small. Any PV installation would be expected to only be able to offset a very small fraction of yearly electrical demand.

The actual degree to which rooftop equipment might be located so as to provide unshaded space for PV panels requires considerable design development and cannot be determined at this stage of design. Hence, the capability to utilize rooftop PV must be left to later stages of design. If it is determined that there is sufficient space for a modest PV array but it is not economically feasible at the time, consideration will be given to making the building PV ready so as not to inhibit the future adaptation of the technology if economics change or there is a break-through in the applicability of PV.

Furthermore, third-party PV installations have recently become commercially commonplace. In such an arrangement, a PV company may build, own and operate a PV array and system at a host facility, and sell the electricity produced to the host under a long term power purchase agreement (PPA). The Proponent would consider, amongst its other alternatives, hosting such a third party PV system, providing appropriate terms and commercial arrangements could be negotiated. However, it is expected that the space available, if any, will be insufficient to attract interest from such third parties.

Solar Hot Water (SHW)

For the same reason as PV, SHW is not expected to be a practical option. Furthermore, SHW would compete with CHP for hot water production and, as noted under CHP, there is insufficient load in the BCCB to accommodate additional hot water generation capacity.

Wind Turbines

There is no available land on the Project site for installation of a wind turbine. Due to the site's constraints, the proximity to high-rise buildings and other factors, it is expected that small building-integrated wind turbines will not be effective at this site. The decision was made, therefore, to not pursue building-integrated wind systems.

Green Energy

Massachusetts utilities offer options that allow the customer to purchase all or part of its electricity requirements from renewable energy sources. The Proponent cannot predict energy prices well into the future, but will include future examination of Green Energy as a potential option. Purchase of Green Energy will be the Proponent's decision once the building comes on line and based on then-available source options and rates.

Enhanced Refrigerant Management

Refrigerants, typically various compounds classified as hydrofluorocarbons (HFCs), are greenhouse gases of stronger effect than CO_2. Releases of HFC, however, are due to leaks or equipment failure and are not routine emissions. Nevertheless, use of low-CO_2-equivalent HFCs is beneficial, providing that the functionality of the refrigeration equipment is maintained.

LEED certification requires adopting a refrigeration management system that allows no chloro-fluorocarbon (CFC) use. The BCCB will be able to achieve this LEED refrigerant management criterion through the appropriate selection of refrigerants and efficient refrigeration systems.

Enhanced Refrigerant Management involves selection of refrigerants with the least ozone depletion potential. Inclusion of the most appropriate refrigerants with a reduced contribution to ozone depletion and reduced GHG-equivalent concentrations will be evaluated during detailed design based on the specific mechanical systems selected.

Regional Content Materials

The Proponent will encourage the specification of regionally-sourced materials wherever possible. Concrete aggregate/cement, wood, glass/glazing products, metals, masonry, and drywall will be evaluated for comparing the cost effectiveness of locally-sourced alternatives. At this time, it is believed that achieving 10% regional materials content (as defined in LEED) is beyond the ability of the BCCB.

Recycled Content Materials

The Proponent will encourage the specification of recycled-content materials wherever practical. Specifications will be written into Project documents requiring contractors and subcontractors to evaluate materials not only by cost, but also report recycled-materials content in relevant submittals provided to the owner or construction manager (CM). Concrete aggregate/cement, wood, glass/glazing products, metals, masonry, and drywall will be evaluated for cost effectiveness of recycled-content alternatives. As part of the LEED effort on the Project, the Proponent has a goal to achieve 20% sustainably sourced materials and products based on overall materials costs.

9.3 819 Beacon Street

The 819 Beacon Street Project will include approximately 202,950 sf of office space, 9,480 sf of retail space and approximately 496 structured parking spaces (199,974 sf) in an eight story structure. It will be constructed, owned and operated by the Proponent and will be designed to be LEED Certifiable. Building design is in the early conceptual stage.

9.3.1 Overview

As with the BCCB, the Baseline analysis utilizes the anticipated adoption of IECC 2012 into the 8th edition of the Code.

The Proposed case includes measures incorporated into the building and MEP systems that are above and beyond those required for Code compliance with the goal of meeting or exceeding energy use reduction of 15% over the Baseline, a level expected to be in compliance with the anticipated, but not yet proposed, SC II. The 819 Beacon Street Project includes the energy efficiency measures indicated in Table 9-1 and described further herein.

The primary elements of the 819 Beacon Street building shell and HVAC components are presented, and are compared to Baseline elements, in Appendix H.1. The following describes the various technologies that are incorporated in the building design at this early point in its design. They are organized, similar to Table 9-1, into Energy Use Reduction, Energy Generation and Other Related.

9.3.1.1 Energy Use Reduction

Building Envelope

Key building design elements that relate to the energy efficiency of the building envelope are compared in Appendix H.1 to Code values for the same parameters. As indicated, proposed roof, walls, and glazing all exceed Code requirements.

Light / Reflective Roofs

Light colored or reflective roofing materials will be utilized to minimize summer urban heat island effects.

Chilled Beams

This technology improves the efficiency of distribution of heating and cooling for building conditioning, reducing fan power significantly.

Heat Recovery

Heat recovery transfers the heat in exhaust ventilation to the incoming fresh air, thus reducing the demand for heating boilers. Energy recovery from the building ventilation exhaust is incorporated into the design.

Room Occupancy Sensors

Room occupancy sensors that turn off the artificial lights when a space is unoccupied are proposed for the common spaces of the building.

High Performance Lighting

Lower lighting power levels are achieved by use of high performance fluorescent or LED lighting fixtures and lamps. Reductions in lighting power density (LPD) include 8% on a building average basis and 15% in the parking garage.

Energy-Star Appliances and Electronics

Energy Star appliances utilize less energy than other models of the same appliances. Kitchens and break rooms will be fit out with Energy Star appliances. Electronics, such as computers, servers, and printers are also expected to be Energy Star rated.

9.3.1.2 Energy Generation

High Efficiency Mechanical Equipment

High efficiency HVAC systems are a combination of energy use reduction and energy generation technologies and include use of high efficiency boilers and chillers, premium electric motors, and incorporating variable frequency drives (VFD) motors, above and beyond the requirements of the Code, where practical. Appendix H.1 presents proposed HVAC equipment and boilers with high thermal efficiencies, better than Code and state-of-the-art for equipment of that size and type.

The 819 Beacon Street Project has shown substantial savings in natural gas in the energy model (see Section 9.3.2) due to the use of a heat wheel and modular, efficient, condensing boilers.

9.3.1.3 Other Related

As described in Section 9.2.1 for the BCCB, 819 Beacon Street will utilize:

- low flow plumbing fixtures;
- recycling collection areas;
- a building energy management system;
- enhanced building commissioning; and
- construction waste management.

Rainwater Harvest

A portion of the rainwater from 819 Beacon Street will be collected and stored for various uses, including groundwater recharge and irrigation. Using rainwater for cooling tower make-up water or toilet flushing will be evaluated as the design progresses.

Regional Content Materials

The Proponent will encourage the specification of regionally-sourced materials for 819 Beacon Street wherever possible and is expected to achieve at least 10% regional materials content (as defined in LEED).

9.3.2 Building Energy Modeling

As with the BCCB, building energy modeling for 819 Beacon Street was conducted by BR+A, a full service consulting firm specializing in the engineering and design of heating, ventilation, air conditioning, electrical, plumbing, fire protection, fire alarm and energy management systems. The eQUEST model, version 3.64, was used in accordance with the ASHRAE 90.1 Appendix G protocol.

Results are summarized in Table 9-4. The eQUEST output tables for both cases are included in Appendix H.2. Modeling was conducted including a 150,000 sf parking garage and manually adjusted for a nearly 200,000 sf garage, as noted in Appendix H.2.

The energy efficiency technologies employed in the proposed design will result in a 35% decrease in natural gas use and 0.4% decrease in electricity use, resulting in a 119 ton/year, 10% decrease in GHG emissions compared to a Code-compliant (IECC 2012) building.

Electricity use savings are generated by reductions in interior area lighting, exterior lighting, and space cooling. These savings can be attributed to the reduced LPD both inside and outside the building as well as energy recovery ventilation, plate and frame heat exchanger, and chilled beams. Some of these items, however, can also cause an electric energy penalty. The chilled beams use year round chilled water, which creates more run hours for the pumps. The added pressure drop of the energy recovery ventilation creates extra fan static pressure which increases the fan energy required.

Actual equipment selections on fans and pumps as well as duct design will be made as the design progresses, and may further reduce the electrical energy use. For example, the chilled beams are currently modeled as constant volume as the Project is very early in the design. The option of variable chilled beams will be analyzed as the Project progresses in the design process. Larger ducts, if space utilization is not critical, could reduce duct pressure losses, hence reducing fan power.

Use of oversized cooling towers will also be addressed in later stages of design. An oversized tower results in better chiller performance at part load conditions. This early in the design, however, the eQUEST model is allowed to size the cooling tower based on maximum load.

Thus it is reasonable to expect that later design will result in further reductions in electricity use and, therefore, in GHG emissions.

EUI calculation, using site energy since CHP is not included in the design, is presented in Table 9-5 and indicates that even at this early stage of design, energy use reduction of 15%, in compliance with what is assumed to be the target requirement of the future SC II, is indicated.

Table 9-4 819 Beacon Street Modeling Results – GHG Emissions Reduction

		Site Energy		
		Case 1 Baseline	**Case 2 Proposed**	**Case 1–>2 Difference**
DIRECT (NATURAL GAS)		MMBtu/yr	MMBtu/yr	
Space Heating		4,990	3,079	
Hot Water		490	488	
Pumps & Auxiliary		50	0	
Solar Hot Water Credit		0	0	
CHP Engine Fuel Use		0	0	
CHP Thermal Credit		0	0	
	subtotal	5,530	3,567	-35%
INDIRECT (ELECTRICITY)		MWh/yr	MWh/yr	
Space Cooling		197	139	
Cooling Tower (Heat Reject.)		9	9	
Space Heating		0	6	
Hot Water		1	1	
Ventilation and Fans		394	509	
Pumps & Auxiliary		105	137	
Ext. Usage		23	22	
Misc. Equipment		815	815	
Area Lighting [1]		822	719	
Energy Star appliance credit		0	0	
CHP Generation Credit		0	0	
PV Generation Credit		0	0	
	subtotal	2,367	2,357	-0.4%

[1] Area lighting includes garage lighting which was manually increased from a 150 ksf area to 200 ksf. See Appendix H.2 of DEIR

GHG EMISSIONS		tons/yr	tons/yr	
Direct	Gas-burning	324	209	-35%
Indirect	Imported Electricity	923	919	0%
	Total	1,247	1,128	**-10%**
			119 ton/yr reduction	

CO_2 Emission Factors:

Electricity [1]	780 lb/MWh
Natural Gas [2]	117 lb/MMBtu

[1] 2011 New England Electric Generator Air Emissions Report, Table 5.4, 2011 value

[2] EIA Fuel Emissions Factors, Weighted National Average (1029 Btu/scf)

Table 9-5 819 Beacon Street Modeling Results – Site Energy and EUI

		Site Energy		
		Case 1 Baseline	Case 2 Proposed	Case 1–>2 Difference
DIRECT (NATURAL GAS)		MMBtu/yr	MMBtu/yr	
Space Heating		4,990	3,079	
Hot Water		490	488	
Pumps & Auxiliary		50	0	
Solar Hot Water Credit		0	0	
CHP Engine Fuel Use		0	0	
CHP Thermal Credit		0	0	
	subtotal	5,530	3,567	-35%
INDIRECT (ELECTRICITY)		MMBtu/yr	MMBtu/yr	
Space Cooling		671	475	
Cooling Tower (Heat Reject.)		31	31	
Space Heating		0	19	
Hot Water		2	2	
Ventilation and Fans		1,346	1,736	
Pumps & Auxiliary		359	467	
Ext. Usage		79	76	
Misc. Equipment		2,782	2,782	
Area Lighting [1]		2,806	2,454	
Energy Star appliance credit		0	0	
CHP Generation Credit		0	0	
PV Generation Credit		0	0	
	subtotal	8,076	8,042	-0.4%

[1] Area lighting includes garage lighting which was manually increased from a 150 ksf area to 200

ENERGY USE INDEX	208,315 gsf conditioned space		
	kBtu/sf/yr	kBtu/sf/yr	difference
	65.3	55.7	**-15%**

9.3.3 Technologies Not Currently in the Design

Orientation

Building footprint is largely constrained by the existing street grid and adjacent buildings. In order to optimize floor plates for maximum construction efficiency, building façades will remain generally parallel to the existing street grid. The design of the exterior envelope will be evaluated later in design on a façade-by-façade basis (each side of the building) for optimal configuration of glazing areas, opaque wall area, shading devices, overhangs, screens, balconies, operable windows, etc. However, such details will not be developed until the detailed design phase of the building. Therefore, as only the basic characteristics of the envelope performance can be accounted for in this early evaluation stage, no credit has been taken at this time in the building energy modeling for overhangs, balconies, screens, or exterior shading devices.

Green Roof

Due to the constraints imposed by MBTA Green Line tunnel running diagonally across the site, the majority of the mechanical and electrical equipment has to be located on the rooftop thus limiting the area available for other uses. The 819 Beacon Street Project is currently contemplating an approximately 7,000 sf vegetated roof area on a portion of the garage roof.

Exterior Shading Devices

The Proponent will study the feasibility of using various forms of external shading during the detailed design phase of the building.

Under-Floor Air Distribution (UFAD)

UFAD reduces energy consumption by extending the amount of time that the HVAC system can run in economizer cycle (i.e., using outside air to cool a space rather than mechanically cooled air) and by reducing the amount of air and the fan horsepower (and thus electrical energy) required to deliver the air. Implementation of UFAD requires a different architectural structure with raised floors and a different configuration and layout of air handling units compared to spaces served by conventional means. For 819 Beacon Street, this creates difficulties marrying the building to the exterior parking garage. UFAD is also not an optimal system if it is anticipated that room partitions will be moved occasionally, which would require rebalancing of the system each time. Therefore, it is not being considered for 819 Beacon Street.

Radiant Heat – Lobby

The small lobby area and reduced traffic flow compared to a commercial building reduce the value of using radiant heat in this space.

Demand-controlled Ventilation

Ventilation systems that adjust flows in accordance with CO_2 levels, temperature, or humidity in a space will be considered during detailed design. The parking garage is open-air, and not forced ventilation.

Daylighting and Daylight Harvesting

Daylighting is the automated control of artificial lighting in response to the amount of natural daylight entering a room. Although it will be considered during detailed design for uses where possible, there is no building lighting design at this stage and so it has not been included in the building energy modeling presented herein.

Daylight harvesting is the design of the interior in a manner that allows natural light to penetrate deeply into the building interior; this strategy complements natural lighting. The 819 Beacon Street building will include large percentages of enclosed offices, making daylight harvesting impractical.

High Performance Exterior Lighting

Exterior use of LED lighting is beginning to be accepted commercially. The Proponent will consider its specific uses and the feasibility of such lighting when 819 Beacon Street reaches an appropriate stage of design.

Advanced Energy Efficient Elevators.

Advanced elevators incorporate belt-drive systems with regenerative braking technologies. The economics of this technology will be examined during the design development phase.

Cogeneration

To be financially feasible, a CHP unit needs to be run at or near full load continuously for most of the year, and there must be a use for the waste heat recovered as hot water or steam. An office building has very little thermal load at night or during the non-heating season and substantially reduced electrical load at night and on weekends. Therefore, CHP is not deemed to be feasible for 819 Beacon Street.

District Heating

There is no district heating distribution system available at this site.

Fuel Cells

Like CHP, fuel cells do not generally serve a need in an office building.

PV

Due to the constraints imposed by the MBTA Green Line tunnel running diagonally across the site, the majority of the mechanical and electrical equipment has to be located on the rooftop. Insufficient rooftop is therefore available for a meaningful contribution from PV.

SHW

An office building does not have a high or consistent demand for domestic hot water. Thus SHW does not generally serve a need.

GSHP and Wind

As described in Section 9.2.3, these technologies are not generally feasible in an urban project.

Green Energy

The Proponent will examine the feasibility of purchasing Green Energy as the Project approaches commissioning based upon available choices and then-current economics.

Refrigerant Management

LEED certification requires adopting a refrigeration management system that allows no CFC use. 819 Beacon Street will be able to achieve this LEED refrigerant management criterion through the appropriate selection of refrigerants and efficient refrigeration systems.

Enhanced Refrigerant Management involves selection of refrigerants with the least ozone depletion potential. Inclusion of the most appropriate refrigerants with a reduced contribution to ozone depletion and reduced GHG-equivalent concentrations will be evaluated during detailed design based on the specific mechanical systems selected for inclusion in the building.

9.4 Mobile Source Emissions

As part of the greenhouse gas evaluation, emissions of carbon dioxide from regional traffic associated with the BCCB (including the Patient and Family Parking Garage) and 819 Beacon Street Projects were evaluated.

9.4.1 Traffic GHG Analysis

In accordance with the MEPA GHG Policy, GHG emissions were estimated for mobile sources within the transportation study area (see Chapters 3 and 4 for the transportation analysis). For mobile source GHG emissions, the methodology follows the same methodology that is outlined in MassDEP guidance for mesoscale analyses.[1] The analysis includes a comparison of the future Build conditions to the No-Build condition. If emissions are greater for the Build conditions, reasonable and feasible mitigation measures will be evaluated. The methodology and parameters for the mesoscale analysis follow methodology approved by MassDEP.

The mesoscale analysis performed for these Projects predicts the change in regional CO_2 emissions due to the proposed Projects. The total vehicle pollutant burden was estimated for the 2012 existing conditions and the No-Build and Build conditions for year 2022 for both the BCCB Project and the 819 Beacon Street Project separately. Traffic conditions are described in more detail in Chapters 3 and 4.

The EPA's MOBILE6.2 computer program was used to estimate motor vehicle emission factors of CO_2 on the roadway network in the Project area. Conservatively, emission factors derived from MOBILE6.2 for CO_2 are based on the worst case of either wintertime or summertime conditions. Daily and yearly emission estimates were calculated using the vehicle count data, mileage between intersections, modeled signalized intersection delay times, and emission factors.

The traffic volumes provided in Chapters 3 and 4 form the basis of the study. Peak hour traffic volumes were provided by the transportation consultant. Estimates of Average Daily Trips (ADT) were made from the peak hour volumes assuming a 10% K-Factor. An average speed of 30 miles per hour was assumed for all city roadways. Distances for the links were estimated with mapping software.

Average per-vehicle idle times were based on SYNCHRO intersection modeling output reports provided by the transportation consultant (see Chapters 3 and 4) to calculate emissions from idling vehicles.

Case 1 represents the difference between the No-Build case and the Build case (i.e., traffic associated with the addition of the Project to the area without any Proponent-proposed mitigation).

While the Projects will not materially impact traffic operations in the area, the Proponent will work with the Massachusetts Department of Transportation (MassDOT) and Boston Transportation Department to improve traffic signal timing and phasing, measures which the transportation analysis identified as improving operations at study area intersections.

[1] MassDEP, Guidelines For Performing Mesoscale Analysis Of Indirect Sources, May 1991.

Traffic signal timing and phasing reports will be completed by the Proponent's transportation engineers to define signal timing and phasing improvements with MassDOT and BTD, if required. The Proponent will implement the approved traffic signal timing and phasing recommendations prior to receiving a Certificate of Occupancy, if appropriate.

In addition, the Proponent has developed a comprehensive TDM program presented in Chapters 3 and 4. The proposed TDM program for both Projects includes the following:

- Designating a Transportation Coordinator;
- Providing bicycle amenities in the form of bicycle storage and bicycle parking;
- Establishing a vehicle management and operations strategy which includes providing electric car charging stations; and
- Promoting travel alternatives.

Tables 9-6 and 9-7 present the results of the transportation GHG source analysis for the BCCB and the 819 Beacon Street Project, respectively. Case 1 results are presented for the study year 2022. All related calculations, including the 2012 Existing and 2022 emissions estimates, are presented in Appendix E.

Project mitigation measures do not include any physical roadway modifications. The TDM program will reduce trips and vehicle miles travelled (VMT); however, no credit has been taken for such a reduction. Since no intersection timing and use modifications are currently proposed, no reductions in GHG from traffic are realized. The BCCB would result in a net increase of 165 tons/year (1.7%) over future No Build from traffic operations while the 819 Beacon Street Project would result in a net increase of 90 tons per year (less than 1%) over future No Build traffic operations.

Table 9-6 Transportation-Related GHG Emissions - BCCB

	Case 1 - Baseline
	Build - No Build
Net VMT, miles/day	640
Net Delay, hrs/day	79
GHG Emissions, tons/yr	
Roadway	126
Intersection	39
Total	165

Table 9-7 Transportation-Related GHG Emissions - 819 Beacon Street

	Case 1 - Baseline
	Build - No Build
Net VMT, miles/day	143
Net Delay, hrs/day	126
GHG Emissions, tons/yr	
Roadway	28
Intersection	62
Total	90

9.5 Summary and Mitigation Commitments

9.5.1 Project GHG Summary

Table 9-8 presents a composite of the building and transportation GHG emissions profiles of the Baseline and Proposed cases.

Table 9-8 Project GHG Emissions Summary

	Baseline	Proposed	Difference	
	tons/yr			%
Stationary Sources				
BCCB	10,510	8,951	-1,558	-15%
819 Beacon	1,247	1,128	-119	-10%
Transportation				
BCCB	165	165	0	0%
819 Beacon	90	90	0	0%
Total	12,011	10,334	-1,677	-14%

9.5.2 Proponent's Commitments to GHG Reduction

The Proponent's commitments to mitigate Project GHG emissions from the stationary sources are extensive, as indicated in Sections 9.2 and 9.3. Numerous additional mitigation measures have not been quantified, primarily because the degree of accuracy or the reliability of the quantification method is uncertain.

Designs for the buildings are in the conceptual stages and only very preliminary information is available. As the Project develops, the Proponent expects that additional technologies described previously, or possibly new technologies developed in the interim period, will be adopted that will further decrease GHG emissions, but these are not yet ripe for selection. The Proponent will continue to evaluate energy efficiency measures as the design develops.

The Proponent is committed to the following mitigation elements for the entire Project or for individual buildings:

- High performance building envelopes;
- Green roof on portions of the BCCB;
- Light or reflective roofs;
- High-efficiency HVAC equipment;
- CHP unit for BCCB
- Energy recovery ventilation;
- Room occupancy sensors in the appropriate spaces of both buildings;
- High-efficiency interior lighting and reduced lighting power density wherever feasible;
- High-performance exterior lighting;
- Low-flow plumbing fixtures and water conservation measures;
- Energy Star appliances and electronics;
- Energy management systems;
- Recycling collection areas;
- Construction waste recycling;
- TDM program as described in Sections 3.1.2.6 for the BCCB and Sections 4.3.5 and 4.1.2.5 for the 819 Beacon Street Project.

The Proponent is committed to implementing the energy efficiency and GHG emission reduction measures presented in this analysis, but must retain an amount of design flexibility to allow for changes that will inevitably occur as design progresses. Case 2 provides a comprehensive estimate of the anticipated GHG reductions that can be achieved based on building energy modeling with preliminary design information. If, during the course of design for an individual building, a specific combination of design strategies proves more advantageous from an engineering, economic, or space utilization perspective, the design of that building may vary from what has been described as Case 2. Energy performance minima (and associated GHG emission reductions) by building, as shown in Tables 9-2 and 9-4, will be adhered to on an individual building design basis. The Proponent will submit a self-certification to the MEPA Office at the completion of each building. The certification will identify the GHG mitigation measures incorporated into the building and will illustrate the degree of GHG reductions from a Baseline case, as Baseline is defined herein, and how such reductions are achieved. Details of the owner's implementation of operational measures will be included.