Massachusetts Institute of Technology

Stephen A. Schwarzman College of Computing

Article 22 Submission

Issue | September 18, 2020 updated October 20, 2020

Job number 271619-00

Arup USA, Inc
60 State Street
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ARUP

Contents

1 Project Introduction

The Stephen A. Schwarzman College of Computing will be a mixed-use building containing office, research laboratory, academic, event, a café, and collaboration and meeting spaces. In total, the building will comprise approximately 174,000 Gross Floor Area (GFA) distributed over eight (8) above-grade floors and a basement level. Public programs are located on floors 1 and 2, while the academic and research programs are located on floors 3-7, with the event space on floor 8. The basement will contain shell space for future use.

Project Rendering: Vassar Street Façade image: SOM

Table 1. Summary of building development characteristics

Site area:	18,300 ft^2
Existing land use(s) and gross floor area, by use:	Institutional/Academic: 16,119 GFA
Proposed land use(s) and gross floor area, by use:	Institutional/Academic: 170,900 GFA Café: 3,100 GFA Total: 174,000 GFA
Proposed building height(s):	118 ft 9 stories (8 above-grade)
Proposed parking spaces:	0 off street
Proposed bicycle parking spaces (Long-term and short-term):	71 short-term[1] & 44 long-term

[1] Bicycle parking required by Article 6.1 has been updated since the Green Building Report was certified on October 15, 2020 to reflect the final building gross floor area, 174,000 GFA not 173,000 GFA as previously stated.

1.1 Project team

Owner: Massachusetts Institute of Technology

The Stephen A. Schwarzman College of Computing design team includes:

- Architect & Structural Engineer: Skidmore, Owings & Merrill LLP
- MEP/FP Engineering: Arup
- Civil Engineering: Nitsch
- Landscape Architect: Reed Hildebrand
- Environmental Engineering: Haley & Aldrich
- Cost Estimating: AECOM
- Lighting Design: HLB
- Sustainability Consulting: Arup
- Acoustics Consulting: Arup
- Code Consulting: Arup
- AV, IT & Security Consulting: Vantage TCG
- Vertical Transportation: Lerch Bates
- Waterproofing consultant: Vidaris
- Lab Planning Consultant: RFD
- Signage and Wayfinding Consultant: Isometric Studio

Green Building Project Checklist

Green Building Project Location: 51 Vassar Street, Cambridge MA 02142

Applicant

Name: Travis Wanat - Massachusetts Institute of Technology

Address: 195 Albany Street Cambridge MA 02139

Contact Information

Email Address: twanat@mit.edu

Telephone #: 617-756-2858

Project Information (select all that apply):

- [x] New Construction – GFA: 174,000
- [ ] Addition – GFA of Addition: ______
- [ ] Rehabilitation of Existing Building – GFA of Rehabilitated Area: ______
  - [ ] Existing Use(s) of Rehabilitated Area: ______
  - [ ] Proposed Use(s) of Rehabilitated Area: ______
- [x] Requires Planning Board Special Permit approval
- [ ] Subject to Section 19.50 Building and Site Plan Requirements
- [ ] Site was previously subject to Green Building Requirements

Green Building Rating Program/System:

- [x] Leadership in Energy and Environmental Design (LEED) – Version: 4 New Construction
  - [ ] Building Design + Construction (BD+C) – Subcategory: ______
  - [ ] Residential BD+C – Subcategory: ______
  - [ ] Interior Design + Construction (ID+C) – Subcategory: ______
  - [ ] Other: ______
- [ ] Passive House – Version: ______
  - [ ] PHIUS+
  - [ ] Passivhaus Institut (PHI)
  - [ ] Other: ______
- [ ] Enterprise Green Communities – Version: ______

Project Phase

☐ **SPECIAL PERMIT**

Before applying for a building permit, submit this documentation to CDD for review and approval.

Required Submissions

All rating programs:

☒ Rating system checklist

☒ Rating system narrative

☒ Net zero narrative (see example template for guidance)

☒ Affidavit signed by Green Building Professional with attached credentials – use City form provided (Special Permit)

Affidavit Form for Green Building Professional Special Permit

Green Building Project Location: 51 Vassar Street, Cambridge MA 02142

Green Building Professional

Name: Hilary Williams PE LEED AP BD+C

☐ Architect

☑ Engineer

Mass. License Number: 55379

Company: Arup USA Inc.

Address: 60 State Street,Boston MA 02109

Contact Information

Email Address: Hilary.Williams@arup

Telephone Number: 617 864 2987

I, Hilary Williams PE LEED AP BD+C, as the Green Building Professional for this Green Building Project, have reviewed all relevant documents for this project and confirm to the best of my knowledge that those documents indicate that the project is being designed to achieve the requirements of Section 22.24 under Article 22.20 of the Cambridge Zoning Ordinance.

9/18/2020

(Signature) *(Date)*

Attach either:

☑ Credential from the applicable Green Building Rating Program indicating advanced knowledge and experience in environmentally sustainable development in general as well as the applicable Green Building Rating System for this Green Building Project.

☐ If the Green Building Rating Program does not offer such a credential, evidence of experience as a project architect or engineer, or as a consultant providing third-party review, on at least three (3) projects that have been certified using the applicable Green Building Rating Program.

LEED AP BD+C

10658894-AP-BD+C

CREDENTIAL ID

01 DEC 2011

ISSUED

28 NOV 2021

VALID THROUGH

GREEN BUSINESS CERTIFICATION INC. CERTIFIES THAT

Hilary Williams

HAS ATTAINED THE DESIGNATION OF

LEED AP® Building Design + Construction

by demonstrating the knowledge and understanding of green building practices and principles needed to support the use of the LEED green building program.

MAHESH RAMANUJAN
PRESIDENT & CEO, U.S. GREEN BUILDING COUNCIL
PRESIDENT & CEO, GREEN BUSINESS CERTIFICATION INC.

Massachusetts Institute of Technology

Stephen A. Schwarzman College of Computing

Article 22: Green Building Narrative

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Appendices

1 LEED v4 New Construction Scorecard Summary

The table below summarizes the LEEDv4 New Construction credit summary for the proposed building design. The project is pursuing points for LEED Gold certification at a high level. Gold certification requires achievement of at least 60 points, 60-79 points. The project is targeting 71 points. The LEED Credit Scorecard can be found in Appendix A.

Table 1. LEED points planned for Gold v4 certification pathway

Category	Points planned (YES)	Maybe Points
IP: Integrative Process	1	-
LT: Location and Transportation	13	-
SS: Sustainable Sites	3	3
WE: Water Efficiency	5	1
EA: Energy and Atmosphere	25	2
MR: Materials and Resources	7	2
EQ: Indoor Environmental Quality	10	3
ID: Innovation in Design	6	-
RP: Regional Priority	1	1
Total	**71**	**12**

A detailed credit by credit narrative is included in the following narrative.

2 LEED Credit Narrative

This section provides a detailed narrative for each LEED credit being pursued, with some credits being indicated as “maybe” for evaluation for their cost benefit using life cycle cost analysis.

The project will meet all three (3) minimum program requirements to (1) be in a permanent location on existing land, (2) use a reasonable LEED boundary and (3) comply with size requirements of at least 1,000 square feet of gross floor area.

Additionally, the project will achieve each of the twelve (12) prerequisites which are discussed under each credit category below.

2.1 Integrative Process

2.1.1 Integrative Process 1 point

The project is pursuing 1 point from this credit with the intention of supporting high-performance, cost-effective project outcomes through an early analysis of the interrelationships among systems. Early analyses for energy-related systems and water-related systems were completed and will be used to inform the basis of design (BOD), design documents, and construction documents. “Simple box” energy modeling was performed during Concept Design phase to evaluate the importance of building envelope attributes including double skin façade systems, and assessment different HVAC alternatives. Water consumption calculations were performed to estimate the project’s indoor and outdoor water demand and set reduction targets. A series of sustainability focused charrettes have been held to define project goals, set targets for energy and water use reduction and review analysis of energy and water related reduction strategies.

2.2 Location and Transportation

LTc2 Sensitive Land Protection 1 point

The project will achieve this credit by being located on land that has been previously developed.

LTc4 Surrounding Density and Diverse Uses 5 points

The project will achieve the full 3 available points under the Surrounding Density criteria, and an additional 2 points for Diverse Uses criteria, for a total of 5 points. The table below includes a calculation of surrounding density, demonstrating exceedance of the LEED threshold of 35,000 square feet per acre of buildable land. The calculations have accounted for the full ¼ mile radius of surrounding area and shows the minimum density threshold is comfortably exceeded.

Table 2. Surrounding density calculations. Data from MIT Space Accounting Database.

Total building area (MIT campus buildings only):	6,737,560 ft^2
Total radius area (including non-buildable land):	0.20 mi^2
	5,473,833 ft^2
	125.7 acres
Combined density:	536,156 ft^2/acre
Non-residential density:	1.16 FAR
Residential density:	4.9 dwelling unit/acre

The project targets an additional 2 points for Diverse Uses, having a main entrance within a ½ mile walking distance of the main entrance for eight (8) or more existing and publicly available diverse uses, as summarized below.

Table 3. Diverse uses by category and use type within 0.5 miles walking distance of project site

Location name	Category	Use type	Distance to site (miles)
Forbes Family Café	Services	Café	0.2
Cambridge Trust	Services	Bank	0.2
455 Main Street	Community anchor	Office	0.2
LaVerde's Market	Food retail	Grocery	0.3
USPS Post Office	Civic & community facilities	Post office	0.3
7-Eleven	Community-serving retail	Convenience store	0.3
Clover Food Lab	Services	Restaurant	0.3
List Visual Arts Center	Civic & community facilities	Museum	0.3
Revela Salon	Services	Hair care	0.4

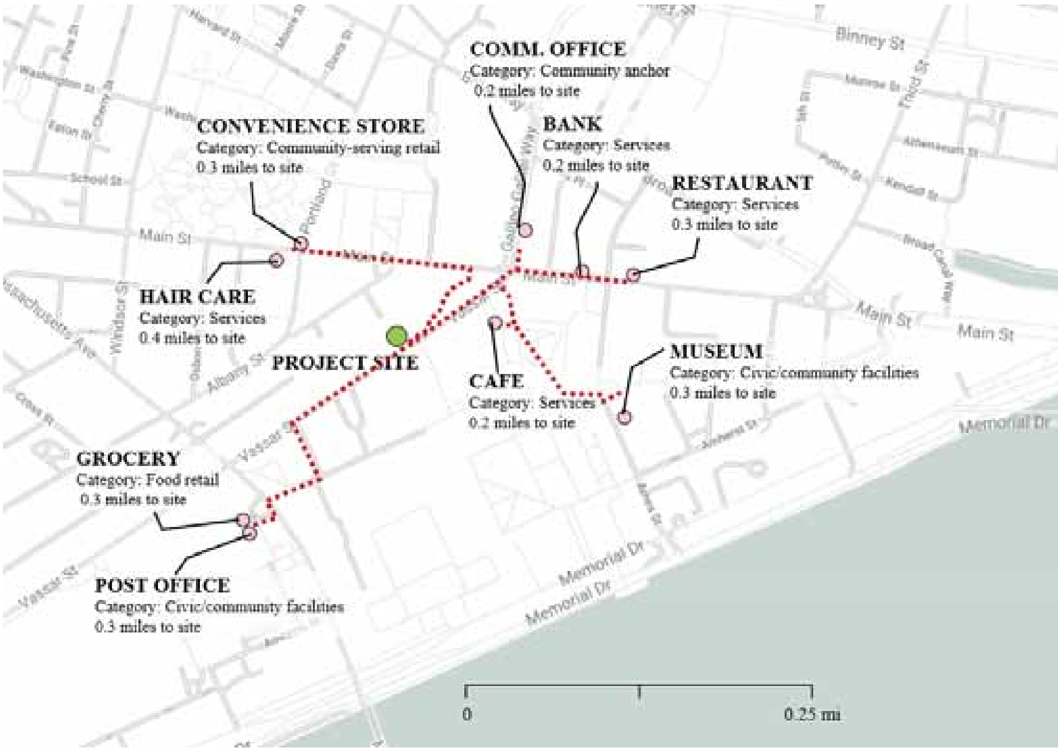

Figure 1. Map of Diverse Uses located within 0.5 miles walking distance of project site.

LTc5 Access to Quality Transit (v4.1) 5 points

The project will achieve 5 points for LTc5 Access to Quality Transit by having a functional entry for the project within a ¼-mile walking distance of existing bus stops and a ½-mile walking distance from the MBTA "T" system. A calculation of frequency of service that fulfill the credit criteria are included in the table below.

Table 4. Transit options in fulfillment of Quality Transit credit

Route	Stop	Distance to site (miles)	Weekday trips	Weekend trips
EZ-Ride	Main/Vassar Street	0.2	77	0
MBTA Red Line	Kendall	0.4	200	157
MBTA 1 Bus	77 Massachusetts Ave	0.2	127	100
		Total:	**404**	**257**
		LEED 5-point threshold:	360	216

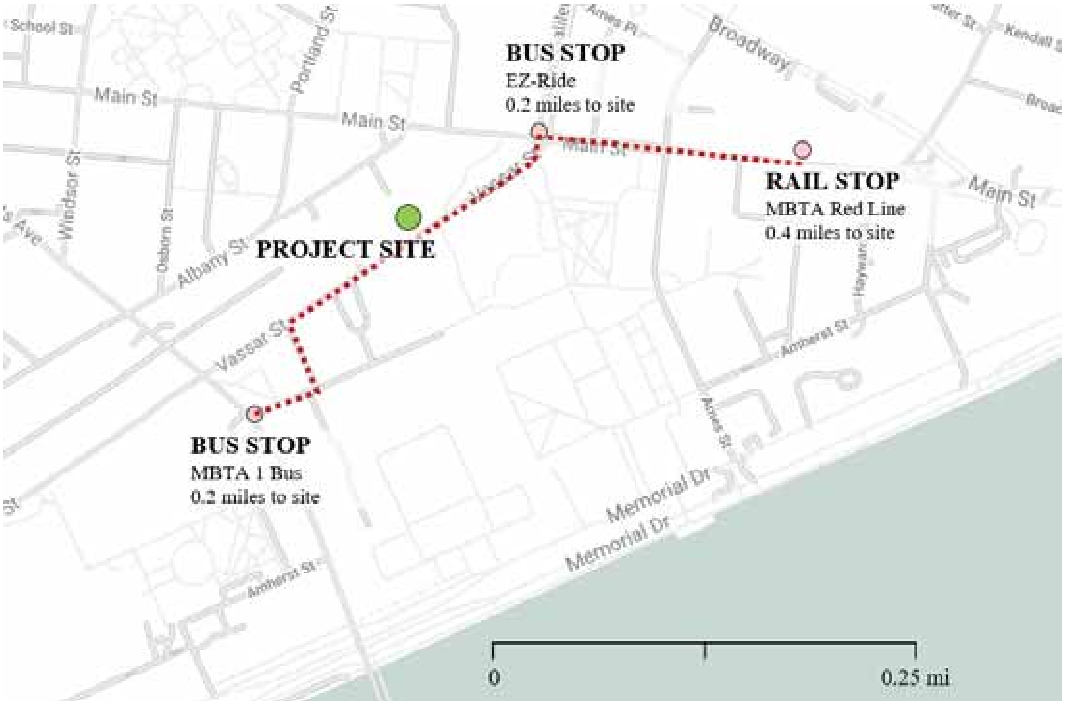

Figure 2. Transit options within ¼ mile walking distance (bus stops) or ½-mile walking distance (rail stop).

LTc6 Bicycle Facilities (v4.1) 1 point

The project will achieve 1 point for providing bike parking and shower and changing facilities per LEED requirements and meet the City of Cambridge Article 6.100, bike parking spaces. Refer to the table below. The City of Cambridge Article 6.100 requirements are more stringent for short-term parking, while LEED is more stringent for long-term parking and requires shower and changing facilities.

Building metrics:

- 174,000[1] GFA
- 850 full-time occupants (FTE)
- 1,100 peak visitors

Table 5. Bicycle parking and showers/changing rooms counts

	Short-term		Long-term		Showers / Changing Rooms	
	Criteria	Result	Criteria	Result	Criteria	Result
Cambridge Article 6.100	0.4 spaces per 1,000 SF	**71**	0.2 spaces per 1,000 SF	**36**	n/a	n/a

[1] Bicycle parking required by Article 6.1 has been updated since the Green Building Report was certified on October 15, 2020 to reflect the final building gross floor area, 174,000 GFA not 173,000 GFA as previously stated.

LEED LTc6	2.5% of peak visitors	**28**	5% of FTE	**44**	1 for first 100 FTE +1 for each 150 after	**9**

The project site is connected to a bicycle network that extends throughout the MIT campus and from Cambridge into Boston and connects to at least 10 diverse uses per LEED requirements.

LTc7 Reduced Parking Footprint (v4.1) 1 point

The project achieves 1 point for this credit under LEED v4.1 criteria, Option 1, by including no offstreet parking.

2.3 Sustainable Sites

SS Prerequisite 1: Construction Activity Pollution Prevention

The project will meet this prerequisite by creating and implementing an erosion and sedimentation control plan for all construction activities associated with the project. The plan will conform to the municipal erosion and sedimentation requirements for the City of Cambridge.

SSc4 Rainwater Management 3 points (maybe)

The project is studying the feasibility for achievement of 3 points under this credit. The project's stormwater reduction strategies include a vegetative roof such as the "Purple Roof" technology which maximizes stormwater retention and plant health, as well as supplemental rainwater retention chambers. Achievement of the credit involves retaining on-site rainwater from the 90th percentile storm event.

SSc5 Heat Island Reduction 2 points

The project has targeted 2 points for achievement under SSc5 Option 1 (Nonroof and Roof). The Nonroof measures that support credit achievement include landscape areas with planting and trees to provide shade. The hardscape materials will incorporate light-colored granite and pre-cast concrete. The roof membrane is a combination of light-colored sand, mortar, and grout with an extensive green roof system.

SSc6 Light Pollution Reduction 1 point

The project will pursue 1 point under this credit using Option 1: BUG Rating Method. Exterior lighting priorities include providing a safe nighttime lighting environment that meets LEED criteria per BUG methodology and to minimize light spill from the building to Vassar Street. Per the Illuminating Engineering

Society Model Lighting Ordinance, the project lies in a Lighting Zone 3 (LZ-3) corresponding to a moderately high lighting level in commercial mixed-use areas.

2.4 Water Efficiency Credits

WE Prerequisite 1: Outdoor Water Use Reduction

The project will fulfill this prerequisite by reducing irrigation water demand by at least 30% from the calculated baseline for the site's peak water month, achieved through plant species selection and irrigation system efficiency, as calculated by the Environmental Protection Agency (EPA) WaterSense Water Budget Tool.

WE Prerequisite 2: Indoor Water Use Reduction

The project will fulfill this prerequisite by installing fittings and fixtures that reduce aggregate water consumption by at least 20% from the baseline as specified in the LEED v4 Reference Guide and will be Water Sense labelled. Applicable water fixtures include toilets, lavatory faucets, kitchen faucets, and showerheads. In addition, appliances such as dishwashers and ice machines will meet the ENERGY STAR or equivalent performance.

WE Prerequisite 3: Building-Level Water Metering

The project will fulfill this prerequisite by installing a whole building water meter to measure the total potable water use for the building and associated grounds, compiled into monthly and annual summaries. The project commits to sharing with USGBC the resulting whole-project water usage data for a five-year period beginning on the date the project accepts LEED certification or typical occupancy, whichever comes first.

WEc1 Outdoor Water Use Reduction — 1 of 2 points

The landscape design will demonstrate at least a 50% reduction in potable water demand for outdoor water use through specification of native species with low water demand and efficient irrigation systems. This will achieve 1 point.

WEc2 Indoor Water Use Reduction — 3 of 6 points

The project will achieve three (3) points or a 36.7% reduction in indoor potable water use by specifying low-flow water fixtures per MIT design standards. Restrooms will all be gender neutral and no urinals will be installed on the project.

Water fixture flow rates have been defined as follows and will be water sense labelled per LEED requirements:

	Design flow rate	Max. Allowable Flow Rate

• Toilets:	1.0 gpf	1.6 gpf
• Lavatories:	0.35 gpm	0.5 gpm
• Showers:	1.5 gpm	2.5 gpm
• Kitchen sinks:	0.5 gpm	2.0 gpm

WEc3 Cooling Tower Water Use 1 point (maybe)

The project is exploring achievement of 1 point under this credit and confirming compliance with the Central Utility Plant for potable water analysis measuring, Ca (as $CaCO_3$), total alkalinity, SiO_2, Cl^-, and conductivity against the maximum levels prescribed in the LEED v4 Reference Guide. In accordance with LEED criteria, cooling tower cycles will be measured to verify whether the maximum number of cycles are achieved without exceeding any filtration levels or affecting operation of condenser water system (up to a maximum of 10 cycles).

WEc4 Water Metering 1 point

Water sub-metering will be implemented on the project to sub-meter water use for two (2) end uses, (1) landscape irrigation and (2) the cafeteria/food service area.

2.5 Energy and Atmosphere Credits

EA Prerequisite 1: Fundamental Commissioning and Verification

In fulfillment of this prerequisite, the project will engage commissioning (Cx) agents for mechanical, electrical, plumbing, and renewable energy systems and assemblies in accordance with ASHRAE Guideline O-2005 and ASHRAE Guideline 1.1-2007 for HVAC&R Systems, as they relate to energy, water, indoor environmental quality, and durability. In addition, a building enclosure commissioning (BECx) agent has been engaged for the project. The Cx and BECx agents will complete all steps outlined in LEED v4 Reference Guide.

EA Prerequisite 2: Minimum Energy Performance

In fulfillment of this prerequisite, the project will follow Option 1: Whole Building Energy Simulation to demonstrate an improvement of at least 5% in the proposed building performance rating compared with an ASHRAE 90.1-2010 Appendix G baseline building. Refer to the description of credit EAc2: Optimize Energy Performance below for detailed energy model results.

EA Prerequisite 3: Building-Level Energy Metering

In fulfillment of this prerequisite, the project will install building-level energy meters and submeters that can be aggregated to provide building-level data representing total building energy consumption. The project commits to sharing with USGBC the resulting energy consumption data for a five-year period beginning on the date the project accepts LEED certification. At a minimum, energy consumption must be tracked at one-month intervals.

EA Prerequisite 4: Building-Level Energy Metering

In fulfillment of this prerequisite, the project commits to not using chlorofluorocarbon (CFC)-based refrigerants throughout major HVAC&R systems.

EAc1 Enhanced Commissioning 6 points

The project will pursue all points under Enhanced Commissioning for Options 1 and 2. The process will exceed the Article 22 Green Commissioning requirements, which require the engagement of a Green Commissioning Authority as defined in Article 2.000 who completes the activities outlined in Section 22.24.2. The commissioning plan includes Option 1 Path 2: Enhanced and Monitoring-Based Commissioning. A commissioning agent will be engaged prior to the end of design development phase with a scope of work aligned with LEED criteria. It is understood that MIT uses KGS Building's Clockworks system as its monitoring-based commissioning platform and that this will be implemented on the project.

Option 2: Envelope commissioning will also be pursued. MIT has engaged Wiss Janney, Elstner Associates (WJE) as the building envelope commissioning agent and they have already been engaged with the project team and informing the curtain wall design.

EAc2 Optimize Energy Performance 18 of 18 points

The building will be connected to the MIT Central Utility Plant and will be served by electricity and campus chilled water. Accordingly, the design team has focused on demand reduction since thermal energy generation is outside of the project scope of work. Preliminary energy modelling was completed aligned with Option 1 Whole-building energy simulation to determine the proposed design performance against a LEED baseline which references ASHRAE 90.1-2010. The analysis utilized LEED guidance for district energy systems, Option 2. **The results indicate the proposed project design would achieve all 18 points available EAc2 Optimize Energy Performance by achieving a 53.7% energy cost savings as compared to an ASHRAE 90.1-2010 baseline.**

It is important to note that the Central Utility Plant (CUP) is undergoing an expansion project that will be fully complete and operational prior to this building being complete. The cost analysis has used MIT's DES Calculator which is populated with FY2019 utility data and a projection for the future 40MW CUP.

The proposed design includes an energy efficient building envelope and energy-efficient lighting. HVAC systems include a heat pump chiller utilizing campus chilled water as a heat sink/source, dedicated outdoor air system (DOAS) air handling unit with V8 dynamic filters and energy recovery at 80% efficiency. The auditorium will be served by a displacement ventilation system, while the ground-floor café and circulation areas will be served by radiant slab heating and cooling system. Fan coil units with high efficiency motors controlled by demand control ventilation sensors are provided throughout occupied spaces . A full description of the energy efficiency strategies, model inputs and assumptions are provided in the Net Zero Narrative.

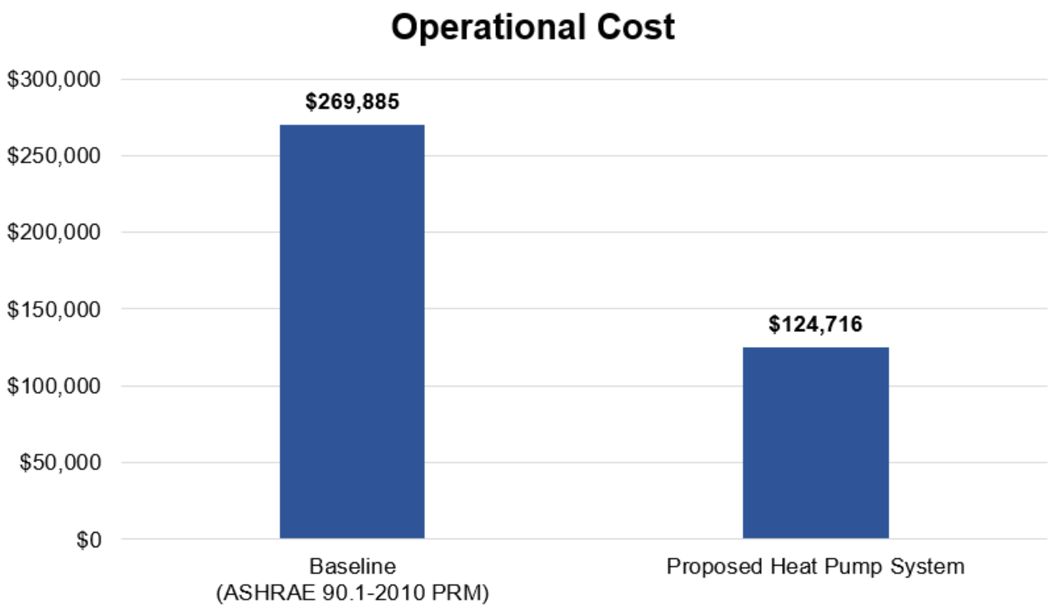

Figure 3. Energy cost of the LEED baseline and proposed design (heat pump system)

Table 6. Summary of Proposed design and LEED baseline results

	Energy Cost ($/year)	**LEED points**
LEED v4 Baseline	$269,885	-
Proposed Design	$124,716	18

EAc3 Advanced Energy Metering 1 point

The project is pursuing 1 point under this credit by installing advanced energy metering for all whole-building energy sources and individual energy end uses that represent 10% or more of the total annual building energy consumption. The metering will meet the prescribed characteristics listed in the LEED v4 Reference Guide for this credit, including having meters that are permanently installed, record both consumption and demand at intervals of one hour or less (and capable of reporting hourly, daily, monthly, and annual energy use), transmit data to a remote location that is remotely accessible. The metering system will be capable of storing all meter data for at least 36 months.

EAc7 Green Power and Carbon Offsets 2 points (maybe)

MIT is currently engaged in a power purchase agreement (PPA) as a part of its campus-wide renewable energy strategy. The project is evaluating the feasibility and alignment with wider Campus goals for renewables and carbon offsets to achieve 2 points under this credit by acquiring 100% of the total project's energy demand by renewable energy certificates (RECs) and/or carbon offsets, for a period of at least 5 years.

2.6 Materials and Resources Credits

MR Prerequisite 1: Storage and Collection of Recyclables

In fulfillment of this prerequisite, the project will provide dedicated areas accessible to waste haulers and building occupants for the collection and storage of recyclable materials for the entire building. Materials to be collected include mixed paper, corrugated cardboard, glass, plastics, and metals, with appropriate measures being taken for the safe collection of batteries, mercury-containing lamps, and electronic waste.

MR Prerequisite 2: Construction and Demolition Waste Management Planning

In fulfillment of this prerequisite, the project will develop and implement a construction and demolition waste management plan adhering to LEED v4 Reference Guide criteria. Requirements will be integrated into section 017419 CONSTRUCTION AND DEMOLITION WASTE MANAGEMENT AND DISPOSAL.

MRc1 Building Life-Cycle Impact Reduction 2 of 5 points (+ 1 point maybe)

The project has committed to track and measure scope 3 emissions for embodied carbon related to construction materials and will pursue Option 4: Whole Building Life Cycle Assessment (LCA). In addition to conducting an LCA, the project has targeted achievement of a 5% reduction in embodied carbon to achieve 2 points.

An additional point is included as a ‘maybe’ if the project is able to demonstrate a 10% reduction.

MRc2 Building Product Disclosure and Optimization (BPDO) Environmental Product Declarations (v4.1) 1 of 2 points

The project will achieve Option 1: Environmental Product Declaration (EPD) for achievement of 1 point under version 4.1 by specifying at least 20 different permanently installed products sourced from at least five different manufacturers that have compliant EPDs. An emphasis will be placed on product specific EPDs and will support achievement of MRc1 and conducting the LCA. Requirements will be integrated into section 018113 SUSTAINABLE DESIGN REQUIREMENTS and coordinated with technical specification sections.

MRc3: BPDO: Sourcing of Raw Materials (v4.1) 1 of 2 points

The project has targeted achievement of 1 point using LEED v4.1 by specifying products sourced from at least three different manufacturers that meet at least one of the responsible sourcing and extraction criteria for at least 20%, by cost, of the total value of permanently installed building products. It is anticipated the credit will be met through specifying FSC-certified wood, recycled content and regional materials. Requirements will be integrated into section 018113 SUSTAINABLE DESIGN REQUIREMENTS and coordinated with technical specification sections.

MRc4 BPDO: Material Ingredients (v4.1) 1 of 2 points (+ 1 point maybe)

The project is pursuing this credit under Option 1: Material Ingredient Reporting, specifying at least 20 different permanently installed products from at least five different manufacturers that demonstrate the chemical inventory of the product to at least 0.1% (1000 ppm). In accordance with the project’s Sustainable Design Requirements, these inventories will conform to one of the following types:

1. A “Declare” product label indicating Red List Free or Declared.
2. Manufacturer inventory (a complete content inventory for the product)
3. Health Products Declaration
4. Cradle to Cradle Certification
5. ANSI/BIFMA e3 Furniture Sustainability Standard
6. UL Product Lens Certification
7. PACTS – NSF/ANSI 226: Sustainability Assessment for Commercial Furnishings Fabric at any certification level
8. Other USGBC-approved program

An emphasis will be placed on specifying Red List Free products as available to reduce chemicals of concern in the interior environment. Requirements will be integrated into section 018113 SUSTAIANABLE DESIGN REQUIREMENTS and coordinated with technical specification sections.

As a part of the project stretch goal, Option 2 (Material Ingredient Optimization) is being considered for 1 additional point. Under this strategy, project material selection would include over 10 Red List-free materials.

MRc5 Construction and Demolition Waste Management (v4.1) 2 points

The project has targeted 2 points for achievement using version 4.1 under Option 1: Diversion which requires at least a 75% diversion rate plus Path 3 or 4. For an additional innovation credit, the project is also targeting achievement of Option 2: Reduction of Total Waste Material which requires not generating more than 7.5 lbs/sf from new construction activities and diverting at least 75% of demolition waste. Requirements will be integrated into section 017419 CONSTRUCTION AND DEMOLITION WASTE MANAGEMENT AND DISPOSAL.

2.7 Indoor Environmental Quality Credits

IEQ Prerequisite 1: Minimum Indoor Air Quality Performance

In fulfillment of this prerequisite, the project will meet ventilation requirements by providing minimum outdoor air in accordance with ASHRAE Standard 62.1-2010.

IEQ Prerequisite 2: Environmental Tobacco Smoke Control

In fulfillment of this prerequisite, the project will prohibit smoking inside the building, outside the building except in designated areas located at least 25 feet from all entries, outdoor air intakes, and operable windows. The project will abide by MIT's existing Campus Smoking Policy which prohibits smoking in all spaces of all MIT buildings.

EQc1 Enhanced Indoor Air Quality Strategies 2 points

The project will achieve 2 points under Option 1 Enhanced IAQ Strategies and Option 2 Additional enhanced IAQ Strategies. For Option 1, strategies A and C will be achieved by installing permanent entryway systems at least 10 feet long in the primary direction of travel to capture dirt and particulates and will install MERV-13 or higher filters at all AHUs supplying outdoor air to occupied spaces. For Option 2, Option C will be achieved by installing CO2 monitoring in densely occupied spaces.

EQc2 Low-Emitting Materials (v4.1) 2 of 4 points (+ 1 point maybe)

The project will pursue 2 points under this credit by specifying three (3) product categories that meet the low-emitting criteria for VOC content and general emissions evaluation. Flooring, Paints and Coatings, and Furniture have been initially identified for compliance. An additional 1 point has been identified as maybe point if a fourth product category is achieved. Composite wood has been initially identified for achievement. Requirements will be integrated into section 018113 SUSTAINABLE DESIGN REQUIREMENTS and coordinated with technical specification sections.

EQc3 Construction Indoor Air Quality Management Plan 1 point

The project will achieve 1 point by requiring the Contractor to develop and implement an indoor air quality (IAQ) management plan for the construction. The plan will meet or exceed all applicable recommended control measures of the Sheet Metal and Air Conditioning National Contractors Association (SMACNA) IAQ Guidelines for Occupied Buildings under Construction, 2nd edition, 2007, ANSI/SMACNA 008–2008, Chapter 3. Additional measures will be implemented to protect absorptive materials stored on-site and installed from moisture damage. Requirements will be integrated into section 018120 CONSTRUCION INDOOR AIR QUALITY MANAGEMENT.

EQc4 Indoor Air Quality Assessment 2 points

The project will achieve 2 points by requiring the Contractor to pursue Option 2: Air Testing. IAQ testing using LEED-specified methods will be carried out after construction ends and prior to occupancy. Requirements will be integrated into section 018120 CONSTRUCION INDOOR AIR QUALITY MANAGEMENT and 018113 SUSTAIANABLE DESIGN REQUIREMENTS.

EQc5 Thermal Comfort 1 point

The project will achieve 1 point using Option 1, by designing to meet the requirements of ASHRAE Standard 55-2010, Thermal Comfort Conditions for Human Occupancy and providing at least 50% of individual occupant spaces with thermal comfort controls. Additionally, thermal comfort controls will be provided for all shared multi-occupant spaces.

EQc6 Interior Lighting 2 points

The project is pursuing 2 points from this credit using both Option 1: Lighting Control and Option 2: Lighting Quality. In accordance with LEED criteria, at least

90% of individual occupant spaces will contain individual lighting controls, and multi-occupant spaces will contain multizone control systems, separate controls for presentation- or projection- focused lighting, and switches or manual controls located in the same space as the controlled luminaires. At least four of the eight lighting control strategies prescribed in the LEED v4 Reference Guide will be incorporated.

EQc7 Daylight (v4.1) 1 of 3 points (maybe)

The project is tentatively pursuing 1 point under this credit and is conducting daylight analysis to confirm if the credit thresholds are met. Under this strategy, manual or automatic glare-control devices would be installed in all regularly-occupied spaces, and 1 point would be targeted under Option 1: Simulation – Spatial Daylight Autonomy and Annual Sunlight Exposure, demonstrating an average sDA300/50% value for the regularly occupied floor area of at least 40%.

EQc8 Quality Views 1 point (maybe)

The project is tentatively pursuing 1 point under this credit by establishing a direct line of sight to the outdoors via vision glazing for 75% of all regularly occupied floor area, and at least 75% of all regularly occupied floor area having at least two of the four kinds of views listed under this credit description in the LEED v4 Reference Guide. This credit will be confirmed later in the design phase when furniture and office layouts are developed.

2.8 Innovation Credits

IDc1 Pilot Credit: Comprehensive Composting 1 point

The project is pursuing 1 point from this credit using Option 1: Regular compost collection and offsite processing. The design will integrate organic waste receptacles and regular organic waste collection in accordance with the LEED v4 Pilot credit criteria.

IDc2 Innovation – MRc5 C&D Waste 1 point

The project is pursuing 1 point as exemplary performance to achieve both Options under MRc5: Construction and Demolition Waste Management Plan. In addition to achievement of Option 1: Diversion, the project will track Option 2: Reduction of Total C&D Waste material using version 4.1 criteria. This require new construction to not generate more than 7.5 lbs/sf of waste and at least 75% of demolition is salvaged or recycled.

IDc3 Innovation – Design for Active Occupants 1 point

The project is pursuing 1 point from this Innovation credit, meeting the criteria outlined in the LEED v4 Innovation Catalog with the intention of improving the health of occupants through physical activity while reducing environmental impacts. The building has a primary main feature stair at the main entrance that enables occupants to travel between the building entrance floor, occupants' destination floors, and common use floors. In addition, the project will include 7 or more of the 11 features outlined in the LEED v4 Innovation Catalog for this credit. Features, 1, 2, 3, 4, 5, 6 and 8 have been initially identified for compliance.

IDc4 Innovation – Green Building Education 1 point

The project is pursuing 1 point from this Innovation credit, meeting the criteria outlined in the LEED v4 Innovation Catalog with the intention of providing public education focusing on green building strategies and solutions through installed signage. The green building education approach will be *actively* instructional, and incorporate:

1. A comprehensive signage program built into the building's spaces to educate occupants and visitors of the benefits of green buildings.
2. Development of a manual, guidelines, or case study to inform the design of other buildings based on this project's successes.

IDc5 Innovation – Purchasing (Lamps) 1 point

The project will pursue 1 point from this credit by establishing a toxic material source reduction program to reduce the amount of mercury brought onto the building site through purchases of lamps. The project will provide primarily an all-LED lighting design with potential for exceptions in select specialty lighting. Any non-LED lighting installed will be energy efficient and meet the mercury limits established in the LEED credit of an overall building average of 70 picograms of mercury per lumen-hour or less.

IDc6 LEED Accredited Professional 1 point

The project will achieve 1 point by having numerous members of the project team who are current LEED Accredited Professionals (APs) with a Building Design and Construction (BD+C) specialty. The Green Building Design Professional is the sustainability and LEED consultant on the project, Rebecca Hatchadorian of Arup, LEED BD+C credential ID #0010055526.

2.9 Regional Priority Credits

RP Credit – Rainwater Management 1 point (maybe)

The project is tentatively pursuing 1 Regional Priority Credit for exceeding the 2-point threshold for SS Credit 4: Rainwater Management.

RP Credit – Energy Performance 1 point

The project is pursuing 1 Regional Priority Credit for exceeding the 8-point threshold for EA Credit 2: Optimize Energy Performance.

Appendix A

LEED Checklist

LEED v4 for BD+C: New Construction and Major Renovation

Project Checklist

Project Name: MIT Stephen A Schwarzman College of Computing
Date: 9/18/2020
Article 22 Green Building Narrative

D = Design submission & C = Construction Submission

Y	?	N			Integrative Process	1
1			D	Credit	Integrative Process	1

Y	?	N			Location and Transportation	16
13	0	3				
			D	Credit 1	LEED for Neighborhood Development	16
1			D	Credit 2	Sensitive Land Protection (previously developed land)	1
		2	D	Credit 3	High Priority Site	2
5			D	Credit 4	Surrounding Density and Diverse Uses	5
5			D	Credit 5	4.1 Access to Quality Transit (T + bus frequency)	5
1			D	Credit 6	4.1 Bicycle Facilities (5% long term + 2.5% short term)	1
1			D	Credit 7	4.1 Reduced Parking Footprint (option 1 no off street)	1
		1	D	Credit 8	4.1 Green Vehicles (2% or 2 spaces EV charging)	1

Y	?	N			Sustainable Sites	10
3	3	4				
Y			C	Prereq	Construction Activity Pollution Prevention	Required
		1	D	Credit 1	Site Assessment	1
		2	D	Credit 2	Site Development - Restore Habitat (25% site area)	2
		1	D	Credit 3	4.1 Open Space (30% total site area)	1
	3		D	Credit 4	4.1 Rainwater Management	3
2			C	Credit 5	Heat Island Reduction (Option 1)	2
1			D	Credit 6	Light Pollution Reduction	1

Y	?	N			Water Efficiency	11
5	1	5				
Y			D	Prereq	Outdoor Water Use Reduction	Required
Y			D	Prereq	Indoor Water Use Reduction	Required
Y			D	Prereq	Building-Level Water Metering	Required
1		1	D	Credit 1	Outdoor Water Use Reduction (50% reduction)	2
3		3	D	Credit 2	Indoor Water Use Reduction (35% reduction)	6
	1	1	D	Credit 3	Cooling Tower Water Use	2
1			D	Credit 4	Water Metering (2 end uses: irrigation + cafe)	1

Y	?	N			Energy and Atmosphere	33
25	2	6				
Y			C	Prereq	Fundamental Commissioning and Verification	Required
Y			D	Prereq	Minimum Energy Performance	Required
Y			D	Prereq	Building-Level Energy Metering	Required
Y			D	Prereq	Fundamental Refrigerant Management	Required
6			C	Credit 1	Enhanced Commissioning (+BECx + MBCx)	6
18			D	Credit 2	Optimize Energy Performance (38% = 15 pts)	18
1			D	Credit 3	Advanced Energy Metering	1
		2	C	Credit 4	Demand Response	2
		3	D	Credit 5	Renewable Energy (2pts = 5% RP)	3
		1	D	Credit 6	Enhanced Refrigerant Management	1
	2		C	Credit 7	Green Power and Carbon Offsets	2

Y	?	N			Materials and Resources	13
7	2	4				
Y			D	Prereq	Storage and Collection of Recyclables (+ compost)	Required
Y			C	Prereq	Construction and Demolition Waste Management Planning	Required
2	1	2	C	Credit 1	Building Life-Cycle Impact Reduction (5% reduction, 10% or 20%)	5
1		1	C	Credit 2	4.1 BPDO - Environmental Product Declarations (Option 1: 20	2
1		1	C	Credit 3	4.1 BPDO - Sourcing of Raw Materials (20% + 40% cost)	2
1	1		C	Credit 4	4.1 BPDO - Material Ingredients (Option 1: 20 Materials w/HPD)	2
2			C	Credit 5	4.1 C&D Waste Management (Options 1 + 2)	2

Y	?	N			Indoor Environmental Quality	16
10	3	3				
Y			D	Prereq	Minimum Indoor Air Quality Performance	Required
Y			D	Prereq	Environmental Tobacco Smoke Control	Required
2			D	Credit 1	Enhanced Indoor Air Quality Strategies	2
2	1		C	Credit 2	4.1 Low-Emitting Materials (3 or 4 product categories)	3
1			C	Credit 3	Construction Indoor Air Quality Management Plan	1
2			C	Credit 4	Indoor Air Quality Assessment	2
1			D	Credit 5	Thermal Comfort (ASHRAE 55 + 50% occupants have control)	1
2			D	Credit 6	Interior Lighting (option 1: control + quality)	2
	1	2	D	Credit 7	4.1 Daylight	3
	1		D	Credit 8	Quality Views	1
		1	D	Credit 9	Acoustic Performance	1

Y	?	N			Innovation	6
6	0	0				
1			D	Credit 1	Pilot - Comprehensive Composting	1
1			D	Credit 2	Innovation - C&D Waste Management Option 2	1
1			D	Credit 3	Innovation - Design for Active Occupants	1
1			D	Credit 4	Innovation - Green Building Education	1
1			D	Credit 5	Innovation - Purchasing- lamps (Low Mercury Lighting)	1
1			D	Credit 6	LEED Accredited Professional	1

Y	?	N			Regional Priority	4
1	1	2				
	1		D	Credit 1	Regional Priority: SS 4 Rainwater Management (2 points)	1
1			D	Credit 2	Regional Priority: EA 2 Energy Performance (8pt)	1
		1	D	Credit 3	Regional Priority: WE 2 Indoor Water Use (4pt = 40%)	1
		1	D	Credit 4	Regional Priority: EA 5 Renewable Energy	1

Y	?	N		TOTALS	Possible Points:	110
71	12	27				

Massachusetts Institute of Technology

Stephen A. Schwarzman College of Computing

Article 22: Net Zero Narrative

Issue | September 18, 2020 updated October 20. 2020

Job number 271619-00

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Contents

Appendices

1 Project Profile

1.1 Development Characteristics

Table 1. Summary of building development characteristics

Site area:	18,300 ft^2
Existing land use(s) and gross floor area, by use:	Institutional/Academic: 16,119 GFA
Proposed land use(s) and gross floor area, by use:	Institutional/Academic: 170,900 GFA Café: 3,100 GFA Total: 174,000 GFA
Proposed building height(s):	118 ft 9 stories (8 above-grade)
Proposed parking spaces:	0 off street
Proposed bicycle parking spaces (Long and short-term):	71 short-term[1] & 44 long-term

1.2 Green Building Rating System

Table 2. LEED rating system details

Rating system and version:	LEED for Building Design and Construction, New Construction and Major Renovation rating system LEED-BC+C NC v4
Seeking certification?	YES
Rating level:	Gold (60-79 points)
Points targeted:	71

The project is already formally registered with GBCI for certification with the title: MIT Schwarzman College of Computing, project #1000130425. Refer to the Green Building Narrative for full details on LEED certification approach.

[1] Bicycle parking required by Article 6.1 has been updated since the Green Building Report was certified on October 15, 2020 to reflect the final building gross floor area, 174,000 GFA not 173,000 GFA as previously stated.

2 Proposed Design Characteristic

2.1 Building Envelope

2.1.1 Description

Table 3. Envelope assembly descriptions

Roof:	Fluid-applied membrane roof with extensive green roof representing 68% roof area.
Exterior walls/glazing:	Southeast face: Closed cavity façade system with shadowbox Specialty glass curtain wall Other faces: Unitized aluminum-framed curtain wall system
Below-grade walls:	Cast-in-place, reinforced concrete
Below-grade floor:	Framed structural hydrostatic slab
Window-to-Wall ratio:	North façade - 11 % East façade - 30 % South façade - 71% West façade - 45% Whole building - 40%

2.1.2 Thermal Performance

Estimates of the thermal transmittance (U-value) for the building envelope compared to the Massachusetts Stretch Energy Code 780 CMR Chapter 13 amended February 7, 2020 are summarized in the table below. Note that these values represent the performance-based pathway baseline per the results presented later in this report.

The building envelope is a high-performance design that in aggregate exceeds the prescriptive performance of a code compliant baseline. The largest contributors are a window to wall ratio of 40% and high-performance glazing including a double skin south-east façade with low-U-values in excess of code minimums.

Table 4. Envelope thermal performance, Proposed Design vs. Prescriptive Code

	Proposed			Baseline[1]		
	Description (per table above)	**Area (ft2)**	**U-value**	**Description**	**Area (ft2)**	**U-value**
Glazing	Exterior glazing	30,775	SE Façade U-0.20 All other orientations U-0.36	Non-operable glazing	30,596	U-0.42
Roof	Roof	24,000	U-0.032	Insulation entirely above roof deck	24,000	U-0.032
Wall	Above-grade wall	45,715	U-0.055 (R-10 continuous + R-13 cavity)	Steel Framed	45,894	U-0.055
	Below-grade wall	8,800	C-0.119	Below-grade wall	8,800	C-0.119

[1] baseline values are per ASHRAE 90.1-2013 per the energy modeling results later in this report.

2.1.3 Envelope Commissioning Process

MIT has engaged Wiss Janney, Elstner Associates (WJE) as the building envelope commissioning agent. WJE have already been engaged with the project team and informing the curtain wall design. WJE will conduct testing and commissioning of the envelope components and report the results in alignment with LEED v4 criteria for credit EAc1 Enhanced Commissioning Option 2. Details on the BECx process are described in Appendix A.

2.2 Building Systems

The proposed design mechanical and electrical systems are summarized in the table below.

Table 5. Mechanical and electrical system descriptions

Space heating/cooling:	• Use of heat pump chillers at the building utilizing the campus chilled water as a heat sink/source to provide supplemental heating or cooling to the building. • Fan Coil Units (FCUs) provide space heating and cooling for regularly-occupied spaces • Stair unit heaters • Supplemental perimeter heating (Along entire south perimeter on first floor, and along central indented portion of perimeter on upper floors)

	• Electrical and IT room cooling is provided from split-type DX computer room air-conditioning (CRAC) units with roof mounted air-cooled condensing units
Heat rejection:	• The building will be connected to the campus chilled water network for heat rejection & extraction. No cooling towers will be installed at the building. • Cooling supply/return 42°F/58°F Summer, 50°F/60°F Winter • Heating supply/return temperatures 150°F/120°F
Pumps & auxiliary:	• No distribution pumps required for chilled water systems in the building.
Ventilation:	• 30,000 CFM DOAS Air Handling Unit • 8,000 CFM Laboratory Exhaust Fan for damp lab spaces • 2,000 CFM Exhaust Fan system for restrooms, janitors' closets, copy rooms, break rooms, and pantry areas • Stairway pressurization between 0.1-0.35 in-water per 780 CMR 909.20.5 • Transfer air ventilation for circulation spaces
Domestic Hot Water:	• Domestic Hot Water (DHW) heating sourced from campus MTHW loop using duplex MTHW heat exchangers. DHW generated at 140°F. • Master thermostatic mixing value and re-circulation piping system with circulating pumps and balancing vales provided to maintain minimum supply water temperature.
Interior lighting:	• Lighting designed to meet or exceed the efficiency requirements prescribed by Massachusetts Stretch Energy Code 780 CMR Chapter 13 and MIT Design Standards • Lutron ESN networked lighting system for building-wide lighting controls and connected to central system that communicates with MIT's central Quantam system
Exterior lighting:	• Priority to provide safe nighttime lighting environment that meets LEED criteria per BUG methodology and to minimize light spill from the building to Vassar Street. • Exterior lighting to be time clock controlled • Current design includes 6 light poles for pedestrian passageways, 7 light poles along Vassar Street, 96 recessed stair riser lights • LED lighting.
Other equipment:	• Backup power provided by 800 kW air-cooled diesel generator located at roof level in weatherproof enclosure • PV-ready rooftop. Conduit and interconnection breakers will be provided in main electrical switchgear.

2.3 MIT Central Utility Plant

MIT is committed to reducing their carbon footprint in support of the City of Cambridge‘s Net Zero Action Plan. Given our current understanding of available technologies, one potential path for Schwarzman College of Computing (SCC) to achieve net zero would be a de-carbonization of the ISO New England electrical grid and deployment of technologies that can take advantage of grid improvements. MIT has begun to explore ways of decarbonizing the electrical grid which can be seen by MIT’s recent alliance with Boston Medical Center and Post Office Square Redevelopment Corporation in a 25-year power purchase agreement (PPA) enabling the construction of a 60-megawatt solar farm (occupying roughly 650 acres) that otherwise would not have been built. MIT will purchase carbon-free electricity, equating to 40% of our current campus electric use.

As noted above, SCC will be connected to MIT’s central plant infrastructure to obtain chilled water, electricity and MTHW only for domestic hot water demand, not for space heating. There are no technical barriers to the building accepting utilities from a de-carbonized or net-zero carbon source.

MIT will continue to explore opportunities to de-carbonize the central plant. MIT is completing a significant central plant upgrade that will reduce emissions across all campus buildings served by the plant. Coupled with an electric grid that decarbonizes in the future, additional GHG emissions savings will be realized.

There is potential for MIT to further de-carbonize the campus through the deployment of alternate technologies (e.g. heat generated electrically to then produce hot water or steam). MIT will explore these options based on changes in low carbon fuel options and the electrical grid’s carbon intensity. As the grid and technology evolves and improves over time, the strategies for MIT to upgrade their central plant will evolve and will use the latest available technology, which may not currently be understood, to support making a transition that is economically feasible, reliable, and decarbonized.

2.4 Building Systems Commissioning Process

Details on the Cx process are described in Appendix B per MIT Design Standards. The project is pursuing LEED EAc1 Enhanced Commissioning Option 1 Path 2 and will engage a Commissioning agent in design development phase. Additionally, the project is pursuing and will install monitoring-based commissioning using KGS Clockworks system.

3 Anticipated Energy Loads and Greenhouse Gas Emissions

3.1 Assumptions

Early phase energy modeling was performed for the proposed design, as well as a baseline building prescribed by the Massachusetts Stretch Energy Code, 780 CMR Chapter 13 amended February 7, 2020. Modeling was performed using the DOE-approved Integrated Environmental Solutions Virtual Environment (IES-VE) software, version 2019. Energy modeling outcomes for both the baseline model and proposed design are subject to change as the architectural and mechanical design and input assumptions and schedules are refined in the subsequent design phases. Additionally, energy modeling is not exact and is used to compare relative performance between alternatives rather than predicting precise energy consumption, cost, and GHG emissions.

A summary of energy model inputs and more detailed results are provided in Appendix C.

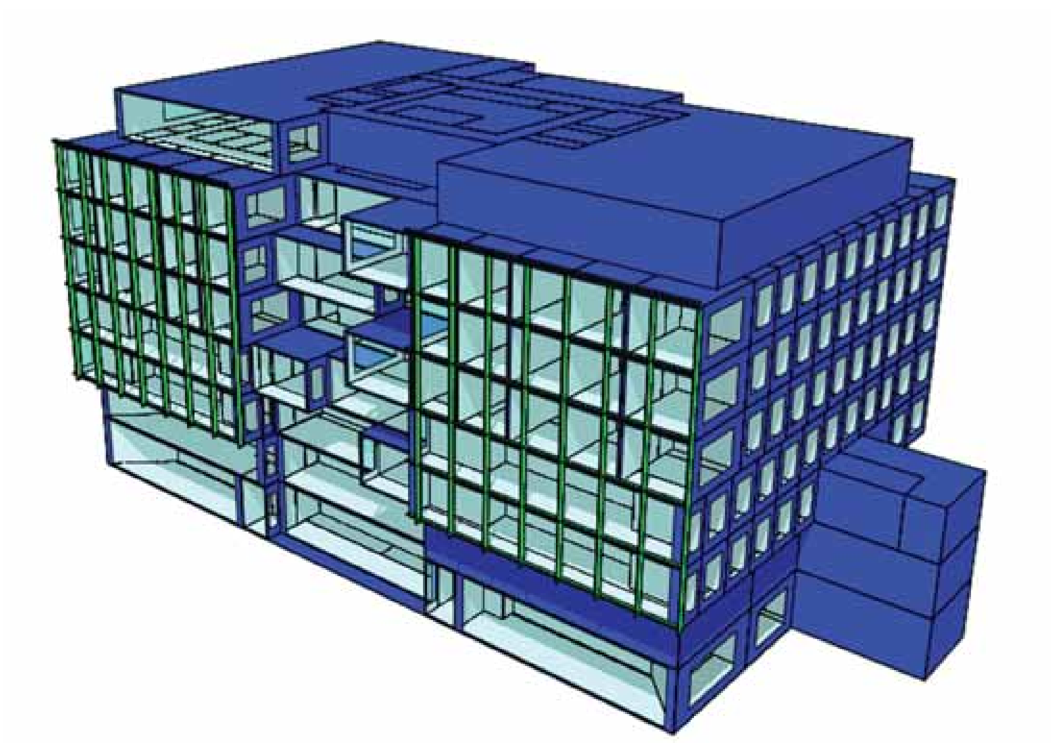

Figure 1. Image of the multizone whole-building energy model in IES-VE software

The proposed building will be supplied by the MIT central utility plant (CUP) for chilled water, electricity and MTHW only for domestic hot water. Energy cost and greenhouse gas (GHG) emissions calculations used the conversion factors from the anticipated CUP plant upgrade; these are summarized in the table below. Note, steam cost and GHG emissions conversion factors have been used for DHW in lieu of MTHW rates which are currently not available.

Table 6. MIT campus utility data per 40MW anticipated values

	Cost	Emissions
Electric	$0.12 / kWh	0.571 lbs / kWh
Steam	$4.10 / MMBtu	144.35 lbs / MMBtu
Campus CHW	$4.74 / MMBtu	66.29 lbs / MMBtu

3.2 Annual Projected Energy Consumption and GHG Emissions

Preliminary energy modelling was completed to determine the proposed design performance against the Stretch Energy Code, 780 CMR, Ninth Edition, Chapter 13: Energy Efficiency Amendments as of 8/7/2020 . In accordance with the requirements, the baseline building incorporates the following three (3) energy conservation measures (ECMs):

1. Reduced lighting power density system in accordance with section C406.3
2. Enhanced lighting controls in accordance with section C406.4
3. High-efficiency service water heating in accordance with section C406.7 (assumes on-site renewable energy service water-heating systems)

The energy model results for annual energy use intensity (EUI) and emissions comparing the baseline and proposed design (BOD) are summarized below.

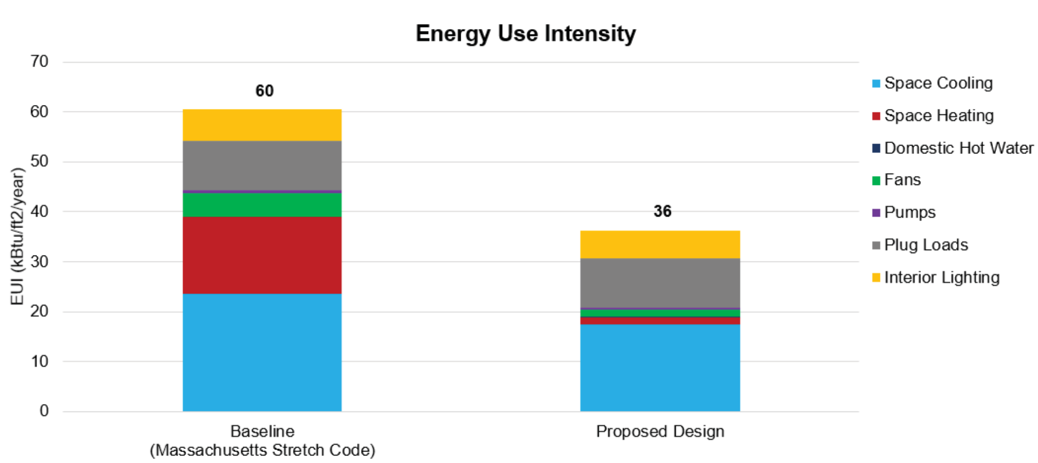

Figure 2. Energy Use Intensity (kBtu/sf/year) of Stretch code baseline and proposed design.

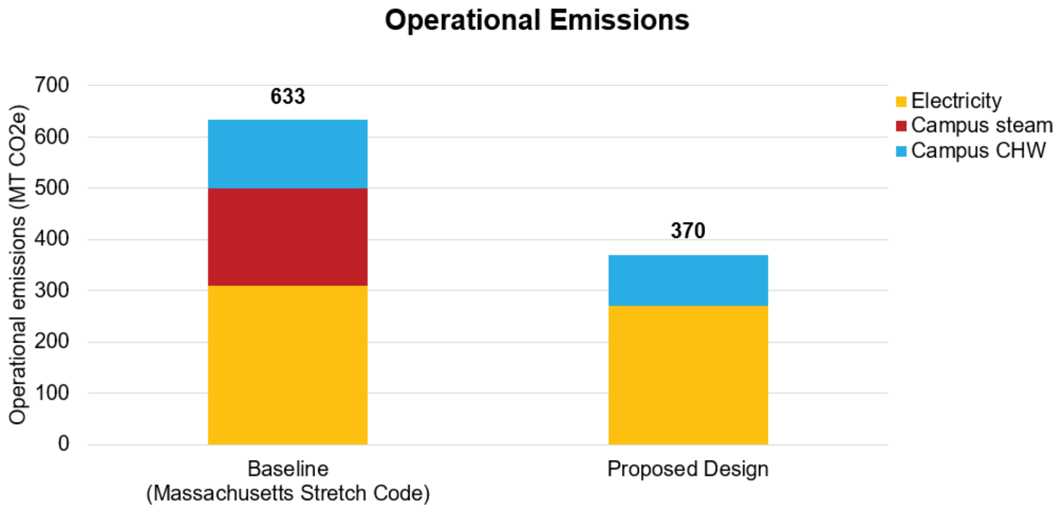

Figure 3. GHG emissions of Stretch energy code baseline and proposed design .

In comparison to the Stretch Energy Code baseline, the proposed design achieves a 40% reduction in energy and a 42% reduction in operational GHG emissions. This far exceeds the minimum Stretch Energy Code requirement for a 10% reduction in energy.

Table 7. Energy model energy and emissions summary[2]

	Baseline		Proposed		Future Scenario[3]	
	Energy (MWh)	% of total	Energy (MWh)	% of total	Energy (MWh)	% of total
Space Heating	850	25%	74	4%	74	4%
Space Cooling	1307	39%	963	48%	963	48%
Heat Rejection	-	0%	-	0%	-	0%
Pumps & Aux	32	1%	22	1%	22	1%
Ventilation	271	8%	79	4%	79	4%
Domestic HW	-	0%	18	1%	18	1%
Int. Lighting	348	10%	310	15%	310	15%
Ext. Lighting	-	0%	-	0%	-	0%
Misc. Equipment	542	16%	542	27%	542	27%
	$US, kBTU, kBTU/SF		$US, kBTU, kBTU/SF	% reduction from baseline	$US, kBTU, kBTU/SF	% reduction from baseline
Total energy cost ($ US)	$176,192		$141,089	20%	$141,089	20%
Total energy use (kBtu)	11,428,338		6,854,965	40%	6,854,965	40%
Site EUI (kBtu/SF)	60		36	40%	36	40%
	MWH	% total energy	MWH	% total energy	MWH	% total energy
On-site renewable energy (MWh)	0	0	0	0	0	0
Off-site renewable energy (MWh)	0	0	0	0	0	0
	Metric tons CO_2[/SF]		Metric tons CO_2[/SF]	%reduction from baseline	Metric tons CO_2[/SF]	% reduction from baseline
GHG emissions (mtCO2e)	633		370	42%	370	42%
GHG emissions (mtCO2e/SF)	0.0034		0.0020	42%	0.0020	42%

The improvement of the proposed design over the Stretch Code baseline is derived from significant heating and cooling energy savings. These savings are a result of the highly efficient heat pump heating and cooling system, the energy

[2] Assumes utility cost and emission rates from the anticipated 40MW CUP upgrade
[3] Refer to section 3.3 for a discussion of the MIT CUP and section 6 for details.

recovery wheel (up to 80% efficient), and the decoupling of space conditioning requirements met by efficient fan coil units and outdoor air requirements met by the central DOAS system with demand control ventilation.

The energy model results incorporate direct consumption of campus chilled water and steam on an energy basis, and don't consider coefficients of performance (COPs) of the campus central utility plant.

4 Building Energy Performance Measures

4.1 Overview

The table below summarizes the ways in which building energy performance has been integrated throughout aspects of the project's planning and design, engineering, and commissioning.

Table 8. Energy performance measures incorporated throughout design

Land uses:	• Adjacency to bicycle paths which connect to the existing Cambridge bicycle network, including 76 short-term and 44 long-term bicycle parking spaces meeting both City of Cambridge and LEED requirements. • Surrounding mixed use density including academic, commercial, and residential space (see LEED LT c3 Surrounding Density and Diverse Uses credit narrative) • Walking distance of public transit options (see LEED LT c4 Access to quality transit credit narrative) • Reduction in impervious surfaces from the existing condition
Building orientation and massing:	• The building massing and orientation is driven primarily by existing conditions with the only street frontage along Vassar Street, and buildings adjacent on both sides. Solar radiation analysis showed that the slight orientation of the south façade to the south east, helps to mitigate solar gains as opposed to a fully south facing façade. • Enhanced double-skin glazing performance on Southeast-facing façade • Regularly occupied spaces and convening spaces have been primarily programmed at the building perimeter for maximum daylighting and quality views for occupants. The central circulation core and with increased glazing on Southeast façade, allows increased daylighting deeper into core spaces of the floor plate.
Envelope systems:	• The Southeast façade incorporates a double skin façade for enhanced thermal performance and thermal comfort of occupants. Shading within the double skin is being assessed for its feasibility and cost benefit. • Concept Phase parametric façade analysis identified sensitivities and drivers of energy performance. • Building envelope commissioning to be completed.

Table 8 (continued)

Mechanical systems:	• High-efficiency heat pump chillers utilizing campus chilled water as a heat sink/source • High-efficiency DOAS system with dynamic v8 filtration and demand-control ventilation. • High-efficiency (up to 80%) energy recovery system on exhaust air to minimize heating and cooling energy consumption. • 4-pipe fan coil units serving regularly occupied spaces • Energy saving measures being explored for lab exhaust systems include customized nozzles to reduce flow rate and reducing or eliminating the need for makeup air, or varying nozzle velocity to reduce flow according to localized wind measurements from an on-site anemometer
Renewable energy systems:	• PV-ready rooftop. Conduit and interconnection breakers will be provided in main electrical switchgear. • Solar PV analysis was conducted for the roof indicating a 138 kW maximum array, capable of producing 179 MWh of carbon-free electricity annually offsetting 46 mtCO2e per MIT's campus electricity emissions factor. An extensive green roof is included in the proposed design.
District-wide energy systems:	• Connection to Central Utility Plant (CUP) providing medium-temperature hot water, chilled water and electricity. • The CUP is currently being expanded to a new high-efficiency, 40 MW system resulting in a reduction of regulated pollutant emissions of approximately 25%. • The chilled water system operates on reset system during winter

4.2 Integrative Design Process

A series of four (4) sustainability focused workshops were held in Programming & Concept Phase, and an additional four (4) in Schematic Design Phase, to collectively refine and review the analysis to support the sustainability and resilience goals and priorities defined in Concept Phase to support a healthy, low carbon building design. Arup has worked collaboratively with MIT, SOM, Reed Hildebrand, and Nitsch Engineering to progress and provide analysis on a range of sustainability strategies so informed decisions could be made.

Through these workshops, the sustainability goals and priorities or project were defined and refined, aligning with the Owner's Project Requirements (OPR) document. These include the following:

- LEED BD+C v4 Gold certification. Refer to the LEED checklist (included with the Green Building Narrative)

- Design the building and project site to be resilient to 2070 flood and heat impacts as defined by MIT and the City of Cambridge Vulnerability Assessment.
- Reduce the existing impervious area within our project boundary and manage stormwater on site as feasible.
- Develop a carbon neutral pathway and set energy and GHG emissions targets for energy use intensity and GHG intensity.
- Track and report on embodied carbon and construction GHG emissions.
- Develop circular economy principles for the project.
- Develop a healthy materials class-based avoidance approach to avoid chemicals of concern and build on the ILFI's Red-List free procurement MIT has already undertaken.

Through design team workshops, the project team established an energy use intensity performance target of 63.8 kBtu/ft2/year, based on a weighted average of the three principle space use types (i.e. office, university and laboratory), area percentages at the time and target EUIs for each, i.e. 45, 75 and 200 kBtu/sf/yr respectively.

4.3 Solar-Ready Roof Assessment

A rooftop solar photovoltaic (PV) analysis was conducted and details are included in Appendix D. The analysis used Helioscope software and assumed high efficiency 340W panels. While the PV system is not incorporated in the proposed project design due to cost feasibility and high payback period, the roof will be designed as solar-ready, meaning that the structural capacity, conduit runs and interconnection breakers will be provided in the main electrical switchgear. An extensive green roof is currently part proposed design. Details related to the project's PV-readiness are summarized in the table below.

Table 9. Solar-ready roof details

Total Roof Area:	24,000 ft2 total roof area 16,486 ft2 extensive green roof area
Modeled Roof Area for PV array:	18,700 ft2
Structural support:	Roof to be rated for between 10 – 40 psf with consideration for future PV installations
Electrical infrastructure:	Conduit and interconnection breakers to be provided in main electrical switchgear.
Capacity of solar array:	138.4 kW module DC nameplate 110.8 kW inverter AC nameplate 179.0 MWh annual production

Financial incentives:	As a non-profit, MIT is not eligible for the Federal Tax Incentive. The SMART program was not assessed as MIT would want to retain the renewable attribute of the solar PV electricity generated.

4.4 Green Building Incentive Program Assistance

The project will involve utility rate incentives through a Memorandum of Understanding (MOU) with Eversource. MIT has engaged Eversource at concept design to begin the Technical Analysis process. The Integrated Design Path for Large Buildings is provided by the Mass Save Program Administrators (Eversource) for projects greater than 100,000 square feet. Eversource and MIT have hired a third-party Engineer to evaluate potential energy saving measures through energy modeling compared to the state energy code baseline. Eversource will be part of the integrative design process through design development. The results of the energy model and pricing exercise will be used to determine utility incentives as well as aid in system decision making.

5 Net Zero Scenario Transition

In October 2015, MIT committed to reduce its GHG emissions a minimum of 32% by 2030 from a 2014 baseline. In the fall of 2016, MIT advanced its climate change mitigation efforts by joining with two local partners, Boston Medical Center and Post Office Square Redevelopment Corporation in a 25-year power purchase agreement (PPA) with Dominion Resources, a Virginia-based utility. The PPA enabled the construction of Summit Farms, a roughly 650-acre, 60-megawatt solar farm that otherwise would not have been built. At the time, it was the largest aggregated renewable-energy purchase by such an alliance of organizations in the U.S.

The impact of this initial PPA on MIT's carbon footprint is equivalent to more than half (17%) of the 32% emissions reductions MIT committed to in its Plan for Action on Climate Change, announced on Oct. 21, 2015

As of 2019, net emissions are 18% below the 2014 baseline.

The table below summarizes the technical framework by which the proposed project can be transitioned to net zero greenhouse gas emissions in the future, including the future condition and process of transitioning from the proposed design to the future condition.

It is important note that the current upgrade and expansion of MIT's CUP will reduce the emissions associated with campus utilities. A comparison of the FY19 utility emissions factors with the anticipated 40MW utility emissions factors are provided below.

Campus Utilities carbon emissions		FY19	40MW anticipated	% reduction
Campus CHW	lbs CO2e /MMBtu	80.05	66.29	17%
Campus Steam	lbs CO2e /MMBtu	150.59	144.35	4%
Campus Electricity	lbs CO2e /kWh	0.639	0.571	11%

As such, the project at initial opening will benefit from this significant investment in the CUP and GHG emissions reduction.

Table 10. Details for net-zero scenario transition

	Net zero condition	Transition process
Building envelope:	The proposed design incorporates a high-performance façade that exceeds prescriptive code compliance to minimize thermal loads and reduce the demands for heating and cooling systems. A 40% window to wall ratio, double skin south east façade and green roof all contribute to the high-performance enclosure. The façade has been designed for a 50-year life and will be commissioned.	The building is being designed with a high-performance envelope that will be maintained throughout its useful life. It is not anticipated that the building envelope will play a significant role in transitioning to Net Zero.
HVAC systems:	The proposed design will be connected to the campus CUP chilled water network. The CUP currently utilizes natural gas and electricity energy sources to generate thermal energy and electricity for the campus. An upgrade and expansion project is underway to expand the CUP to 40MW and reduce GHG emission associated with campus utilities. The project has therefore focused on demand reduction and as demonstrated above is a highly energy efficient building design, exceeding the new Stretch Energy Code by 40%. As equipment reaches its end of life, opportunities for further efficiency will be evaluated but it is anticipated the building will remain connected to the CUP into the future. Therefore, the building's Net Zero approach will significantly rely on the CUP transitioning away from natural gas and procurement of off-site renewables.	Refer to section below on the MIT CUP transition. There are no technical barriers to the building accepting utilities from a de-carbonized or net-zero carbon source.
Domestic hot water:	The proposed system will be connected to campus MTHW utility.	DHW will continue to be provided by the campus MTHW utility. As the CUP decarbonizes over time, this end use will also decarbonize.

Lighting:	High-efficiency lighting with occupant controls. Lighting will utilize LED and low lighting power densities by space type.	It is not anticipated that significant additional energy savings will be realized through lighting. As lighting relies on electricity, the transition to Net Zero relies on off-site renewable electricity supply.
Renewable energy systems:	The roof is being designed to be PV-ready roof. PV analysis identified that a maximum 138 kW system could be installed using 340W panels which is a small percentage of the predicted annual energy consumption of the highly energy efficient building.	MIT will assess the cost benefit of on-site versus off-site renewable energy procurement to transition to Net Zero. Without significant advancement in PV panel efficiency, on-site solar PV will only contribute a very small amount to a Net Zero transition. As such, the project will rely on off-site renewable energy to achieve Net Zero. It is anticipated that off-site renewable energy contracts will be a key component of the transition to Net Zero at MIT, potentially also including carbon offset. These decisions will be made on at a campus level and not particular to one (1) building project.

Appendix A

Building Envelope Commissioning Plan

A1 Building Envelope Commissioning

The BECx process is summarized below, as outlined in the MIT BECx Project Commissioning Manual (PCM). The components to be tested and the corresponding test criteria include:

- Waterproofing of below-grade construction including foundations, basements, and slab-on-grade that functions as part of the exterior enclosure system.
- Superstructure floor and roof construction that functions as part of the exterior enclosure system.
- Exterior enclosure construction, above grade, including exterior opaque walls, windows, and doors including sheathing, framing, and insulation, and interior finish materials attached to the exterior wall.
- Roofing, including roofing system, roofing insulation, and skylights, hatches, and other roof openings.

Table 11. Envelope components and BECx test criteria

Component	Test Criteria
Fenestration & Curtain Wall	Any significant leakage identified will be assessed to determine if a specific cause can be identified and addressed to prevent during full-scale installation.
	Maximum air leakage of 0.10 cfm/ft at an air pressure differential of 6.24 psf.
	No uncontrolled water leakage when tested under a pressure difference of 8.0 lbf/sq. ft.
Air Barrier Assemblies	No major air leaks. A major leak is defined as air and smoke are visible and easily detectable by hand within one inch of the leak location(s). Pass/fail criteria shall be no bubbles observed in the leak detection liquid at 1.57 psf.
Sealant	Sealant pull testing shall be performed on sealant joints installed through the building enclosure. Pass/fail criteria shall require all sealants fail cohesively within themselves at or above the minimum manufacturer's anticipated elongation percentage.
Dynamic Water	575 Pa (12.0 psf). Failure Criteria will need to be determined prior to testing.
Dynamic Water	Water infiltration
Whole Building Performance	LEED Homes Mid Rise Testing

Appendix B

HVAC Systems Commissioning Plan

B1 HVAC Systems Commissioning Plan

The HVAC commissioning process will cover the following components and phases, with all pre-functional testing, functional testing, and reporting to be carried out by a dedicated commissioning agent (CxA) and as outlined in the MIT Project Commissioning Manual (PCM).

A CxA will be engaged in design development phase for a scope of work that meets MIT Standards and LEED v4 EAc1 Enhanced Commissioning requirements.

Table 12. Building systems commissioning scope of work

Component / Phase	Scope
Recirculating air handling units	• Chilled water system • Controls • Associated supply, transfer, return and exhaust fans • Terminal units
100% outside air and exhaust air handling units	• Chilled water system • Steam system • Associated supply and exhaust fan systems • Supply and exhaust terminal units • Controls
Supply and exhaust fans	• Controls • Terminal equipment
Terminal units	• Constant volume and VAV boxes w/and w/o reheat coils (supply and exhaust) • Laboratory supply and exhaust flow controls • Fan coil units (FCU, FCW, FCH, FCA) • Radiation (FTR) • Chilled Beams • Unit heaters (UH, CUH, RR, PR) • In duct heating coils (RHC) • Return air systems • Heat Exchanger and Pumps (HW)
Chilled water systems	• Chilled water • Chilled Beam active and passive systems • Chilled Beam water/pumps • Distribution Equipment (AHU, AC, FCU, FCW, FCH, FCA)

Hot water systems	• Lab heating • Radiation heating • Heat exchangers • Pumps, AD, ET • VFD • Distribution Equipment (UH, CUH, RR, PR, RHC)
Fuel oil system	• Emergency generator fuel oil day tank transfer systems. • Storage tank and FOP 1&2 pumping transfer systems
Control systems	• Building automation system (BAS) • Fume hood control & laboratory control • HVAC and Exhaust systems • Atrium smoke management • Pneumatic air system • AHU and conference room CO2 sensing and control • Energy meters • Spectroscopy complete lab control sequences
Testing and balancing (TAB) phase	• TAB water-side • TAB air-side • TAB equipment and systems • TAB electrical

Appendix C

Energy Model Detailed Assumptions and Results

Appendix C. Energy modeling detailed inputs and results

Input
Calculation
Notes

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ZONE TYPES

Name	Conditioned (Y/N)	Thermostat Schedule	Heating SP (°F)	Heating Setback (°F)	Cooling SP (°F)	Cooling Setback (°F)	Zone Level DCV (Y/N)	DCV SP (ppm)	Source/Comments
Auditorium	Y	7 days, 8am - 10pm	70.0	65.0	74.0	80.0	Y	800	Setpoints and schedules per OPR dated 2020-03-25
Café	Y	7 days, 8am - 10pm	70.0	65.0	74.0	80.0	Y	800	Setpoints and schedules per OPR dated 2020-03-25
Circulation	Y	7 days, 8am - 10pm	70.0	65.0	74.0	80.0	Y	800	Setpoints and schedules per OPR dated 2020-03-25
Classroom	Y	7 days, 8am - 10pm	70.0	65.0	74.0	80.0	Y	800	Setpoints and schedules per OPR dated 2020-03-25
Conference	Y	7 days, 8am - 10pm	70.0	65.0	74.0	80.0	Y	800	Setpoints and schedules per OPR dated 2020-03-25
IT	Y	24/7	70.0	65.0	74.0	80.0	N		
Elevators	N		N/A	N/A	N/A	N/A	N		
Laboratory - Dry	Y	7 days, 8am - 10pm	70.0	65.0	74.0	80.0	Y	800	Setpoints and schedules per OPR dated 2020-03-25
Lobby	Y	7 days, 8am - 10pm	70.0	65.0	74.0	80.0	Y	800	Setpoints and schedules per OPR dated 2020-03-25
MEP	N		70.0	65.0	74.0	80.0	N		
Office - Open	Y	7 days, 8am - 10pm	70.0	65.0	74.0	80.0	Y	800	Setpoints and schedules per OPR dated 2020-03-25
Office - Private	Y	7 days, 8am - 10pm	70.0	65.0	74.0	80.0	Y	800	Setpoints and schedules per OPR dated 2020-03-25
Restroom	N		70.0	65.0	74.0	80.0	N		
Stairwells	N		70.0	65.0	74.0	80.0	N		
Storage	N		N/A	N/A	N/A	N/A	N		

Input
Calculation
Notes

Internal Gains

Zone Types

Name	Occ. Density (ft²/person)	Occ. Schedules	Equipment Power Density (W/ft²)	Equipment Schedules	Lighting Power Density (Baseline) (W/ft²)	Lighting Power Density (Proposed) (W/ft²)	Lighting Schedules	Infiltration (cfm/ft² facade)	Source/Comments
Auditorium	50	Occupancy_Classroom	0.25	Equipment_Classroom	0.71	0.61	Lighting_Classroom	0.08 cfm/ft2 façade	
Café	100	Occupancy_Cafe	0.1	Equipment_Cafe	0.86	0.4	Lighting_Cafe	0.08 cfm/ft2 façade	
Circulation	75	Occupancy_Office	0.5	Equipment_Office	0.41	0.41	Lighting_Office	0.08 cfm/ft2 façade	
Classroom	75	Occupancy_Classroom	0.5	Equipment_Classroom	0.71	0.71	Lighting_Classroom	0.08 cfm/ft2 façade	
Conference	75	Occupancy_Office	0.75	Equipment_Office	0.97	0.97	Lighting_Office	0.08 cfm/ft2 façade	
IT	N/A		25		0.43	0.94		0.08 cfm/ft2 façade	
Elevators	N/A		N/A		0.84	0.84		0.08 cfm/ft2 façade	
Laboratory - Dry	75	Occupancy_Lab	3	Equipment_Lab	1.11	1.11	Lighting_Lab	0.08 cfm/ft2 façade	
Lobby	75	Occupancy_Lobby	0.25	Equipment_Lobby	0.84	0.84	Lighting_Lobby	0.08 cfm/ft2 façade	
MEP	N/A		1		0.43	0.43		0.08 cfm/ft2 façade	
Office - Open	275	Occupancy_Office	0.75	Equipment_Office	0.61	0.61	Lighting_Office	0.08 cfm/ft2 façade	
Office - Private	275	Occupancy_Office	0.75	Equipment_Office	0.74	0.74	Lighting_Office	0.08 cfm/ft2 façade	
Restroom	275		N/A		0.98	0.63		0.08 cfm/ft2 façade	
Stairwells	N/A		N/A		0.49	0.49		0.08 cfm/ft2 façade	
Storage	N/A		N/A		0.51	0.51		0.08 cfm/ft2 façade	

Input
Calculation
Notes

Envelope

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	Units	Baseline	BOD	Source/Comments
OPAQUE ENVELOPE				
Wall type/name		Exterior wall assembly - Steel-framed	Proposed exterior wall assembly	
Wall conduction	hr-ft²-F/Btu (R-Value)	18.18	18.18	
Roof type/name		Roof assembly - Insulation entirely above roof deck	Proposed roof assembly	
Roof conduction	hr-ft²-F/Btu (R-Value)	31.25	31.25	
Slab type/name		Slab	Slab	
Slab conduction	Btu/hr-ft-F (F-factor)	0.73	0.73	
Infiltration	(cfm/ft² facade)	0.08	0.08	Inputs at standard pressure
GLAZING (VERTICAL)				
Window type/name		Non-operable metal-frame glazing	Exterior glazing assembly	
WWR	%	22% overall (Applied to each face in same proportion as BOD)	North façade - 11 % East façade - 30 % South façade - 71 % West façade - 45 % Whole building - 40%	
Window conduction	Btu/hr-ft²-F (U-Value)	U-0.42	SE double skin: U-0.2 All other glazing: U-0.36	
Window SHGC	SHGC	0.4	SE double skin: U-0.39 All other glazing: U-0.38	
Window VLT	%	0.76	0.73	
SKYLIGHTS				
Skylight type/name		N/A	N/A	
Skylight-to-Roof ratio	%	N/A	N/A	
Skylight conduction	Btu/hr-ft²-F (U-Value)	N/A	N/A	
Window SHGC	SHGC	N/A	N/A	
Window VLT	%	N/A	N/A	

Energy Model Input Summary

Input
Calculation
Notes: Baseline per 90.1 2016

Detailed HVAC Information

	Units	Baseline	Proposed Design	Source/Comments
HVAC Airside				
System Type		Occupied zones: ASHRAE 90.1-2013 PRM System 7 VAV (1 per floor) IT rooms: ASHRAE 90.1-2013 PRM System 3 Packaged single-zone AC	DOAS / FCU Auditorium displacement ventilation Radiant heating/cooling at ground level café/circulation	
Total Cooling Capacity	kBtu/h	Autosized	Autosized	
Total Heating Capacity	kBtu/h	Autosized	Autosized	
Supply Airflow	cfm	Autosized	Autosized	
Outdoor Airflow	cfm	Autosized	Autosized	
Demand Controlled Ventilation	(Y/N)	N	Y	
Economizer High Limit Shutoff	(°F)	70	70	
Supply Air Temperature Reset	(°F)	See "Space Types' tab	See "Space Types' tab	
Energy Recovery	(Y/N)	Yes, for baseline VAV systems qualifying for exhaust air energy recovery per ASHRAE 90.1-2013 Section 6.5.6.1	Y	
Energy Recovery Effectiveness	%	50	82	
Supply fan power	kW	Autosized	Autosized	
Return or relief fan power	kW	Autosized	Autosized	
Exhaust fan power	kW	Autosized	Autosized	
System Minimum Turndown	%	0	10	
HVAC Waterside - Cooling System				
Cooling type		Campus CHW	Heat Pump Chiller connected to Campus CHW network	
Number and type of chillers (and capacity per chiller if more than one type or size of chiller)		Campus CHW	1 heat pump chiller	
Total cooling capacity	Tons	Autosized	Autosized	
Chilled water (CHW) supply temp	(°F)	44	44	
CHW ΔT	(°F)	16	16	
Distribution Heat Loss (if applicable)		5%	5%	
HVAC Waterside - Heating System				
Heating type		Campus steam	Heat pump chiller extracting heat from campus CHW network	
Total heating capacity	kBtu/h	Autosized	Autosized	
HHW Return	(°F)	105	105	
HHW Supply	(°F)	140	140	

Input
Calculation
Notes

Schedules

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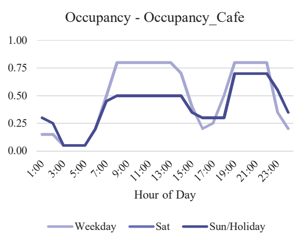
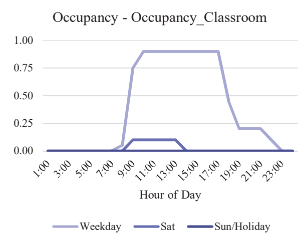
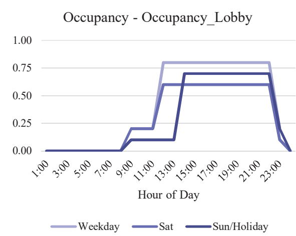
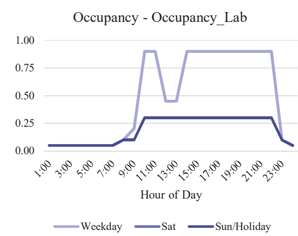
Occupancy

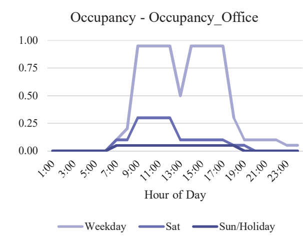
Occupancy	Schedule	Day of Week	1:00	2:00	3:00	4:00	5:00	6:00	7:00	8:00	9:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00	17:00	18:00	19:00	20:00	21:00	22:00	23:00	0:00	Source/Comments
Occupancy - Occupancy_Cafe	Occupancy_Cafe	Weekday	0.15	0.15	0.05	0.05	0.05	0.20	0.50	0.80	0.80	0.80	0.80	0.80	0.80	0.70	0.40	0.20	0.25	0.50	0.80	0.80	0.80	0.80	0.35	0.20	Schedule applied for cafe space Based on ASHRAE 90.1-2016 User's Manual restaurant schedules Morning hours adjusted to reflect building schedule
		Sat	0.30	0.25	0.05	0.05	0.05	0.20	0.45	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.35	0.30	0.30	0.30	0.70	0.70	0.70	0.70	0.55	0.35	
		Sun/Holiday	0.30	0.25	0.05	0.05	0.05	0.20	0.45	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.35	0.30	0.30	0.30	0.70	0.70	0.70	0.70	0.55	0.35	
Occupancy - Occupancy_Classroom	Occupancy_Classroom	Weekday	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.05	0.75	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.45	0.20	0.20	0.20	0.10	0.00	0.00	Schedule applied for classroom and auditorium spaces Based on ASHRAE 90.1-2016 User's Manual school schedules Afternoon and evening schedule adjusted to reflect MIT class schedule
		Sat	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.10	0.10	0.10	0.10	0.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
		Sun/Holiday	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
Occupancy - Occupancy_Lobby	Occupancy_Lobby	Weekday	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.20	0.20	0.20	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.20	0.00	Schedule applied for lobby spaces Based on ASHRAE 90.1-2016 User's Manual assembly schedules Evening hours adjusted to reflect building schedule
		Sat	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.20	0.20	0.20	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.10	0.00	
		Sun/Holiday	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.10	0.10	0.10	0.10	0.10	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.20	0.00	
Occupancy - Occupancy_Lab	Occupancy_Lab	Weekday	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.10	0.20	0.90	0.90	0.45	0.45	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.10	0.05	Schedule applied for lab spaces Based on ASHRAE 90.1-2016 User's Manual laboratory schedules Evening hours adjusted to reflect building schedule
		Sat	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.10	0.10	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.10	0.05	
		Sun/Holiday	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.10	0.10	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.10	0.05	
Occupancy - Occupancy_Office	Occupancy_Office	Weekday	0.00	0.00	0.00	0.00	0.00	0.00	0.10	0.20	0.95	0.95	0.95	0.95	0.50	0.95	0.95	0.95	0.95	0.30	0.10	0.10	0.10	0.10	0.05	0.05	Schedule applied for office, conference, and corridor spaces Based on ASHRAE 90.1-2016 User's Manual office schedules
		Sat	0.00	0.00	0.00	0.00	0.00	0.00	0.10	0.10	0.30	0.30	0.30	0.30	0.10	0.10	0.10	0.10	0.10	0.05	0.05	0.00	0.00	0.00	0.00	0.00	
		Sun/Holiday	0.00	0.00	0.00	0.00	0.00	0.00	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.00	0.00	0.00	0.00	0.00	0.00	





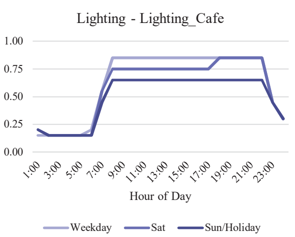


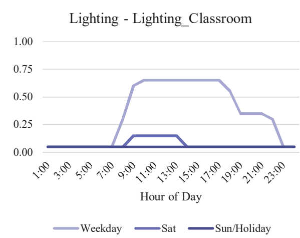


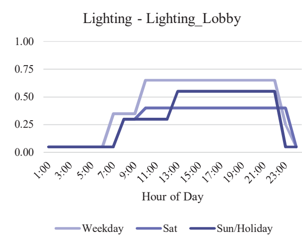


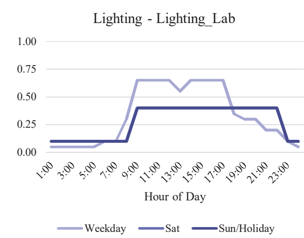
Lighting

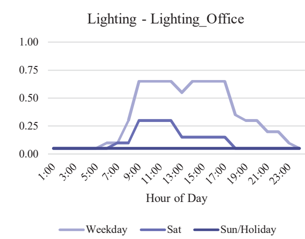
Lighting		Schedule	Day of Week	1:00	2:00	3:00	4:00	5:00	6:00	7:00	8:00	9:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00	17:00	18:00	19:00	20:00	21:00	22:00	23:00	0:00	Source/Comments
Lighting - Lighting_Cafe		Lighting_Cafe	Weekday	0.15	0.15	0.15	0.15	0.15	0.20	0.55	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.45	0.30	Schedule applied for cafe space Based on ASHRAE 90.1-2016 User's Manual restaurant schedules Morning hours adjusted to reflect building schedule
			Sat	0.20	0.15	0.15	0.15	0.15	0.15	0.55	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.85	0.85	0.85	0.85	0.85	0.45	0.30	
			Sun/Holiday	0.20	0.15	0.15	0.15	0.15	0.15	0.45	0.65	0.65	0.65	0.65	0.65	0.65	0.65	0.65	0.65	0.65	0.65	0.65	0.65	0.65	0.65	0.45	0.30	
Lighting - Lighting_Classroom		Lighting_Classroom	Weekday	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.30	0.60	0.65	0.65	0.65	0.65	0.65	0.65	0.65	0.65	0.55	0.35	0.35	0.35	0.30	0.05	0.05	Schedule applied for classroom and auditorium spaces Based on ASHRAE 90.1-2016 User's Manual school schedules Weekdays adjusted to reflect MIT class schedule
			Sat	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.15	0.15	0.15	0.15	0.15	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	
			Sun/Holiday	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	
Lighting - Lighting_Lobby		Lighting_Lobby	Weekday	0.05	0.05	0.05	0.05	0.05	0.05	0.35	0.35	0.35	0.65	0.65	0.65	0.65	0.65	0.65	0.65	0.65	0.65	0.65	0.65	0.65	0.65	0.25	0.05	Schedule applied for lobby spaces Based on ASHRAE 90.1-2016 User's Manual assembly schedules Evening hours adjusted to reflect building schedule
			Sat	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.30	0.30	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.05	
			Sun/Holiday	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.30	0.30	0.30	0.30	0.30	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.05	0.05	
Lighting - Lighting_Lab		Lighting_Lab	Weekday	0.20	0.20	0.20	0.20	0.20	0.20	0.30	0.50	0.90	0.90	0.90	0.90	0.80	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.30	0.20	Schedule applied for lab spaces Based on ASHRAE 90.1-2016 User's Manual laboratory schedules Evening hours adjusted to reflect building schedule
			Sat	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.10	0.10	
			Sun/Holiday	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.10	0.10	
Lighting - Lighting_Office		Lighting_Office	Weekday	0.05	0.05	0.05	0.05	0.05	0.10	0.10	0.30	0.65	0.65	0.65	0.65	0.55	0.65	0.65	0.65	0.65	0.35	0.30	0.30	0.20	0.20	0.10	0.05	Schedule applied for office, conference, and corridor spaces Based on ASHRAE 90.1-2016 User's Manual office schedules
			Sat	0.05	0.05	0.05	0.05	0.05	0.05	0.10	0.10	0.30	0.30	0.30	0.30	0.15	0.15	0.15	0.15	0.15	0.05	0.05	0.05	0.05	0.05	0.05	0.05	
			Sun/Holiday	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	





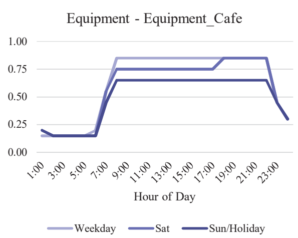


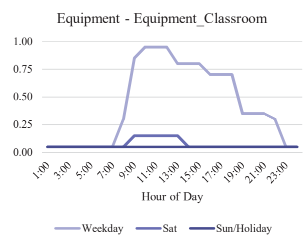


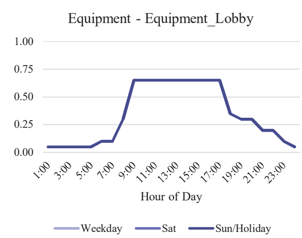


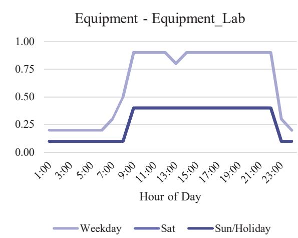
Equipment

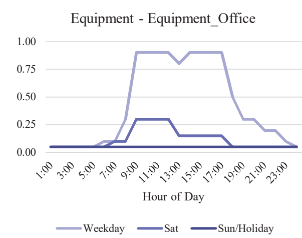
	Schedule	Day of Week	1:00	2:00	3:00	4:00	5:00	6:00	7:00	8:00	9:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00	17:00	18:00	19:00	20:00	21:00	22:00	23:00	0:00	Source/Comments
Equipment - Equipment_Cafe	Equipment_Cafe	Weekday	0.15	0.15	0.15	0.15	0.15	0.20	0.55	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.45	0.30	Schedule applied for cafe space Based on ASHRAE 90.1-2016 User's Manual restaurant schedules Morning hours adjusted to reflect building schedule
		Sat	0.20	0.15	0.15	0.15	0.15	0.15	0.55	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.85	0.85	0.85	0.85	0.85	0.45	0.30	
		Sun/Holiday	0.20	0.15	0.15	0.15	0.15	0.15	0.45	0.65	0.65	0.65	0.65	0.65	0.65	0.65	0.65	0.65	0.65	0.65	0.65	0.65	0.65	0.65	0.45	0.30	
Equipment - Equipment_Classroom	Equipment_Classroom	Weekday	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.30	0.85	0.95	0.95	0.95	0.80	0.80	0.80	0.70	0.70	0.70	0.35	0.35	0.35	0.30	0.05	0.05	Schedule applied for classroom and auditorium spaces Based on ASHRAE 90.1-2016 User's Manual school schedules Weekdays adjusted to reflect MIT class schedule
		Sat	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.15	0.15	0.15	0.15	0.15	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	
		Sun/Holiday	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	
Equipment - Equipment_Lobby	Equipment_Lobby	Weekday	0.05	0.05	0.05	0.05	0.05	0.10	0.10	0.30	0.65	0.65	0.65	0.65	0.65	0.65	0.65	0.65	0.65	0.35	0.30	0.30	0.20	0.20	0.10	0.05	Schedule applied for lobby spaces Based on ASHRAE 90.1-2016 User's Manual office schedules Evening and weekend hours adjusted to reflect building schedule
		Sat	0.05	0.05	0.05	0.05	0.05	0.10	0.10	0.30	0.65	0.65	0.65	0.65	0.65	0.65	0.65	0.65	0.65	0.35	0.30	0.30	0.20	0.20	0.10	0.05	
		Sun/Holiday	0.05	0.05	0.05	0.05	0.05	0.10	0.10	0.30	0.65	0.65	0.65	0.65	0.65	0.65	0.65	0.65	0.65	0.35	0.30	0.30	0.20	0.20	0.10	0.05	
Equipment - Equipment_Lab	Equipment_Lab	Weekday	0.20	0.20	0.20	0.20	0.20	0.20	0.30	0.50	0.90	0.90	0.90	0.90	0.80	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.30	0.20	Schedule applied for lab spaces Based on ASHRAE 90.1-2016 User's Manual laboratory schedules Evening hours adjusted to reflect building schedule
		Sat	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.10	0.10	
		Sun/Holiday	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.10	0.10	
Equipment - Equipment_Office	Equipment_Office	Weekday	0.05	0.05	0.05	0.05	0.05	0.10	0.10	0.30	0.90	0.90	0.90	0.90	0.80	0.90	0.90	0.90	0.90	0.50	0.30	0.30	0.20	0.20	0.10	0.05	Schedule applied for office, conference, and corridor spaces Based on ASHRAE 90.1-2016 User's Manual office schedules
		Sat	0.05	0.05	0.05	0.05	0.05	0.05	0.10	0.10	0.30	0.30	0.30	0.30	0.15	0.15	0.15	0.15	0.15	0.05	0.05	0.05	0.05	0.05	0.05	0.05	
		Sun/Holiday	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	





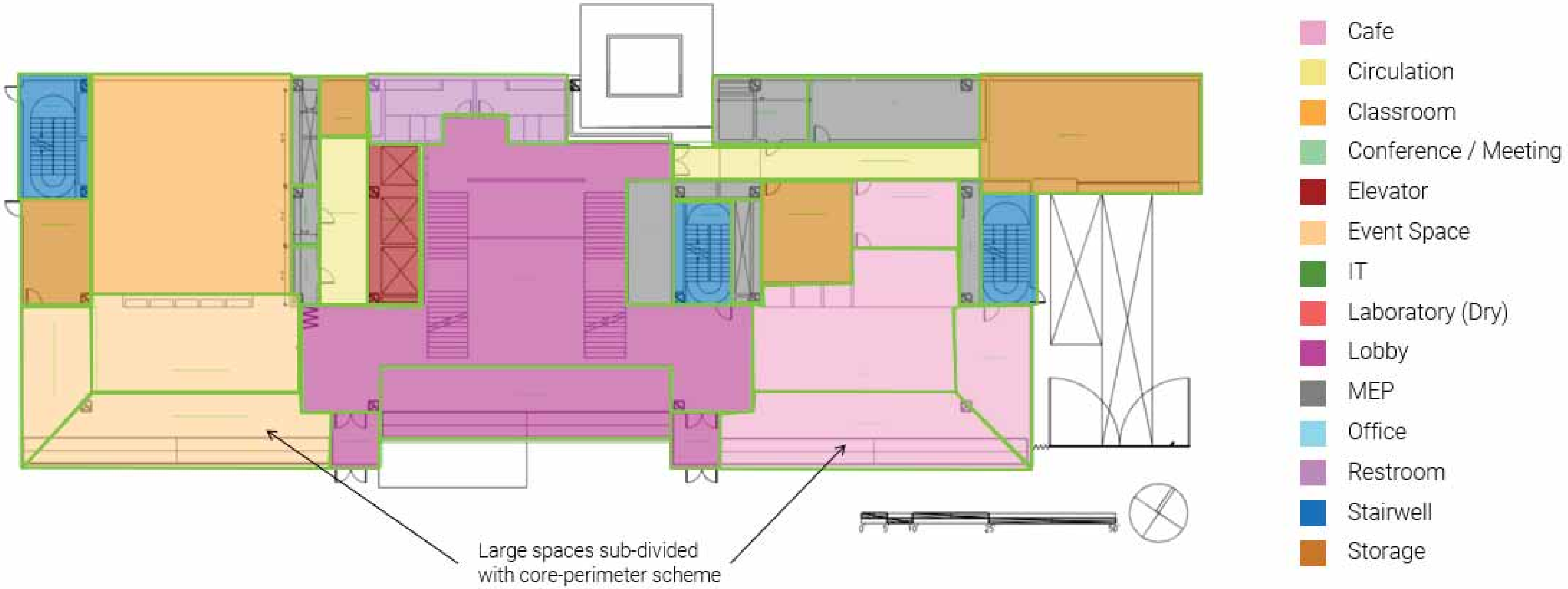






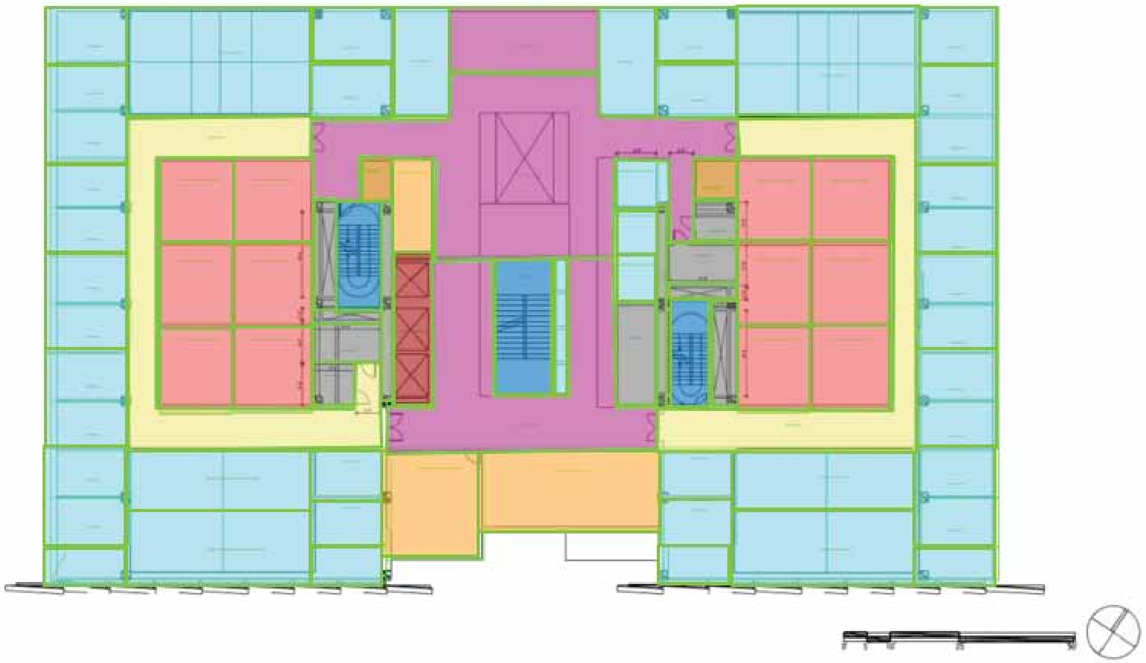
Energy model

Thermal Zoning – Level 1



Energy model

Thermal Zoning– Typical Levels 4-7



MIT SCHWARZMAN COLLEGE OF COMPUTING
SKIDMORE, OWINGS & MERRILL LLP

RESULTS (MWh)
Baseline (Massachusetts Stretch Energy Code)

Date	Interior Lighting	Receptacle Equipment	Space Heating	Service Water Heating	Space Cooling	Heat Rejection	Interior Central Fans	Exhaust Fans	Pumps
Jan	30.15	47.19	140.17	0.00	17.41	0.00	23.47	0.00	2.18
Feb	26.68	41.55	103.81	0.00	15.34	0.00	21.12	0.00	1.74
Mar	28.71	44.42	86.82	0.00	23.40	0.00	22.85	0.00	1.75
Apr	28.99	45.31	61.89	0.00	35.16	0.00	22.52	0.00	1.80
May	29.49	45.88	45.54	0.00	121.66	0.00	21.90	0.00	2.72
Jun	28.21	43.85	44.01	0.00	190.66	0.00	21.36	0.00	3.44
Jul	30.15	47.19	43.41	0.00	307.13	0.00	24.75	0.00	4.65
Aug	28.71	44.42	43.65	0.00	290.90	0.00	22.81	0.00	4.53
Sep	28.99	45.31	38.14	0.00	178.39	0.00	21.98	0.00	3.11
Oct	30.15	47.19	54.49	0.00	78.55	0.00	23.31	0.00	2.28
Nov	27.55	42.54	79.71	0.00	27.64	0.00	21.69	0.00	1.82
Dec	30.15	47.19	108.05	0.00	20.42	0.00	23.41	0.00	1.92
Summed total	347.95	542.05	849.68	0.00	1306.67	0.00	271.16	0.00	31.95

RESULTS (MWh)
Proposed Design

Date	Interior Lighting	Receptacle Equipment	Space Heating	Service Water Heating	Space Cooling	Heat Rejection	Interior Central Fans	Interior Local Fans	Exhaust Fans	Pumps
Jan	28.49	47.19	20.84	1.57	24.23	0.00	5.45	1.82	0.08	2.62
Feb	24.25	41.55	14.52	1.40	25.33	0.00	4.81	1.38	0.07	2.13
Mar	25.60	44.42	10.16	1.52	34.62	0.00	5.16	1.19	0.07	1.98
Apr	25.25	45.31	4.04	1.51	50.94	0.00	5.19	0.92	0.07	1.49
May	25.24	45.88	0.87	1.55	93.83	0.00	5.25	1.13	0.07	1.42
Jun	23.66	43.85	0.24	1.48	123.27	0.00	5.05	1.35	0.07	1.65
Jul	25.22	47.19	0.06	1.57	183.78	0.00	5.37	1.96	0.08	2.38
Aug	24.59	44.42	0.05	1.52	163.20	0.00	5.12	1.66	0.07	2.05
Sep	25.47	45.31	0.16	1.51	119.29	0.00	5.18	1.35	0.07	1.46
Oct	27.38	47.19	2.06	1.57	74.12	0.00	5.39	1.04	0.08	1.46
Nov	25.80	42.54	7.67	1.46	39.60	0.00	4.94	1.05	0.07	1.71
Dec	28.73	47.19	13.39	1.57	30.94	0.00	5.42	1.37	0.08	2.22
Summed total	309.68	542.05	74.07	18.24	963.14	0.00	62.34	16.21	0.88	22.48

Appendix D

Rooftop Solar PV Analysis

D1 Rooftop Solar PV Analysis

The following report details the rooftop solar PV analysis and results that was completed for the project via Helioscope software.

ARUP

Annual Production Report produced by Geoff Gunn

Full roof MIT SaS CoC, 2885 Vassar St.

Report

Project Name	MIT SaS CoC
Project Address	2885 Vassar St
Prepared For	MIT
Prepared By	Geoff Gunn geoff.gunn@arup.com

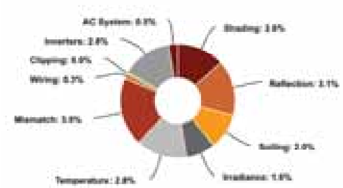
System Metrics

Design	Full roof
Module DC Nameplate	138.4 kW
Inverter AC Nameplate	110.8 kW Load Ratio: 1.25
Annual Production	179.0 MWh
Performance Ratio	82.0%
kWh/kWp	1,293.3
Weather Dataset	TMY, MA, CAMBR4-CENTSQ, White Box Technologies (custom)
Simulator Version	5aaa168e77-c241cea3f8-0d743b72b3-a541694093

Project Location

Monthly Production

Sources of System Loss



Annual Production

	Description	Output	% Delta
Irradiance (kWh/m²)	Annual Global Horizontal Irradiance	1,444.3	
	POA Irradiance	1,577.4	9.2%
	Shaded Irradiance	1,535.9	-2.6%
	Irradiance after Reflection	1,489.0	-3.1%
	Irradiance after Soiling	1,459.2	-2.0%
	Total Collector Irradiance	**1,459.2**	**0.0%**
Energy (kWh)	Nameplate	201,871.2	
	Output at Irradiance Levels	198,618.3	-1.6%
	Output at Cell Temperature Derate	193,030.9	-2.8%
	Output After Mismatch	185,742.8	-3.8%
	Optimal DC Output	185,140.5	-0.3%
	Constrained DC Output	185,052.8	0.0%
	Inverter Output	179,893.0	-2.8%
	Energy to Grid	**178,994.0**	**-0.5%**
Temperature Metrics			
	Avg. Operating Ambient Temp		13.9 °C
	Avg. Operating Cell Temp		23.4 °C
Simulation Metrics			
		Operating Hours	4449
		Solved Hours	4449

 1/2 December 17, 2019

ARUP

Annual Production Report produced by Geoff Gunn

Condition Set

Description	Condition Set 1
Weather Dataset	TMY, MA_CAMBR4-CENTSQ, White Box Technologies (custom)
Solar Angle Location	Meteo Lat/Lng
Transposition Model	Perez Model
Temperature Model	Sandia Model

Temperature Model Parameters

Rack Type	a	b	Temperature Delta
Fixed Tilt	-3.56	-0.075	3°C
Flush Mount	-2.81	-0.0455	0°C
East-West	-3.56	-0.075	3°C
Carport	-3.56	-0.075	3°C

	J	F	M	A	M	J	J	A	S	O	N	D
Soiling (%)	2	2	2	2	2	2	2	2	2	2	2	2

Irradiation Variance	5%
Cell Temperature Spread	4° C
Module Binning Range	-2.5% to 2.5%
AC System Derate	0.50%

Module Characterizations

Module	Uploaded By	Characterization
Q.PEAK DUO-G7 340 (Hanwha Q Cells)	Folsom Labs	Qcells_Q.PEAK DUO-G7_340_Rev3.PAN, PAN

Component Characterizations

Device	Uploaded By	Characterization
SunnyBoy 10KW (SMA)	Folsom Labs	Default Characterization

Components

Component	Name	Count
Inverters	SunnyBoy 10KW (SMA)	11 (110.8 kW)
Strings	10 AWG (Copper)	33 (3,826.4 ft)
Module	Hanwha Q Cells, Q.PEAK DUO-G7 340 (340W)	407 (138.4 kW)

Wiring Zones

Description	Combiner Poles	String Size	Stringing Strategy
Wiring Zone	12	9-13	Along Racking

Field Segments

Description	Racking	Orientation	Tilt	Azimuth	Intrarow Spacing	Frame Size	Frames	Modules	Power
Field Segment 1	Fixed Tilt	Landscape (Horizontal)	15°	147°	1.6 ft	1x1	415	407	138.4 kW

Detailed Layout

  December 17, 2019