BOSTON
COMMUNITY ENERGY STUDY

Exploring the Potential for Local Energy Generation, District Energy, and Microgrids

2016

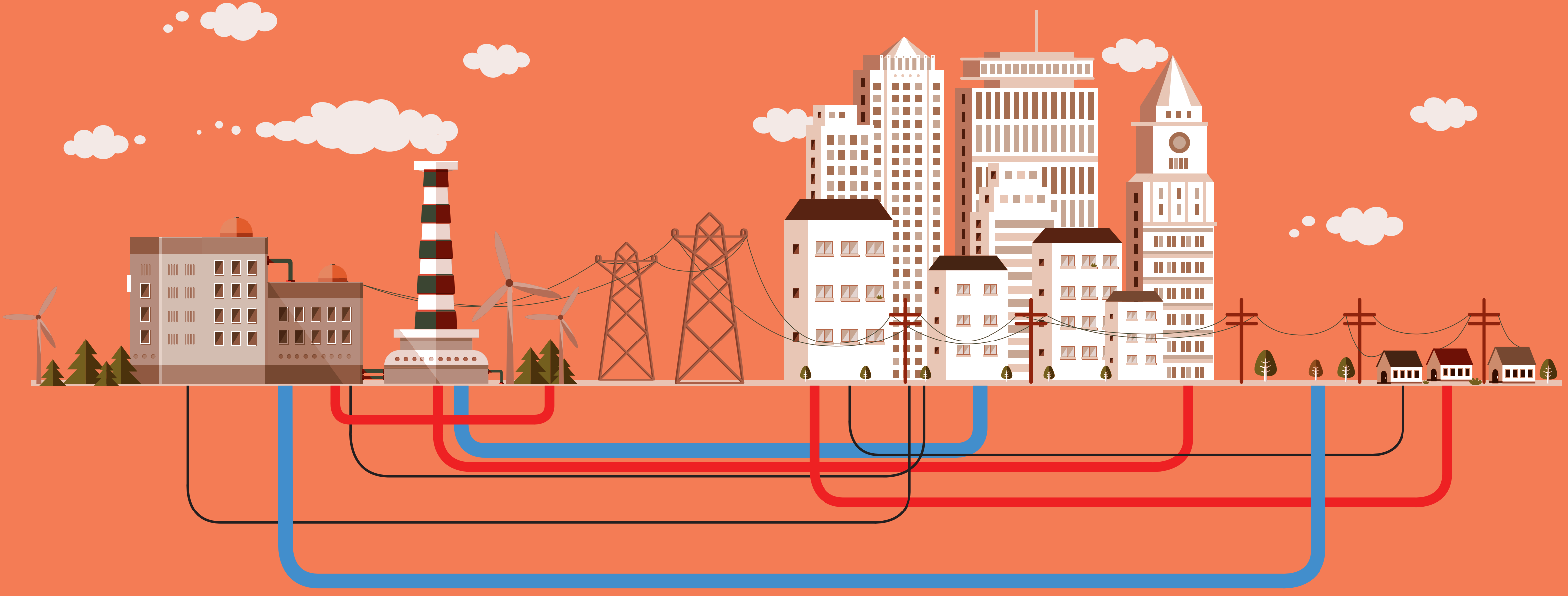

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Table of Contents

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REQUESTS

Requests can be online at the BRA **website**.

ABOUT OUR SPONSORS

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LETTER FROM MAYOR MARTIN J. WALSH

Dear Friends,

Boston is emerging as a world leader in the innovation and knowledge economy. Our expertise in technology, education, research, design, engineering, and financing is fueling unprecedented growth and attracting world-renowned businesses and international talent to our city.

With the release of the Boston Community Energy Study, we are taking the first steps to focus these collective resources on imagining the future of Boston's energy system. The City of Boston and the Boston Redevelopment Authority have worked in partnership with the Massachusetts Institute of Technology, Lincoln Laboratory, the Massachusetts Clean Energy Center, and our local utilities, Eversource and National Grid, to develop a pioneering framework for understanding citywide energy usage. This study examines new energy supply solutions, assesses environmental and community benefits, and explores financial and technical feasibility.

We're fortunate to have existing models, such as the Longwood Medical Area's energy microgrid, to build upon. With this study we begin the process of identifying other potential locations for community-based energy solutions.

Our goals go far beyond responding to climate change and meeting Boston's aggressive greenhouse gas reduction targets. By challenging ourselves to invent new practices, employ new technologies, and pilot a set of community energy solutions, we will support job growth in businesses that provide cleaner, more affordable, and more resilient energy to Boston.

Given our leadership in green and energy positive buildings, we are uniquely positioned to accomplish these goals. Working together with our partners, we have an opportunity to meet today's challenges and imagine a thriving Boston supported by cleaner, more resilient energy systems.

Sincerely,

Martin J. Walsh
Mayor of Boston

EXECUTIVE SUMMARY

The City of Boston is committed to reducing greenhouse gas emissions and preparing for climate change impacts. The 2014 Climate Action Plan Update recommends expanding the use of on-site combined heat and power, renewable energy technologies and district energy to help meet these commitments.

The purpose of the Boston Community Energy Study is to explore the potential for local energy generation, district energy and microgrids within the City of Boston. This exploration utilizes a combination of technologies referred to as Community Energy Solutions.

Community Energy Solutions, which include local energy generation, energy storage technologies, and resilient infrastructure (microgrids and district energy), are designed to provide added resiliency, reduce greenhouse gas emissions and lower energy costs for their customers.

GOALS

1. Identify potential districts where these technologies are most feasible,
2. Provide hypothetical engineering solutions, and
3. Quantify the overall benefits of Community Energy Solutions in Boston.

This study was produced in partnership with MIT Sustainable Design Lab and MIT Lincoln Laboratory to create a replicable framework which can be used by other local governments in Massachusetts. The three partners collaboratively developed the study methodology and framework.

STRUCTURE

Energy Mapping: The foundation of the Study is the Boston Energy-Map developed by MIT Sustainable Design Lab. The Energy Map is an hourly simulation of energy use for every building in Boston. The map allows the Study team to analyze patterns of energy demand, scope the engineering solutions, and assess the feasibility of potential local generation.

DEFINITIONS

Community Energy Solutions refer a group of technologies used among two or more buildings:

Local Generation - energy that is generated in close proximity to users by Combined Heat and Power (CHP) and solar photovoltaic (PV) panels. CHP power plants can simultaneously produce heating and electricity with natural gas.

District Energy - a system that supplies thermal energy to multiple buildings via underground pipes carrying steam, hot water, and cold water.

Microgrid - an electrical distribution network with underground wires that serves two or more buildings in a local area. Microgrids can enter into ‘island mode’ and separate from the larger electrical grid when there is a major outage- self supplying with locally generated energy.

Energy Storage - thermal and electric systems such as hot and cold water storage and batteries. These technologies allow users to store excess energy and use it during times of peak demand. Storage technologies allow greater economic utilization of energy produced onsite and off peak.

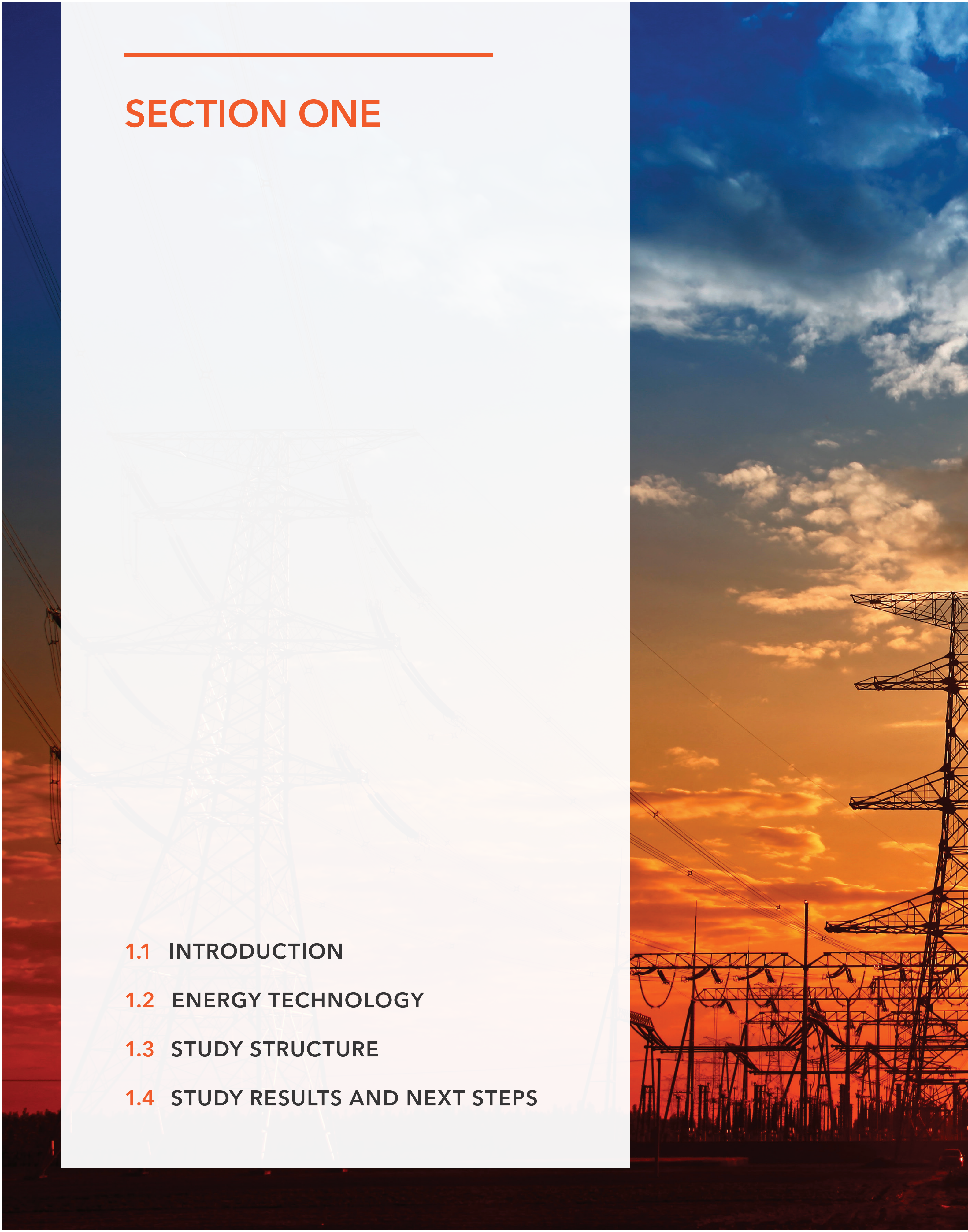
District Suitability Analysis & Engineering Analysis: Next, the Study brings together the Energy-Use Map with other analytical tools to identify districts where local, clean and renewable energy supply is feasible at the community scale- based on population, critical facilities, and energy use. The MIT Lincoln Laboratory analysis identified forty two districts in various neighborhoods of Boston. Lincoln Laboratory developed custom-tailored energy solutions for each district using the Distributed Energy Resources Customer Adoption Model (DER-CAM) software, a product of Lawrence Berkeley National Labs.

Sustainable Return on Investment Analysis (SROI): Finally, the SROI model quantifies both the financial and long-term sustainability impacts of energy efficiency investments. The SROI modeling provides both a traditional benefits and costs analysis and an estimate of the financial impacts for the broader community by calculating not only the consumer savings on energy costs but also quantifying the economic benefits of lower greenhouse gas emissions from Community Energy Solutions.

FINDINGS

The Energy Mapping simulation bridged a major gap in energy data that is available to the City (customer-level energy use data is not available to the City). Forty eight energy profiles were created to represent the energy demand of individual buildings throughout the City. The simulated results were 94% accurate for electric consumption and 83% accurate for natural gas consumption compared to Boston’s measured annual energy demand. The district suitability analysis provided three classifications of potential districts for Community Energy Solutions, each based on high energy use, density of affordable housing, or density of critical facilities. Forty two potential districts were selected through this spatial analysis. Results from the engineering analysis demonstrate the benefits and limitations of Community Energy Solutions, which can serve as a starting point when exploring more detailed project feasibility. These include detailed recommendations for local generation, energy storage, and basic heating and cooling technologies based on energy demand from buildings, capital costs, and operating costs. As a focal point of the engineering analysis, combined heat and power recommendations range in size from 488 kW to 15 MW. Finally, The SROI analysis shows over 1 billion dollars in savings and community benefits can be achieved between energy costs and greenhouse gas emissions reductions; however, these results require deeper exploration into the financial impacts associated with building retrofits, road excavation and to account for the benefits of the existing steam system.

This study provides stakeholders with the concepts, technologies and benefits of Community Energy Solutions and identifies next steps for potential pilot project locations. The City of Boston, working in partnership with our utility providers Eversource, National Grid, and Veolia will use these findings to begin the transformation of our energy systems in the City. This partnership approach to energy system planning responds to the needs of Boston businesses and residents for clean, affordable and resilient power systems. Boston’s thriving innovation and knowledge economy and booming urban growth are an ideal platform for innovations in the energy system.



SECTION ONE

SECTION 1.1

INTRODUCTION

Boston's colleges and hospitals already utilize innovative energy technologies in existing microgrids and district energy systems. These technologies and systems provide affordable, reliable, and clean energy supply to the users. The same type of technologies helped New York City residents and businesses survive through Superstorm Sandy in 2012- providing reliable power to campuses when the larger electric grid failed. This study looks to identify additional areas in Boston where local energy supply, district energy and microgrids are suitable among non-institutional buildings. The engineering and mapping solutions depicted in this study emphasize localized energy supply and its benefits for resiliency, affordability, and greenhouse gas emissions reductions.

The Boston Redevelopment Authority worked in partnership with world-leading researchers to test solutions and quantify the benefits that would result from community energy solutions. The study is intended for two audiences: communities within Boston and energy system stakeholders. Communities can explore the study results and inquire about the possible next steps. Resources such as the **Community Energy Planning Guide**, published by the International District Energy Association, can help communities engage this topic. With these study results and the underlying data, communities can engage engineers, utilities, and local government to develop local energy plans.

The second audience is energy system stakeholders including regulators, utilities, and the regional transmission authority. These stakeholders are responsible for the stability, operation, affordability and regulation of the exiting electrical system in New England. The study results can be used to calibrate local generation capacity within Boston. Localized energy supply can offset strains on the local and regional transmission infrastructure, providing an alternative to traditional transmission, distribution, and generation infrastructure investment.

KEY QUESTIONS OF THE STUDY

- Where are these technologies most feasible in Boston?
- What are the environmental and economic impacts of expanding Boston's local generation, district energy and microgrid infrastructure through Community Energy Solutions?
- What can we learn from a powerful dataset of energy use for every building in Boston?

THE CITY OF BOSTON'S COMMITMENT TO CLIMATE ACTION

The City of Boston is committed to fostering clean, renewable, resilient, and affordable energy. Goals outlined in the 2014 Climate Action Plan Update include the following:

- Promote on-site combined heat and power (CHP) and renewables
- Facilitate the expansion of district energy
- 2020 Energy Supply Targets include:
    - → 15% energy use from co-generation (CHP)
    - → 10 MW of commercial solar generation within the City

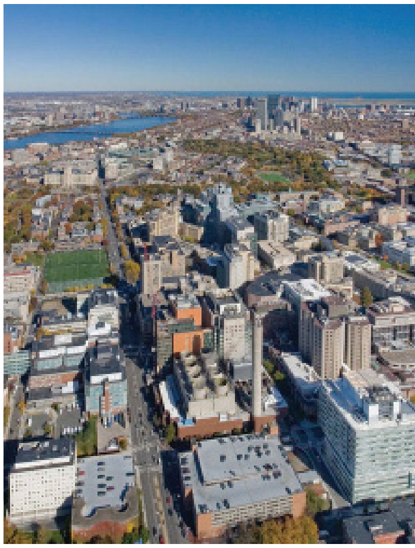
EXAMPLES OF COMMUNITY ENERGY SOLUTIONS

Community Energy Solutions are already prominent in the Military, Universities, Science, and Hospitals (MUSH) market. The following are examples of Community Energy Solutions.

HOSPITAL CAMPUS

LONGWOOD MEDICAL AREA, BOSTON, MA

The Medical Area Total Energy Plant (MATEP) serves the hospitals and research facilities in a densely populated 213-acre area of Boston called the Longwood Medical Area (LMA). MATEP generates and distributes steam, chilled water and electricity to buildings in the area for space heating and cooling, domestic hot water, lighting, fans, humidity control and process applications. Its design allows MATEP to operate during natural gas service interruptions for as long as 10 days while still meeting the energy needs of its customers.



MATEP featured in this photo is a free standing energy production facility nested within the Longwood Medical Area. Photo Credit: Medical and Academic Science Community Organization (MASCO)

SCIENCE CAMPUS

BIOGEN IN CAMBRIDGE, MA

Biogen researches, develops and manufactures medical treatments with a campus of over 1 million square feet. This campus energy system goes unnoticed on the campus grounds, as it is sound insulated and located within the basement of a lab building. The project paid for itself seven months ahead of schedule, in four and a half years. Because it was such a financial and operational success, Biogen is planning an expansion of the existing plant to achieve higher energy security, reduce greenhouse gas emissions and improve system financial performance.

UNIVERSITY CAMPUS

NEW YORK UNIVERSITY, MANHATTAN, NY

Throughout Manhattan, over 250 large buildings were without power for several weeks, and in many cases months, due Superstorm Sandy caused flooding. On the campus of New York University (NYU), home to 38,000 students, the lights stayed on and the buildings had heating, hot water and cooling. The Campus provided New York residents a safe and warm haven during the storm and emergency personnel were able to set up a command post to better assist with storm response.

Hidden from sight and sound, the Biogen energy plant is nested beneath a research building in the Kendall Square area. Photo credit: Google Earth

MULTIFAMILY EXAMPLE

CO-OP CITY, BRONX, NY

During Superstorm Sandy, the area surrounding Co-op City was heavily impacted with trees uprooted and power outages. However, the CHP plant provided the 60,000-plus residents of the development with electricity and heating throughout the storm and its aftermath. The facility is equipped with a 40 Megawatt Combined Cycle CHP plant.

SECTION 1.2
ENERGY TECHNOLOGY

Community Energy Solutions draw from different technologies, ranging from local energy generation to enabling underground infrastructure. The technologies can be mixed and matched to achieve different goals. Some technologies will reduce CO_2 emissions, some will lower the cost of energy, and some simultaneously accomplish both.

LOCAL GENERATION AND ENERGY STORAGE

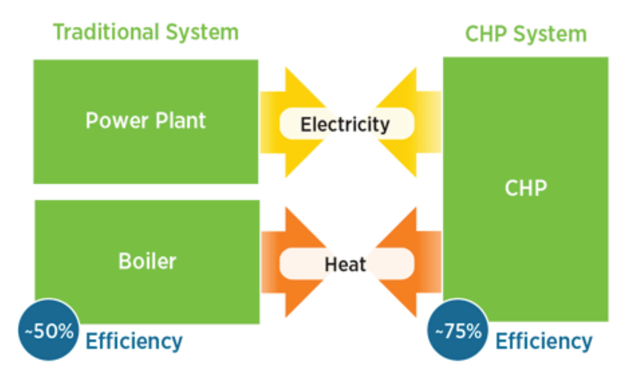
Building owners use local generation and energy storage to reduce peak loads, energy costs , greenhouse gas emissions and to increase resiliency to power outages. Below is a representative cross-section of the technologies which were considered in this Study. See “Section 2.3 Engineering Analysis” to learn more about the technologies and why they were selected.

Local Generation
Photovoltaic / Solar Panels
Solar Thermal Panels
Combined Heat and Power (CHP)

Energy Storage
Heat Storage
Cold Storage
Battery Storage

Heating and Cooling Production
Absorption Chiller
Refrigeration
Air Source Heat Pump
Ground Source Heat Pump

COMBINED HEAT AND POWER (CHP)
US. Department of Energy, 2015



Definition from US Department of Energy Website, 2015

COMBINED HEAT AND POWER (CHP) IS DEFINED AS:

- The concurrent production of electricity or mechanical power and useful thermal energy (heating and/or cooling) from a single source of energy.
- A type of distributed generation, which, unlike central station generation, is located at or near the point of consumption.
- A suite of technologies that can use a variety of fuels to generate electricity or power at the point of use, allowing the heat that would normally be lost in the power generation process to be recovered to provide needed heating and/or cooling

ENABLING INFRASTRUCTURE

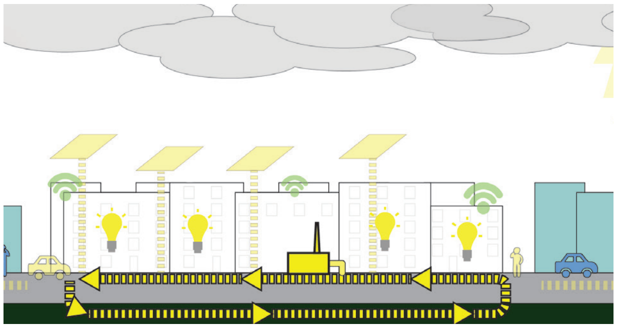
Community Energy Solutions require infrastructure to enable better management of energy resources at the community scale. Most existing neighborhood streets and buildings would require significant retrofits to take full advantage of Local Generation and Energy Storage.

SMART BUILDINGS

Building controls that can respond to price signals by lowering usage at the most expensive times.

BENEFITS

Optimized use of energy within buildings, energy cost savings, energy use and peak load reduction, access to revenue generating markets.

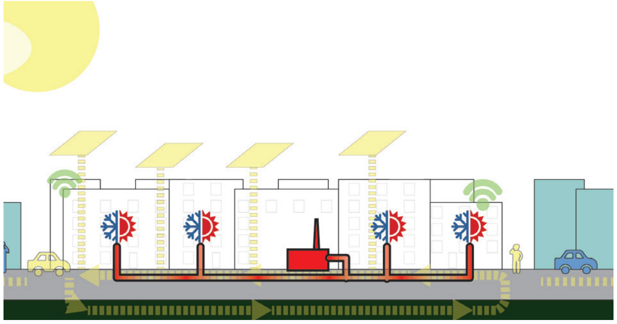


DISTRICT ENERGY

A network of underground pipes that deliver heating and cooling directly to buildings from low-carbon, local energy source via steam, hot water and/or cold water.

BENEFITS

Availability of low-carbon heating/cooling sources, outsourcing boiler and chiller operations to a central energy plant, reducing upfront capital expenditures on boiler and chiller equipment.

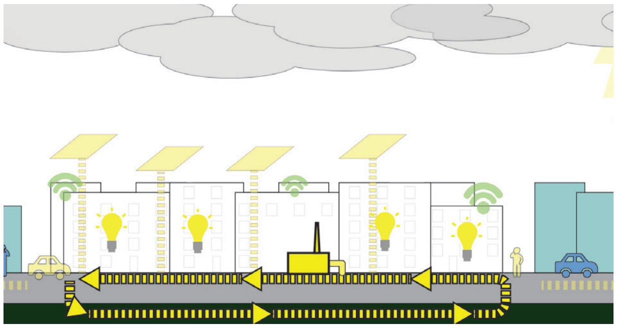


MICROGRIDS

An electrical grid that can isolate a group of buildings and self-power with local generation.

BENEFITS

Protection against long-durations of grid outage, controls help balance energy demand and supply among co-located buildings.



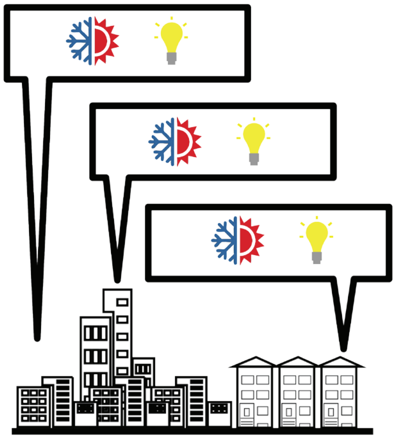
SECTION 1.3
STUDY STRUCTURE

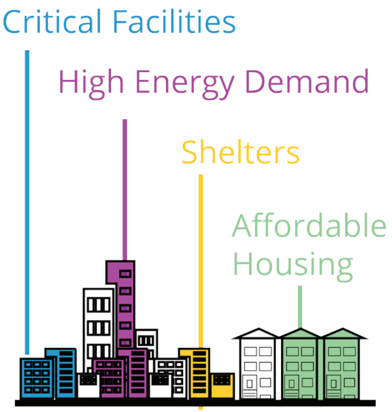
STEP ONE
ENERGY-USE MAPPING

An hourly simulation of energy use for every building in the City of Boston shows electricity, heating and cooling demand data. The foundation of this Study, this map encompasses over 85,000 structures, 12 different energy use profiles, and Gigabytes of data.

STEP TWO
LOCATING SUITABLE DISTRICTS

The study identifies districts where local, clean and renewable energy supply is feasible at the community scale- based on population, critical facilities, and energy use. This analysis yields co-located buildings which are then grouped together to form a single energy demand district profile.



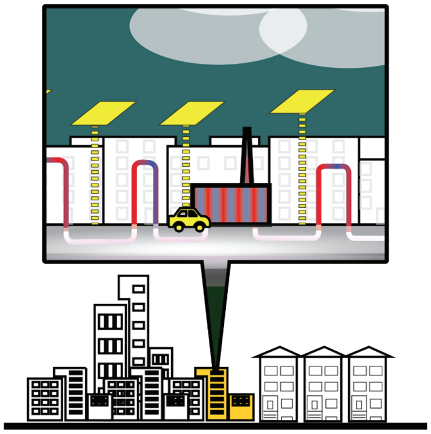


METHOD OF ANALYSIS	The MIT Sustainable Design Lab built upon their existing Urban Modeling Index (UMI) tool leveraging data from the Boston Redevelopment Authority Geospatial Lab. Energy validation data were pulled from many sources.	MIT Lincoln Laboratory pioneered a geospatial analysis method that guided the selection of the districts, building on best practices in community resilience research.
OUTCOMES	Patterns of energy use at the City scale, New England specific profiles of building energy demand, preliminary fuel consumption and emissions data.	Maps of feasible districts for Community Energy Solutions, which are accessible online for communities to explore
LEARN MORE	See Section 2.1 " Energy Use Mapping" of this report See Appendix A for detailed report by MIT Sustainable Design Lab	See Section 2.2 "Locating Suitable Districts" of this report See Appendix B for a detailed report by MIT Lincoln Laboratory

STEP THREE

ENGINEERING ANALYSIS

The engineering analyses simulates energy technologies in action. By custom tailoring local generation and storage technologies to fit the aggregate energy demand of the district, the analysis shows how the hypothetical technologies would lead to cost savings and carbon emissions reductions.



STEP FOUR

SUSTAINABLE RETURN ON INVESTMENT ANALYSIS

The Sustainable Return on Investment Analysis quantifies the benefits of this hypothetical infrastructure, if it were implemented. This economic model quantifies the monetary value of the infrastructure in operation over 25 years.

METHOD OF ANALYSIS	MIT Lincoln Laboratory built upon the Distributed Energy Resource Customer Adoption Model (DER-CAM) software developed by Lawrence Berkeley National Labs, editing source code for the software and adapting for a citywide application.	The BRA Research Division used a mature economic modeling methodology and adapted it for energy infrastructure costs and benefits.
OUTCOMES	Citywide understanding of local energy generation and storage capacity at the community scale	Economic figures that demonstrate cost savings and environmental savings that would accrue over the lifetime of the hypothetical infrastructure assets
LEARN MORE	See Section 2.3 "Engineering Analysis" of this report See Appendix C for a detailed report by MIT Lincoln Laboratory	See section 2.4 "Sustainable Return on Investment Analysis" of this report

SECTION 1.4

STUDY RESULTS & NEXT STEPS

At its core, The Boston Community Energy Study explores a way to make actionable the goals of the 2014 Climate Action Plan. By simulating the costs and benefits of local energy infrastructure innovations, stakeholders can explore the interplay between technology choices and local impacts. The study results indicate strong feasibility for Community Energy Solutions in many locations in Boston and the potential to realize broad community benefits.

RESULTS FROM STUDY QUESTION #1

Where are these technologies most feasible in Boston?

The Study identified forty-two districts around Boston that are good candidates for Community Energy Solutions based on technical criteria (building location and energy demand) and socio-demographic criteria (critical facilities and affordable housing). This starting point will enable the City of Boston and communities to engage in further dialogue; however, more data are needed to identify other dimensions of project feasibility. Future discussions will consider the state of the existing infrastructure in the area, the costs associated with building retrofit/ street excavation, and the willingness of building owners to support Community Energy Solutions.

RESULTS FROM STUDY QUESTION #2

What are the environmental and economic impacts of expanding Boston's local generation, district energy and microgrid infrastructure through Community Energy Solutions?

The district suitability and engineering analyses indicate that Community Energy Solutions can simultaneously provide a lower cost of energy and lower greenhouse gas emissions for the buildings within the districts.

The engineering results are widely varied. Some engineering scenarios show up to 30% energy cost savings, a huge cost advantage for businesses and residents. Other scenarios show up to 30% reduction in greenhouse gas emissions, which would contribute significantly to the City meeting its greenhouse gas emissions reductions targets.

Some scenarios show an increase in on-site fuel consumption as a result of the Combined Heat and Power systems that generate electricity locally with greater efficiencies. Some scenarios show a dramatic reduction in on-site fuel consumption, achieved by adding technologies that more prudently use fuel than the baseline condition. This Study illuminates the many dimensions of the technical, economic, and environmental issues – helping policy makers understand the correlations between technology choices, greenhouse gas emissions reductions, and end-user savings.

RESULTS FROM STUDY QUESTION #3

What can we learn from a powerful dataset of energy use for every building in Boston?

Future application of the Boston Energy-Use Map can help identify energy engineering solutions from the building scale to the transmission scale. These data can be used to target spending for energy efficiency programs, identify areas of the city with high peak demand, and test the cost and benefit of local energy supply versus large transmission projects. The future applications of this data will help policy makers, utilities, and the energy markets better serve energy customers in Boston and New England.

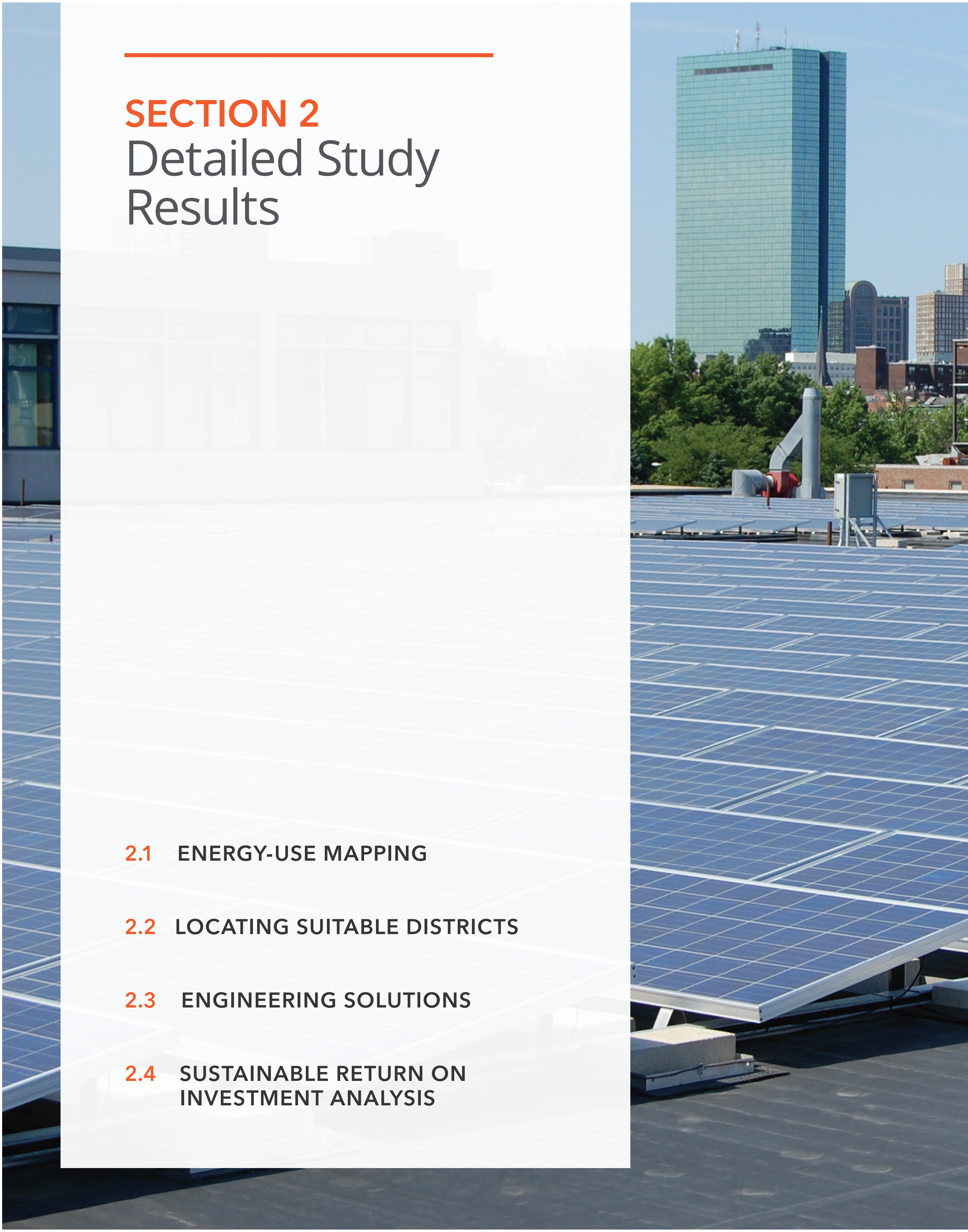
Finally, the Study has created a replicable framework that can be utilized by other communities. At each step of the Study, the framework can be adapted for the needs of other municipalities. Working collaboratively, the Study team developed a new way to address the challenge of locating Community Energy Solutions and quantifying their benefits.

A series of next steps are recommended to further our understanding of potential Community Energy Solutions and envisioning our future energy system:

- Engage area residents and businesses.
- Partner with key stakeholders including our local utilities and the regional energy system operators.
- Recognize and expand existing and planned microgrids and Community Energy Solutions.
- Identify resources to expand and deepen feasibility analysis of Community Energy Solutions.
- Refine and upgrade the Boston Energy Map as new and better data become available including BERDO, local energy supply information, and the emissions savings from the existing steam system.
- Investigate public right-of-way infrastructure solutions and develop modeling tools to include costs.
- Identify existing building retro-fits costs and develop strategies to phase-in Community Energy Solutions.
- Develop pilot projects in new and existing areas to demonstrate feasibility and benefits of Community Energy Solutions.

The Boston Energy Map has the potential to transform the way policy is developed and implemented. As the Energy Map simulation becomes more accurate and is validated with more granular data, it can be used to identify building-level energy efficiency opportunities. Future simulations can build on the Boston Community Energy Study by exploring the trade-offs between regional transmission investments and local energy supply investments.

Boston's economy continues to grow as major businesses like General Electric relocate in the city and major City planning initiatives identify new development opportunities. This growth coincides with a Grid Modernization process, a mandate from Massachusetts energy regulators that compels electric utilities to modernize their grid services. These forces can converge to create value for residents, businesses, and utility shareholders through the planning and implementation of truly innovative energy infrastructure. With the completion of this study, the City of Boston and its utility partners are on the path to achieving our Climate Action goals and supporting future generations with high performance, affordable energy supply.



SECTION 2
Detailed Study Results

SECTION 2.1

ENERGY-USE MAPPING

The foundational data for this Study are simulated energy demand for every structure in Boston. These data had to be created via simulation, as customer-level energy use data cannot legally be shared outside of the utility without customer permission. MIT Sustainable Design Lab created energy use data for each building including hourly demand data for lighting, plug loads, heating, cooling, and hot water.

Twelve virtual building types were created to represent Boston's building stock. Within these tweleve virtual building types, there were subdivisions of the data based on building vintage. To validate their enery-use, these archetypes depended on inputs such as utility data and national energy consumption benchmarks like the Commercial Building Energy Consumption Survey (CBECS). Leveraging their existing energy simulation platform, MIT Sustainable Design lab carried out the mapping exercise and is now exploring further uses for the data set.

ANNUAL ENERGY CONSUMPTION IN BOSTON

Because utilities are mandated to protect customer-level energy data, the City of Boston collects electric and gas data at the ZIP Code level. The City of Boston's Environment Department collects energy data from electric and gas utilities to measure progress on energy efficiency and climate change mitigation goals. The Boston Energy Map's modeled data have proven accurate when compared to these annual consumption reports. For electricity consumption, the Boston Energy Map is within 94% accuracy of the reported annual consumption. For natural gas, the Boston Energy Map is within 83% accuracy of the reported consumption.

ANNUAL ENERGY USE IN BOSTON

Comparison of simulated energy data to actual energy consumption as measured by Boston Environment Department in Gigawatt hours

2015, Boston Redevelopment Authority

CONSUMPTION IN BOSTON	BOSTON ENERGY MAP	REPORTED BY UTILITIES	
	SIMULATED (GWH)	ACTUAL (GHW)	ERROR
ELECTRICITY	7,067	6,687	6%
NATURAL GAS	12,322	10,186	17%

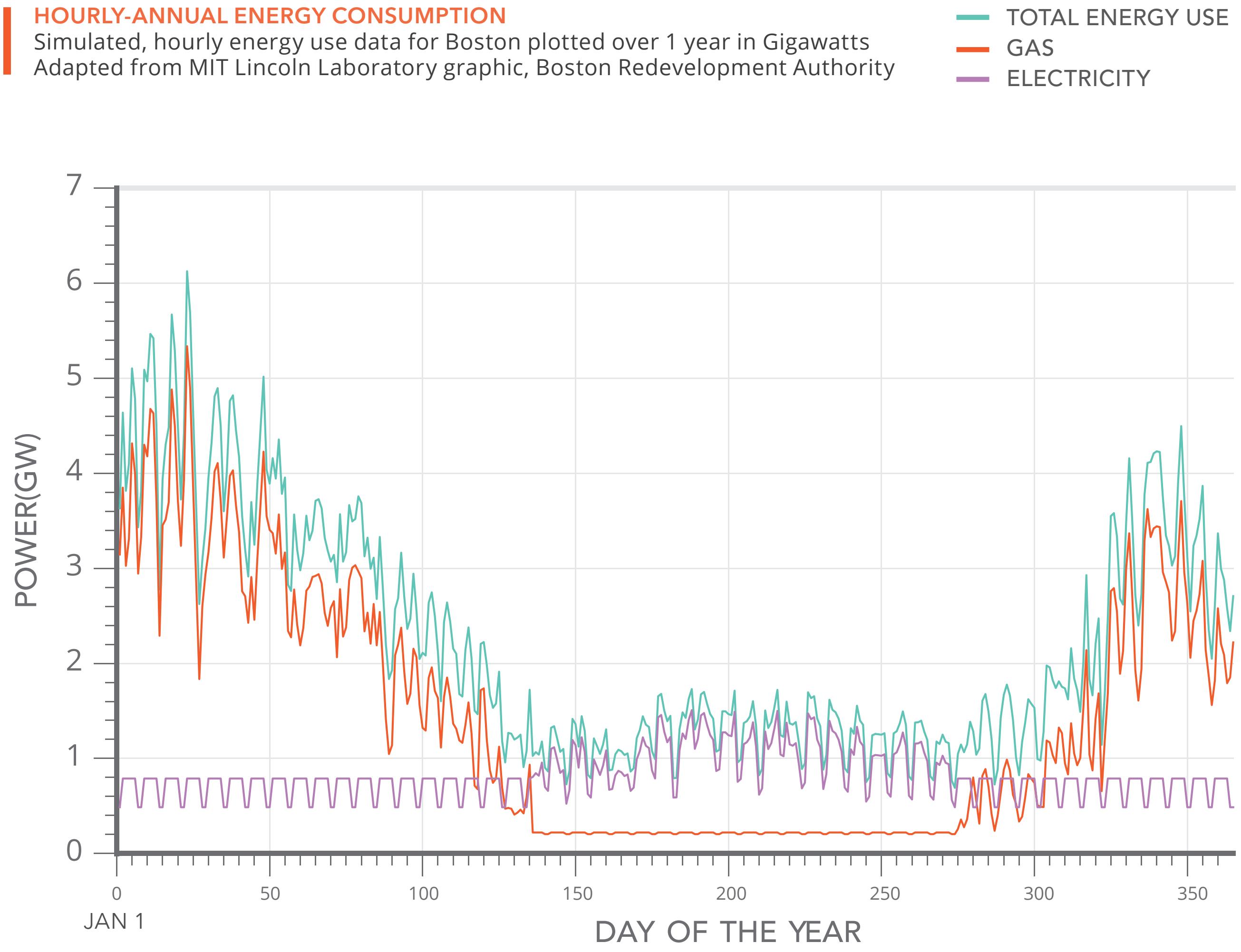
To learn more about the Boston Energy Map- see Appendix A

HOURLY ENERGY CONSUMPTION AND PEAK DEMAND

The Boston Energy Map is unique in that simulates hourly energy use for every building in the city. Whereas most energy maps created by local governments show annual consumption, the Boston energy-use data set shows hourly and daily patterns of energy use.

According to the Boston Energy Map, Boston's annual peak electric demand occurs in the summer at 1.8 Gigawatts of instantaneous demand. For reference, 1.8 Gigawatts is slightly less than the full production capacity of the Mystic Generating Station in Everett, MA near Boston. The Boston Energy Map also simulates the patterns of natural gas use. The peak consumption for natural gas is simulated as 5.4 Gigawatts, or 17,064 dekatherms, or the equivalent of an instantaneous consumption of 2,941 barrels of oil. Unlike the validation data collected by the Boston Environment Department for annual energy consumption at the ZIP Code level, there is no equivalent for hourly data.

HOURLY-ANNUAL ENERGY CONSUMPTION
Simulated, hourly energy use data for Boston plotted over 1 year in Gigawatts
Adapted from MIT Lincoln Laboratory graphic, Boston Redevelopment Authority



SECTION 2.2.1

DISTRICT SUITABILITY ANALYSIS

MIT Lincoln Laboratory analyzed the Boston landscape to identify districts that were suitable for local energy generation, district energy, and microgrids. One key criterion was a high building heating demand that would ensure the economical utilization of Combined Heat and Power (CHP) technology. Other criteria included affordable housing, critical facilities, and mixed use buildings. The mapping exercise was performed using Geographic Information Systems (GIS) and considered many data layers, including the Boston Energy Map, the Homeland Security Infrastructure Program (HSIP) Gold database, City of Boston's list of emergency shelters and critical facilities, affordable housing, flooding hazard maps, and other hazard maps. The Study team applied a combination of engineering expertise, urban planning, and critical facility protection best practices to inform this selection process. Geospatial data on existing electrical and natural gas distribution infrastructure is not available for the entire City. However, local infrastructure specialists were consulted to understand how existing natural gas and electrical infrastructure may enable or constrain the location of certain districts.

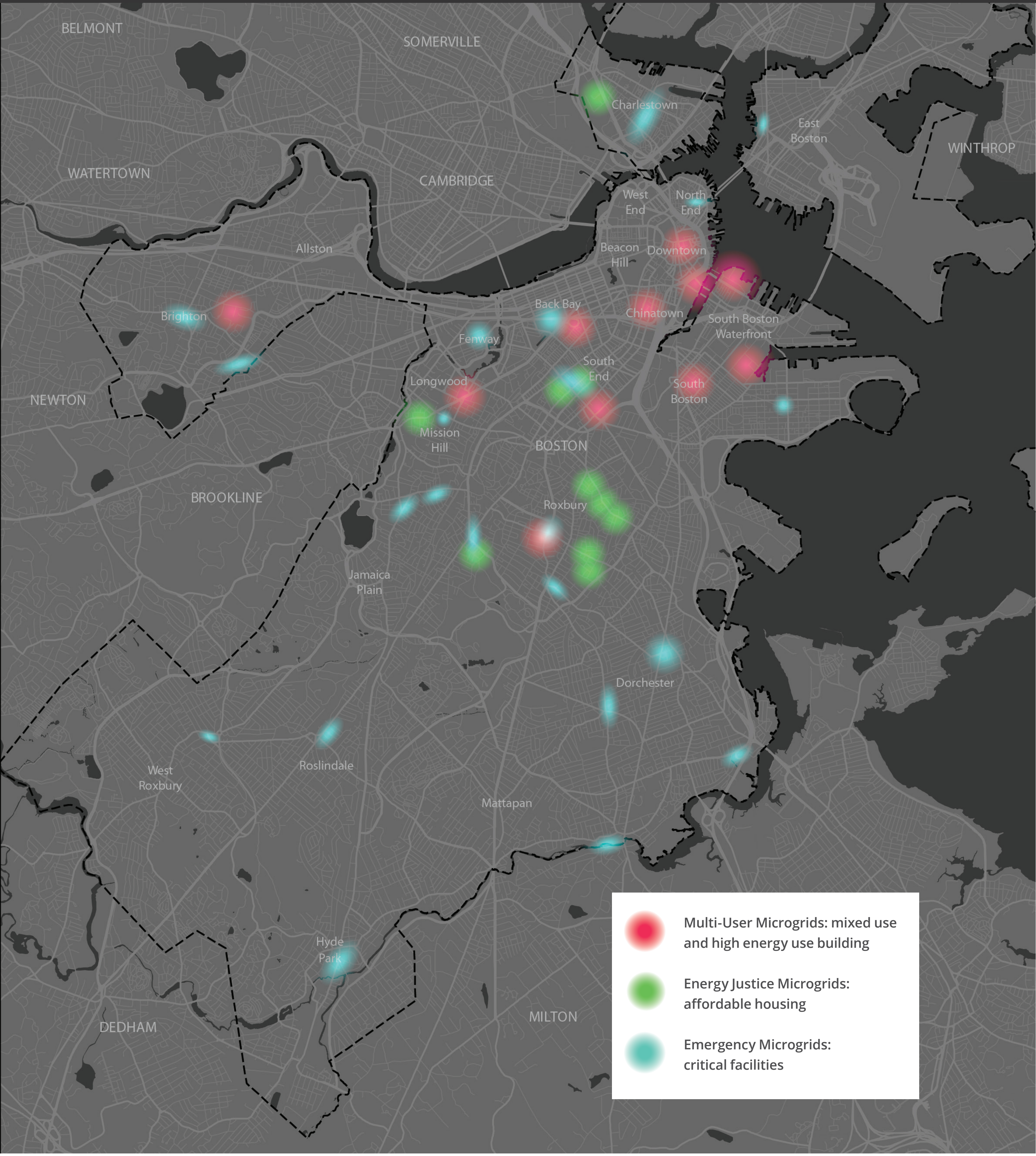
MULTI-USER MICROGRIDS are suitable in areas with the highest diversity of buildings and a thus a more balanced demand of energy throughout the day and throughout the year. A balance of demand throughout the day enables energy systems to perform at their highest utilization and efficiency. Many of the districts selected as sites for Multi-user Microgrids also include critical facilities.

ENERGY JUSTICE MICROGRIDS are suitable in locations of dense, affordable housing. Because energy costs represent a significant portion of annual household income for lower-income residents, the Energy Justice Microgrid scenarios aim to reduce costs for Boston's lower-income residents while reducing the impact on the environment. Vulnerable populations located in affordable housing, particularly the elderly, are significantly affected by grid outage and thus are well served by resilient power systems. Additionally, Energy Justice Microgrids include critical facilities such as health centers and shelters that become places of refuge when neighborhoods lose power. Much like the Multi-user Microgrids, these community energy designs aim to achieve a balanced energy demand throughout the day and throughout the year.

EMERGENCY MICROGRIDS center around districts with a concentration of critical facilities. These facilities include health and shelter facilities, grocery stores and food warehouses, and critical infrastructure such as cell phone towers and gas stations. Boston's hospitals are already equipped with resilient power systems, and Emergency Microgrids aim to identify similar energy security opportunities in Boston's neighborhoods. In recent years, many state governments including Massachusetts, New York, New Jersey and Connecticut have issued grant programs focused on supporting the municipal development of emergency microgrids.

To learn more about the District Suitability Analysis - See Appendix B

POTENTIAL COMMUNITY ENERGY SOLUTIONS



SECTION 2.2.2

EXISTING DISTRICT STEAM SYSTEM

Boston’s existing steam network, owned and operated by Veolia Energy North America, is an invaluable source of low-carbon energy for some Boston and Cambridge buildings. This steam network, along with the Medical Area Total Energy Plant (MATEP) provide a starting point for some of the potential districts identified by the Study.

DISTRICTS THAT OVERLAP WITH EXISTING DISTRICT ENERGY SYSTEMS

These potential districts (shown in yellow on the map) can take advantage of the existing Veolia Steam system. Technologies that may compliment the steam system include district cooling infrastructure, large scale absorption cooling, thermal and electric storage, and renewable energy supply.

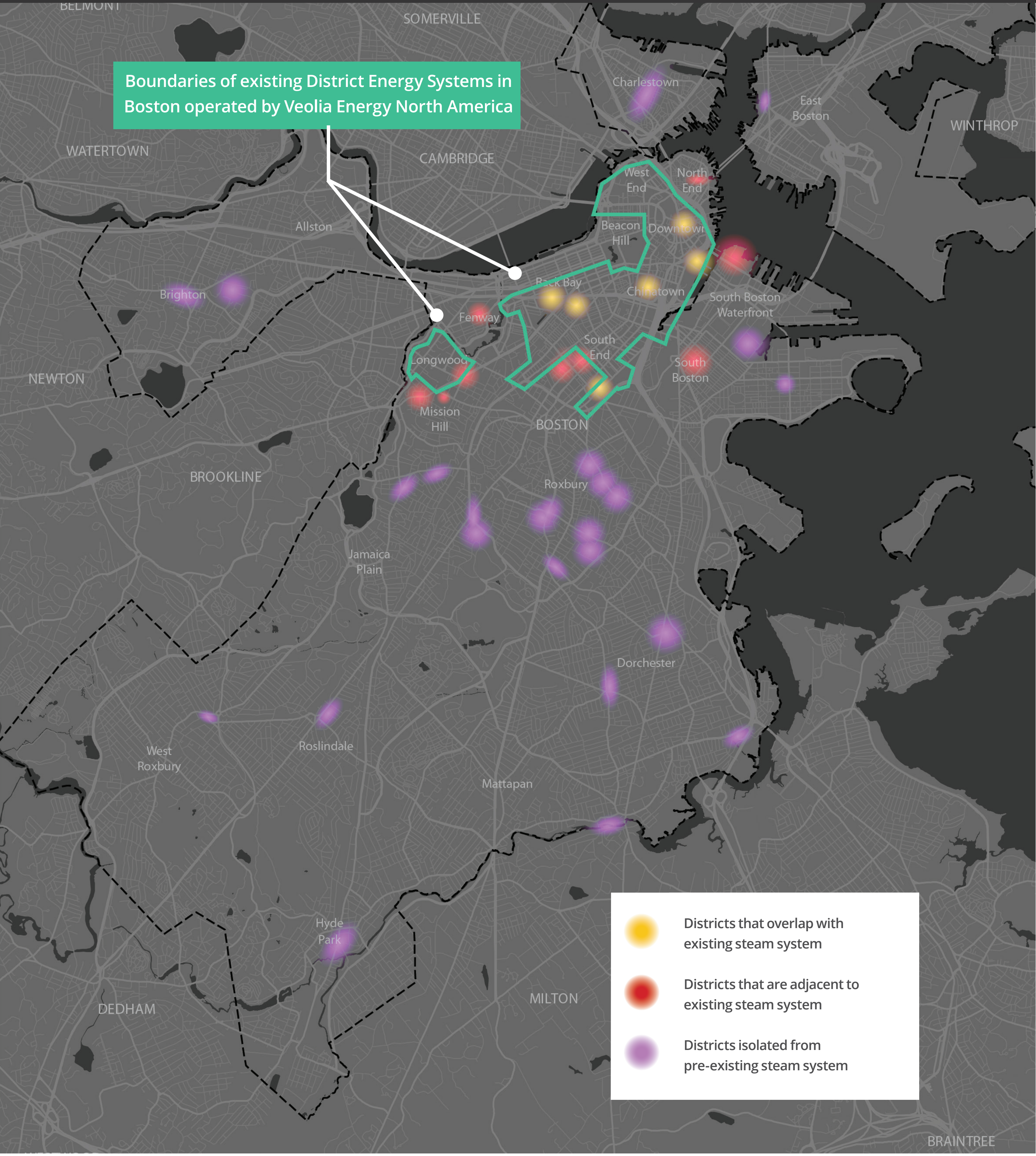
DISTRICTS THAT ARE ADJACENT TO EXISTING DISTRICT ENERGY ASSETS:

These potential districts near the Longwood Medical Area and near Boston Medical Center are adjacent to existing district energy systems (shown in red on the map). There may be opportunities to expand adjacent district energy infrastructure into the districts identified here.

DISTRICTS THAT ARE ISOLATED FROM EXISTING DISTRICT ENERGY SYSTEMS

These potential districts in most neighborhoods of Boston are isolated from existing district energy systems (shown in purple on the map). These districts would be starting from scratch and require building retrofits, road excavation, and a central plant for local generation and energy storage technologies. Since these zones do not abut existing district energy assets, a deeper analysis would be required to understand building retrofit costs and available land.

EXISTING + POTENTIAL DISTRICT ENERGY SYSTEMS



Boundaries of existing District Energy Systems in Boston operated by Veolia Energy North America

● Districts that overlap with existing steam system

● Districts that are adjacent to existing steam system

● Districts isolated from pre-existing steam system

SECTION 2.2.3

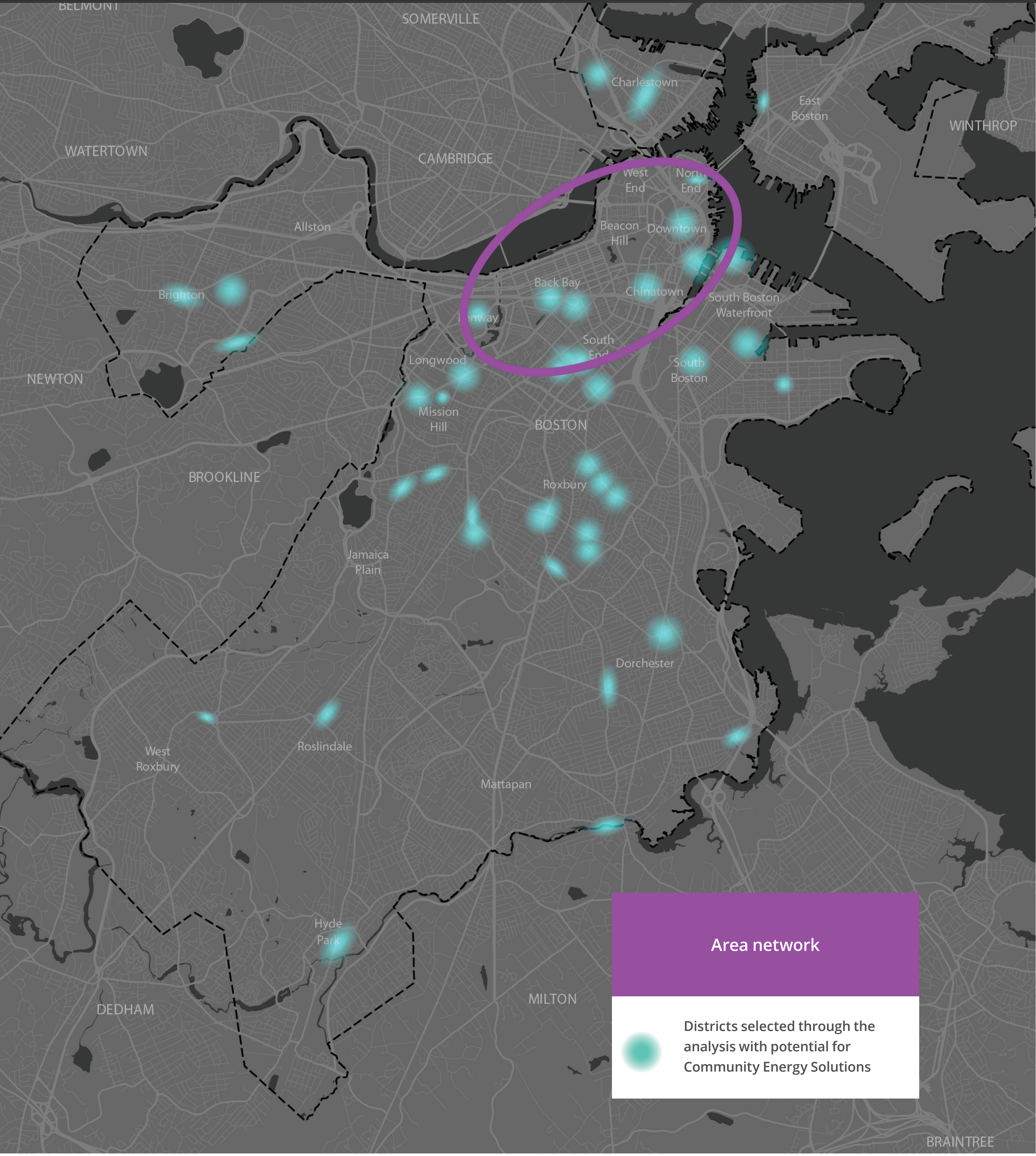
EXISTING AREA NETWORK

Boston hosts an advanced electrical grid called the Area Network which is a specially designed distribution grid to ensure a very high level of reliability.

Because the Area Network is not designed to export energy and due to the criticality of the system, interconnected local energy generation is currently limited to less than 15 kW and less than 1/15th of the customers minimum load by Eversource Energy, the owner operator of the enitre electrical network in Boston including the Area Network. The Area Network covers most of the Back Bay, Beacon Hill, Business District, Chinatown, South Boston, North End and Fenway neighborhoods.

The local generation envisioned by this Study would far exceed the thresholds set by Eversource Energy. This challenge is not unique to Boston. Technology developers are overcoming these limitations by reducing or eliminating export of locally generated electricity to the grid.

POTENTIAL COMMUNITY ENERGY SOLUTIONS



SECTION 2.3

ENGINEERING ANALYSIS

By analyzing the energy demands of the buildings within each district, Lincoln Laboratory was able to recommend the most economical, highest performing set of technologies for each district. The Study team compared the existing conditions, simulated from the Boston Energy Map, to a hypothetical design which deploys local energy generation and storage. The technologies considered in this analysis include:

Local Generation
Photovoltaic / Solar Panels
Solar Thermal Panels
Combined Heat and Power (CHP)

Energy Storage
Heat Storage
Cold Storage
Battery Storage

Heating and Cooling Production
Absorption Chiller
Refrigeration
Air Source Heat Pump
Ground Source Heat Pump

THE KEY TAKEAWAYS FROM THE ENGINEERING ANALYSIS

Engineering recommendations from the CO_2 Optimization Scenarios would reduce CO_2 emissions within the districts by an average of 18%. This figure is an average of each type of district: Multiuser Microgrids would reduce CO_2 emissions within their districts by 15%, Energy Justice Microgrids would reduce CO2 emissions by 21%, and Emergency Microgrids would reduce CO_2 emissions by 18%.

Engineering recommendations from the Cost Optimization Scenarios simultaneously reduce costs, reduce greenhouse gas emissions and increase the use of fuel that is consumed on-site. Cost savings are achieved through a combination of on-site power generation, heating, and thermal storage. The greenhouse gas emissions reductions are half of those achieved by the CO_2 optimization scenario and there is a distinct increase in on-site fuel consumption. This is a result of Combined Heat and Power using fuel to produce heating, cooling, and electric on-site when it is cheaper than buying from the grid. In some instances, the engineering recommendations replace electric cooling in the summer months with absorption cooling-the process of converting heat from the CHP into cooling. This leads to an annual increase in on-site fuel consumption, but the analysis does not specify how this increase affects peak demand of on-site fuel.

Natural gas is the default on-site fuel for Combined Heat and Power technology. With a track record of resilient supply infrastructure, natural gas is being used globally as the fuel source of choice for resilient, local power supply. However; CHP can also utilize biofuels at their main fuel source.

OPTIMIZING FOR ENVIRONMENT AND ECONOMICS

EACH HYPOTHETICAL DISTRICT CONTAINS TWO ENGINEERING RECOMMENDATIONS: A COST OPTIMIZATION SCENARIO AND A CO_2 OPTIMIZATION SCENARIO.

ENERGY COSTS, TECHNOLOGY SELECTION, AND BENEFITS- SAMPLE OF ONE DISTRICT

Results of the Study for one sample district
MIT Lincoln Laboratory, 2015

ENGINEERING RECOMMENDATIONS FOR A SAMPLE DISTRICT NEAR THE MOAKLEY COURTHOUSE			
CATEGORY	BASELINE ENERGY USE	COST OPTIMIZED SCENARIO	CO_2 OPTIMIZED SCENARIO
TOTAL ANNUAL ENERGY COST	$19,409,639	$13,847,713	$20,330,091
SAVINGS - TOTAL ENERGY COST	0	$5,561,926	$-920,452
ANNUAL CO_2 EMISSIONS [$KGCO_2$]	53,640,996	47,079,208	44,914,709
SAVINGS- CO_2 EMISSIONS [$KGCO_2$]	0	6,561,788	8,726,287
LOCAL ENERGY GENERATION			
COMBINED HEAT AND POWER [KW]	0	15,000	20,000
PHOTOVOLTAIC [KW]	0	100	100
SOLAR THERMAL [KW]	0	100	100
ENERGY STORAGE			
COLD STORAGE [KWH]	0	19,501	0
HEAT STORAGE [KWH]	0	19,445	15,128
HEATING AND COOLING PRODUCTION			
ABSORPTION CHILLERS [KW]	0	630	0
AIR SOURCE HEAT PUMP [KWH]	0	6,483	20,269
COLD STORAGE [KWH]	0	19,501	0

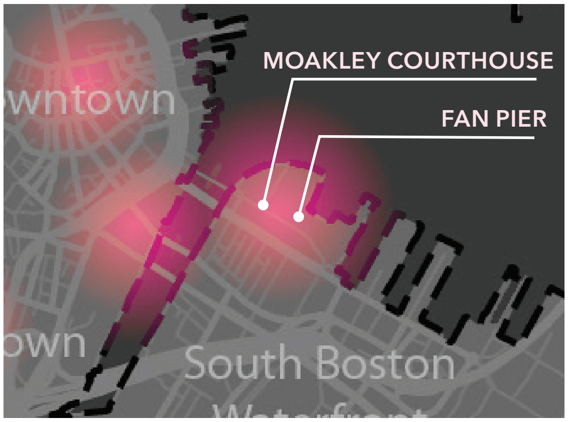
OPTIMIZING FOR ENERGY COSTS

This scenario identifies technologies that yield an overall lower total cost of energy. Notice the utilization of absorption chilling because it can efficiently utilize waste heat from the CHP system.

OPTIMIZING FOR CO_2 EMISSIONS

This scenario identifies technologies that are greener and cleaner for the environment overall, based on the total amount of CO_2 emissions. Notice this engineering scenario favors the airsouce heat pump technology, which may have a higher capital costs but achieves greater CO_2 emissions savings for this specific district.

MAP OF POTENTIAL DISTRICT



SECTION 2.4

SUSTAINABLE RETURN ON INVESTMENT ANALYSIS

OVERVIEW OF METHODOLOGY

The Sustainable Return on Investment (SROI) model quantifies both the financial and long-term sustainability impacts of energy efficiency investments. The model provides a traditional benefit and cost analysis, and estimates the financial impacts of a project. The SROI model was originally developed for the BRA to analyze the benefits of energy efficiency investments in Boston from the 2009 American Recovery and Reinvestment Act (ARRA). SROI helps to communicate the full value of investments including direct costs and savings, as well as externalities that are generally overlooked in economic assessment. The SROI model was recently updated to reflect the most current economic and energy parameters. The framework captures the following:

- Expenditures and savings:
  - Direct upfront capital and long-term operations expenditures of a new infrastructure investment; and
  - Electric, gas, and water utility costs or savings generated from the investments.

- Externalities or net sustainability benefits:
  - Direct sustainability impacts such as tons of emissions avoided and gallons of fresh water saved; and
  - Monetized environmental benefits from reduced Nitrogen Oxides (Nox), Sulfur Dioxide (SO_2), and Carbon Dioxide (CO_2) emissions.

The model's outputs include return on investment (ROI) measures such as: net present value (NPV), benefit-cost ratio, internal rate of return (IRR), and payback period. The minimum input requirements for the model are:

- Capital and operations and maintenance costs
- Net energy and utility savings or costs:
  - Therms of natural gas
  - kWh of electricity
  - Gallons of water

The model estimates the financial utility savings and environmental benefits from these inputs, and when more accurate data are available, the user has the ability to override the model's default parameters. The model then monetizes the utility savings and externalities using a variety of parameters from the Energy Information Administration (EIA), Environmental Protection Agency (EPA), National Highway Traffic Safety Administration, and other agencies.

MICROGRID SCENARIO ASSUMPTIONS

Two separate scenarios were considered for the microgrid analysis. The Cost Optimization scenario implements technology and an energy strategy to minimize user energy costs. The CO_2 Optimization scenario focuses on strategies and technology to reduce CO_2 emissions from energy production. The outputs from the Lincoln Laboratory energy analysis were aggregated for both scenarios across ten different microgrid clusters to estimate the total citywide impact of implementing microgrid technology in Boston. The scenarios are relative to baseline future conditions using existing infrastructure and energy strategies. Engineering cost estimates were not available for roadway infrastructure construction and existing building mechanical system retrofits and are not included.

EACH SCENARIO ASSUMES THE FOLLOWING:

- Microgrids begin construction in 2018 and become operational in 2021.
- Microgrids operate at 80% capacity in 2021 and become 100% operational in 2022.
- Microgrids operate 25 years before requiring any major capital reinvestment. Benefits accrue for that same period.
- A five percent discount rate applies.

MODEL INPUTS

The direct inputs for each scenario are as follows:

- Capital Costs ($): total installation cost distributed over 3 years (2018 to 2020)
- Operations and Maintenance Costs ($): $0.01 per kWh of electricity produced
- Total CO_2e Reductions (tons)
- Utility Electric Costs Savings ($)
- Natural Gas Costs Savings ($)

For each scenario, the following values were used as inputs.

SCENARIO	CAPITAL COSTS PER YEAR, FROM 2018 TO 2020	OPERATIONS AND MAINTENANCE COST PER YEAR, 2022 AND LATER*	TOTAL CO_2 REDUCTION PER YEAR (TONS), 2022 AND LATER*	UTILITY ELECTRICITY COST SAVINGS PER YEAR ($), 2022 AND LATER*	NATURAL GAS COST SAVINGS ($), 2022 AND LATER*
COST OPTIMIZATION	$67.4 million	$9.7 million	18,271 tons	$120.2 million	$-51.1 million**
CO_2 OPTIMIZATION	$69.6 million	$3.9 million	72,468 tons	$9.6 million	$10.9 million

** In 2021, the microgrids are expected to only operate at 80% capacity, and incur 80% of normal costs and benefits.*
*** The Cost Optimization Scenario uses more natural gas each year than the base scenario, meaning the cost "savings" are actually negative.*

SUMMARY FINDINGS AND RESULTS

The two microgrid scenarios, Cost Optimization and CO_2 Optimization, were run through the model separately. Each scenario produced distinct costs and benefits. The Cost Optimization Scenario produced large net utility cost savings benefits, while the CO_2 Optimization Scenario significantly reduced emissions. The following table shows the model results.

THE SUSTAINABLE RETURN ON INVESTMENT ANALYSIS FOR MULTI-USER MICROGRIDS
Analysis by Boston Redevelopment Authority, Research Division
2015

ANALYSIS RESULTS OF SAVINGS TO ENERGY CUSTOMERS- MONETARY SAVINGS ONLY			
SCENARIO	BENEFIT-COST RATIO ("OUT-OF-POCKET" ONLY)	ROI ("OUT-OF-POCKET" ONLY)	NET CASH FLOW ("OUT-OF-POCKET" ONLY)
COST OPTIMIZATION	2.77	9%	$480.9 million
CO_2 OPTIMIZATION	1.04	-1%	$8.5 million

ANALYSIS RESULTS OF SAVINGS TO ENERGY CUSTOMERS- ALL SAVINGS			
SCENARIO	BENEFIT-COST RATIO (MONETARY AND EXTERNALITIES)	ROI (MONETARY AND EXTERNALITIES)	NET CASH FLOW (MONETARY AND EXTERNALITIES)
COST OPTIMIZATION	2.82	9%	$493.6 million
CO_2 OPTIMIZATION	1.27	1%	$58.7 million

FINANCIAL COSTS + SAVINGS: COST OPTIMIZED VS. CO_2 OPTIMIZED

Considering only the monetary benefits, the dollar savings associated with the project, the Cost Optimization scenario yields a benefit-cost ratio of 2.77. Through annual electric utility cost savings, the upfront investments pay for themselves by 2025. This results in a return on investment of 9%. The associated net cash flow in present value is $480.9 million.

In the CO_2 Optimization scenario, the long-term benefits narrowly exceed the costs, with a benefit-cost ratio of 1.04. Only considering the monetary dollar expenses, the program will pay for itself by 2043; however, the return on investment is -1%. The associated net cash flow in present value is $8.6 million.

If only the monetary costs of the microgrid investment are considered, the Cost Optimization scenario outperforms the CO_2 Optimization scenario.

EXTERNALITIES AND MONETARY SAVINGS

COST OPTIMIZED VS. CO_2 OPTIMIZED

Once the environmental externalities are considered, the CO_2 Optimization scenario reduces CO_2 equivalent (CO_2e) emissions more than the Cost Optimization scenario, when both are compared to the status-quo base scenario. The Cost Optimization scenario yields a benefit-cost ratio of 2.82, not much different than when only the out-of-pocket benefits were considered. The scenario focuses on reducing the base scenario's out-of-pocket expenditures and less on reducing emissions, resulting in slight change in environmental benefits. The investments continue to pay for themselves by 2025, and the return on investment remains at 9%. The associated net present value of the net cash flow rises slightly to $493.6 million, a difference of $12.7 million.

The CO_2 optimization scenario's results improve when CO_2 emissions are considered. The benefit cost ratio increases to 1.27. The investment pays for itself by 2036, seven years sooner when emissions are not considered. The return on investment also turns positive, at 1%. The net present value of the cash flow rises considerably, to $58.7 million, a difference of $50.1 million.

Over the entire 25 year period, the mix of cost savings and benefits differs between the two scenarios. The Cost Optimization scenario notably produces many of its benefits from direct savings on utilities, while the CO_2 Optimization scenario produces a greater proportion of its benefits from carbon emissions reductions. The table below compares the financial savings and monetized environmental benefits for each scenario.

COMPARISON OF FINANCIAL SAVINGS AND MONETIZED ENVIRONMENTAL BENEFITS

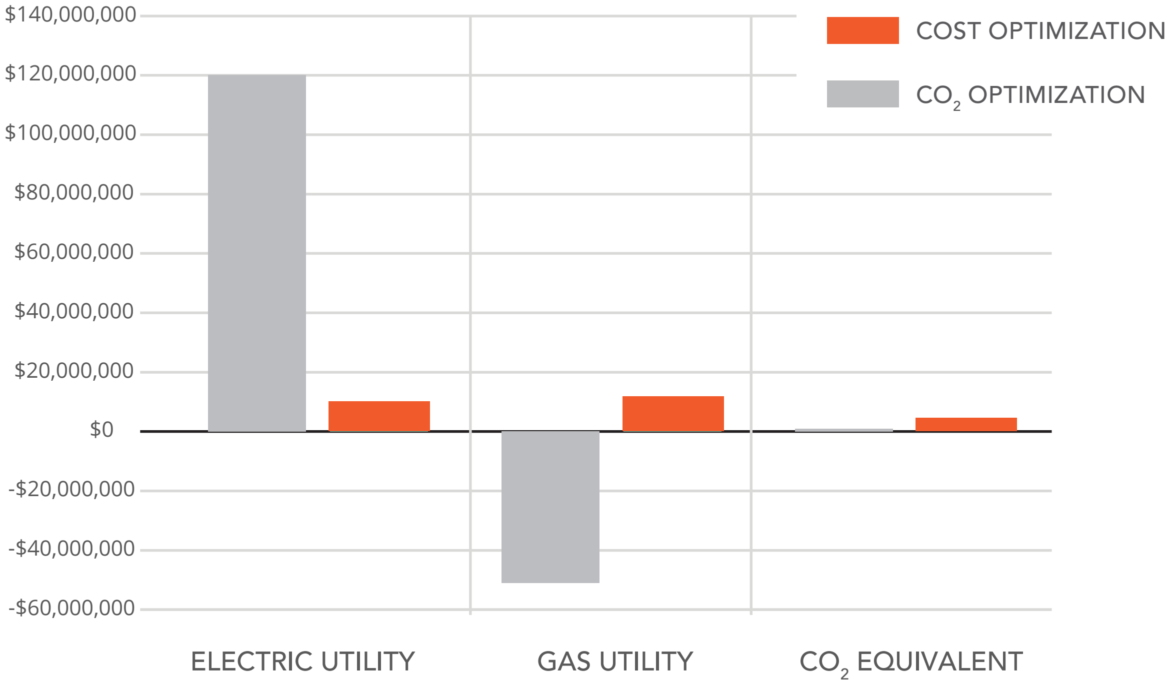
Analysis by Boston Redevelopment Authority, Research Division
2015

SCENARIO	TOTAL ELECTRICITY UTILITY COST SAVINGS OVER 25 YEARS	TOTAL NATURAL GAS UTILITY COST SAVINGS OVER 25 YEARS	TOTAL GHG EMISSIONS SOCIAL COST SAVINGS OVER 25 YEARS	TOTAL BENEFITS OVER 25 YEARS
COST OPTIMIZATION	$2,980.7 million	$ -1,266.8 million**	$30.0 million	$1,743.8 million
CO_2 OPTIMIZATION	$237.1 million	$272.2 million	$119.2 million	$628.5 million

***The Cost Optimization Scenario uses more natural gas each year than the base scenario, meaning the cost "savings" are negative.*

In the tenth year of operation, the cost optimization scenario yields most of its benefits from electric utility savings, with only a small portion coming from CO_2e savings. Natural gas actually incurs new costs in the Cost Optimization Scenario, as energy production shifts to natural gas. However, in the tenth year, the CO_2 optimization scenario produced 39% of its benefits from electric savings, 45% from gas savings, and 16% from CO_2e savings. The annual benefit split for each scenario is shown below for the year 2027.

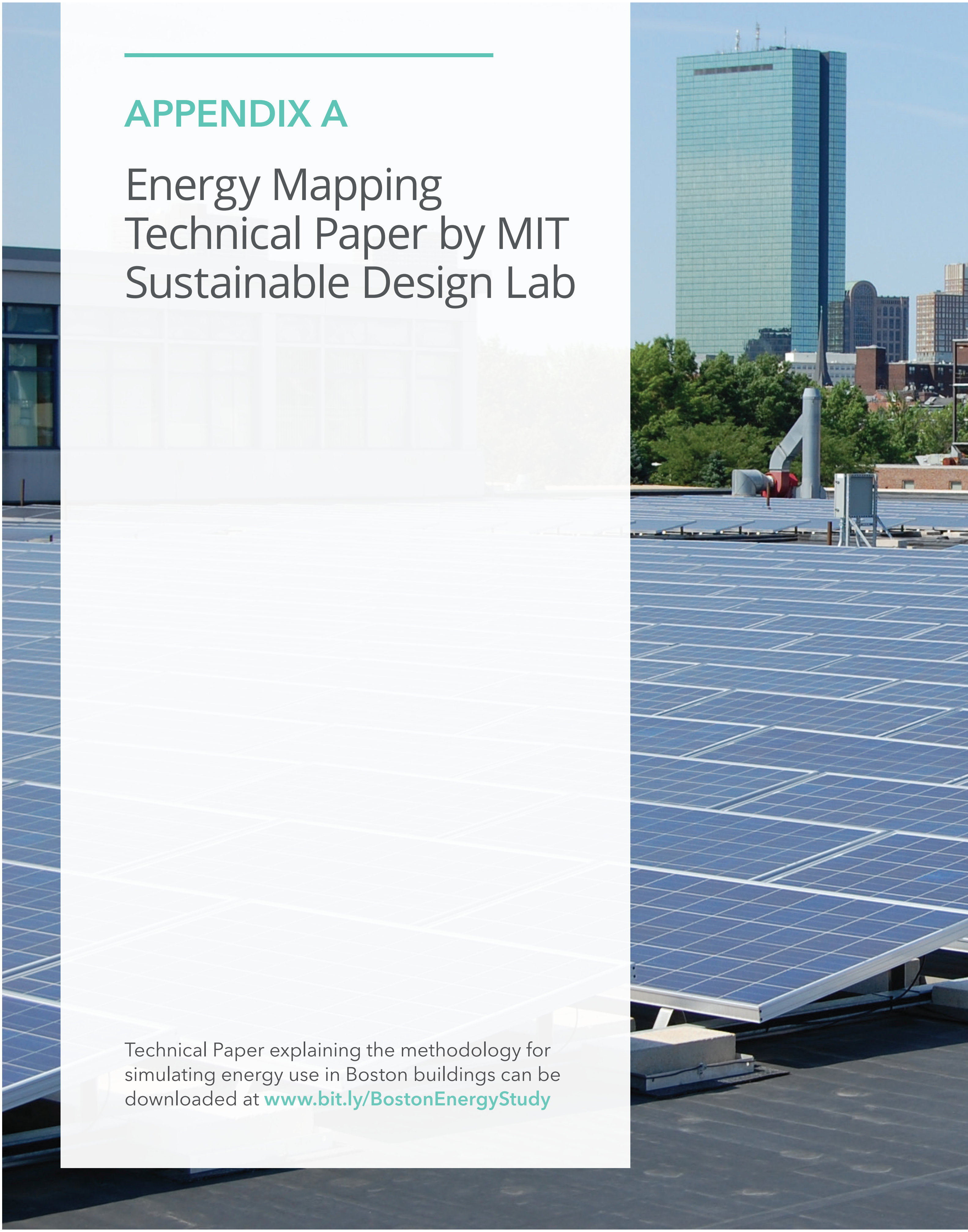
BENEFITS ANALYSIS, SNAPSHOT OF BENEFITS IN THE 10TH YEAR OF 25 YEAR INVESTMENT CYCLE
Analysis by Boston Redevelopment Authority, Research Division
2015



CONCLUSION OF THE SUSTAINABLE RETURN ON INVESTMENT ANALYSIS

Considering only the out-of-pocket expenditures, the Cost Optimization scenario performs better across all metrics. Even considering the additional benefits of emissions reductions (externalities), the Cost Optimization scenario still outperforms the CO_2 Optimization scenario.

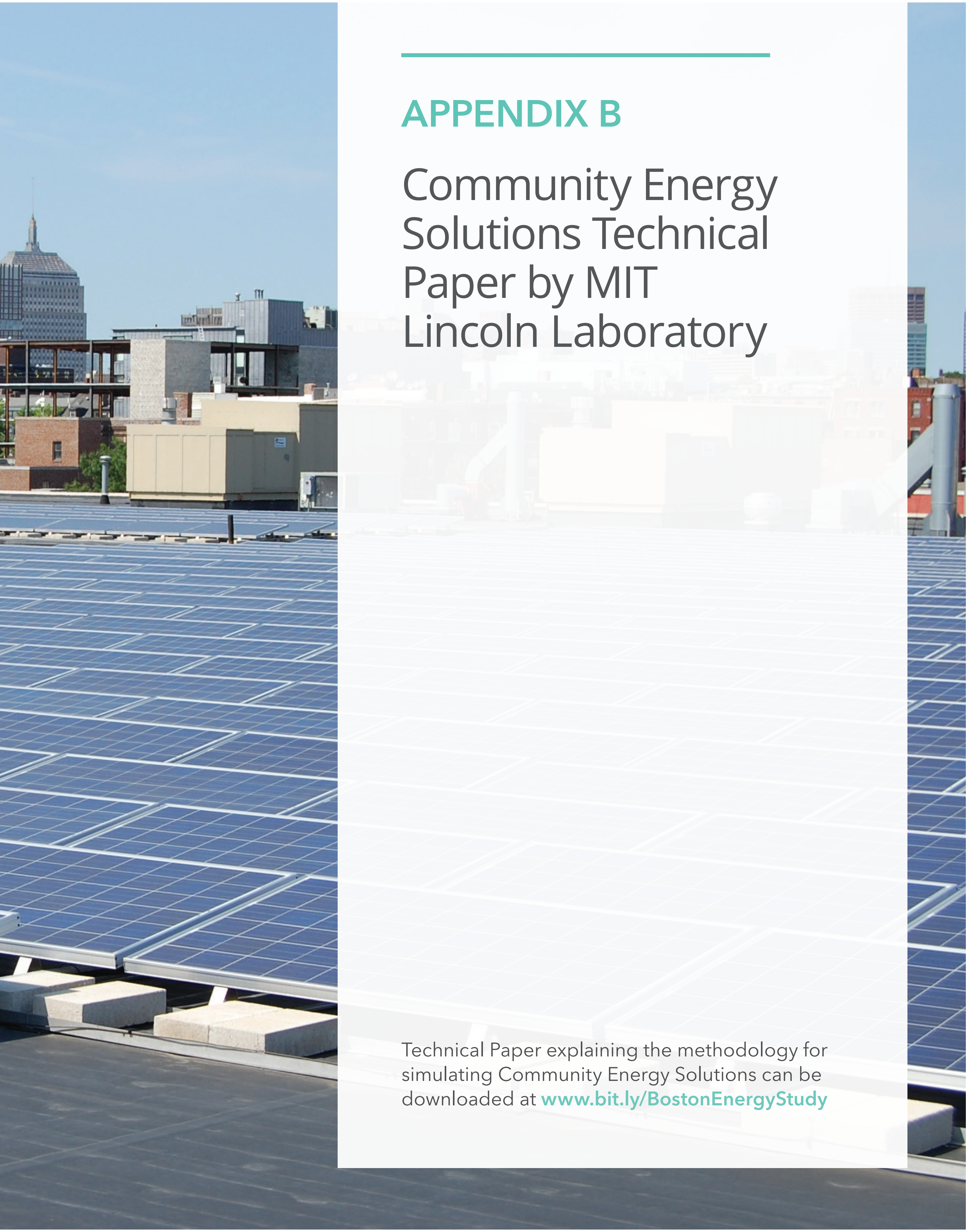
However, both scenarios produce a net positive impact, in terms of out-of-pocket returns and emissions reductions, and each have a benefit-cost ratio greater than one. What differentiates these two scenarios is the mix of net benefits, the year in which the investment pays off, and the overall return on investment. Finally, it should be noted that this analysis provides high-level estimates of impact, and not an absolute recommendation. These results are based upon the best available data at the time, and evaluate the relative benefits for each scenario. Changes in data or assumptions will affect the results of this analysis. The final results were presented relative to baseline, and differentiate between the out-of-pocket benefits and externalities. As both scenarios produce positive results compared to the baseline, policy priorities between project finance and sustainability should be the most important determining factors.



APPENDIX A

Energy Mapping Technical Paper by MIT Sustainable Design Lab

Technical Paper explaining the methodology for simulating energy use in Boston buildings can be downloaded at **www.bit.ly/BostonEnergyStudy**



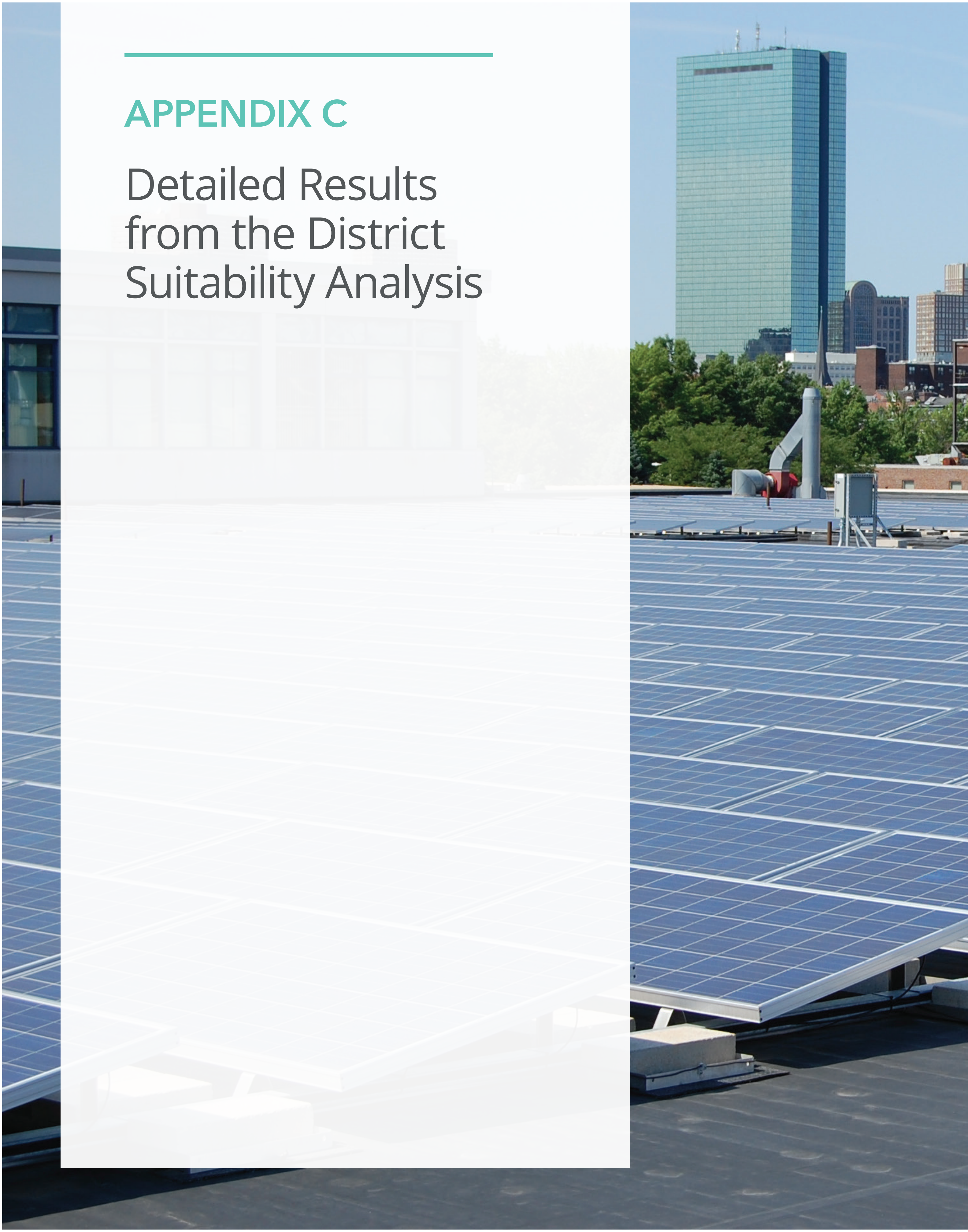
APPENDIX B

Community Energy Solutions Technical Paper by MIT Lincoln Laboratory

Technical Paper explaining the methodology for simulating Community Energy Solutions can be downloaded at **www.bit.ly/BostonEnergyStudy**

APPENDIX C

Detailed Results from the District Suitability Analysis



APPENDIX C

DETAILED RESULTS FROM THE DISTRICT SUITABILITY ANALYSIS

MULTI-USER MICROGRIDS: DISTRICT CHARACTERISTICS

PARCELS, FLOOR AREA, AND HEAT DENSITY OF MULTI USER MICROGRIDS

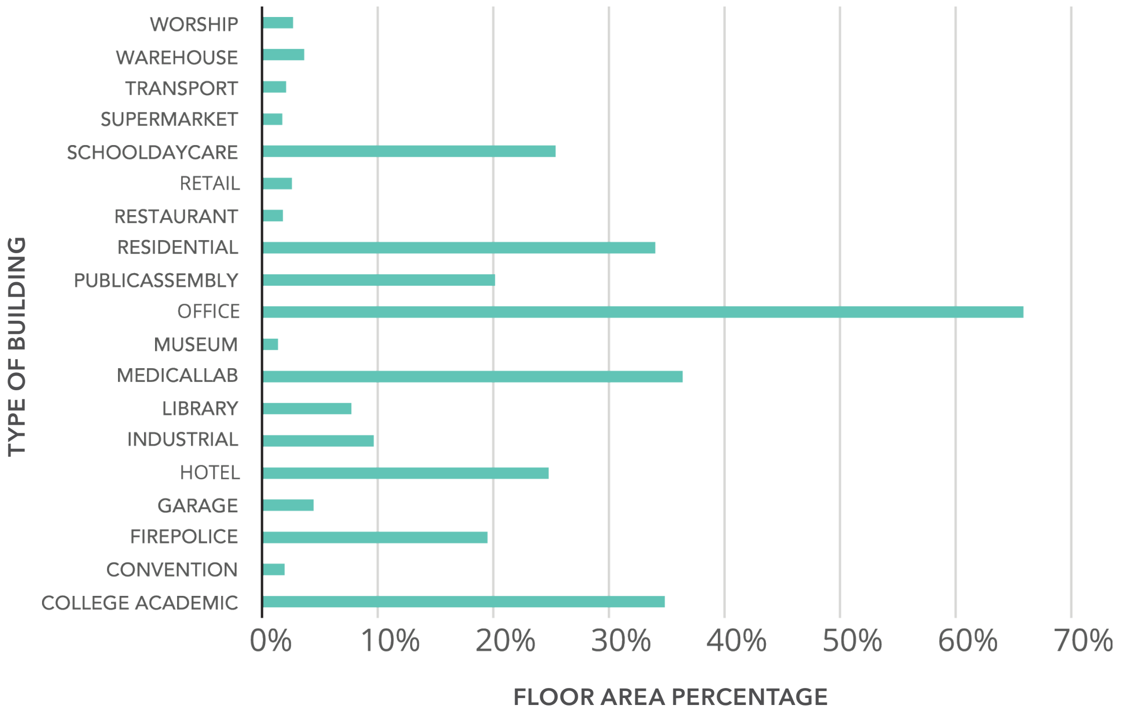
Data from MIT Lincoln Laboratory analysis
Boston Redevelopment Authority

ENERGY JUSTICE MICROGRID CHARACTERISTICS			
	AVERAGE	MINIMUM	MAXIMUM
NUMBER OF PARCELS	88	19	142
FLOOR AREA (SQUARE FEET)	6,441,613	688,760	13,574,925
HEAT DENSITY [KWH/M^2]	251	76	533

“Heat density” describes how much space heating for buildings is demanded per square meter of land are. District energy providers use this metric to assess the economic viability of installing district energy pipework. A minimum heat density must be met to justify investment in underground district energy infrastructure. Based on examples for district heating systems in Europe, the the minimum allowable value for heat density 45kWh/m^2 of land area.

BUILDING TYPES IN MULTIUSER MICROGRIDS

Average proportion of floor areas from all districts in Multiuser Microgrid category
Data from MIT Lincoln Laboratory analysis, Boston Redevelopment Authority



ENERGY JUSTICE MICROGRIDS: DISTRICT CHARACTERISTICS

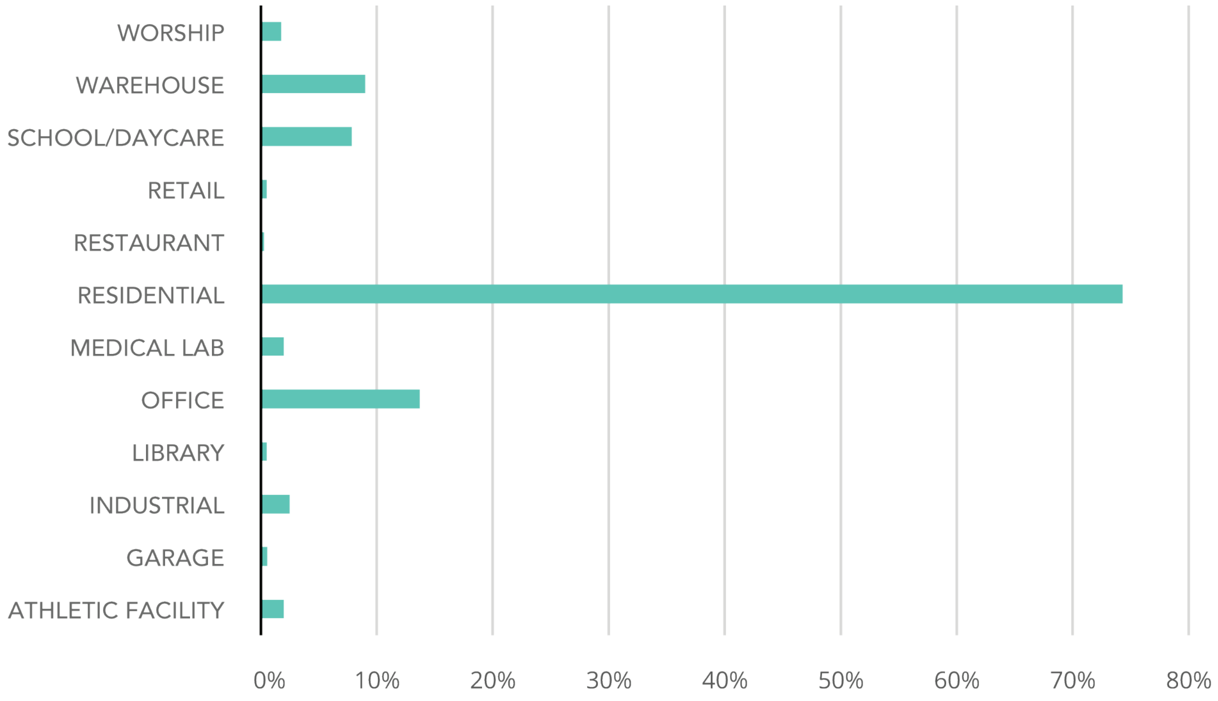
PARCELS, FLOOR AREA, AND HEAT DENSITY OF ENERGY JUSTICE MICROGRIDS

Data from MIT Lincoln Laboratory analysis
Boston Redevelopment Authority

ENERGY JUSTICE MICROGRID CHARACTERISTICS			
	AVERAGE	MINIMUM	MAXIMUM
NUMBER OF PARCELS	124	54	207
FLOOR AREA (SQUARE FEET)	848,066	481,749	1,449,036
HEAT DENSITY [KWH/M2]	161	131	185

BUILDING TYPES IN ENERGY JUSTICE MICROGRIDS

Average proportion of floor areas from all districts in Energy Justice Microgrid category
Data from MIT Lincoln Laboratory analysis, Boston Redevelopment Authority



EMERGENCY MICROGRIDS: DISTRICT CHARACTERISTICS

PARCELS, FLOOR AREA, AND HEAT DENSITY OF EMERGENCY MICROGRIDS
Data from MIT Lincoln Laboratory analysis
Boston Redevelopment Authority

EMERGENCY MICROGRID CHARACTERISTICS

	AVERAGE	MINIMUM	MAXIMUM
NUMBER OF PARCELS	105	6	480
FLOOR AREA (SQUARE METERS)	326,200	64,906	856,182
HEAT DENSITY [KWH/M^2]	71	14	199

CRITICAL ASSETS IN EMERGENCY MICROGRIDS
Data from MIT Lincoln Laboratory analysis
Boston Redevelopment Authority

EMERGENCY MICROGRID CHARACTERISTICS- CRITICAL FACILITIES	
BUILDINGS THAT INCLUDE AFFORDABLE HOUSING	88
EMERGENCY SHELTERS	16
GAS/ELECTRIC ASSETS (SUBSTATIONS, GAS STATIONS)	24
PHARMACIES	30
SUPERMARKETS	14
BOSTON CENTER FOR YOUTH AND FAMILIES FACILITIES	9
HOTELS / MOTELS	8
LIBRARIES	14
MALLS	1
MUSEUMS	2
PUBLIC SCHOOLS	3
PUBLIC GOOD SHELTERS (HOMELESS SHELTERS, ETC)	14
FIRE STATIONS	6
POLICE STATIONS	3

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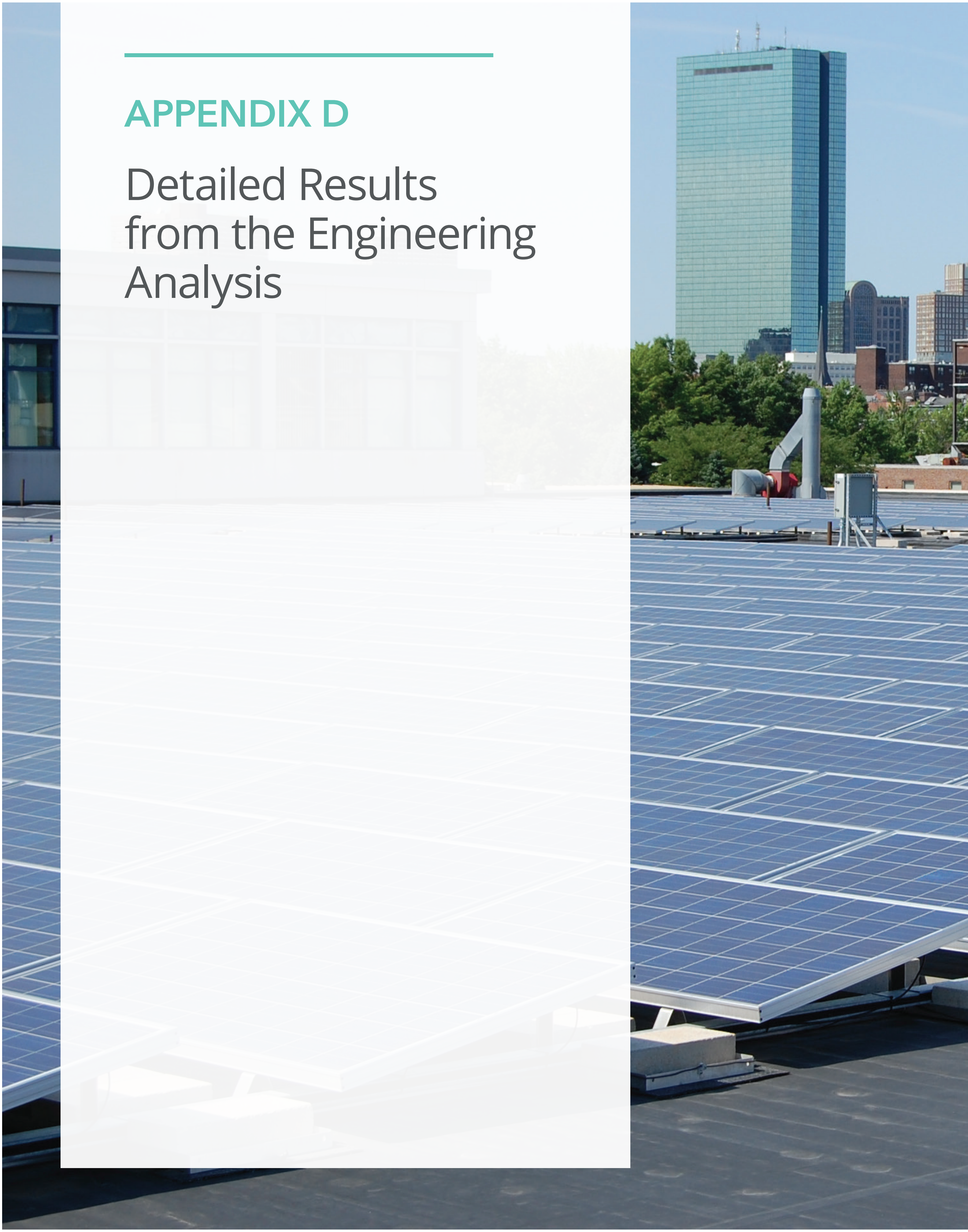
APPENDIX D

Detailed Results from the Engineering Analysis



SUMMARY OF MULTI-USER MICROGRID SCENARIO CHARACTERISTICS

MULTI-USER MICROGRID CHARACTERISTICS			
	AVERAGE	MINIMUM	MAXIMUM
BASE CASE			
ANNUAL TOTAL ENERGY DEMAND (GAS + ELECTRIC) IN KWH	209,212,832	40,471,474	395,295,710
COST IN DOLLARS	18,174,456	2,865,128	36,224,638
TOTAL FLOOR AREA IN SQUARE FEET	598,446	63,988	1,261,153
NUMBER OF PARCELS	88	19	142
AVERAGE HOURLY NATURAL GAS CONSUMPTION IN MWH	122,960	29,946	215,618
AVERAGE HOURLY ELECTRIC CONSUMPTION IN MWH	86,253	10,526	179,677
HEAT TO ELECTRIC CONSUMPTION	166%	120%	285%
COST OPTIMIZATION SCENARIO			
SIZE OF CHP IN KW	14,750	2,500	30,000
SIZE OF SOLAR PV IN KW	68	0	100
SIZE OF SOLAR THERMAL IN KW	83	0	150
NATURAL GAS CONSUMPTION AS PERCENTAGE OF THE BASE CASE	184%	139%	216%
SAVINGS AS A PERCENT OF ORIGINAL ENERGY COSTS	21%	6%	29%
CO_2E EMISSIONS REDUCTIONS	8%	4%	12%
GHG OPTIMIZATION SCENARIO			
SIZE OF CHP IN KW	15,028	2,500	30,000
SIZE OF SOLAR PV IN KW	85	0	133
SIZE OF SOLAR THERMAL IN KW	235	100	750
NATURAL GAS CONSUMPTION AS PERCENTAGE OF THE BASE CASE	79%	72%	89%
SAVINGS AS A PERCENT OF ORIGINAL ENERGY COSTS	-4%	-6%	-4%
CO_2E EMISSIONS REDUCTIONS	15%	13%	18%

SUMMARY OF ENERGY JUSTICE MICROGRID SCENARIO CHARACTERISTICS

ENERGY JUSTICE MICROGRID CHARACTERISTICS			
	AVERAGE	MINIMUM	MAXIMUM
BASE CASE			
ANNUAL TOTAL ENERGY DEMAND (GAS + ELECTRIC) IN KWH	19,178,148	14,723,871	31,698,590
COST IN DOLLARS	1,404,308	1,021,947	2,570,370
TOTAL FLOOR AREA IN SQUARE FEET	843,825	479,339	1,441,782
NUMBER OF PARCELS	125	54	207
AVERAGE HOURLY NATURAL GAS CONSUMPTION IN MWH	14,516	8,619	21,994
AVERAGE HOURLY ELECTRIC CONSUMPTION IN MWH	5,569	2,694	10,699
HEAT TO ELECTRIC CONSUMPTION	280%	143%	341%
COST OPTIMIZATION SCENARIO			
SIZE OF CHP IN KW	488	0	1,000
SIZE OF SOLAR PV IN KW	105	100	153
SIZE OF SOLAR THERMAL IN KW	90	0	100
NATURAL GAS CONSUMPTION AS PERCENTAGE OF THE BASE CASE	110%	99%	136%
SAVINGS AS A PERCENT OF ORIGINAL ENERGY COSTS	2%	0%	7%
CO_2E EMISSIONS REDUCTIONS	8%	2%	16%
GHG OPTIMIZATION SCENARIO			
SIZE OF CHP IN KW	1,100	1,000	2,000
SIZE OF SOLAR PV IN KW	90	0	100
SIZE OF SOLAR THERMAL IN KW	165	100	750
NATURAL GAS CONSUMPTION AS PERCENTAGE OF THE BASE CASE	84%	77%	91%
SAVINGS AS A PERCENT OF ORIGINAL ENERGY COSTS	-7%	-8%	-6%
CO_2E EMISSIONS REDUCTIONS	21%	18%	23%

SUMMARY OF EMERGENCY MICROGRID SCENARIO CHARACTERISTICS (SAMPLE OF 2 ENGINEERING SOLUTIONS)

EMERGENCY MICROGRID CHARACTERISTICS			
	AVERAGE	MINIMUM	MAXIMUM
BASE CASE			
ANNUAL TOTAL ENERGY DEMAND (GAS + ELECTRIC) IN KWH	61,424,978	43,575,246	79,274,710
COST IN DOLLARS	4,483,457	3,458,182	5,508,731
TOTAL FLOOR AREA IN SQUARE FEET	324,568	64,586	851,890
NUMBER OF PARCELS	105	6	480
AVERAGE HOURLY GAS CONSUMPTION IN MWH	1,877	348	5,188
AVERAGE HOURLY ELECTRIC CONSUMPTION IN MWH	946	204	2,239
HEAT TO ELECTRIC CONSUMPTION	198%	171%	232%
COST OPTIMIZATION SCENARIO			
SIZE OF CHP IN KW	3750	2500	5,000
SIZE OF SOLAR PV IN KW	100	100	100
SIZE OF SOLAR THERMAL IN KW	100	100	100
NATURAL GAS CONSUMPTION AS PERCENTAGE OF THE BASE CASE	155%	138%	171%
SAVINGS AS A PERCENT OF ORIGINAL ENERGY COSTS	13%	11%	16%
CO_2E EMISSIONS REDUCTIONS	8%	5%	10%
CO_2 OPTIMIZATION SCENARIO			
SIZE OF CHP IN KW	3,750	2,500	5,000
SIZE OF SOLAR PV IN KW	100	100	100
SIZE OF SOLAR THERMAL IN KW	100	100	100
NATURAL GAS CONSUMPTION AS PERCENTAGE OF THE BASE CASE	75%	70%	81%
SAVINGS AS A PERCENT OF ORIGINAL ENERGY COSTS	-6%	-8%	-5%
CO_2E EMISSIONS REDUCTIONS	18%	16%	18%

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APPENDIX E

Community Solar

APPENDIX E

COMMUNITY SOLAR

FUTURE EXPLORATION

COMMUNITY SOLAR OWNERSHIP AND DISTRICT-SCALE SOLAR

Community Solar is defined as a solar-electric system that is owned, invested in, or benefits an entire community. This map identifies districts that are suitable for Community Solar projects based on a high density of rooftop solar potential. Boston building owners can already explore online maps to identify rooftop solar potential; however, few solar maps identify Community Solar potential. This analysis examines potential for large-scale solar projects with a minimum 500 kW of solar production potential. Future community energy planning efforts can integrate these findings more closely with the Community Energy Solutions presented within the Boston Community Energy Study.

To learn more about the emerging trend of community solar projects, examples, and project development strategy- visit the U.S. Department of Energy website for Community and Shared Solar.

“Community Solar advocates are driven by the recognition that the on-site solar market comprises only one part of the total market for solar energy.

A 2008 study by the National Renewable Energy Laboratory found that only 22 to 27% of residential rooftop area is suitable for hosting an on-site photovoltaic (PV) system after adjusting for structural, shading, or ownership issues. Clearly, community options are needed to expand access to solar power for renters, those with shaded roofs, and those who choose not to install a residential system on their home for financial or other reasons.” – Excerpt from the US. Department of Energy “Guide to Community Solar: Utility, Private, and Non-profit Development”

This mapping analysis was generously contributed by the Google Project Sunroof team.

Google Project Sunroof’s data approximates the annual solar power production potential for rooftops in the Boston Area. This data was then used to identify each ‘district’ depicted in the map by grouping rooftops into clusters that meet a minimum of 500 kW of solar production using the projected production values from the base layer data.

MAP OF DISTRICT-SCALE SOLAR POTENTIAL