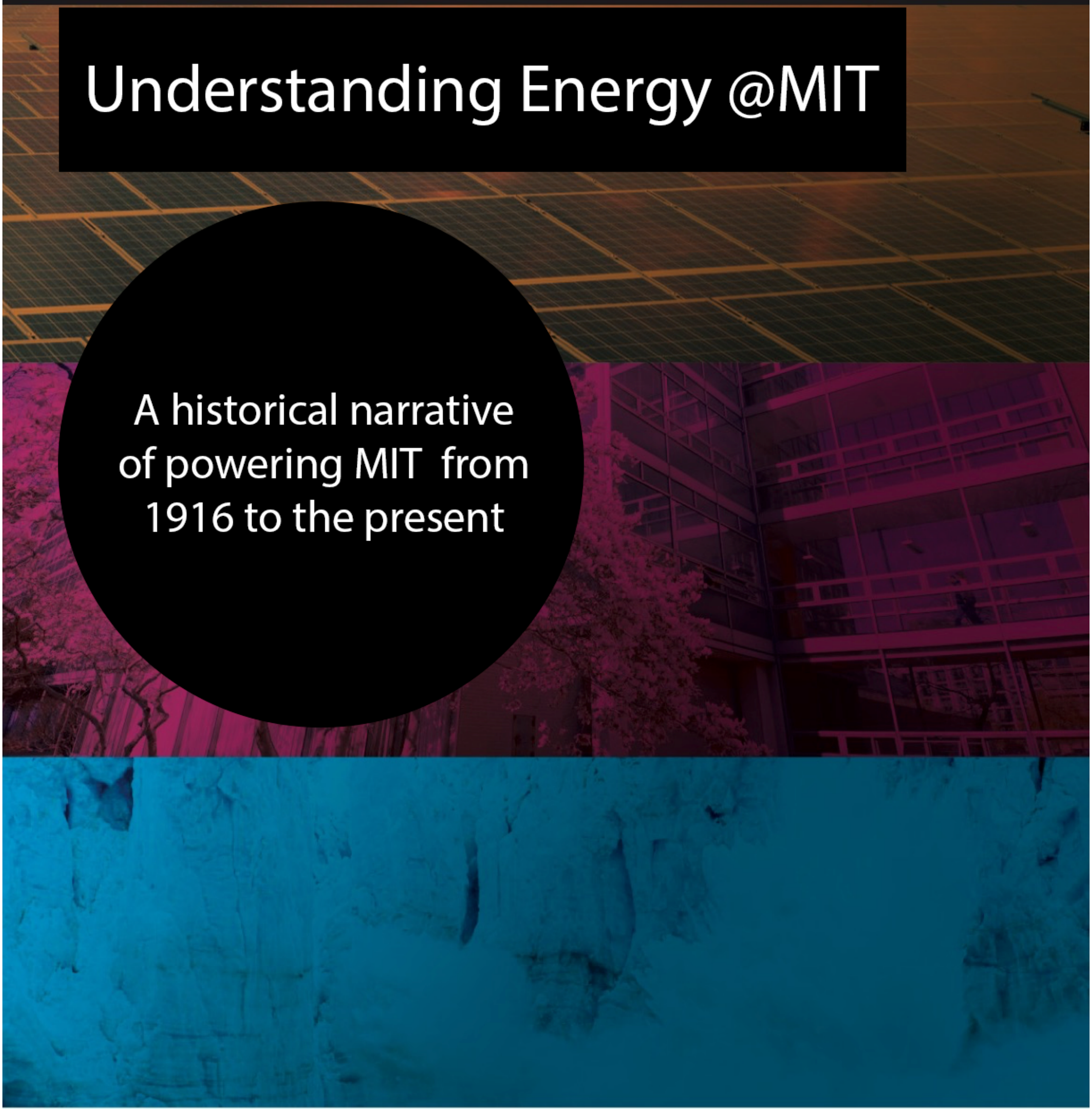
Office of Sustainability

Department of Facilities

START STUDY SOLVE

Understanding Energy @MIT

A historical narrative of powering MIT from 1916 to the present



Massachusetts Institute of Technology

2017

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A long history of innovation and efficiency in powering MIT

Our context

The Massachusetts Institute of Technology is committed to leveraging MIT's broad expertise in research, education, and campus energy management to create a more sustainable, energy-efficient, and high-performing campus. Since its founding, MIT has made critical decisions in its long-term planning to prioritize campus energy efficiency and has tackled for the last century challenges in meeting the energy needs of an urban research campus. When MIT relocated to Cambridge in 1916, it chose efficient strategies to power the campus. Upon moving to Cambridge, MIT designed, installed, and embraced a state-of-the-art district utility system, powered by coal to produce steam (and by the mid-1930s, oil-powered) to provide energy to the campus – an efficiency-driven decision that prevented it from having to install numerous small-scale furnaces across campus. When the campus central utility plant (CUP) was expanded to provide a natural gas-fired combined heat and power system - also known as co-generation - to produce electricity and steam simultaneously in the mid-1990s. This decision, too, reflected a desire to prioritize energy efficiency, as co-generation is prized for its efficiency gains as it captures and uses the heat that would otherwise have been wasted out the exhaust stack. Since then, the MIT community has embraced with passion and commitment the challenge of advancing more sustainable energy practices on campus, and MIT aims to establish itself as a leader in smart, effective climate action and is committed to sharing our learning.

An energy history in support of our future work

As MIT embarks on the next generation of powering its campus and takes on the challenge of climate change as an Institutional priority, this report is intended to provide background information on MIT's past campus energy history. This energy narrative seeks to inform and support the MIT community with a baseline of information on the choices MIT has made since its founding in Cambridge to provide and manage energy and utilities for our growing campus. Powering MIT in a reliable and responsible manner is paramount for supporting the intense and diverse research and teaching mission of the Institute.

To meet the call in President Reif's 2016 Plan for Action on Climate Change to use the campus as a test bed to reduce greenhouse gas emissions beyond 32%, MIT has developed a **Campus Greenhouse Gas Reduction Strategy and implementation plan** available from the Office of Sustainability. MIT's historical plans for powering the campus have informed and shaped MIT current Campus Greenhouse Gas Reduction Strategy. This energy narrative provides the historical context of our future plans, as well as provides background information that might help spur new innovation and approaches. This report should be used to provide additional background information to MIT's Campus Greenhouse Gas Reduction Strategy report available **here** from the Office of Sustainability.

Powering the campus

Historic and current energy sources: fuel choices and co-generation; transmission and distribution on campus; and our regional context

Energy sources through the years

The Central Utilities Plant, co-generation and upcoming renovations, and prospects for renewables

MIT's historical energy sources reflect the campus' pursuit of efficiency, cost effectiveness, and reliability. MIT's Cambridge campus has included a district steam power plant, **the Central Utilities Plant (CUP)** since the campus was built in 1916. Adjacency to the Grand Junction Railway provided MIT with a direct route for delivering coal to the CUP. Though run by coal, this type of facility was considered more efficient than the alternative, which would have been to install many coal-fired furnaces across campus. Coal was replaced in 1935 by oil – considered a better quality primary energy source. MIT began to buy electricity from the grid in 1938, after the grid and provider became more reliable. In 1950 the CUP was transitioned to use natural gas in addition to oil. In addition, taking advantage of the latest boiler technology, two boilers replaced the original ones, which more than doubled the output potential of the facility.

The CUP underwent a major transformation in 1995 after opening the William R. Dickson Co-generation facility. Co-generation is also known as **combined heat and power**, for it allows heat and power (electricity) to be created at the same time from a single primary fuel source. As a result, it implicitly cuts emissions compared to producing both utilities separately. With the addition of co-generation at the CUP, campus emissions were reduced and energy efficiency increased.

The CUP produces chilled water, heat, and electricity to send to the campus. It provides energy to over 100 campus buildings and contributes well over half of the campus' electricity needs, and nearly all of its steam and chilled water needs. The additional electricity comes from the local electricity provider. The CUP is now powered primarily by natural gas and will be, almost exclusively, for the foreseeable future. Along with the CUP renovations (discussed below), MIT is phasing out the regular use of #6 (heavy) and #2 (heating) fuel oil and plans to reserve the latter only for emergencies and testing. This transition alone helps to reduce carbon emissions, due to the lower carbon content of natural gas relative to fuel oil. In addition, the electricity MIT generates at the CUP is less carbon-intensive than the electricity it purchases from the grid. Since it came on-line in 1995, the co-generation facility within the CUP – in comparison to traditional energy generation – has avoided approximately 1,230,000 metric tons of carbon dioxide emissions. For detailed information on MIT's strategy for reducing greenhouse gas emissions on campus, please the **MIT's Greenhouse Gas Emissions Reduction Strategy** available from the Office of Sustainability.

In 2015, MIT began the permitting phase for the renovations to the CUP, known as the **Second Century Project**. The renovations are essential as the current co-generation turbine is nearing the end of its useful life. Now approved, the renovations should be completed by 2020 when the current turbine will be phased out and two new gas-fired turbines would be put on-line. Specifically, the renovations will increase the amount of power the plant can generate by installing additional co-gen capacity; install two new chillers; grant Eversource access to the CUP to bolster natural gas delivery to the surrounding area; put in three cooling towers, which are more efficient than the current six; accommodate a future hot water coil to facilitate the recovery and reuse of waste heat; and transition to less carbon-intensive and environmentally preferable fuels, including natural gas to power the plant and #2 fuel oil for emergencies. These renovations, while necessary from an equipment-upgrade perspective, also satisfy several goals: they bolster the resilience of the campus in the face of local and regional utility disruptions, improve local air quality and reduce emissions, and align with campus sustainability objectives. MIT's co-generation upgrade will serve as a bridge to future energy technologies and equipment, while reducing GHG emissions and enhancing power reliability. Flexible in its design and adaptable to change, the system will enable MIT to incorporate innovations as they emerge, improving plant efficiency and optimizing operations. As the 21st century unfolds, MIT will continue to pursue new energy solutions in our own campus energy management strategy. Our energy strategy will evolve, and the CUP will continue to evolve and take advantage of emerging climate-positive technologies and approaches.

Renewable energy on campus

In addition to the power provided by the CUP, MIT has considered and capitalized on opportunities for supplementing conventional power sources with small-scale on-site renewal energy systems with grant and alumni support. In 2002, the Massachusetts Renewable Energy Trust awarded MIT through its Community Solar Power Initiative grant program $455,700 to fund solar photovoltaic systems at 25 locations across metropolitan Boston, in addition to 3 systems on campus totaling 20 kilowatts of electrical generation capacity. The program was designed to cluster installations in a geographic location to promote local capacity in design, installation, and inspection services. MIT Department of Facilities was the program manager for the project, in collaboration with MIT's Laboratory for Energy and Environment. The three rooftop systems are on buildings W20, N51, and 14. In 2007, in response to the **Great Dome exterior re-lighting project**, a 40 kW solar panel system was added to the overall campus PV system to **counterbalance the electricity needed** for lighting the Dome and produces an estimated 50,000 kWh of clean energy annually, the equivalent of a 65,000 pound carbon dioxide reduction. Both the Massachusetts Technology Collaborative and an alumni contribution helped fund this installation. Located on the roof of the Alumni Pool, these panels comprise the biggest single PV system on campus. In 2011, a fifth solar PV system was installed on campus at the Sloan School of Business building, E62, with panels donated by the energy company, BP.

MIT has also conducted limited wind assessments on campus to explore the potential for on-site wind turbines, including both ground- and building mounted systems. Preliminary analysis indicated that the wind resource on campus was not adequate to sustain an economically viable wind installation. In 2009 and 2010, a group of graduate students collaborated with the Department of Facilities, Campus Energy Task Force, and other groups to assess the feasibility of on-site wind turbine installation. The group, known as Project Full Breeze, installed a meteorological tower on Briggs Fields to measure wind resources on campus to determine if a 3.7 kilowatt wind turbine was feasible at this site. Read the **Feasibility Study Report**. While several consultant geothermal assessments have been done for certain construction projects, a more comprehensive assessment of MIT's geothermal energy potential should be undertaken. A 2015 study by MIT students conducted an assessment of new roof-top solar PV system potential and identified several possible promising locations that are under consideration as part of a comprehensive roof assessment program.

The solar PV systems not only provide a modest amount of locally generated electricity, they also offer opportunities for research and academic initiatives: for instance, **coursework in the past** has done diagnostics on the campus PV system, which has been presented to the Department of Facilities. Campus solar PV systems have also been the subject of numerous campus sustainability tours for classes and events.

Campus central utility transmission and distribution

In addition to providing electricity for the campus, the CUP also provides campus heating and cooling. As of 2016, MIT's electrical distribution occurs through seven loops, or circuits, across campus. This number is expected to increase to 20 with the CUP renovations, thereby alleviating strain on a single loop and enhancing load-shedding capabilities. Furthermore, this makes the campus more resilient, in the face of local utility power limitations or failures. More loops can prevent the CUP from service delays, too, as the load can be brought on gradually.

The CUP produces all of the non-electrical utilities (chilled water, hot water, and steam) for the campus (Figure 1). But as Figure 1 illustrates, not all campus buildings are connected to the CUP – some buildings receive electricity or primary fuels directly from local utilities. From the CUP, steam travels by pipe and tunnel to individual buildings. Upon reaching the buildings, the pressure is decreased. Though campus heating is largely steam-based, the campus is working towards more efficient hot water-based heating where feasible. Hot water is more efficient than steam in terms of distributing heating capacity across campus, and it will help the campus continue to reduce GHG emissions. The distribution of low- and medium-degree hot water also increases energy efficiency gains within individual buildings. Figure 2 shows the campus steam distribution system, as well as its system condition. Given the current age and condition of the overall steam distribution system on the west side of campus, this area is under consideration for a steam-to-hot water overhaul through the West Campus Hot Water Distribution Plan.

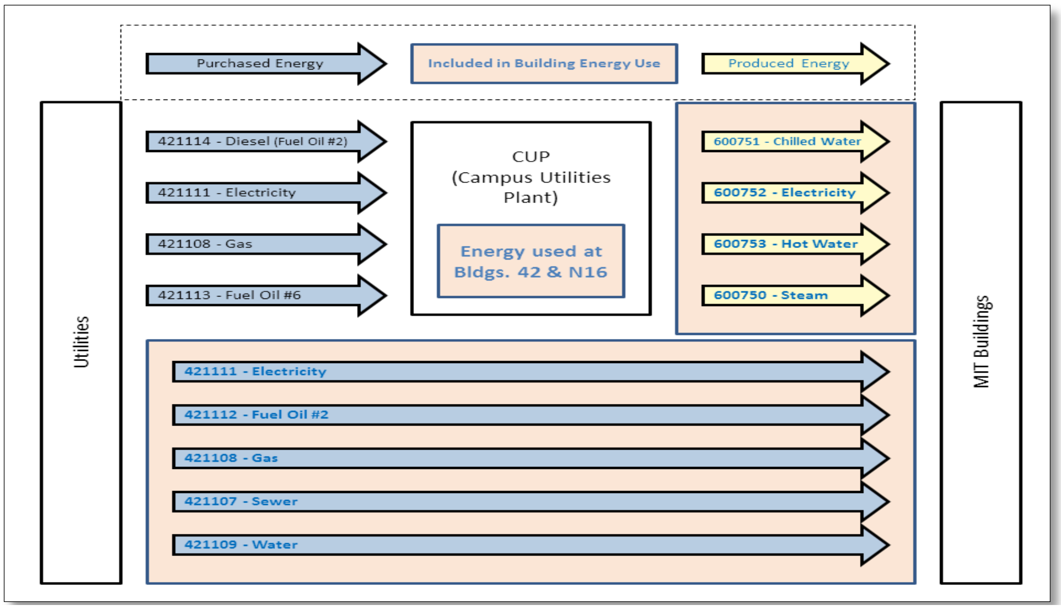

FIGURE 1: MIT'S PROCESS FOR PROVIDING UTILITIES. (SOURCE: MIT OFFICE OF SUSTAINABILITY AND DEPT. OF FACILITIES.)

FIGURE 2: THE CAMPUS STEAM DISTRIBUTION NETWORK AND QUALITY. (SOURCE: MIT 2015 TOWN GOWN PRESENTATION TO THE CITY OF CAMBRIDGE)

Regional context

There have been clear historic benefits to the campus operating its own power plant, and both MIT's historic and future energy decisions are shaped by the opportunities and limitations of the regional grid.

Massachusetts is served by ISO New England. The transmission lines in New England span approximately 8,600 miles in total. Roughly half of New England's power comes from natural gas, due to a move away from other, more polluting primary energy sources such as oil and coal. **Heating and electricity requirements for the region are only increasing**, but at the same time, the region is constrained by insufficient infrastructure for natural gas. Consequently, the **Massachusetts Department of Public Utilities** mandated a grid modernization plan (2014) from each electricity provider, requesting a vision through 2025. In addition, Massachusetts, as of summer 2016, has a small contribution from renewable energy. This share is likely to increase, in light of the 2016 **state energy bill** that mandates an increase in renewable energy sourcing, including offshore wind. Massachusetts also participates in the Regional Greenhouse Gas Initiative (RGGI) alongside other New England states. RGGI is a cap-and-trade program for carbon emissions that result from energy generation and is considered the country's **"first mandatory, market-based"** program of its kind.

The CUP renovations address some of the limitations of the regional grid. Given these limitations, MIT's decision to renovate and improve the CUP is not only sensible, but **necessary**, especially as a natural gas-powered **co-generation plant will "bridge" the campus** to new processes in the future. Though the campus has plans in place to reduce energy use, the campus and its energy needs are also growing. Consequently, improvements to the CUP will offset the expected growth in campus energy demand. Furthermore, the CUP renovations will make the campus more resilient, largely due to the improved robustness of the plant and its increased potential generation; strengthen the distribution of the local utility, as Eversource will be given space for a gas regulator station in the renovated plant; and bolster New England's efficiency and grid expansion efforts.

Understanding campus energy use

Powering the buildings

Both building energy use trends on campus in aggregate (***Campus-level energy use)*** and at the individual building level (***Building-level energy use***) should be considered to better understand their aggregate impact alongside their individual impact. Buildings consume the vast majority of purchased and generated campus energy, and buildings are the source of 97% of 2016 GHG emissions on campus.

Campus-level energy use

In terms of how much energy is used by campus buildings, academic (including lab) buildings are some of the biggest users. Figure 3. shows total campus energy use (in million BTUs) for on-campus, MIT-owned buildings from FY 2007 through FY 2016, which indicates a downward trend in overall energy consumption, despite a 13% growth in building space over the same period. This trend is reflected in the findings from the **campus GHG inventory** emissions and energy use analysis. Included in the analysis is a historical snapshot of MIT’s total building energy use from 1990 through 2016, and its associated greenhouse gas emissions, which was derived from the original student thesis work on MIT’s greenhouse gas inventory. MIT’s historical building energy use can be overlaid with five periods of campus development including pre-co-generation, co-generation, campus growth, investment in efficiency, and climate leadership as summarized in Figure 4. More detailed information on MIT’s current greenhouse gas emissions footprint is provided in the section *Our campus greenhouse gas emissions footprint* in this report.

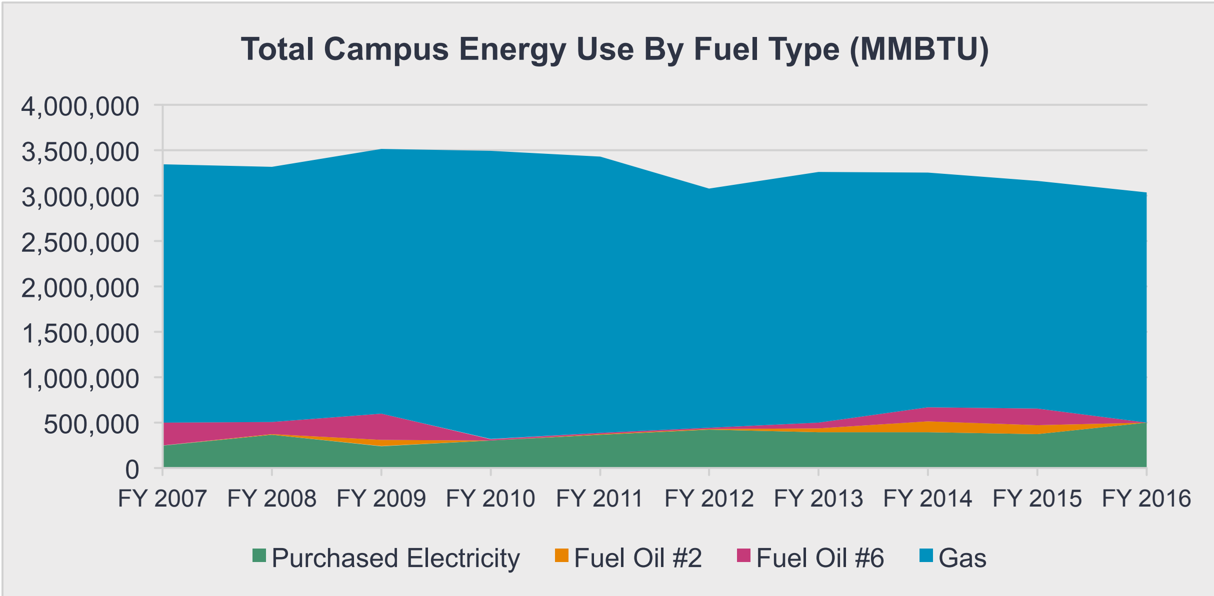

FIGURE 3 TOTAL CAMPUS ENERGY USE BY FUEL TYPE, 2007-2016.

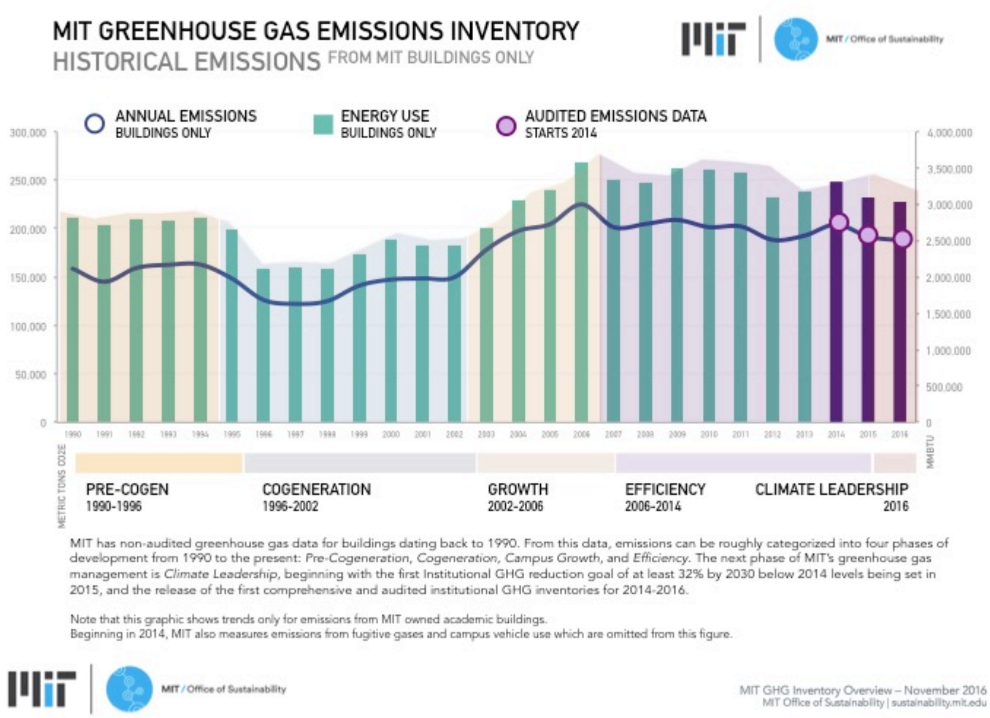

FIGURE 4 HISTORICAL ENERGY AND GHG EMISSIONS 1990-2016 AND OVERLAPPING PHASES OF CAMPUS DEVELOPMENT.

At the Central Utility Plant, primary fuels of natural gas, fuel oil, and purchased electricity are used to generate the utilities that are used to power our campus in the form of steam for heating, chilled water for cooling, and additional electricity for powering its electrical needs. Figure 5. shows the proportion of utilities produced at the CUP from the combustion of natural gas and fuel oil. The mix of produced energy products or utilities is 40% steam, 33% chilled water, and 27% electricity. Additional electricity is purchased by MIT directly from the grid utility companies.

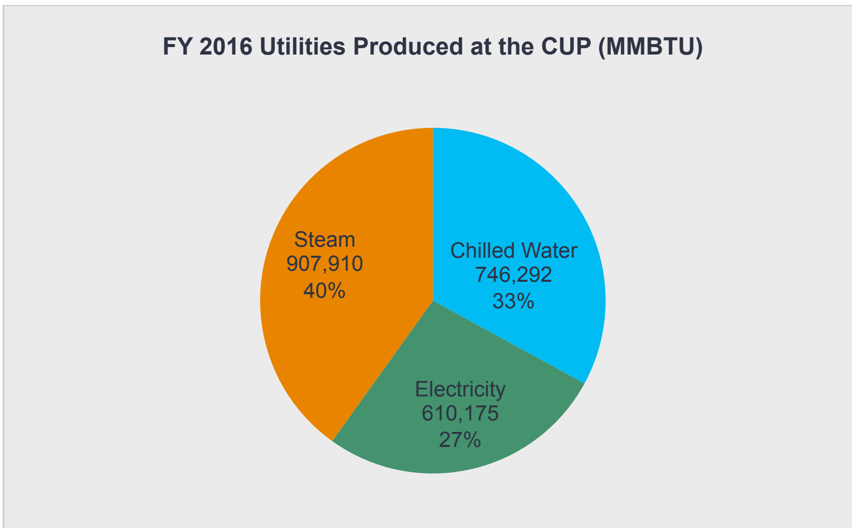

FIGURE 5. FY2016 PROPORTION OF UTILITIES PRODUCED AT THE CUP IN MMBTU.

Building-level energy use

The diversity of building-level energy use is shown below. Figure 6. demonstrates the range of total energy use in a building as well as the range of intensity of use per square foot of space. Energy use intensity is often measured by the total energy a building uses per year, normalized by the total gross square footage of the building, expressed as thousand BTUs per gross square foot per year (kBTU/GSF/year). Total building energy use is expressed simply as the total quantity of the BTUs contained in the underlying utilities used in the building in a single year, expressed in million BTUs (MMBTU). Drivers of energy use include the total size of the building, and the activities that are being conducted therein. Laboratories on campus tend to use higher amounts of energy per square foot than administrative or residential uses, due to higher demands for air circulation, energy-intensive research equipment, and higher density of research activities. Because of advances in energy efficient design, newer lab building tend to use less energy per square foot compared to older lab buildings, but their total annual energy use may be high due to the sheer size of recent new lab buildings.

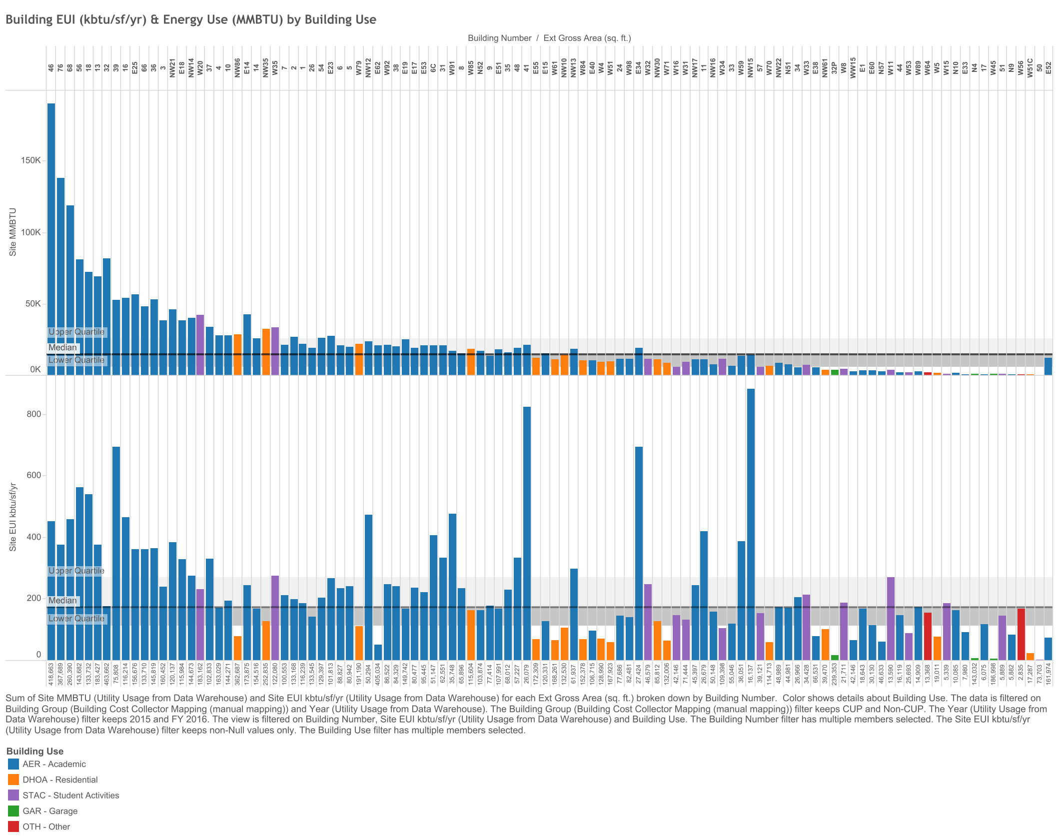

FIGURE 6 BUILDING ENERGY USE AND ENERGY USE INTENSITY (FY2016)

In addition to the visualizations shown here, MIT provides a **building energy dashboard**, available to the MIT community.

Reducing our energy use

Strategies for new construction, renovations, and campus retrofits

Deepening with the Stata Center design and construction, MIT has incorporated energy efficiency strategies into new construction, renovations, and campus retrofits, and will continue to do so through design guidelines and programs. MIT has historically strived for energy efficiency, and campus energy use reduction strategies are prioritized to reflect this.

Strategies

Design guidelines and programs have been two strategies through which MIT has established a foundation for energy efficiency and sustainability and will continue to build on.

Design Guidelines: MIT's **Building Systems Design Handbook**, once known as the "Red Book," outlines principles to guide campus-based plans, new construction, and renovations. As of summer 2016, the standards are being updated and modified, and the modifications will reinforce sustainability strategies on campus. Moving forward, MIT's **Sustainability Working Group Recommendations** will guide enhancement of sustainable design standards including identifying energy efficiency strategies for the campus, including tailored sustainability standards with a LEED Version 4 framework and alternatives for non-LEED-certified projects; a product and materials sustainability assessment; and sustainable building operations and maintenance guidelines.

Prior to MIT recently adopting LEED Version 4 Gold for new construction and major renovations on campus, all new capital projects and major renovations had to meet Silver or better standards of the US Green Building Council's (USBGC) Leadership in Energy and Environmental Design (LEED) certification program, in addition to meeting the energy efficiency goals of the City of Cambridge's **Stretch Energy Code**.

In the past decade, MIT made considerable progress in constructing its new buildings with many sustainable features. The **Department of Facilities** maintains a comprehensive list of additional information on current and planned construction projects. Examples of past LEED building projects include:

- The **Massachusetts Green High Performance Computing Center (MGHPCC)**, an openly accessible computational research facility jointly operated by Boston University, Harvard, MIT, Northeastern, and the University of Massachusetts, was built in 2012 and serves as a sustainability role model for research hubs. The MGHPCC was the first university research data center ever to achieve LEED Platinum Certification, the highest level awarded by the Green Building Council's Leadership in Energy and Environmental Design Program.

- The new **Sloan School of Management building (E62)**, was completed in 2010 and is LEED Gold certified. Post occupancy studies show that the building is meeting aggressive energy efficiency targets, using about 45% less energy than a typical building of a similar size that simply meets code requirements. The building incorporates a high-performance envelope with operable windows in office areas, (partial) green roof, low-wattage lighting, demand ventilation, occupancy sensor controls, water-based terminal heating and cooling units, and easy access to usable outdoor spaces. Read more about the design and operation of the building **here**.

- The **Koch Institute** for Integrative Cancer Institute, completed in Fall 2010, is MIT's first LEED Gold certified research lab. The project demonstrates the viability of combining sustainability and scientific function in building design and operation. Reports confirm that the building is using 35 percent less energy than a standard laboratory research building. Designing an energy efficient ventilation system was a priority; Koch has over a hundred fume hoods that flush contaminated air away from researchers, which are a major source for energy consumption. To learn about more about Koch's sustainable features, read **here**. Other sustainable design features include: redevelopment of a brownfield site, a reflective roof, and a storm water filtration system.

- **Ashdown House (NW35)** is a LEED Gold certified graduate residence hall completed in 2008 that houses more than 400 students. The building received LEED Gold certification in 2009 and includes many sustainable design features including light pollution reduction, Energy Star appliances, nontoxic materials.: landscaping and irrigation systems that use water from a non-potable source; a storm-water management system that reduces storm-water runoff; maximized daylight available in 95 percent of regularly occupied spaces; and low-flow fixtures that reduce water use by more than 20 percent. Read more **here**.

- MIT's **Brain and Cognitive Science** Complex is the world's largest center for neuroscience research, opened in 2005 and received LEED Silver certification in 2008. Sustainable features include: a high-performance building envelope, gray water reuse, exhaust-fan heat recovery, and daylight-balanced lighting. Read more **here**.

- The iconic **Stata Center**, completed in 2004, was designed to meet a LEED Silver rating and has an innovative storm water management system, displaced ventilation systems, and a roof design that uses native vegetation and a white reflective surface to reduce the heat island effect.

Figure 7 shows the campus LEED-certified, and expected LEED-certified buildings; and buildings that have had targeted energy efficiency investments completed.

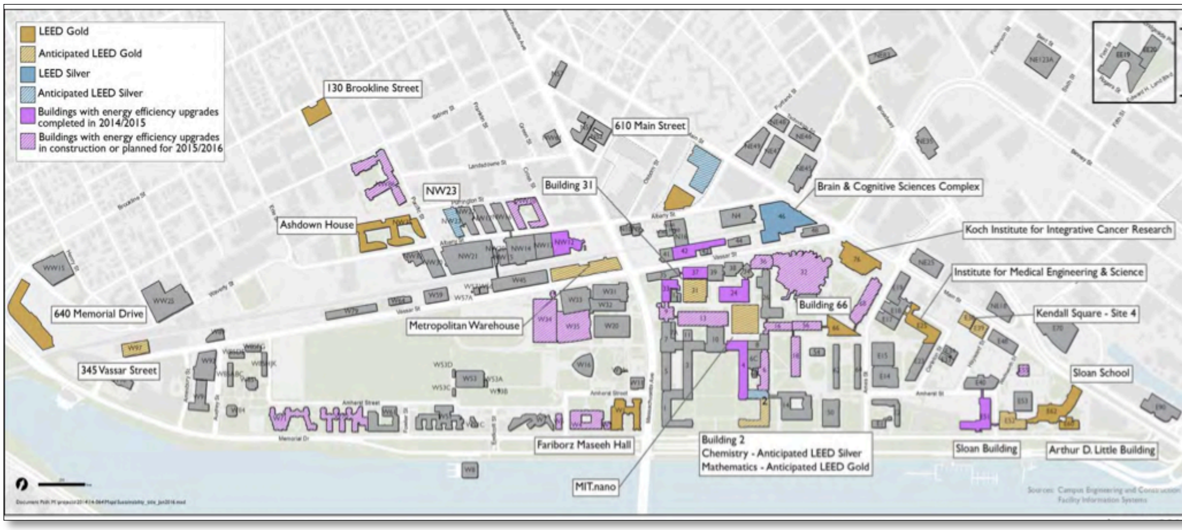

FIGURE 7: LEED-CERTIFIED AND EXPECTED LEED-CERTIFIED BUILDINGS ON CAMPUS, AS WELL AS BUILDINGS THAT HAVE RECEIVED TARGETED ENERGY EFFICIENCY INVESTMENTS. (SOURCE: MIT 2015 TOWN GOWN PRESENTATION TO THE CITY OF CAMBRIDGE)

Programs: In May 2010, MIT established **MIT Efficiency Forward** as a three-year, $13M collaborative energy conservation and efficiency program with its electric and gas utility company Eversource. The program is a first-ever-of-its-kind with a utility company and was the single largest energy efficiency project Eversource had developed with a customer. The program initially committed nearly $13M over three years, with an innovative funding strategy consisting of funds from MIT, Eversource incentive payments, and reinvestment of energy savings seeking to save 34 million kWh. In 2013, with the project having successfully met its first three-year target of 15% energy reduction across campus - a savings of over 34 Million kilowatt-hours annually - MIT launched its second 3-year program that resulted in an additional 21 million kWh additional electricity saved and 150,000 therms of heating and cooling energy saved. The first term's round of investments went toward coil cleaning, continuous commissioning, lighting improvements and upgrades, and overseeing and replacing steam traps. Since then, Efficiency Forward-related improvements have spanned retrofitted HVAC and mechanical systems; improved controls and lighting; and efficient features in newly constructed buildings. As of June 2016, the campus reached its goal of reducing since the start of the program 55 million kWh annually. In addition, the program also fostered on campus a decrease in natural gas use, and as of June 2016, the program cut natural gas use by over 1,000,000 therms. Recent savings were achieved in these major investment areas: capital projects, lighting, building retro- and continuous-commissioning, mechanical system upgrades, and utility insulation. The cumulative savings that now accrue annually to MIT each year for the life of the measures is expected to be $6.5 million.

In summer 2017, the program will be entering its third three-year term. In addition to the benefits on campus, Efficiency Forward served as a model program for other partnerships between campuses, businesses and utilities. After MIT's accomplishments, **Eversource pursued similar partnerships with other campuses,** like the University of Massachusetts-Amherst in 2014, and other consumers.

Since 2010, when Efficiency Forward started, the following results have been achieved.

Total Impact for 6 Years of Efficiency Forward Program (2010-2016)

	Projects Completed	Annual kWh Savings	Annual Therm Savings	Total Project Cost	Total Incentives	Annual Cost Avoid
Totals	252	54,815,372	1,124,460	$19,364,092	$11,167,878	$6,473,161
Total project lifetime savings expected*			$205,572,163			

*defined as the cumulative total expected savings over the course of each measure's expected equipment useful lifetime. Estimate provided by Eversource.

Specifically, a summary of the activities carried out in 2015 and 2016 show the diversity of campus-wide energy efficiency projects.

Summary of Efficiency Forward Results from July 1, 2014 - June 30, 2015 (Fiscal Year '15)

		Project Energy Savings	
Discipline	**Counts**	**kWh Savings Achieved**	**Therm Savings Achieved**
Capital Projects	3	1,207,044	92,994
Lighting	24	3,665,324	-
Retro-Commissioning	1	-	-
Mechanical	3	268,755	1,473
Insulation	1	-	13,044
Monitor-Based Commissioning	5	1,302,362	471,317
Equipment Incentive	1	1,640,000	

Other (-80 Freezer monitoring)	1		
Totals	39	8,083,485	578,828

Summary of Efficiency Forward Results from July 1, 2015 - June 30, 2016 (Fiscal Year '16)			
	Project Energy Savings		
Discipline	**Counts**	**kWh Savings Achieved**	**Therm Savings Achieved**
Capital Projects	7	1,207,748	25,344
Lighting	18	4,576,001	-
Retro-Commissioning	3	-	-
Mechanical	6	740,995	-
Insulation (jackets)	3	0	85,515
Monitor-Based Commissioning	15	813,974	198,966
Water			
Other (Studies, Overhead, etc.)	3	5840	-
Totals	55	7,344,558	309,825

Individual behavioral change is another method through which energy efficiency has been encouraged on campus. Efforts to inform and engage the broader community to advance sustainable practices has included a “Lights Out” outreach program to cut down on wasteful lighting; electricity use competitions between units (i.e., dorms, labs, and office groups); “Shut the Sash” to motivate sustainable lab fume hood behavior; “Resolve to Revolve” campaign to encourage revolving door use; eco-friendly settings and management of computers; the Sustainable Spaces and Sustainable Events programs; the Green Labs program; Green Ambassadors; and **Access MIT.**

Measuring to manage

Tools for analyzing, managing, and tracking and reporting

MIT is tackling the issue of energy data measurement head-on and harnessing the findings for management purposes. Data measurement and management allows the campus to inform decision-makers accurately and increase knowledge of system-wide operations.

Collecting and analyzing

Metering | Building Energy Forecasting Tool | Roof Assessment | Life-Cycle Cost Analysis Tool

MIT is collecting and analyzing energy data in order to measure how energy is used across campus and to identify where there are opportunities for reducing energy use or implementing new technologies. A non-exhaustive list of tools that exemplify these efforts include:

Metering: Metering tracks and stores utility distribution data from across campus and allows for the improvement of building management systems (BMS). In June 2016, a metering study was conducted to determine the metering potential for over 130 buildings across campus. It helped identify multi-building meters, as well as the necessary pre-requisites to bring metering to each building on campus. As of summer 2016, 70 buildings have individual metering and are part of the **PI System metering**. A proposal for a comprehensive metering upgrade program is under development to improve our energy analytics.

Building Energy Forecasting Tool: An environmental design consultancy helped MIT create a **building energy use-forecasting tool**, per the recommendations of the campus' Net Zero Energy Working Group. The tool combines building characteristics with energy use information, and it makes projections based on scenarios involving construction and renovation plans. Building improvements are considered from the perspective of the envelope; heating, ventilation, and air conditioning (HVAC); controls; and lighting. The tool will serve as the foundation for a dynamic energy use-forecasting tool that will be built into MIT's emerging Sustainability Data Hub, described below.

Roof Sustainability Planning Tool: In September 2015, an architecture and design firm completed a roof sustainability study for the campus. MIT's goals in undertaking this assessment were to determine how to reduce negative environmental impact and support the ecology of the surroundings, especially the Charles River; to increase research potential on campus; to take advantage of the need to renovate roofs across campus; to work with the City of Cambridge on the issues of global warming and flood potential; to bolster campus sustainability efforts; and to realize renewable power generation potential and make the community aware of this potential. From this sustainability study came the Roof Sustainability Planner Tool that will determine the potential for implementing sustainable features across campus rooftops. These sustainable features include blue/white/green roofs[1], added insulation capacity, and solar photovoltaic panels. The goal of the Tool is to help mitigate the urban heat island phenomenon the campus is facing. As of summer 2016, the Tool contains data for 20 buildings, and more buildings are in the process of being added.

Life-Cycle Cost Analysis (LCCA) Tool: System choices for the campus affect energy efficiency, and consequently utilities costs. To ensure that system choices properly account for this impact, evaluation methods, such as lifecycle costing, and strategic project selection, like bundling, can be used. In terms of evaluation methods, the campus has developed a Lifecycle Cost Analysis (LCCA) Tool, which incorporates a shadow price for carbon based on the EPA-determined **social cost of carbon**. Carbon pricing is one of the recommendations put forth by the Sustainability Working Groups. The LCCA Tool is intended for capital projects and is meant to provide a lifecycle cost assessment for interacting ventures – that is, systems-level measures that are bundled together. The basic inputs include energy costs, according to energy model outputs; first costs; maintenance costs; and avoided costs. As of summer 2017, the LCCA Tool is poised for expansion to water and eventually materials.

Sustainability DataHub: The Sustainability DataHub is a next-generation open data platform that will house various types of data, including utilities data and energy consumption data; embed data analysis tools; and report data. It is intended to be a resource that the MIT community can use to guide decisions and facilitate research or academic study. It tracks track campus energy use and provides insights on energy efficiency and sustainability efforts. MIT has launched its campus energy dashboard, **Energize_MIT** on the Hub. An overview of the DataHub is shown in Figure 8.

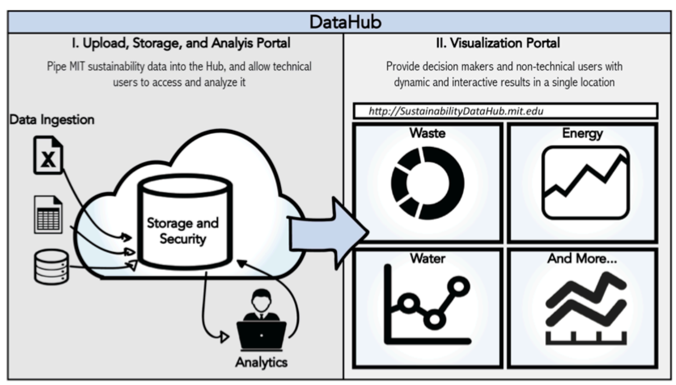

FIGURE 8: DATAHUB PROCESS SCHEMATIC (SOURCE: MIT OFFICE OF SUSTAINABILITY)

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[1] *Blue roofs* house stormwater, delaying its travel to the ground. *White roofs* provide a reflective coating to prevent overheating. *Green roofs* support plants, as well as house stormwater. Blue, white, and green roofs have cooling capacity.

Managing

Piloting Energy Management Frameworks

MIT's decision to test the development of an energy management system started in 2012. MIT participated, as the first university, in the DOE Global Superior Energy Performance (GSEP) Partnership, geared toward large-scale energy efficiency projects. To a large degree, GSEP supported a campus energy management system (EnMS) for the campus to facilitate energy efficiency projects. MIT developed a pilot EnMS alongside a test run with ISO 50001 standards. As part of the pilot management system, a draft energy management policy was developed:

> *The Massachusetts Institute of Technology, MIT, is committed to being a leader in environmentally responsible operations, development of new and renewed facilities, and education. The idea of sustainability weaves throughout the projects, from construction to maintenance. MIT continually seeks to improve our environmental footprint while working to serve the needs of the community. To ensure that MIT remains a leader in environmentally responsible operations, we are demonstrating our commitment across the campus to continual energy performance improvement through the development of this energy policy and the implementation and maintenance of an Energy Management System (EnMS).*

This draft policy was intended to:

- *Support continual improvement of our energy performance*
- *Ensure the availability of information and resources to achieve the objectives and targets of the EnMS*
- *Comply with applicable legal and other requirements to which MIT subscribes related to energy use, consumption and efficiency.*
- *Support the purchasing of energy efficient products and services and design for energy performance improvement*
- *Communicate the policy to the campus community*

The EnMS was a pilot exercise and provided valuable input to MIT's current energy efficiency strategies.

Tracking and reporting

Measurement is a critical piece of understanding the campus' environmental impact, and greenhouse gas emissions accounting and tracking is an important component. This tracking is accomplished through the development of a campus greenhouse gas inventory, which is an accounting of greenhouse gases emitted to or removed from the atmosphere by an organization over a period of time. MIT is using its GHG inventory to identify emissions sources, track emission trends, establish a basis for developing an action plan, develop mitigation strategies and policies, and assess progress.

MIT's first GHG inventory was conducted in 2004 as a **graduate student's thesis**. MIT now carries out its GHG inventory annually using the industry standard **GHG Protocol** for the following MIT campus sources: building energy use, fleet vehicles, and fugitive gases. Each year, the Office of Sustainability completes this inventory. MIT's first official GHG inventory was published in January 2016 including emissions in 2014 and 2015. To learn more, please visit the Office of Sustainability's **Greenhouse Gas Inventory** resources. Following is a summary of MIT's GHG emissions profile.

Our campus greenhouse gas emissions footprint

GHG inventory and sources

MIT's current **greenhouse gas emissions inventory** includes emissions from three principal areas: Cambridge academic building energy use, fugitive gases, and campus-owned vehicles. Building energy and vehicle emissions are associated with the combustion of fossil fuels to produce power. Fugitive gases are GHGs that are emitted on campus through non-combustion processes including research, refrigeration, and electrical insulation.

In 2016, MIT's inventoried GHG emissions across all sources totaled 198,038 metric tons of carbon dioxide equivalent (MTCO2e). Total greenhouse gas emissions have declined each year since our inventory was first published. Between 2014 and 2016, the campus achieved a 7 percent reduction in overall emissions, from 213,428 MTCO2e in 2014 to 198,038 MTCO2e in 2016. In 2016, reductions in MIT's own building emissions accounted for the vast majority of the total reduced, followed by reductions in fugitive gases, and fleet vehicle emissions, while emissions associated with leased space grew in the same period. Additional detail can be found in the **MIT Greenhouse Gas Inventory** from the Office of Sustainability. MIT has used its GHG inventory to inform the development of MIT's **GHG reduction strategy outlined here**.

Collaborating across scales

Engaging communities on all levels: campus, city, and globe

In addition to the measures MIT can take on campus, the Institute collaborates across scales to both learn from and contribute to best and emerging practices around the globe.

The campus

As stated in the MIT Plan for Action on Climate Change, the campus serves as a "test bed for faculty, student and staff ideas." The notion of the campus as a test bed is rooted in collaboration – the Plan for Action describes how the intention is to "share pertinent results of our reduction strategies and related research projects, in case it could be helpful to similar campuses and organizations around the world." Furthermore, sustainable design and building methods will be tested on MIT labs.

The city

MIT has advanced energy efficiency and use reduction strategies on campus, and these are shared priorities in the greater Cambridge community. MIT lies in the heart of Kendall Square, and is engaged with other local businesses and organizations to explore the possibilities of developing a Kendall Square EcoDistrict. **EcoDistricts** are a strategy to accelerate neighborhood sustainability through concrete improvements and innovations. A key belief of EcoDistricts is that neighborhoods are an effective unit for accelerating sustainability—they are small enough to innovate quickly but big enough to have a meaningful impact in a larger context.

In Cambridge, MIT was an active participant on the **Getting to Net Zero Task Force**, and it supports carbon neutrality as advocated for by the Task Force. It also participates in the **Cambridge Climate Protection Action Committee** (CPAC), which serves as an advisory group to the City Manager on the Climate Protection Plan. MIT also complied with the **Building Energy Use Disclosure Ordinance** in Cambridge, which started in 2014 and aims to pinpoint the biggest energy users (as nearly 80% of Cambridge emissions from greenhouse gases come from buildings). (The report is available **here**.) In addition, the City of Cambridge, along with Harvard and MIT, has created the **Cambridge Community Compact for a Sustainable Future**, or the Cambridge Compact. The Compact is intended to streamline the sustainability efforts of members and align their approach to climate change.

In Boston, MIT is also a member of the **Boston Green Ribbon Commission**, as part of the Higher Education Working Group (HEWG). The Green Ribbon Commission is tasked with organizing climate impact reduction efforts across the city and broader metropolitan area so that they are aligned with the Boston preparedness plan, Climate Ready Boston. The **HEWG** specifically concentrates on advising Climate Ready Boston; collaborating on renewable energy prospects; and *green labs*.

The globe

Looking beyond the campus and city, MIT has also engaged national and international partners on climate change impact reduction. MIT is a member of the **Association for the Advancement of Sustainability in Higher Education** (AASHE), which focuses on enabling sustainable initiatives across university divisions and units; the **International Sustainable Campus Network** (ISCN), which focuses on embedding sustainable initiatives across university actions; the **Ivy Plus Sustainability Consortium**, which focuses on amplifying greenhouse gas emissions reductions; and the **Northeast Campus Sustainability Consortium** (NECSC), which focuses on "education and action" for sustainability in the university setting. In September 2016, MIT hosted **World Symposium on Sustainable Development at Universities**. This year's symposium featured 175 participants, from six continents, most of whom presented research papers or participated in panel discussions at the three-day meeting. The symposium brought together international academics and practictioners to explore the theme "Designing Tomorrow's Campus: Resiliency, Vulnerability, and Adaptation."

Appendix

Additional information in support of the Energy Narrative is provided below.

Resources

Central Utilities Plant Second Century Project, "Single Environmental Impact Report, EEA #15453," May 2016.

MIT Central Utilities Plant: Upgrade Project.

MIT Environmental Research Council, "Report of the Environmental Research Council: Prospectus for an Initiative on Global Environment at MIT," April 2010.

MIT Report, Cambridge Town Gown.

MIT Story Timeline.

Time line: campus events and initiatives:

- **Central Utility Plant construction (1916):** MIT builds its Central Utility Plant adjacent to the Grand Junction Railway to simplify coal drop off, and this facility centralizes the campus's power source.
- **Switch to oil from coal (1933):** MIT switches to oil from coal, which establishes the Institute's unwavering preference for higher quality fuel.
- **Buying electricity from the grid (1938):** MIT starts to buy electricity from the grid, which reflects growing strength and accountability of the utility company.
- **CUP transitions to natural gas from oil (1950):** The Central Utilities Plant (CUP) transitions to using natural gas instead of oil. Taking advantage of the latest boiler technology, two boilers replace the original ones, which more than double the output potential of the facility.
- **Lighting retrofit with EPA's Green Lights (1992):** A campus-wide lighting retrofit program through the EPA's Green Lights Program reduces 11 million kWh of electricity use and over 6,000 metric tons of greenhouse gas emissions a year, which jumpstarts energy efficiency improvements on campus.
- **Functional campus co-generation facility (1995):** $40 million is invested in an advanced, gas-fired co-generation power facility to improve energy efficiency, increasing plant efficiency by over 18% and reducing MIT's total greenhouse gas emissions at the time by 32%.
- **Community Solar Power Initiative (2002):** The Massachusetts Renewable Energy Trust awards the MIT Community Solar Power Initiative $455,700, which will be used to fund solar panels at approximately 40 locations across metropolitan Boston in addition to on campus.

- **On-site, small-scale solar power generation (2003):** The *Community Solar Power Initiative* supports 25 solar-photovoltaic installations on the campus and in the community, bringing 75 kilowatts of installed capacity on-line. MIT starts on-site, small-scale solar power generation, using the roofs of the Stratton Student Center (W20) and the MIT Museum (N51).
- **First informal campus GHG inventory (2004):** MIT produces its first informal greenhouse gas inventory as part of a Master's student's thesis.
- **Campus' third round of solar panels (2004):** The third round of solar panels is added to campus rooftops, this time at Hayden Library (14).
- **MITEI (2006):** The MIT Energy Initiative (MITEI) is formed, which amplifies and streamlines energy research, education and campus energy management.
- **BEEP (2006):** MIT begins the Building Energy Efficiency Program (BEEP), which focuses on boosting energy efficiency in existing buildings.
- **MIT Campus Energy Task Force (2007-2013):** The Campus Energy Task Force (often referred to as the "Walk the Talk" Task Force) was established in 2007 to develop and coordinate a campus energy program outlined in the Energy Research Council report to the President and Provost.
- **LEED Silver certification at the Brain and Cognitive Science Complex (2008):** The Brain and Cognitive Science (BCS) (46) Complex marks the inaugural LEED certification (at the Silver level) at MIT
- **LEED Gold certification at Ashdown House (2009):** Ashdown (NW35), the graduate student residence, is the recipient of the campus' inaugural LEED Gold certification.
- **Greening MIT (2009):** The "Greening MIT" campus-wide engagement campaign begins, under the guidance of the Campus Energy Task Force.
- **Efficiency Forward (2010):** Efficiency Forward, a collaborative energy efficiency program between MIT and NSTAR (Eversource), begins its first-of-a-kind, three-year program for accelerating energy efficiency investments.
- **Silverman Evergreen Fund (2010):** The Silverman Evergreen fund is developed to finance energy efficiency investments around campus as a revolving investment fund that reinvests a proportion of the savings in additional projects.
- **Commercial Building Partnerships Program (2010):** MIT joins the Commercial Building Partnerships Program through the Department of Energy, which identifies opportunities to improve building efficiency by bringing together industry leaders and operators of commercial buildings.
- **GULF-ISCN Sustainable Campus Charter Endorsement (2011):** MIT pledges support for the GULF-ISCN Sustainable Campus Charter, which emphasizes the role of sustainability and collaboration on sustainability with partner institutions.
- **LEED Gold certification at Sloan School and Koch Institute (2011):** The newly built Sloan School building (E62) and Koch Institute for Integrated Cancer Research (76) become LEED Gold-certified
- **LEED Gold certification at Maseeh Hall and Little Building (2012):** The newly built Fariborz Maseeh Hall (W1) and Arthur D. Little Building (E60) become LEED Gold-certified.

- **Global Superior Energy Performance Pilot, US DOE (2012):** MIT becomes the first university to undertake the GSEP Partnership. It begins a pilot program in which it creates and utilizes an Energy Management System (EnMS) in line with the ISO 50001 Standard.
- **Office of Sustainability formed (2013):** The MIT Office of Sustainability is created to develop MIT leadership in campus sustainability across all units and practices on campus.
- **Cambridge Compact for a Sustainable Future (2013):** The City of Cambridge, Harvard, and MIT officially align their sustainability efforts by creating the Cambridge Community Compact for a Sustainable Future, which builds off of the strengths of each partner.
- **Yearlong Conversation on Climate Change (2014):** The President's Office hosts a yearlong Conversation on Climate Change to identify how MIT can most effectively develop global climate change solutions.
- **Plan for Action on Climate Change (2015):** The Plan for Action on Climate Change reflects the recommendations developed through the Conversation on Climate Change, establishing an MIT goal of reducing campus GHG by at least 32% by 2030 from a 2014 baseline while aspiring for carbon neutrality as soon as possible.
- **Plans to expand the Central Utilities Plant (2015):** MIT plans to expand and enhance the Central Utilities Plant to increase efficiency, capacity, and reliability.
- **Inaugural SustainabilityConnect Conference (2015):** The MIT Office of Sustainability hosts the first annual SustainabilityConnect conference to advance the efforts of campus Sustainability Working Groups.
- **Adopted Sustainability Working Group recommendations (2015):** MIT's first Sustainability Working Group Recommendations are adopted by the administration to establish the foundational practices for a sustainable campus.
- **GHG reduction strategies guided by official 2014 and 2015 inventory (2015):** MIT releases its first official GHG inventory for 2014 and 2015 to establish the baseline and guide implementation of the GHG reduction activities to support the overarching campus GHG goal.
- **Cutting-edge, energy efficient windows in the Simons Building (2016):** The Simons Building (2) undergoes energy efficient renovations, featuring a cutting-edge type of window with unsurpassed insulation.

Document draft date 1-02-17.

Energy History MIT

1916

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A campus-wide lighting retrofit program through the EPA's Green Lights Program reduces 11 million kWh of electricity use and over 6,000 metric tons of greenhouse gas emissions a year, which jump-starts energy efficiency improvements on campus

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Functional campus co-generation facility
$40 million is invested in an advanced, gas-fired co-generation power facility to improve energy efficiency, increasing plant efficiency by over 18% and reducing MIT's total greenhouse gas emissions at the time by 32%

1996

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***Environment, Health & Safety Policy* adopted**
A comprehensive *Environment, Health & Safety Policy* adopted by the MIT Academic Council commits MIT to embracing environmental stewardship and pollution prevention, including a green building standard to seek LEED Silver for new construction and major renovations

2002

Community Solar Power Initiative awarded funding
The Massachusetts Renewable Energy Trust awards the MIT Community Solar Power Initiative $455,700, which will be used to fund solar panels at approximately 40 locations across metropolitan Boston in addition to on campus

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On-site, small-scale solar power generation
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