Smart Utilities Vision

Phases I & 2: Base Case & Opportunities

Boston Planning & Development Agency

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PREPARED BY AECOM

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Executive Summary

The Boston Smart Utilities Vision Project (Project) reconsiders the way utility infrastructure is designed and implemented in Boston. The Project will provide engineering and policy recommendations for the future implementation of water, energy, communication and transit infrastructure. Specifically, the Project aims to accomplish the following:

- Promote Utilities that are easier to build, maintain and upgrade
- Reduce Energy/water costs for residents/businesses
- Harden Infrastructure against flooding and heat waves
- Attract businesses through world-class utilities
- Integrate cutting edge technologies for innovation

The Smart Utilities Vision Project is based on the *PLAN: South Dorchester Avenue Planning Initiative,* adopted December 2016 *(PLAN)*. The PLAN is an initiative that focuses on144-acres in South Boston and envisions significant new real estate development, thereby creating a demand for enhanced utility infrastructure. Specifically, the PLAN proposes 12 to16 million square feet of new real estate, 14,000 to 16,000 new residents and 2 miles of new roads and sidewalks.

The PLAN provides the opportunity to pilot a new approach for providing world-class utility services. It sets the stage for city-wide policies that can be applied throughout Boston whenever roads are reconstructed and whenever utility infrastructure needs arise. By improving coordination among utilities and implementing smart utility technologies, the Project aims to make urban districts more affordable, resilient, connected, and sustainable all the while supporting the anticipated new growth.

The Smart Utilities Vision Project is separated into six phases:

Phase 1: Describe the Base Case: “Business-as-usual” approach for utility planning and implementation

Phase 2: Define the Opportunity: Modeling of Best Practices and Smart Utilities Technologies

Phase 3: Define the Construction Plan: Approach to the development of roads, utility and data management

Phase 4: Sketch the Implementation: Data frameworks, engineering plans, governance structures

Phase 5: Take it to Scale: Plan on how to implement in other areas of Boston

Phase 6: Chart the Course Forward: Next steps for the Smart Utilities Vision Project

The *Smart Utilities Vision Phase 1 & 2: Base Case & Opportunities* Report includes the results for Phase 1 and Phase 2.

The Base Case included interviews with individual utilities, reviews of existing plans and documents, development scenarios provided by the BPDA, and growth projections prepared by AECOM. The two development scenarios are variations of mixed-use development projections and project phasing over a twenty year period (2017 to 2037). One scenario plans for a higher residential share of new development and the second scenario plans for more office and laboratory uses. The pace of development phasing over the twenty-year period is the same for each of the scenarios. Growth demand projections are based on these two scenario build-outs. These demand projections were considered alongside the capacity of existing utilities and required capital infrastructure to estimate the social and environmental impacts in a triple bottom line modeling approach.

The second phase of the Project, Define the Opportunity, identifies the following list of priority best practices and smart utility technologies which were narrowed down from a more comprehensive list of 63 best practices and smart utility technologies[1] :

Smart Energy

- District Energy Microgrid
- Solar Photovoltaic + Battery Storage Microgrid

Smart Transportation

- Autonomous Vehicles
- Electric Vehicles
- Adaptive Signal Technology

Smart Water

- Water reuse
- Green Infrastructure

Smart Communications

- Telecommunications Utilidor

The model compares the costs and benefits of these best practices and smart utility technologies to the Base Case. (The benefits are compared against five categories of benefits: Environmental, Resilience, Fiscal and Economic, End User, and Capacity). The modeling results are included in Section 3.2 and were refined after the January 2017 Whiteboarding Session and through further coordination with stakeholders.

While smart utilities technologies help achieve operational goals, implementation solutions help make these goals actionable. Six preliminary Implementation Solutions were identified for the January 2017 Whiteboarding Session:

1. Flexible Blueprints[2] (design guidelines to accommodate future technical innovations)

2. Center of Excellence (clearing house for new ideas, standards, implementation strategies)

3. One Big Pipe[3] (a utilidor that contains all utility assets in one large “tunnel”)

4. Data Hub (a hub for 3D mapping, data acquisition, big-data monetization, security guidelines)

5. Legislative Authority & Financing Vehicles (public/private partnerships, business improvement districts, impact investment, revolving loan funds, tax exempt bonds, etc. and associated legislation)

6. Master Services/Condo Agreement (agreements for shared cost/benefits of utility development)

Implementation Solutions will be further evaluated during future phases of the Smart Utilities Vision Project.

[1] The more comprehensive list can be located in Appendix F
[2] The *Flexible Blueprints* solution was later renamed to *Smart Utility Standards*
[3] The *One Big Pipe* solution was later reimagined as a *Telecommunications Utilidor* to house solely telecommunications conduit and fiber

1. Introduction

The City of Boston, through the Boston Planning and Development Agency (BPDA), is examining utility infrastructure design and implementation with its Smart Utilities project (Project). The Project focuses on a 144-acre redevelopment area in South Boston that is intended to serve as a model for innovative urban growth as outlined in the *PLAN: South Dorchester Avenue Planning Initiative,* adopted December 2016 *(PLAN).* For the limits of the Project area, please refer to Figure 1 Project Area Plan.

The Boston Smart Utilities Vision is a collaborative venture between city government and Boston's utility companies that will offer a new model for integrated planning among energy, transit, water, and communications entities. A diverse group of public and private stakeholders collaborating with the BPDA includes the Mayor's Offices of Streets, Transportation and Sanitation, New Urban Mechanics, Environment Energy and Open Space, the Department of Information Technology, as well as the Public Works Department (PWD), and the Boston Transportation Department (BTD). Other stakeholders include the Boston Water and Sewer Commission (BWSC), Massachusetts Bay Transportation Authority (MBTA), Eversource Energy, National Grid and multiple telecommunications providers.

By improving coordination among utilities and implementing smart utility technologies, the Project aims to make urban districts more affordable, resilient, connected, and sustainable.

The most promising approaches are intended for a pilot in the Project area. It is envisioned that the pilot will result in a practical utility infrastructure implementation roadmap for innovations that improve social equity, affordability, and climate resiliency. Specifically, the Project aims to accomplish the following:

- Make utilities easier to build, maintain and upgrade;
- Reduce energy/water costs for residents/businesses;
- Harden infrastructure against flooding and heat waves;
- Attract businesses & jobs through world-class utilities;
- Integrate cutting edge technologies to continue to innovate.

The Project will create a model to replicate and scale innovation in other parts of Boston.

The Project focuses on four types of Smart Utilities Technologies (SUT) that are central to achieving the Project's goals:

- Energy
- Transportation
- Water
- Fiber/High Speed Communications

The first step in the Project was to develop and analyze a business-as-usual base case (Base Case) for infrastructure development and operation to support the anticipated new growth envisioned in the PLAN. Inputs for the Base Case included interviews with individual utilities, reviews of existing plans and documents, development scenarios provided by the BPDA, and growth projections prepared by AECOM.

Figure 1 Project Area Plan

Figure 2 Project Existing Conditions

Source: Final Draft Report PLAN South Boston – BPDA Board document dated 12/13/2016

2. Describe the Base Case

The first phase of the Project established a “Base Case” that uses the conventional, or business-as-usual, approach for utility coordination, planning, design, construction and operation. *Describe the Base Case* requires understanding the existing infrastructure conditions in the Project area, including available capacity and planned investments, as well as projecting future needs based on development build-out scenarios. To accomplish this, BPDA and AECOM gathered critical information from public and private stakeholders including Eversource Energy, National Grid, Veolia, BWSC, MBTA, BTD, PWD, and telecommunications companies. The information requested from the stakeholders revolved around six categories of interest: Existing Infrastructure, Capital Plans, Design Standards, Construction Process, Permits/Approvals, and Costs/Funding. For the Base Case, AECOM received information on Existing Infrastructure, Capital Plans, and some costing estimates. Additional information regarding Design Standard, Construction Process, and Permits/Approvals was collected in future phases of the Project, specifically those related to Construction and Implementation planning.

Based on this information AECOM projected utility demand and required utility capacity expansions for two real estate development build-out scenarios. From these projections, costs and impacts were estimated, using a modeling approach that accounts for the financial as well as the quantifiable environmental and social impacts of the Base Case. This type of modeling is typically referred to as a triple bottom line model, meaning the model estimates economic, environmental, and social impacts.

This section describes the various inputs and assumptions used to estimate the two Base Case scenarios and the resulting impacts. These scenarios provide the foundation on which the impact of a variety of smart future scenarios can be tested.

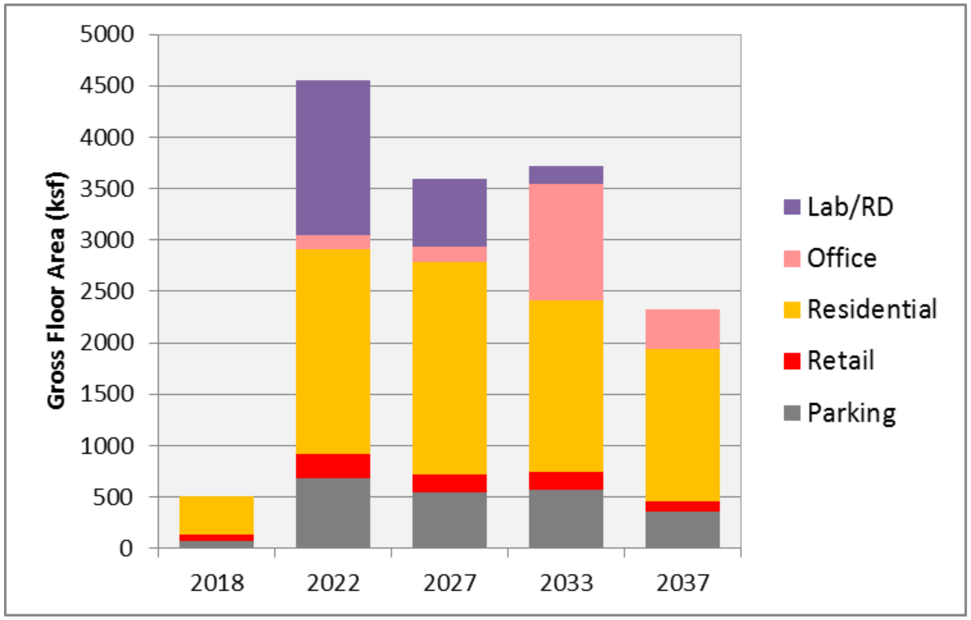
2.1 Real Estate Development Build-Out

The BPDA provided two real estate build-out scenarios for Base Case modeling that depict variations of mixed-use development projections and project phasing over a twenty year period (2018 to 2037). One scenario plans for a higher residential share of new development and the second scenario plans for more office and laboratory uses. The pace of development phasing over the twenty-year period is the same for each of the scenarios. The two scenarios are described in Tables 1 and 2, and Figures 3, 4, 5, and 6.

Table 1. High Residential Build-Out Scenario

Component	Area (sq. ft.)	Percentage
Laboratory/RD	2,400,000	15%
Office	2,400,000	15%
Residential	8,000,000	50%
Retail	800,000	5%
Parking	2,400,000	15%
Total Built Area	**16,000,000**	**100%**

Figure 3. High Residential Build-Out Phasing

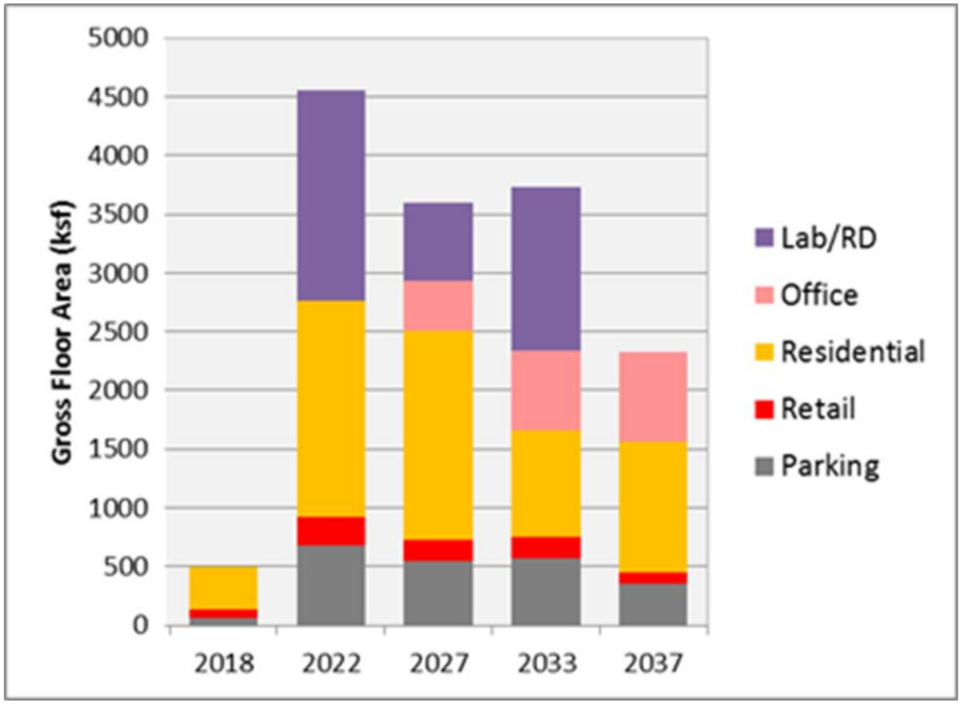


Note: The table above represents the full buildout planned in the Project area and the graph in Figure 3 reflects only the sites that will be developed through 2037. As such, the gross floor areas are not equal.

Table 2. High Office/Laboratory Build-Out Scenario

Component	Area (sq. ft.)	Percentage
Laboratory/RD	4,800,000	30%
Office	1,920,000	12%
Residential	6,080,000	38%
Retail	800,000	5%
Parking	2,400,000	15%
Total Built Area	**16,000,000**	**100%**

Figure 4. High Office/Laboratory Build-Out Phasing



Note: The table above represents the full buildout planned in the Project area and the graph in Figure 3 reflects only the sites that will be developed through 2037. As such, the gross floor areas are not equal.

Summaries of these build-out scenarios and the resulting development characteristics are shown in the following figures. These site development summaries are used as a basis for future utility demand. The gross floor area (GFA) includes the new development outlined in Figure 3 and Figure 4, as well as the existing industrial and residential buildings in the northwest and southeast corners of the Project area that are not contemplated to be changed.

Figure 5. Site Development Summary – High Residential Scenario

Total Site Area	**143.5**	**Ac**	
Area under Roads	46.6	Ac	32%
Area under Parcels	96.9	Ac	68%
Building Coverage	50.0	Ac	35%
Open Space	18.4	Ac	13%
Other Paved Area	28.6	Ac	20%

All Streets	**59,906**	**Ft**	**100%**
Principal Arterial	13,724	Ft	23%
Collector	150	Ft	0%
Minor Collector	9,523	Ft	16%
Local	36,509	Ft	61%

Main Signalized Intersections	14	#
Other Intersections	45	#

Total Built GFA	**17.3**	**Msf**	**100%**
Residential GFA	8.6	Msf	50%
Commerical Office GFA	2.4	Msf	14%
Lab/Research GFA	2.4	Msf	14%
Retail GFA	0.92	Msf	5%
Other Uses	0.6	Msf	4%
Parking	2.4	Msf	14%

Residential Units*	7,275	Dus
Total Residential Equivalent Units (ERUs)	9,524	ERUs
Residential Population**	15,278	persons
Estimated Employment***	17,816	jobs
Site Imperviousness	87.2%	

* assumption of average 1200 sf per DU (for new High Density)

** assumption of HH size as 2.1 persons/HH

*** based on ITE space standards

ERU Equivalency assumed to be 2,500 sf/ERU

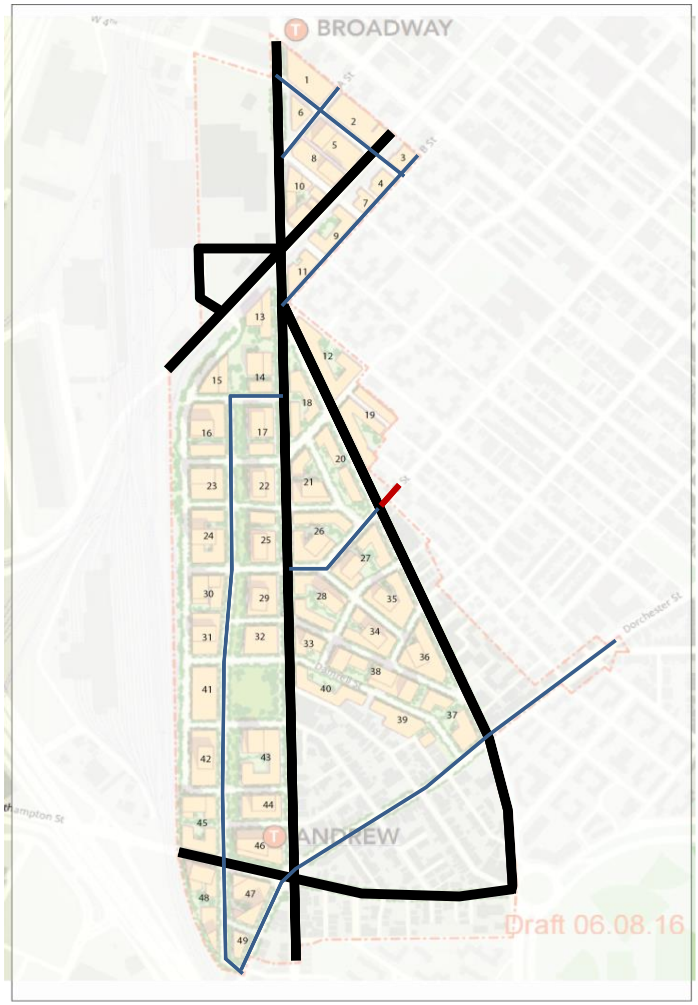


Figure 6. Site Development Summary – High Office/Laboratory Scenario

Total Site Area	**143.5**	**Ac**	

Area under Roads	46.6	Ac	32%
Area under Parcels	96.9	Ac	68%
Building Coverage	50.0	Ac	35%
Open Space	18.4	Ac	13%
Other Paved Area	28.6	Ac	20%

All Streets	**59,906**	**Ft**	**100%**
Principal Arterial	13,724	Ft	23%
Collector	150	Ft	0%
Minor Collector	9,523	Ft	16%
Local	36,509	Ft	61%

Main Signalized Intersections	14	#
Other Intersections	45	#

Total Built GFA	**17**	**Msf**	**100%**
Residential GFA	6.6	Msf	38%
Commerical Office GFA	1.8	Msf	10%
Lab/Research GFA	4.8	Msf	28%
Retail GFA	0.93	Msf	5%
Other Uses	0.6	Msf	4%
Parking	2.4	Msf	14%

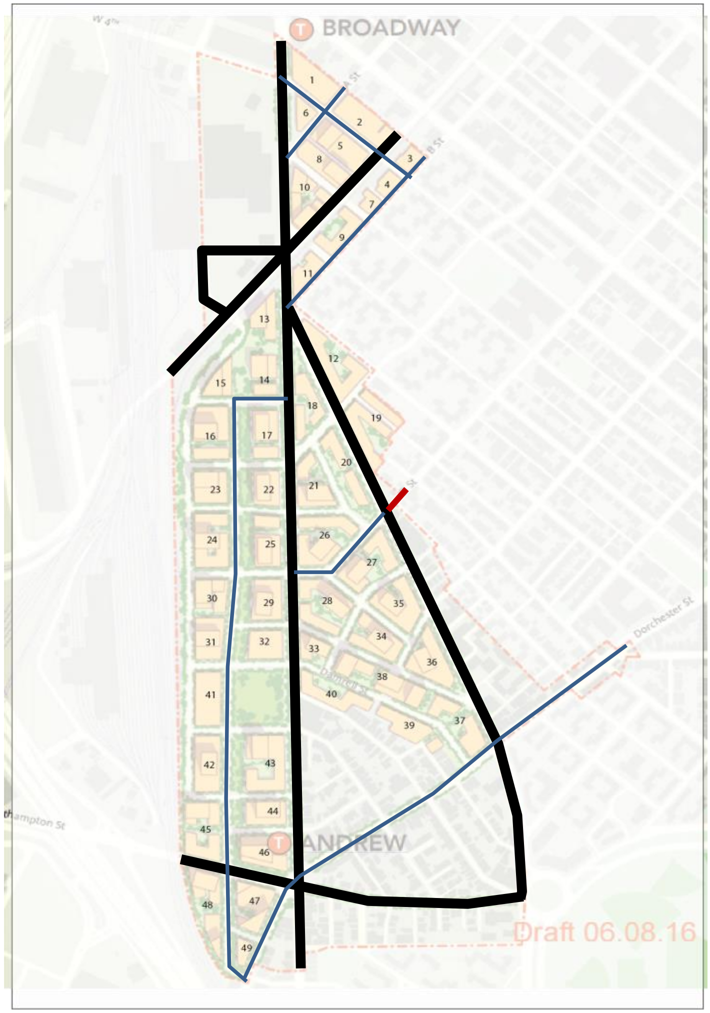
Residential Units*	5,930	Dus
Total Residential Equivalent Units (ERUs)	8,941	ERUs
Residential Population**	12,453	persons
Estimated Employment***	21,428	jobs
Site Imperviousness	87.2%	

* assumption of average 1200 sf per DU (for new High Density)

** assumption of HH size as 2.1 persons/HH

*** based on ITE space standards

ERU Equivalency assumed to be 2,500 sf/ERU



2.2 Utility Demand Projection & Required Capital Projects

AECOM used the phased build-out scenarios, existing infrastructure information, capital plans, and energy and water usage assumptions to derive Base Case utility demand projections and to estimate required capacity expansions. Future demand for telecommunications is not projected because the model assumes a gigabit broadband backbone which should be sufficient to cover future demand.

2.2.1 Energy & Water Usage Assumptions

Energy usage projections are based on DOE reference buildings constructed to ASHRAE 90.1 2004 Standards and usage profile data from the national Commercial Buildings Energy Consumption Survey. These projections were then adjusted to ASHRAE 90.1 2013 Standards by applying the factors in the following table.[4]

Table 3. ASHRAE 2004 to 2013 Adjustment Factors

Energy End Use	(% change in 2013 from 2004 baseline)	
	Commercial	Residential
Heating	- 30%	- 20%
Cooling	- 8%	0%
Ventilation	5%	20%*
Hot Water	0	0
Lighting	- 45%	- 35%
Plug Loads	- 30%	15%**

* Energy demand increase in ventilation comes from building requirements for increased ventilation

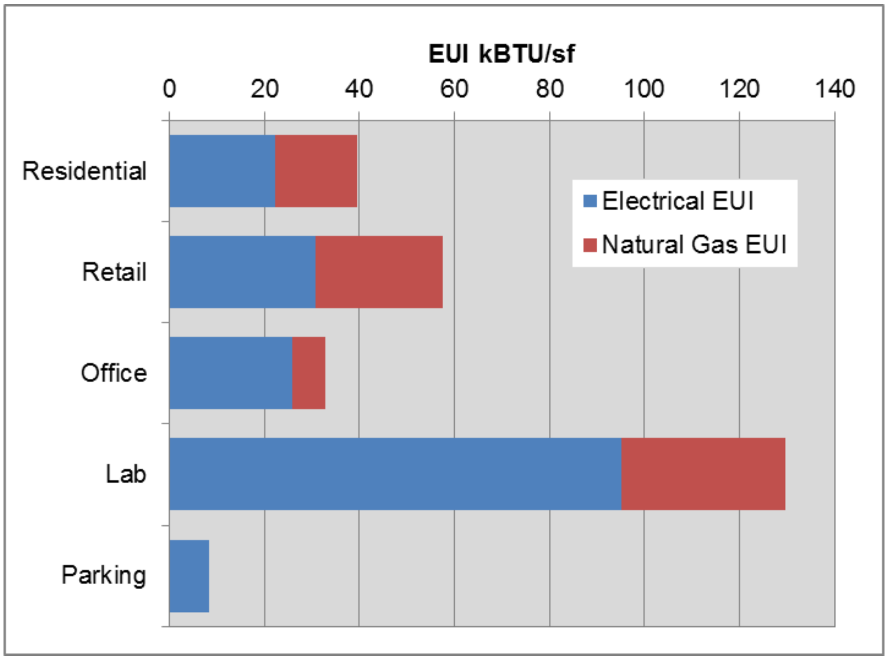
** Increase in home electronic use is greater than gains in efficiency

To develop the projected energy demands for the project site, energy models were developed based upon Department of Energy Commercial Building Prototype models – each representing a primary building type built to ASHRAE 2013 code standards – and simulated using local weather data. MA's current code requirement (as of 01/01/2017) is to comply with ASHRAE 2013 for new commercial and high-rise residential buildings. However, we anticipate energy code standards to be increased during the course of the development, and furthermore that achieving these higher standards is likely to require going beyond incremental improvements to envelope and HVAC systems as non-process load will already have been diminished. We have therefore used ASHRAE 2013 code standards to provide a best-estimate of average future code requirements in order to ensure the development is best placed to respond to increasing energy code requirements. Natural gas is assumed to be used for hot water, cooking, and space heating, while electricity is used for ventilation, lighting, plug loads, cooling, and all other building demands.

Energy usage assumptions used in the Base Case modeling are shown in the following figure.

[4] The ASHRAE 2013 standards exceed those required in the Massachusetts Building Code Stretch Energy Code.

Figure 7. Annual Energy Usage Intensity (EUI) Assumptions



Sources: CBECs; National Grid; BERDO

The EUIs were compared to the Boston University reported data of existing energy use intensity in Boston. In general, the EUIs were approximately 50% lower than existing buildings (see Table 4).

Table 4. Energy Usage Intensity Comparisons

	Office	Retail	Lab	Residential
Boston University	80	72	226	72
BERDO	58	65	150-350	42
ASHRAE 2004	50	81	170	43
ASHRAE 2013	33	57	130	40

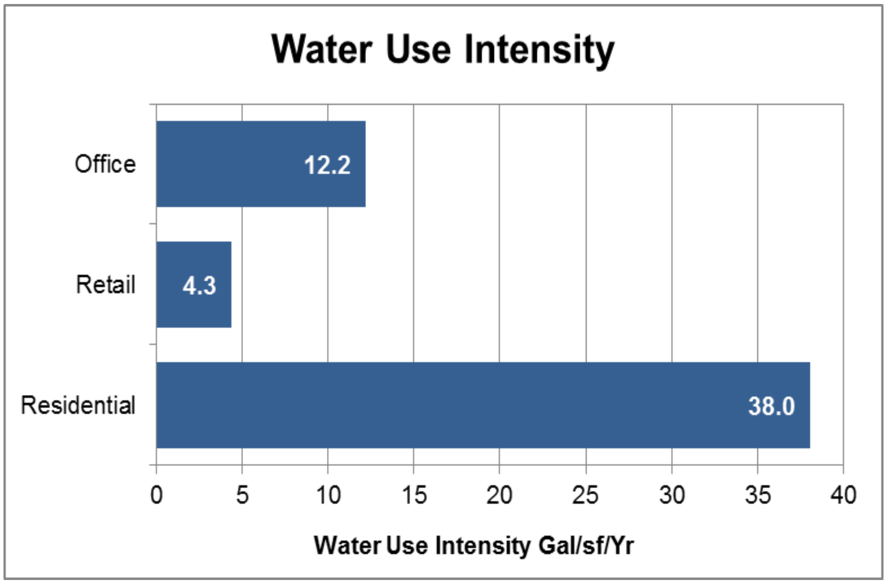
AECOM also compared these EUIs to recent examples of new-build EUIs:

- The NASA Ames lab constructed in 2010 has an EUI of 130 kBtu/SF/year.
- NREL Research support facility building in Colorado is an office-lab in a heating-heavy environment with an EUI of 35 kBtu/SF/year.

These are examples of some of the more energy efficient buildings recently constructed and the trend in building codes suggest these performance will be the standard practice in new developments over the next decade.

Water usage assumptions are based on water calibrations from previous AECOM studies and are shown in Figure 8. In addition to the use-specific intensities below, cooling water demands were estimated through modeling to be 35.4M Gallons/Yr and 47M gallons/Yr for the High Residential and High Office/Laboratory buildouts respectively.

Figure 8. Projected Annual Water Use Intensity Assumptions



Source: AECOM Project Experience

2.2.2 Existing Infrastructure & Design Assumptions

Information regarding existing infrastructure has been gathered through the interview and data gathering process. Overviews of information gathered are organized below by system: Electrical, Gas, Steam, Water, Wastewater Sewer and Storm Drainage, Telecommunications (Wired and Wireless), Transportation, and Street Lighting. Not all necessary information on available capacity and system conditions were available. As such, specific assumptions are detailed in the system descriptions below. In general, it is believed that additional capacity in all these systems will be needed to support the Project.

Electrical System

Eversource Energy owns the distribution system in the Project area. Several 13.8 kV distribution circuits run the length of Dorchester Avenue within the Project Area. The customer demand in the Project area itself is fed by 4 kV circuits.

Neither the existing 13.8 kV circuit, nor the 4 kV circuits, will have the capacity to serve new load (with the exception of small pockets); additional 13.4 kV circuits will be required, and some of the 4 kV circuits may require conversion to 13.8 kV

According to Eversource, "Due to on-going infrastructure improvement projects, the available capacity in the area exceeds 80 MW." The new load for the area will not be fed by the local supply station since it is currently heavily loaded, but rather will be fed via new circuits at a nearby supply station.

It should be noted that per Eversource's Construction Standards, duct banks and vaults owned by Eversource Energy are not to be shared by other utilities, with the exception of communications fiber. Eversource standards also require a minimum separation of ten feet from steam and one foot from all other utilities.

Gas System

National Grid provides natural gas to Boston customers for heating and non-heating (i.e., cooking and hot water) use. National Grid's gas piping within the Project area consists of a low pressure distribution system made up of pipe ranging in size from 3" to 24" diameter. Most commonly, the low pressure pipe in the Project area is 8" in diameter. This low pressure system is connected with pressure-reducing regulators to an intermediate pressure piping system. The intermediate pressure system delivers additional capacity to the low pressure distribution system when demand is high.

The gas piping materials in the Project area vary in type, age and condition. The distribution network is comprised primarily of older cast iron piping, a significant amount of plastic piping and carbon steel piping, and a small amount of wrought iron material. The age of pipes that could be identified range in age, with the oldest line being W. Broadway Street, which is dated 1889/1894. However, the majority of the lines are more contemporary, with some new lines being constructed as recently as 2014. (Note that the material, age and condition of some of the gas pipes were not identified.)

Interviews with National Grid indicate that the low pressure system is able to service current loads efficiently with some limited capacity for new development, but would likely need to be upgraded to accommodate a significant load growth related to a Project of this size and type. System improvements would include some modernization and reinforcements to the localized low pressure distribution system in addition to an extension of the intermediate pressure system.

The installation of the intermediate pressure main within the Project area will also provide capacity that could open opportunities for gas-fired Cogeneration (Combined Heat and Power) systems. Cogeneration, or Combined Heat and Power (CHP) in this context, is the use of a gas-fired engine/turbine to generate electricity and useful heat at the same time.

Steam System

Veolia North America steam provides thermal energy to customers in select districts of Boston**.** The steam is produced as a by-product of burning natural gas and fuel oil at back-up stations as fuel and using water to cool turbines. The thermal energy from the steam can be transported by pipe and reused for heating. Most steam supplied to the Boston network is produced in Veolia's cogeneration plant at Kendall Station in Cambridge, MA. A portion of the Veolia steam distribution system is located near the Broadway MBTA Station. The existing system has spare capacity. The amount of spare capacity available was requested but not provided by Veolia.

Water System

The water system piping within the Project area ranges in size from 6" to 30" in diameter. The majority of the pipe network is cast iron or older pit-cast iron material with a limited amount of more recent ductile-iron cement-lined pipes. The majority of the pipes have been rehabilitated or replaced with cement-lined ductile iron pipe in the past few decades, with a few exceptions which date back approximately to the early 1900s. Information regarding the condition of individual pipes and the overall water piping system in the Project area was not available.

The Project area is serviced by three large diameter water mains (one 30" and two 20") which enter/exit the Project limits at 6 points. These water mains interconnect at a few points in the vicinity of the project to create a system loop arrangement. A local water distribution network, predominantly consisting of 8" and 12" piping with some 16" piping, delivers water service to the array of secondary streets located in the Project area.

BWSC maintains two levels of water service: high-pressure service (SH) and low-pressure service (SL). These systems can only be interconnected by means of a division gate to regulate pressure and flow. There is one 16" HS water main in the Project area.

According to interviews with BWSC, the overall Boston water supply system has the capacity to produce 150 million gallons per day (MGD) and currently uses 67 MGD; however, the un-utilized capacity may not be readily available to the Project area depending on the configuration of the water main piping system conveying the water from interconnections with the Massachusetts Water Resource Authority (MWRA) system. Detailed analysis of the water mains interconnections is required to determine the extent of additional capacity locally available to the Project. For purposes of modeling, it has been assumed that a new water main will be installed along Dorchester Avenue.

Wastewater Sewer and Storm Drainage System

The overall Project area is serviced by a storm drainage system, a “separated” wastewater sewer system only (sanitary), and a “combined” wastewater and storm drainage sewer system[5], with the majority of the area serviced by the combined system. Areas that have the separate wastewater sewer system have an independent storm drainage system. The separated wastewater sewers and the combined sewers flow to the wastewater treatment plant. The storm drainage system flows to Boston Harbor.

The combined sewer system in the Project area consists of pipes with varying material and condition with sizes ranging from 8” to 102” in diameter. The “separated” wastewater sewer system consists of reinforced concrete pipes ranging in size from 12” to 24” in diameter. A portion of the existing sewer system is embedded within the structural envelope over the MBTA Red Line tunnel. No information regarding the age of the combined sewer system was found in the course of the study; the ages of three segments of the “separated” wastewater sewer system were identified. Two lines were built in 2001 and one was built in 2014.

The storm drainage system routes a small percentage of the storm drainage from the Project area to Boston Harbor; the majority of the storm drainage is routed through the combined sewer system. There are two existing underground sewer/drainage regulator structures in the Project area which must remain in place without new building construction above. The proposed developments within the project area will need to comply with Mass Department of Environmental Protection (DEP) offset requirements for Infiltration and Inflow with regards to combined sewers.

Due to the considerable development that has occurred and is planned for South Boston, including the Project, the BWSC has initiated a study for the planning and design of sewer separation projects in South Boston. The study includes the analysis of sewer separation and rehabilitation of existing wastewater sewer systems where possible. The Study is anticipated to be completed in 2018.

For purposes of the Base Case, it has been assumed that the existing combined wastewater sewer system will remain in place for the routing of both existing and future wastewater within the Project area and the current tributary storm drainage from outside the Project area[6]. (The Base Case further assumes that both the upstream and downstream flows entering and existing the combined wastewater system will remain as “combined” and the capacities upstream/downstream will not affect the designs within the Project area.) The separate wastewater system will remain in place and continue to route existing wastewater, as well as future wastewater from the Project area.

Without extensive analysis of the hydraulics of this existing storm drainage system and final roadway designs, it is uncertain whether the existing storm drainage system will have sufficient capacity or flow dynamics to meet the needs of the Project in that specific area. Therefore, AECOM modeling assumes the construction of a completely new drainage system in this area. The assumption that storm drainage flows both in and out of Project area will remain.

Telecommunications

Several telecommunications utilities own infrastructure within the Project area. The telecommunications infrastructure is made up of both wired and wireless assets. Wired telecommunications uses physical cable, including copper and/or fiber-optic cable, to transmit data. Wireless telecommunications use electromagnetic waves instead of wire to transmit signals across the communication path. Appendix A provides a summary of telecommunication infrastructure ownership within the Project area.

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[5] According to the BWSC web page, “The City of Boston is served by two types of wastewater collection systems: separated and combined. A separated sewer system is comprised of sanitary sewers and storm drains. Sanitary sewers are designed to transport only sanitary flow and storm drains are designed to transport stormwater flows. However, a combined system performs the dual function of transporting sanitary flow as well as storm water runoff in one pipe. This type of system is common in older cities.”

[6] Please note that it has also been assumed that that none of the existing wastewater systems that are anticipated to be reused for the Project would require rehabilitation, i.e. the systems’ existing conditions allow the systems to be reused.

Wired System
The wired telecommunications system is majority fiber optics-based with the various stakeholders including Crown Castle, Centurylink, Lightower, RCN, Level 3, Verizon Business, AT&T, and City of Boston's PIC. The lines range in length from 300 feet to 3,100 feet. The age and condition of the lines was requested but was not provided to the research team.

Wireless System
Five wireless telecommunications systems including a wire center for Verizon, a teleduct for Verizon business, an AT&T tower, a BTD street box, and an unknown Comcast feature are located within the Project area. The AT&T tower was placed in 2013, but the ages and conditions of the remaining features are unknown. Seven companies have distributed antenna systems (DAS)/Small Cell installations within the Project area.

Data needs are growing significantly, limiting the capacity of many existing telecommunications systems and thus requiring additional infrastructure almost everywhere – include the Project area. Telecommunications companies are researching higher bandwidth alternatives. At this point, a higher bandwidth alternative is not advanced enough to include in our model. What is assumed and included in the installation of a higher fiber count backbone and related telecommunication distribution network off the new main backbone.

Transportation System

The MBTA Red Line subway and ten bus routes comprise the mass public transit available in the Project area. The MBTA Red Line is the most utilized of all of subway lines in the MBTA subway system. The Red Line's Andrew and Broadway stations approximately define the north and south limits of the Project area. Both of these stations are currently over capacity during the peak travel period.

Recently, the MBTA Fiscal and Management Control Board approved the replacement of all Red Line cars. According to public statements by the MBTA, the new cars are scheduled to be in service by 2024 and, once in place, will increase passenger capacity by 50% during peak hour service.

The ten bus routes that serve the Project area are also over capacity during peak hours. These bus routes provide vital connections both in and out of the Project area and are critical in linking the South Boston neighborhoods with the Broadway and Andrew Stations (and thus, a link to all the other MBTA stations throughout the Metro region). The bus system is constrained by the number of buses that the MBTA can deploy for bus service. The MBTA Bus Facilities are at capacity and, without added infrastructure i.e., Bus Maintenance Facility(s), expansion of bus service will not be possible.

The MBTA system is serviced by communications and electrical systems which are located in cable duct banks along the area streets. A traction power station is located at Andrew Square.

Street Lighting System

In 2010, the City of Boston Public Works Department began upgrading its 42,000 mercury vapor and 22,000 high pressure sodium street lights to efficient LED lighting. As of December 2014, 65% of the City's lighting had been upgraded. Along Dorchester Avenue, Old Colony Avenue and Dorchester Street in the Project area all lights have been replaced with LED Lighting. For purposes of the model, new street lighting is included for the new streets only.

2.2.3 Capital Plans Review

The interview and data gathering process revealed that not all stakeholders have established capital plans. Private entities in particular face unpredictable changes in customer base and market fluctuations. The following entities have capital plans that span between one- and five-year planning horizons:

- **City of Boston:** Capital Plan Fiscal Years (FY) 2017-2021
- **Boston Water and Sewer Commission:** Capital Improvement Program 2016-2018

- **Massachusetts Bay Transportation Authority**: *Capital Investment Program FY2016*
- **Massachusetts Department of Transportation**: *2017-2021 Capital Investment Plan*

The projects identified within or in close proximity to the Project area are generally focused on rehabilitating existing infrastructure. These projects reflect the needs of the agencies to maintain their assets in good working condition for current demand.

In addition to the capital plans, which are focused on shorter-term implementation, long-term plans were also reviewed. The City of Boston's *Draft Imagine Boston Expanding Opportunity* (November 2016) describes the overarching actions to help the City reach the vision for Boston in 2030. In it, the Dorchester Avenue area in South Boston is described as an "Expanded Neighborhood" meaning it is an established neighborhood that has been identified a place for transformative change. Improvements for this type of neighborhood would aim to "improve neighborhood vitality, services, and affordability while affirming each neighborhood's distinct identity".

The *Draft Go Boston 2030 Vision Framework* (Framework) is a citywide plan focused on the long-term vision for Boston's transportation network. Through data collection and public input, the Framework defines the goals and measurement of the desired result of these goals. The goals are access, safety, reliability, experiential quality, innovation and technology, affordability, sustainability and resiliency, governance, and health. Future improvements in South Boston will contribute to meeting these goals.

City of Boston

The capital planning process and documents for the City of Boston include all of the City's Departments. The City's *Capital Plan Fiscal Years (FY) 2017-2021* includes over 300 projects. A review of this five-year plan, revealed four projects within or in close proximity to the Project area. These projects are listed in **Table 5.** The capital plan does not indicate the estimated year of work on these projects. While not explicitly listed in the plan, Boston's Public Works Department also conducts resurfacing and reconstruction (i.e., sidewalk improvements) each year throughout the City. The following streets within the Project area are included on the "Priority Streets List": Dorchester Avenue between Andrew Square and Old Colony Avenue, Dorchester Avenue between Howell Street and Dorchester Street; Southampton Street between Dorchester Avenue and Massachusetts Avenue, and Preble Street between Dorchester Avenue and Old Colony.

Table 5. City of Boston Capital Improvement Projects near Project Area

Project Title	Project Description	Location
Ellery Street. Southbound	Improve from Dexter Street. Southbound to Southampton Street.	Within Project area
Flaherty Park	Renovate park, including play lot, pathways, and passive areas.	Outside Project area, but nearby
Old Colony Housing Roadways	Reconstruct roadways in the redevelopment of the Old Colony housing development.	Outside Project area, but nearby
Strategic Planning Area Transportation Study	Analyze transportation capacity and develop conceptual design and cost for future infrastructure improvements for Dorchester Avenue	Various neighborhoods

In addition to the Project area improvement projects, one city-wide project - the expansion of Boston's BoNet fiber optic network- may affect the Project area. This could result in the expansion of the City's free Wi-Fi as well as its public safety communications systems.

Boston Water and Sewer Commission

The Boston Water and Sewer Commission is required to annually prepare a three-year Capital Improvement Program (CIP). The latest is the *Capital Improvement Program 2016-2018*. One project has been identified that could potentially affect the Projects listed in **Table 6**[7].

Table 6. BWSC Projects near Project Area

Project Title	Project Description	Location	Estimated Year of Construction
South Boston, East Boston & Hyde Park Contract No. 14-308-005	Replacement of water pipes	• F Street. W.8th Street. to W. Broadway in South Boston (1,700-ft of 8-in pipe) • F Street. W. 8th Street.to W. Broadway in South Boston (1,560-ft of 16-in pipe) • W. 8th Street. F Street. to Dorchester Street. in South Boston (230-ft of 12-in pipe) • F. Street. W. 8th Street. to #32 F. Street. in South Boston (300-ft of 12-in pipe)	2016/2017

Massachusetts Bay Transportation Authority

Typically, the Massachusetts Bay Transportation Authority produces a five-year capital plan. However, the latest plan, Capital Investment Program FY2016 does not span five years. A new five-year plan for FY2017-2021 is underway. The transit improvement projects related to the Project area and included in the FY2016 plan are listed in **Table 7**.

Table 7. MBTA Projects near Project Area

Project Title	Project Description	Location	Estimated Year of Construction
Red Line third rail replacement and third rail heater upgrade.	Replacement of aged infrastructure which accumulates ice and impacts service	• Between Andrew and North Quincy stations and Andrew and Ashmont stations	Completion 2017
Red Line Infrastructure Improvements	Infrastructure improvements (e.g., track, facilities) in advance of the arrival of new Red Line vehicles	• Includes improvements to Cabot Carhouse, Cabot Test Track, and Cabot Yard along Dorchester Avenue in South Boston	Completion 2019
Red Line Signals and Power	Replacement of Red Line DC feeder cable and return cable	• System wide	

[7] Please reference the Wastewater Sewer and Storm Drainage information in the Existing Infrastructure and Design Assumption section for information regarding BWSC's planned study for potential wastewater and storm drainage sewer separation and/or rehabilitation.

Massachusetts Department of Transportation

The current capital plan for the Massachusetts Department of Transportation (MassDOT) is their *2017-2021 Capital Investment Plan*. This five-year plan does not have any projects identified specifically within the Project area nor does it include any improvements to major routes in close proximity to the Project area (e.g., I-90 and I-93).

2.2.4 Demand Projections

To develop the projected energy demands for the project site, energy models were developed based upon Department of Energy Commercial Building Prototype models – each representing a primary building type built to code standards – and simulated using local weather data.

The results of these models were parametrically extrapolated using the development scenarios both in terms of building type and phase of construction to provide an understanding of the overall energy use of the proposed development.

Energy Demand Projection

High Residential Scenario
Based on energy demand modeling (see **Figure 9**), at full build-out the Project area is estimated to have an approximate annual energy consumption of 225,000 MWh. Average daily peak demand for electricity is estimated at 42 MW in the summer. On a sample winter day, the peak electricity demand is 32 MW. The peak heating demand is in the morning around 7 am when the commercial office heating is highest. Cooling demand peaks in the summer months at around 4 pm. The average daily heating load is estimated to be around 190 Million BTU-Hrs and the average daily cooling demand is around 17,600 tons.

High Office/Laboratory Scenario
Based on energy demand modeling (see **Figure 10**), at full build-out, the site is estimated to have an annual energy consumption of 290,000 MWh. Average daily peak demand for electricity is estimated at 59 MW in the summer. A sample winter day has a peak demand of 45 MW. The average daily heating load is estimated to be around 230 Million BTU-Hrs and the average daily cooling demand is around 22,700 Tons.

Figure 9. Energy Demand Projections - High Residential Scenario

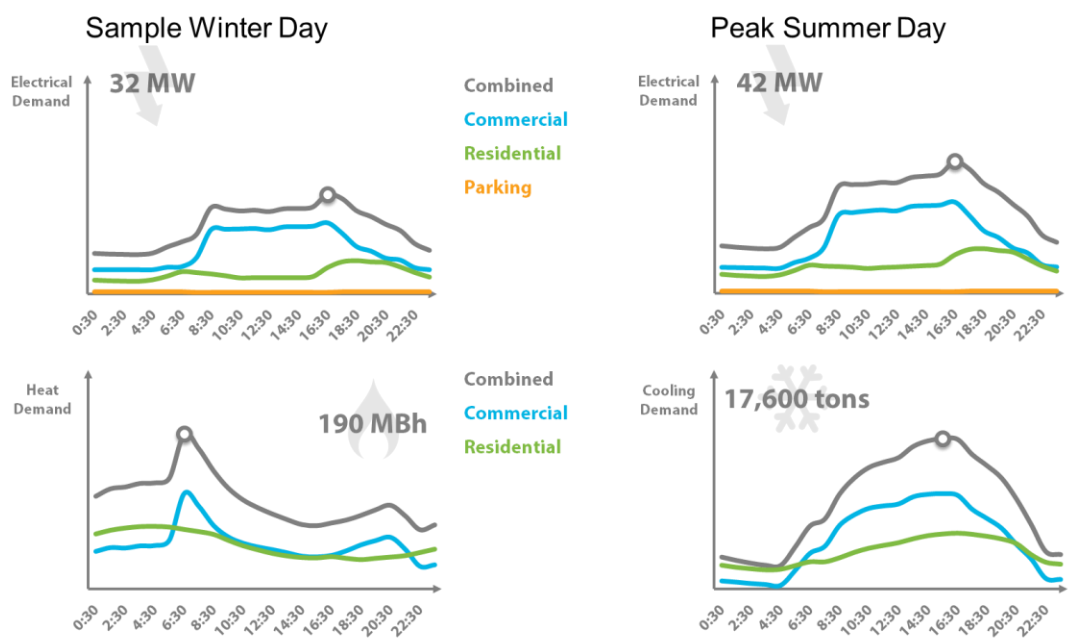
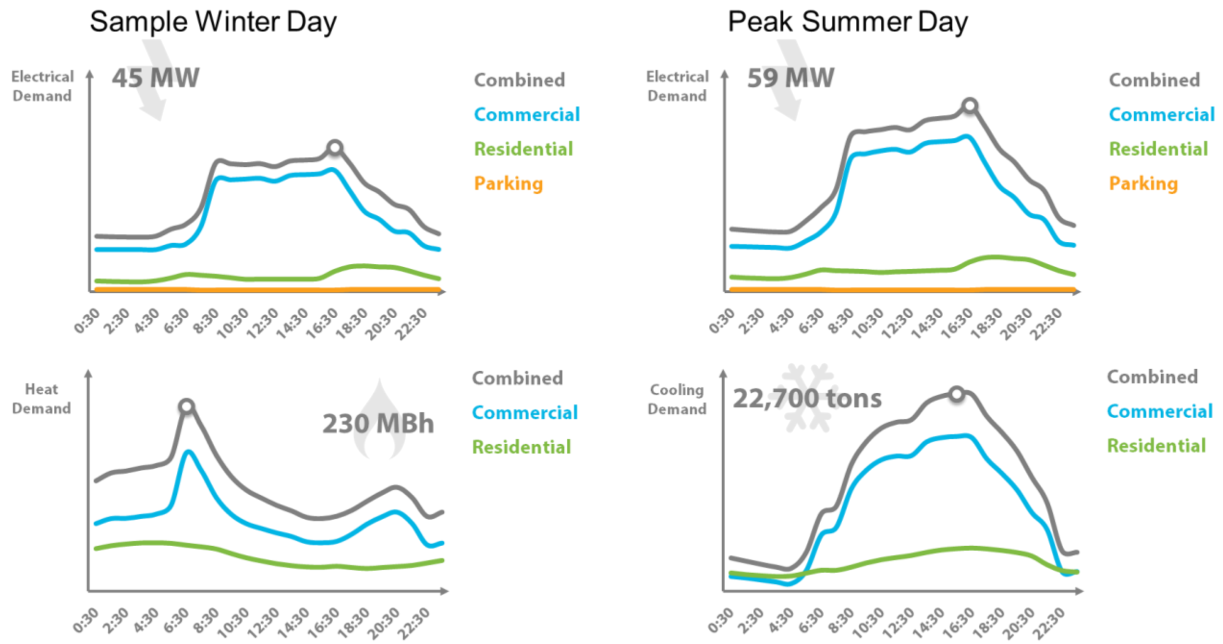


Figure 10 Energy Demand Projections - High Office/Laboratory Scenario



Based on these projections, Table 8 outlines the average requirements per resident per day for the Project area and the subsequent sections outline modeling results for energy and water demand.

Table 8. Average Utility Demand

Component	Average Per Person Per Day
Total Energy	67 kWh
Water	32 Gallons
Wireless (MB/day)	100
Number of Devices	4.4
Broadband Data Requirements	3 GB

Source: GlobalWebIndex and iGR estimate of 190 GB/month/household

Water, Wastewater Sewer and Storm Drainage Demand Projections

The water demand projections were estimated to be the same for both build-out scenarios. Using the development typologies and densities, AECOM modeled and estimated the annual water use of the proposed development as 371 million gallons per year for the high residential scenario and 322 million gallons per year for the high office and laboratory scenario. The wastewater outflow was estimated as 316 million gallons per year for the high residential buildout and 273 million gallons per year for the high office/laboratory buildout. Using the Massachusetts Stormwater Management guidelines and an assumption of a 1” stormwater storage requirement for all parcels, it was estimated that 354,215 cubic feet of stormwater detention capacity would need to be incorporated into the development parcels for run-off management. Impacts of additional Best Management Practices (BMPs)[8] will be evaluated in subsequent phases of the project.

[8] Stormwater Best Management Practices are physical or procedural means that mitigate stormwater runoff quantity and quality.

2.2.5 Infrastructure & Capital Requirements

Using the data, assumptions, and estimates discussed in this section, AECOM calculated the infrastructure and capital requirements necessary to support the proposed development build-out scenarios. While energy, water and wastewater demand projections differ between the two development build-out scenarios, the estimated infrastructure needed for both scenarios is constant, i.e. the difference between the projected demands is not significant enough to require different infrastructure system designs. The resulting estimates are shown in **Table 9**. Please see Appendix B for additional unit cost assumptions and Appendix C and Appendix D for a detailed discussion of utility placement and road segmentation. Mains are assumed to run down Dorchester Avenue and as part of Plan: Dot Ave, a new road parallel to the existing Dorchester Avenue is proposed. Some of the utility mains that now congest Dorchester Avenue could be moved to this road. The quantities of various infrastructure components required represent the total quantity of new infrastructure necessary to support the entire development.

While energy and water projections differ between the two development build-out scenarios, the estimated infrastructure needed to support the development is assumed constant.

Table 9. Infrastructure & Capital Requirements Summary

Component	Quantities	Units	Cost Rate/Unit	Capital Construction Costs	Annual O&M Costs
ROADWAY INFRASTRUCTURE					
Arterial Resurfacing	13,724	ft	$398.00	$5,000,000	$5,000
New Local Streets	10,050	ft	$700.00	$7,000,000	$3,000
New Collector Streets	3,700	ft	$1,000.00	$4,000,000	$5,000
New Sidewalks	27,500	ft	$500.00	$14,000,000	$0
New Streetlights	110	#	$33,000.00	$4,000,000	$0
New Signalized Intersections	14	#	$250,000.00	$4,000,000	$0
New Intersection Walkways	45	#	$15.00	$0	$0
New Curb & Gutter	13,750	ft	$214.24	$3,000,000	$0
Total Streets & Roadways				**$40,000,000**	**$12,000**
WATER INFRASTRUCTURE					
Feeder Lines (Pipe Only)	27,142	ft	$150	$4,000,000	$15,000
Primary Mains (Pipe Only)	6,609	ft	$160	$1,000,000	$59,000
Trenching & Manholes	33,751	ft	$103	$3,000,000	$0
Water Service Lines	7,800	ft	$150	$1,000,000	$0
Fire Hydrants	200	#	$3,500	$1,000,000	$0
Total Water Distribution	**33,751**	**ft**		**$10,000,000**	**$74,000**
STORMWATER INFRASTRUCTURE					
Distribution (Pipe Only)	25,909	ft	$250	$6,000,000	$25,000
Mains (Pipe Only)	0	ft	$ 250	$0	$270,000
Trenching and Backfill	25,909	ft	$103	$3,000,000	$0
Curb Inlets	0	#	$4,000	$0	$0
Catch Basins (Shallow)	345	#	$6,000	$2,000,000	$0
Storm Manholes	86	#	$5,000	$400,000	$0
Detention	354,215	cf	$8.50	$3,000,000	$5,000
Total Stormwater Infrastructure	**25,909**	**ft**		**$15,000,000**	**$300,000**
SEWER INFRASTRUCTURE					
Distribution	25,909	ft.	$250	$6,000,000	$13,000

Component	Quantities	Units	Cost Rate/Unit	Capital Construction Costs	Annual O&M Costs
Trunk	0	ft.	$250	$0	$50,000
Manholes	80	#	$5,000	$400,000	$0
Trenching and Backfill	25,909	ft.	$103	$3,000,000	$0
Total Sewer	**25,909**	**ft.**		**$10,000,000**	**$60,000**
ELECTRICAL DISTRIBUTION INFRASTRUCTURE					
Main Lines (12 duct 15 kV)	6,609	ft.	$112.00	$1,000,000	
Distr Connections (4 duct 15kV)	12,593	ft.	$76.00	$1,000,000	
Electrical Conduit Trenching	19,202	ft.	$103.00	$2,000,000	
Total Electrical Infrastructure	**38,404**			**$4,000,000**	**$0**
NATURAL GAS INFRASTRUCTURE					
Main Lines (60 PSI 8" SDR 11)	6,609	ft.	$110.49	$1,000,000	
Distr Connections (60 PSI 6" SDR 11)	12,593	ft.	$81.08	$1,000,000	
Trenching and Backfill	19,202	ft.	$103.00	$2,000,000	
Total Gas Infrastructure	**19,202**			**$4,000,000**	**$0**
TELECOM INFRASTRUCTURE					
Gigabit Fiber Trunk	6,609	ft.	$192.00	$1,000,000	-
Secondary Fiber Mains	0	ft.	$48.00	$0	-
Distr Fiber Connections (...)	12,593	ft.	$24.00	$300,000	-
Trenching and Backfill	19,202	ft.	$103.00	$2,000,000	
Total Telecom Infrastructure	**38,404**	**ft.**		**$4,000,000**	**-**
BUILDING SYSTEM					
Building Boilers & HVAC				**$95,000,000**	

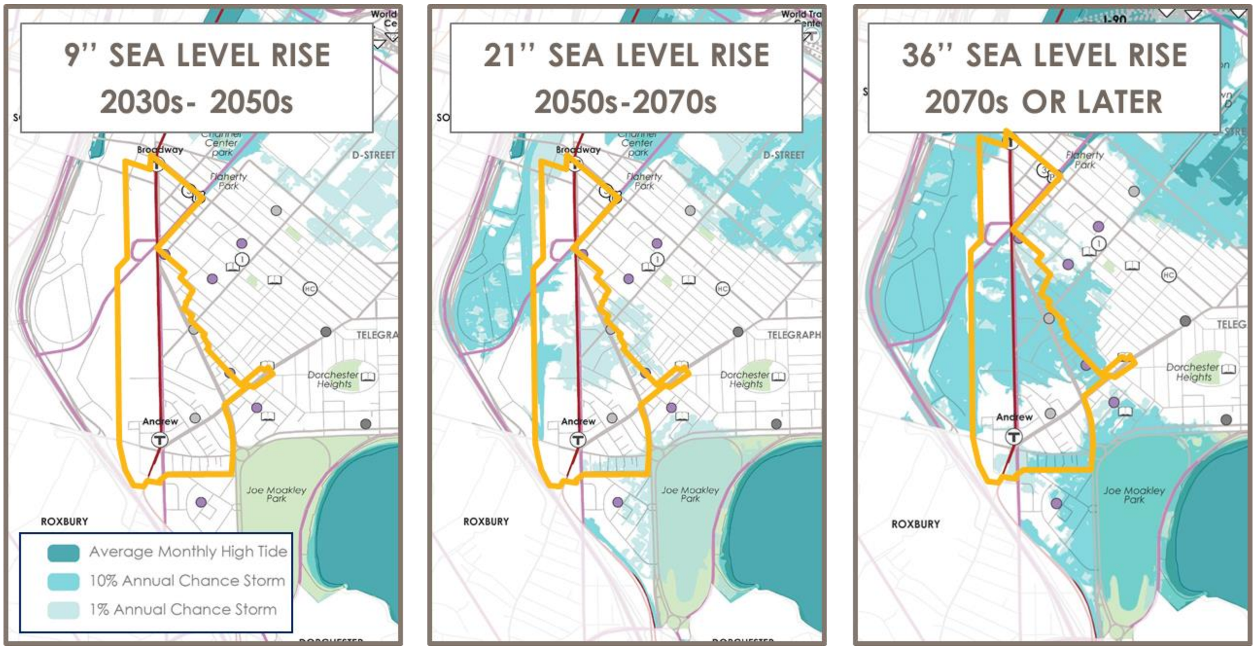
Subtotal Infrastructure Costs			**$181,000,000**	**$400,000**
Traffic Control/Management/Police		**10%**	**$18,000,000**	**$40,000**
Underground Interferences/Re-routes		**15%**	**$27,000,000**	**$70,000**
Temporary Utility Services & Tie-ins		**15%**	**$27,000,000**	**$70,000**
Geotechnical Considerations / Groundwater Dewatering		**5%**	**$9,000,000**	**$20,000**
Environmental Issues (e.g., Remediation, Permitting)		**10%**	**$18,000,000**	**$40,000**
Planning Level Contingency Costs		**30%**	**$50,000,000**	**$130,000**
Total Infrastructure Costs			**$335,000,000**	**$1,000,000**

Note: Standard street widths assumed for roadway per foot costing

2.3 Climate Considerations

Climate Ready Boston, a recent study by the City of Boston, highlights the need to plan for additional flooding in the Project area as a result of climate change. The following figures depict the flood risk in the Project area. By 2070, over 50% of the project land area is expected to experience flooding every 1 in 10 years without proper flood mitigation. Flooding adaption measures will be a key focus of the infrastructure planning project (**Figure 11**).

Figure 11. Sea Level Rise and Flooding



2.4 Impacts

AECOM uses this business-as-usual Base Case to estimate the impacts of implementing specific smart utility technologies (SUT). This analysis compares the impacts of the developments on a variety of social, economic, and environmental factors. Specifically, AECOM measures the impacts of the SUTs against five benefit categories: Environmental Benefits, Resilience Benefits, Fiscal and Economic Benefits, End User Impacts, Capacity Impacts. Impact is measured as the difference between the costs and benefits of the Base Case and the *Define the Opportunity* smart utility scenarios. The SUTs that comprise the impact analysis and the associated costs and benefits are discussed in the next section.

3. Define the Opportunity

The second phase of the Project is to *Define the Opportunity* as it relates to smart utility technologies (SUT) and practices. *Define the Opportunity* is a five step process:

1. Identity priority best practices for future development scenarios;
2. Run these priority best practices through the impact model to compare their costs and benefits to those of the business-as-usual Base Case scenario;
3. Gather feedback on priority best practices and model results from stakeholders (January 2017 Whiteboarding session);
4. Incorporate feedback and identify targeted SUTs for implementation scenarios;
5. Conduct an assessment of the costs and benefits for the targeted SUTs.

This five step process for *Define the Opportunity* sets the stage for the third phase of the Project, *Define a Construction Plan*.

To assess the impact of targeted SUTs in the Project area, AECOM conducted an analysis of the social, environmental, and economic impacts of specific future built-out scenarios. To do this work, impact from a baseline is calculated on key quantifiable metrics, some of which are also monetized. These key metrics fall into the five key benefit areas as discussed previously:

- Fiscal and Economic Benefits
- Resilience Benefits
- End User Impacts
- Environmental Benefits
- Capacity Impacts

To holistically *Define the Opportunity* of Smart Utilities, Section 3 introduces two key elements: Technologies and Implementation Solutions. The Smart Utility Technologies help achieve our operational goals, while Implementation Solutions help to make those actionable. Section 3 begins by describing the operational benefits of the Smart Utilities Technologies, and then describes the Implementation Solutions that can be deployed to achieve those goals.

Implementation Solutions:
Enables SUTs to be regulated, built, operated, and financed. Creates the market conditions for SUTs to thrive and unlocks synergies among SUTs.

Smart Utilities Technologies:
Optimize operations and enhance resiliency compared to the baseline infrastructure assets

Benefits:
- Make utilities easier to build, maintain and upgrade;
- Reduce energy/water costs for residents/businesses;
- Harden infrastructure against flooding and heat waves;
- Attract businesses & jobs through world-class utilities;
- Integrate cutting edge technologies to continue to innovate.

3.1 Smart Utility Technology Best Practices

Smart technologies and practices are being implemented by cities, utilities, and industries across the globe. Their experience provides applicable examples of best and emerging practices and technologies that can assist Boston in achieving its goals. AECOM conducted a detailed review of best and emerging practices in each Smart Utility Technology area. Best and emerging practices included technologies and case studies. For each practice, AECOM identified the potential benefits and assessed the viability and cost effectiveness for each practice it reviewed. Individual SUTs were screened for applicability, cost-effectiveness, and relative impact to select targeted SUTS for further analysis.

3.1.1 Selection of Best Practices

Drawing on experience from past smart city projects, input from infrastructure experts, and research on effective technologies, AECOM created a catalogue of best practices for both Smart Utility Technologies and integrated infrastructure delivery. The research identified a range of technologies, case studies and applications that included proven technologies and best and emerging practices. These practices were screened for applicability to the specific conditions in the Project area; AECOM generated a final list of specific smart utility opportunities relevant to and impactful in the development area. A preliminary list of 63 smart strategies and practices is in Appendix F. This list was narrowed to a priority list of strategies, whose associated costs and potential benefits are outlined in the Modeling Results in the next section. These priority strategies fall into the following categories:

Smart Energy
- District Energy Microgrid
- Solar PV and Battery Storage Microgrid

Smart Transportation
- Autonomous Vehicles
- Electric Vehicles
- Adaptive Signal Technology

Smart Water
- Water reuse
- Green Infrastructure

Smart Communications
- Telecommunications Utilidor

AECOM analyzed the costs and benefits of these priority strategies. Results of this analysis are discussed in detail in the *Assessment of Costs and Benefits* document.

3.1.2 Proposed Solutions to Implementation

The first Boston Smart Utilities whiteboarding session ("session") convened by the BPDA was held at District Hall on May 25th, 2016 in Boston. The primary purpose of the Whiteboarding Session was to solicit feedback from multiple stakeholder groups on a preliminary draft Request for Proposals (RFP) for consultant services to initiate the Smart Utilities Vision. During this process, various Implementation Solutions emerged in the tabletop discussions. The six preliminary Implementation Solutions below are a consolidated list of stakeholder feedback. These proposed solutions were refined in the January Whiteboarding session and through subsequent follow up.

Table 10. Proposed Implementation Solutions

1	**Flexible Blueprints**[9] Different districts of the city will require different types of utilities services. The Smart Utilities Vision will produce design guidelines for utility infrastructure located within the public right of ways. The design guidelines will accommodate future technical innovations and thus provide solutions that are flexible for various public works conditions.
2	**Center of Excellence**[10] This entity is tasked with data collection and planning coordination. The entity could take the form of a committee within government or a non-governmental organization that served as an impartial clearinghouse for new ideas, new standards, and new implementation strategies. Suggestions include this be anchored within a university, within State Government, or Special Purpose Entity that has procurement authority

[9] The *Flexible Blueprints* solution was later renamed to *Smart Utility Standards*
[10] No immediate action was taken on the *Center of Excellence* based on the 1-year timeline of this project.

3	**One Big Pipe**[11] Utilidors contain all utility assets in one large tunnel that reduce surface-street disruptions for utility upgrades. There are noted examples around the globe of "utilidors", such as those used on college and military campuses. This would include physical Security Guidelines that are amenable to all utility security standards.
4	**Data Hub**[12] The Data Hub would be a virtual clearinghouse for project Underground 3D Mapping, Data Acquisition, big-data Monetization, and would clearly indicate the Data Security guidelines required by each of the participating utilities and organizations. The Data Hub could be a product of the Center of Excellence.
5	**Legislative Authority & Financing Vehicles** The most successful examples of high-coordinated utility implementation strategies involved public/private partnerships and the financing strategies that support those partnerships. Financing strategies such as business improvement districts, impact investment, Revolving Loans Funds, and tax-exempt bonds, would possibly need legislative support and potential changes to regulatory instruments (like tariff structures).
6	**Master Services / Condo Agreement**[13] Property owners in the Boston Seaport District have a formal agreement with terms for coordination of public realm improvements, such as sidewalk beautification, known as a "Master Services Agreement". The costs and benefits of coordinated utility planning can be shared among property owners by creating the equivalent of a condo association, whose purpose is to jointly bear the cost of utilities development.

3.2 Modeling Results & Cost-Benefit Analysis

The identified priority strategies were modeled to determine the cost at full development build-out, the change in this cost from the Base Case infrastructure build-out, and the potential benefits. Details of system design for the technologies and strategies are described in the *Assessment of Smart Utility Technologies Costs & Benefits*. **Table 11** is an outline of the model outputs. These model outputs were used to conduct a Cost-Benefit Analysis. Results of the Cost-Benefit Analysis can be found in the *Assessment of Smart Utility Technologies Costs & Benefits*.

[11] The *One Big Pipe* solution was later reimagined as a *Telecommunications Utilidor* to house solely telecommunications conduit and fiber
[12] No immediate action was taken on the *Center of Excellence* based on the 1-year timeline of this project.
[13] The *Master Services / Condo Agreement* was broadened to include a variety of policy and legal mechanisms whereby Smart Utility Technologies might be recommended on developments of a certain size.

Table 11. Smart Utility Technologies and Strategies Costs & Annualized Benefits Scenario 1 – High Residential

Note: Values represent cost or benefit at full-buildout. Values are not inflated. Values are rounded.

Asset Class	SUT	Full Build-out Cost *Million USD*	Cost Impact (Δ) *Million USD*	Environmental Benefits				Economic/Fiscal Impacts						Equity Impacts			Climate Resilience	Capacity Impacts	
				Energy Reduction	CO_2 Reduction	Water Reduction	Storm water & Wastewater Reduction	Avoided Capital Costs *Million USD*	Reduced Business Loss	Lower O&M Costs	Lower Developer Construction Costs *Million USD*	Depreciation Benefits	Change in Real Estate Space Availability	Utility Cost Savings *Million USD*	Accident Reduction	Reduced Traffic Fatalities & Injuries	# Residents & Businesses with continuous service	Peak Demand & Import Reduction (Energy)	Peak Demand & Import Reduction (Water)
Smart Energy	**District Energy Microgrid** - Tri-generation	$22	$17	5,830 MWh/ year	275 MTCO2/year	N/A	N/A	N/A	Not Quantified	$103,000/year	$5	N/A	67,600 SF	$1.3/year	N/A	N/A	N/A	N/A	N/A
Smart Energy	**District Energy Microgrid** - Tri-generation + Thermal Energy Storage	$25	$20	5,830 MWh/ year	275 MTCO2/year	N/A	N/A	N/A	Not Quantified	$103,000/year	$5	N/A	67,600 SF	$1.6/year	N/A	N/A	N/A	N/A	N/A
Smart Energy	**Solar PV + Battery Storage Microgrid –** with Electric Vehicle Charging Infrastructure	$34	$34	26,000 MWh/ year	9,700 MTCO2/year	N/A	N/A	$2/ year	Not Quantified	$400,000/year	N/A	N/A	N/A	$7.3/year	N/A	N/A	Not Quantified	$1 million/ year	N/A
Smart Transportation	**Autonomous Vehicles** - Striping Maintenance, Extra Traffic Signals, Roadside Equipment Device	$0.7	$0.7	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	2.2 accidents per year	0.06 events per year	N/A	N/A	N/A

Asset Class	SUT	Full Build-out Cost *Million USD*	Cost Impact (Δ) *Million USD*	Environmental Benefits				Economic/Fiscal Impacts						Equity Impacts			Climate Resilience	Capacity Impacts	
				Energy Reduction	CO_2 Reduction	Water Reduction	Storm water & Wastewater Reduction	Avoided Capital Costs *Million USD*	Reduced Business Loss	Lower O&M Costs	Lower Developer Construction Costs *Million USD*	Depreciation Benefits	Change in Real Estate Space Availability	Utility Cost Savings *Million USD*	Accident Reduction	Reduced Traffic Fatalities & Injuries	# Residents & Businesses with continuous service	Peak Demand & Import Reduction (Energy)	Peak Demand & Import Reduction (Water)
Smart Transportation	**Adaptive Signal Technology**	$0.7	$0.7	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	Not Quantified	Not Quantified	N/A	N/A	N/A
Smart Water	**On Site Water Reuse** - Rainwater + Greywater	$2	$2	N/A	N/A	26 MGal /year	16 MGal /year	N/A	N/A	N/A	N/A	N/A	N/A	Not Quantified	N/A	N/A	N/A	N/A	Not Quantified
Smart Water	**Green Infrastructure**	$1.2	$1.2	N/A	N/A	N/A	1.43 MGal /year	N/A	N/A	N/A	N/A	N/A	N/A	Not Quantified	N/A	N/A	N/A	N/A	N/A
Smart Communications	**Telecom Utilidor –** New Ellery Pilot	$6	$2	N/A	N/A	N/A	N/A	N/A	N/A	$170,000/year	N/A	$100,000/year	N/A	N/A	N/A	N/A	N/A	N/A	N/A

Asset Class	**SUT**	**Full Build-out Cost** *Million USD*	**Cost Impact (Δ)** *Million USD*	**Environmental Benefits**				**Economic/Fiscal Impacts**						**Equity Impacts**			**Climate Resilience**	**Capacity Impacts**	
				Energy Reduction	CO_2 Reduction	Water Reduction	Storm water & Wastewater Reduction	Avoided Capital Costs *Million USD*	Reduced Business Loss	Lower O&M Costs	Lower Developer Construction Costs *Million USD*	Depreciation Benefits	Change in Real Estate Space Availability	Utility Cost Savings *Million USD*	Accident Reduction	Reduced Traffic Fatalities & Injuries	# Residents & Businesses with continuous service	Peak Demand & Import Reduction (Energy)	Peak Demand & Import Reduction (Water)
Smart Communications	**Telecom Utilidor –** Dorchester Avenue Replacement	$12	$8	N/A	N/A	N/A	N/A	N/A	N/A	$170,000/year	N/A	$120,000/year	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Smart Communications	**Telecom Utilidor –** Resilient Loop	$17	$13	N/A	N/A	N/A	N/A	N/A	N/A	$170,000/year	N/A	$180,000/year	N/A	N/A	N/A	N/A	Not Quantified	N/A	N/A

Appendix A Telecommunication Infrastructure Ownership in the Development Area

Below is a summary table of telecommunication infrastructure owned in the Project area as determined during the information gathering process. This list may not be exhaustive.

	Wired			Wireless	
Company Name	Fiber Backhaul (Intra-City, Long Haul)	Wireline (CLECs, Inter-city)	Resellers (No Physical Assets)	Fixed Wireless	DAS/Small Cell
186 COMMUNICATIONS	X	X	X		
American Tower			X	X	X
AT&T	X	X			
AT&T Wireless			X	X	X
CenturyLink	X	X	X		
Cogent		X	X		
Comcast	X	X			
Crown Castle		X	X	X	X
DSCI		X	X		
Earthlink	X	X	X		
Eversource Electric		X	X		
ExteNet Systems, Inc.		X	X	X	X
First Light			X		
GENESIS COMMUNICATIONS		X	X		
Last Mile Solutions/Sunesys		X	X		
Level 3 Communications LLC	X	X	X		
Lightower	X	X	X		
Megapath	X	X	X		
Oxford Networks	X	X	X		
RCN		X	X		
Sprint	X	X	X	X	X
Teleport Communications America, LLC		X	X		
Towerstream	X		X	X	X
Verizon	X	X	X	X	X
Verizon Business	X	X	X		
Wicked Bandwidth, Inc.		X	X		
XO Communications Services, Inc.	X	X	X		
Zayo Group, LLC	X	X	X		

Appendix B Unit Costs for Modeling

Category	Item	Size	Units	Unit Rate
Gas				
Gas Pipes	60" PSI 40' joints with coupling, 8" diameter, SDR 11	8"	LF	$110.49
Gas Pipes	60" PSI 40' joints with coupling, 6" diameter, SDR 11	6"	LF	$81.08
Electrical				
Electrical Conduit	12 Underground ducts @ 5" Dia.	5"	LF	$54.00
Electrical Conduit	4 Underground ducts @ 5" Dia.	5"	LF	$18.00
Electrical Cable	15kV aluminum cable, 500MCM	15 kV	LF	$58.00
Trenching	Trench, backfill, and concrete encasement, 4' deep	4' deep	LF	$226.00
Electrical Manhole	Manhole - 6'x10'x7'		EA	$14,900.00
Electrical Manhole	Manhole - 4'x6'x7'		EA	$11,850.00
Water				
Water	Fire Hydrants		EA	$ 3,500.00
Water	Waterline - 4"		LF	$ 150.00
Water	Water Main		LF	$ 160.00
Water	Trenching+Backfill for Water Utilities		LF	$ 75.00
Water	Manhole		LF	$ 28.00
Water	O&M Costs - Distribution		MG	$ 40.00
Water	O&M Costs - Main		MG	$ 160.00
Water	O&M Costs - Supply, Treatment, Storage, Pumping		MG	$ 400.00
Stormwater				
Stormwater	12" Storm Sewer		LF	$ 250.00
Stormwater	15" Storm Sewer		LF	$250.00
Stormwater	18" Storm Sewer		LF	$250.00
Stormwater	36" Storm Sewer		LF	$300.00
Stormwater	42" Storm Sewer		LF	$350.00
Stormwater	8" Extra Strength Concrete Pipe		LF	$250.00
Stormwater	10" Extra Strength Concrete Pipe		LF	$250.00
Stormwater	21" Extra Strength Concrete Pipe		LF	$250.00
Stormwater	24" Extra Strength Concrete Pipe		LF	$250.00
Stormwater	30" Extra Strength Concrete Pipe		LF	$300.00
Stormwater	48" Extra Strength Concrete Pipe		LF	$350.00
Stormwater	60" Extra Strength Concrete Pipe		LF	$450.00
Stormwater	Elliptical Pipe 23x14 (18" eqv.)		LF	$250.00
Stormwater	Elliptical Pipe 30x19 (24" eqv.)		LF	$250.00
Stormwater	Elliptical Pipe 45x29 (36" eqv.)		LF	$300.00
Stormwater	End Wall - Precast		EA	$1,000.00
Stormwater	Drop Inlet		EA	$3,000.00

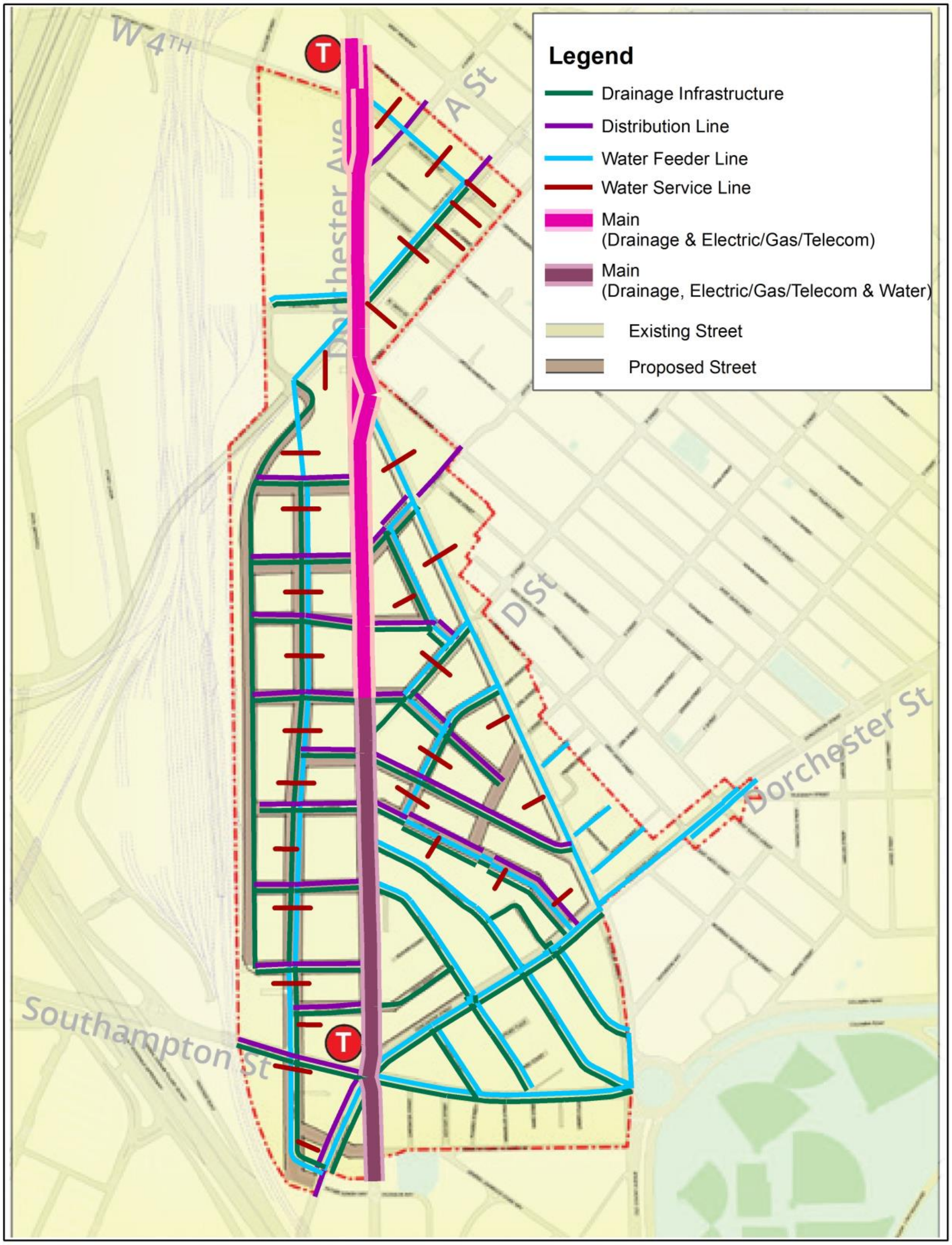
Category	Item	Size	Units	Unit Rate
Stormwater	Curb Drop Inlet		EA	$4,000.00
Stormwater	Median Drop Inlet		EA	$4,200.00
Stormwater	Catch Basin		EA	$ 6,000.00
Stormwater	Storm Manhole		EA	$ 5,000.00
Stormwater	Box Culvert - 4'x4'		LF	$340.00
Stormwater	Box Culvert - 6'x6'		LF	$500.00
Stormwater	Box Culvert - (Detention)		CF	$8.50
Stormwater	Valve Box - 6" Gate		EA	$ 2,000.00
Stormwater	O&M Costs - Collection		LF	$0.80
Stormwater	O&M Costs - Collection		LF	$4.50
Stormwater	O&M Costs - Detention		LF	$5,000.00
Sewer				
Sanitary Wastewater	Sanitary Sewer Manhole		EA	$5,000.00
Sanitary Wastewater	Mains		LF	$250.00
Sanitary Wastewater	Distribution		LF	$250.00
Sanitary Wastewater	Adjust Utilities to Grade		LS	$300.00
Sanitary Wastewater	Sewer Pump Station (Concrete)		EA	$520,000.00
Sanitary Wastewater	O&M Costs - Distribution		MG	$40.00
Sanitary Wastewater	O&M Costs - Trunk		MG	$160.00
Sanitary Wastewater	O&M Costs - (WWTP Treatment and Disposal)		MG	$600.00
Sanitary Wastewater	O&M Costs - (Clustered Septic Systems)		Connection	$45.00
Telecommunications (Fiber)				
Fiber	432 count fiber 1.25" conduit	1.25"	LF	$6.00
Trenching for Fiber	Trench, backfill, and concrete encasement, 4' deep	4'	LF	$226.00
Junction Boxes				
Cell Tower				
Roadway				
Roadway	Arterial Full Reconstruction		LF	$1,500.00
Roadway	Residential Full Reconstruction		LF	$700.00
Roadway	Collector Construction		LF	$1,000.00
Roadway	Sidewalk Only Reconstruction	7 ft wide	LF	$500.00
Roadway	Mill and Overlay Arterial		SF	$1.70
Roadway	Mill and Overlay Residential		SF	$1.35
Roadway	New Intersection Walkways		EA	$15.00
Roadway	New Curb & Gutter (what about sidewalk?)		LF	$214.24
Roadway	Signalized Intersection		EA	$250,000.00
Roadway	O& M Costs - street repairs (Local)		LF	$0.08
Roadway	O& M Costs - Street Sweeping (Local)		LF	$0.20

Category	Item	Size	Units	Unit Rate
Roadway	O& M Costs - street repairs (Major)		LF	$0.17
Roadway	O& M Costs - Street Sweeping (Major)		LF	$0.18
Street Lighting				
Street Lighting	Lines, Trenches, Circuits and Controls		EA	$ 13,000.00
Street Lighting	Street Light (pendant - post, bracket arm, luminare, base)		EA	$ 12,000.00
Street Lighting	Park Standard, 14' Pole, Luminare, Base (acorn - post, luminare, base)		EA	$ 8,000.00
Street Lighting	Audiovisual Exterior Electrical Service Outlets		EA	$500.00
Street Lighting	Pedestrian Lighting Fixtures, 12' Pole (see Park Standard above)		EA	$ 8,000.00
Street Lighting	Roadway Lighting Fixtures, 20' Pole (see Street Light above)		EA	$ 12,000.00
Street Lighting	Exterior Electrical Outlets (with service)		EA	$800.00
Street Lighting	Accent Lighting (not low voltage)		EA	$1,000.00
Street Lighting	2" Conduit and 3" Conduit (does not include backfill)		LF	$ 45.00
Street Lighting	Circuitry (wiring?)		LF	$ 2.50
Street Lighting	Junction Box Jb-S1 (pull box)		EA	$ 1,500.00

Appendix C Assumed Locations Of Capital Projects

The following map shows the assumed infrastructure locations. They were used to determine on which segments of the roadways specific infrastructure needed to be built.

Figure 12 Assumed Location Future Business-as-Usual Utilities



Appendix D Road Segmentation

To model the cost and impacts of the proposed infrastructure development, AECOM used the *Massachusetts Department of Transportation 2014 Road inventory* GIS data and the *2014 City of Boston's Sidewalk Inventory* GIS data to assign the existing streets in the Project area unique reference numbers and associated characteristics (e.g., road width, sidewalk width, segment length). AECOM assigned proposed street segments unique reference numbers as well. A map of these Segment Reference Numbers is shown below. A table of the associated characteristic by segments is on the following page.

Figure 13 Street Segment Reference Numbers

Table 12 Road Segmentation Data & Base Case Infrastructure Assignments

Segment ID	Street	Length (mi)	Year Constructed	Road	Water		Sewer		Electricity		Natural Gas		Telecom Fibers	
				New Const (ft.)	Mains (ft.)	Distr (ft.)	Mains (ft.)	Distr (ft.)	Mains (ft.)	Distr (ft.)	Mains (8") (ft.)	Distr (6") (ft.)	Gigabit Main (ft.)	Distr (ft.)
4540700	A STREET	0.03	Existing	0	0	0	0	0	0	0	0	0	0	0
5398700	A STREET	0.02	Existing	0	0	0	0	0	0	115	0	115	0	115
4542400	A STREET	0.03	Existing	0	0	0	0	0	0	152	0	152	0	152
5398800	A STREET	0.03	Existing	0	0	0	0	0	0	148	0	148	0	148
5681500	ALGER STREET	0.11	Existing	0	0	557	0	557	0	557	0	557	0	557
5330500	ALGER STREET	0.06	Existing	0	0	0	0	337	0	337	0	337	0	337
5681600	ALGER STREET	0.01	Existing	0	0	56	0	56	0	0	0	0	0	0
5590200	B STREET	0.06	Existing	0	0	0	0	0	0	0	0	0	0	0
4545900	B STREET	0.03	Existing	0	0	0	0	0	0	0	0	0	0	0
5198900	B STREET	0.03	Existing	0	0	0	0	0	0	0	0	0	0	0
5199000	B STREET	0.03	Existing	0	0	0	0	0	0	0	0	0	0	0
4553200	B STREET	0.06	Existing	0	0	0	0	0	0	0	0	0	0	0
4547600	B STREET	0.03	Existing	0	0	0	0	0	0	0	0	0	0	0
5474900	BAXTER STREET	0.10	Existing	0	0	0	0	0	0	0	0	0	0	0
4616400	BOSTON STREET	0.02	Existing	0	0	89	0	0	0	89	0	89	0	89
5627902	BOSTON STREET	0.03	Existing	0	0	171	0	0	0	171	0	171	0	171
5844400	BOSTON STREET	0.09	Existing	0	0	470	0	470	0	470	0	470	0	470
5475000	C STREET	0.01	Existing	0	0	0	0	0	0	0	0	0	0	0
5475100	C STREET	0.02	Existing	0	0	0	0	0	0	117	0	117	0	117
5475200	C STREET	0.03	Existing	0	0	0	0	0	0	168	0	168	0	168
4614300	CARPENTER STREET	0.05	Existing	0	0	0	0	0	0	0	0	0	0	0
5482900	COTTAGE STREET	0.05	Existing	0	0	264	0	0	0	0	0	0	0	0
5843300	CROWLEY-ROGERS WAY	0.05	Existing	0	0	0	0	0	0	0	0	0	0	0
5756700	D STREET	0.01	Existing	0	0	0	0	0	0	0	0	0	0	0
4578900	D STREET	0.02	Existing	0	0	106	0	106	0	0	0	0	0	0

Segment ID	Street	Length (mi)	Year Constructed	Road	Water		Sewer		Electricity		Natural Gas		Telecom Fibers	
				New Const (ft.)	Mains (ft.)	Distr (ft.)	Mains (ft.)	Distr (ft.)	Mains (ft.)	Distr (ft.)	Mains (8") (ft.)	Distr (6") (ft.)	Gigabit Main (ft.)	Distr (ft.)
5591300	D STREET	0.01	Existing	0	0	0	0	0	0	0	0	0	0	0
4585200	D STREET	0.10	Existing	0	0	544	0	544	0	0	0	0	0	0
5756600	D STREET	0.01	Existing	0	0	0	0	0	0	0	0	0	0	0
5312700	DAMRELL STREET	0.13	Existing	0	0	0	0	686	0	686	0	686	0	686
5312800	DAMRELL STREET	0.05	Existing	0	0	0	0	264	0	264	0	264	0	264
4614400	DEVINE WAY	0.03	Existing	0	0	0	0	0	0	0	0	0	0	0
5772500	DEXTER STREET	0.06	Existing	0	0	0	0	317	0	317	0	317	0	317
4617000	DORCHESTER AVENUE	0.03	Existing	0	184	0	0	184	184	0	184	0	184	0
5627101	DORCHESTER AVENUE	0.02	Existing	0	113	0	0	0	113	0	113	0	113	0
5844600	DORCHESTER AVENUE	0.07	Existing	0	353	0	0	353	353	0	353	0	353	0
5267300	DORCHESTER AVENUE	0.01	Existing	0	77	0	0	77	77	0	77	0	77	0
5250000	DORCHESTER AVENUE	0.15	Existing	0	815	0	0	0	815	0	815	0	815	0
5844800	DORCHESTER AVENUE	0.02	Existing	0	131	0	0	131	131	0	131	0	131	0
46178200	DORCHESTER AVENUE	0.07	Existing	0	384	0	0	0	384	0	384	0	384	0
4545400	DORCHESTER AVENUE	0.06	Existing	0	317	0	0	0	317	0	317	0	317	0
5627100	DORCHESTER AVENUE	0.03	Existing	0	138	0	0	0	138	0	138	0	138	0
6266700	DORCHESTER AVENUE	0.03	Existing	0	174	0	0	0	174	0	174	0	174	0
4539100	DORCHESTER AVENUE	0.04	Existing	0	212	0	0	0	212	0	212	0	212	0
5590100	DORCHESTER AVENUE	0.08	Existing	0	437	0	0	0	437	0	437	0	437	0
4590900	DORCHESTER AVENUE	0.05	Existing	0	240	0	0	240	240	0	240	0	240	0
6266600	DORCHESTER AVENUE	0.04	Existing	0	223	0	0	0	223	0	223	0	223	0
4585300	DORCHESTER AVENUE	0.10	Existing	0	504	0	0	0	504	0	504	0	504	0
5772400	DORCHESTER AVENUE	0.04	Existing	0	199	0	0	199	199	0	199	0	199	0

Segment ID	Street	Length (mi)	Year Constructed	Road	Water		Sewer		Electricity		Natural Gas		Telecom Fibers	
				New Const (ft.)	Mains (ft.)	Distr (ft.)	Mains (ft.)	Distr (ft.)	Mains (ft.)	Distr (ft.)	Mains (8") (ft.)	Distr (6") (ft.)	Gigabit Main (ft.)	Distr (ft.)
5627102	DORCHESTER AVENUE	0.01	Existing	0	45	0	0	0	45	0	45	0	45	0
5681100	DORCHESTER AVENUE	0.04	Existing	0	206	0	0	206	206	0	206	0	206	0
5681200	DORCHESTER AVENUE	0.08	Existing	0	432	0	0	432	432	0	432	0	432	0
46178100	DORCHESTER AVENUE	0.08	Existing	0	406	0	0	0	406	0	406	0	406	0
5875100	DORCHESTER AVENUE	0.04	Existing	0	201	0	0	0	201	0	201	0	201	0
4593600	DORCHESTER AVENUE	0.04	Existing	0	220	0	0	220	220	0	220	0	220	0
4595900	DORCHESTER AVENUE	0.04	Existing	0	211	0	0	211	211	0	211	0	211	0
5121100	DORCHESTER AVENUE	0.03	Existing	0	174	0	0	0	174	0	174	0	174	0
5615000	DORCHESTER AVENUE	0.03	Existing	0	158	0	0	0	158	0	158	0	158	0
5615100	DORCHESTER AVENUE	0.01	Existing	0	55	0	0	0	55	0	55	0	55	0
5757300	DORCHESTER STREET	0.04	Existing	0	0	0	0	0	0	0	0	0	0	0
5778400	DORCHESTER STREET	0.05	Existing	0	0	247	0	247	0	0	0	0	0	0
47436200	DORCHESTER STREET	0.05	Existing	0	0	244	0	244	0	0	0	0	0	0
4589700	DORCHESTER STREET	0.07	Existing	0	0	362	0	0	0	0	0	0	0	0
47435600	DORCHESTER STREET	0.05	Existing	0	0	247	0	0	0	0	0	0	0	0
5778200	DORCHESTER STREET	0.01	Existing	0	0	57	0	57	0	0	0	0	0	0
47436000	DORCHESTER STREET	0.01	Existing	0	0	35	0	35	0	0	0	0	0	0
5591500	DORCHESTER STREET	0.01	Existing	0	0	0	0	0	0	0	0	0	0	0
5757200	DORCHESTER STREET	0.04	Existing	0	0	203	0	0	0	0	0	0	0	0
47435800	DORCHESTER STREET	0.05	Existing	0	0	266	0	266	0	0	0	0	0	0
5777700	DORCHESTER STREET	0.05	Existing	0	0	248	0	248	0	0	0	0	0	0

Segment ID	Street	Length (mi)	Year Constructed	Road	Water		Sewer		Electricity		Natural Gas		Telecom Fibers	
				New Const (ft.)	Mains (ft.)	Distr (ft.)	Mains (ft.)	Distr (ft.)	Mains (ft.)	Distr (ft.)	Mains (8") (ft.)	Distr (6") (ft.)	Gigabit Main (ft.)	Distr (ft.)
47435300	DORCHESTER STREET	0.04	Existing	0	0	195	0	0	0	0	0	0	0	0
47435700	DORCHESTER STREET	0.01	Existing	0	0	30	0	0	0	0	0	0	0	0
47435400	DORCHESTER STREET	0.05	Existing	0	0	252	0	0	0	0	0	0	0	0
47436300	DORCHESTER STREET	0.11	Existing	0	0	598	0	598	0	0	0	0	0	0
47436100	DORCHESTER STREET	0.03	Existing	0	0	153	0	153	0	0	0	0	0	0
4591000	DORCHESTER STREET	0.02	Existing	0	0	102	0	0	0	0	0	0	0	0
47435200	DORCHESTER STREET	0.09	Existing	0	0	459	0	0	0	0	0	0	0	0
5777900	DORCHESTER STREET	0.04	Existing	0	0	207	0	207	0	0	0	0	0	0
5844900	DORCHESTER STREET	0.07	Existing	0	0	344	0	344	0	0	0	0	0	0
5778100	DORCHESTER STREET	0.02	Existing	0	0	128	0	128	0	0	0	0	0	0
4584600	E STREET	0.04	Existing	0	0	0	0	0	0	0	0	0	0	0
5512000	EARL STREET	0.03	Existing	0	0	0	0	0	0	0	0	0	0	0
4593800	EAST EIGHTH STREET	0.05	Existing	0	0	0	0	0	0	0	0	0	0	0
5757400	EAST NINTH STREET	0.04	Existing	0	0	0	0	0	0	0	0	0	0	0
4615700	ELLERY STREET	0.11	Existing	0	0	557	0	557	0	0	0	0	0	0
5681400	ELLERY STREET	0.02	Existing	0	0	117	0	117	0	0	0	0	0	0
5323400	ELLERY STREET	0.01	Existing	0	0	69	0	0	0	0	0	0	0	0
5603200	ELLERY STREET	0.04	Existing	0	0	207	0	207	0	0	0	0	0	0
5364500	EWER STREET	0.10	Existing	0	0	543	0	543	0	0	0	0	0	0
5364600	EWER STREET	0.03	Existing	0	0	0	0	0	0	0	0	0	0	0
4617100	FATHER SONGIN WAY	0.04	Existing	0	0	211	0	0	0	211	0	211	0	211
4554500	FLAHERTY WAY	0.09	Existing	0	0	0	0	0	0	0	0	0	0	0
5473100	FREDERICK STREET	0.06	Existing	0	0	0	0	0	0	0	0	0	0	0
5533900	GIFFORD PLACE	0.03	Existing	0	0	0	0	0	0	0	0	0	0	0
5520000	GLOVER COURT	0.04	Existing	0	0	0	0	0	0	0	0	0	0	0

Segment ID	Street	Length (mi)	Year Constructed	Road	Water		Sewer		Electricity		Natural Gas		Telecom Fibers	
				New Const (ft.)	Mains (ft.)	Distr (ft.)	Mains (ft.)	Distr (ft.)	Mains (ft.)	Distr (ft.)	Mains (8") (ft.)	Distr (6") (ft.)	Gigabit Main (ft.)	Distr (ft.)
5698600	GOLD STREET	0.06	Existing	0	0	0	0	0	0	0	0	0	0	0
45634900	GOLD STREET	0.02	Existing	0	0	0	0	0	0	0	0	0	0	0
5801000	GOODWIN COURT	0.03	Existing	0	0	0	0	0	0	0	0	0	0	0
5513601	GUSTIN STREET	0.02	Existing	0	0	131	0	0	0	0	0	0	0	0
5513600	GUSTIN STREET	0.02	Existing	0	0	80	0	0	0	0	0	0	0	0
45261400	HAUL ROAD	0.52	Existing	0	0	2764	0	0	0	2764	0	2764	0	2764
5121200	HAUL ROAD	0.13	Existing	0	0	705	0	0	0	705	0	705	0	705
5180000	HAUL ROAD	0.42	Existing	0	0	0	0	0	0	0	0	0	0	0
6317000	JENKINS STREET	0.00	Existing	0	0	0	0	0	0	0	0	0	0	0
47435900	JENKINS STREET	0.00	Existing	0	0	25	0	25	0	0	0	0	0	0
5778300	JENKINS STREET	0.09	Existing	0	0	452	0	452	0	0	0	0	0	0
5550000	LARK STREET	0.02	Existing	0	0	0	0	0	0	0	0	0	0	0
4606100	LEEDS STREET	0.07	Existing	0	0	0	0	370	0	0	0	0	0	0
5532900	LIBERTY PLACE	0.03	Existing	0	0	0	0	0	0	0	0	0	0	0
5338000	MIDDLE STREET	0.01	Existing	0	0	75	0	75	0	0	0	0	0	0
47433600	MIDDLE STREET	0.01	Existing	0	0	29	0	29	0	0	0	0	0	0
5681800	MIDDLE STREET	0.08	Existing	0	0	428	0	428	0	0	0	0	0	0
5681700	MIDDLE STREET	0.02	Existing	0	0	127	0	127	0	0	0	0	0	0
5794900	MIDDLE STREET	0.05	Existing	0	0	256	0	256	0	0	0	0	0	0
5439100	MITCHELL STREET	0.02	Existing	0	0	122	0	0	0	0	0	0	0	0
5439101	MITCHELL STREET	0.06	Existing	0	0	300	0	0	0	0	0	0	0	0
4614200	MOHAWK STREET	0.04	Existing	0	0	0	0	0	0	0	0	0	0	0
5590400	OLD COLONY AVENUE	0.02	Existing	0	0	131	0	0	0	0	0	0	0	0
6261300	OLD COLONY AVENUE	0.05	Existing	0	0	287	0	0	0	0	0	0	0	0
6289200	OLD COLONY AVENUE	0.01	Existing	0	0	0	0	0	0	0	0	0	0	0
6317200	OLD COLONY AVENUE	0.05	Existing	0	0	259	0	0	0	0	0	0	0	0
6261200	OLD COLONY AVENUE	0.07	Existing	0	0	348	0	0	0	0	0	0	0	0

Segment ID	Street	Length (mi)	Year Constructed	Road	Water		Sewer		Electricity		Natural Gas		Telecom Fibers	
				New Const (ft.)	Mains (ft.)	Distr (ft.)	Mains (ft.)	Distr (ft.)	Mains (ft.)	Distr (ft.)	Mains (8") (ft.)	Distr (6") (ft.)	Gigabit Main (ft.)	Distr (ft.)
6261000	OLD COLONY AVENUE	0.11	Existing	0	0	561	0	0	0	0	0	0	0	0
5590900	OLD COLONY AVENUE	0.02	Existing	0	0	0	0	0	0	0	0	0	0	0
47433900	OLD COLONY AVENUE	0.01	Existing	0	0	34	0	0	0	0	0	0	0	0
5301600	OLD COLONY AVENUE	0.12	Existing	0	0	644	0	0	0	0	0	0	0	0
6255600	OLD COLONY AVENUE	0.01	Existing	0	0	59	0	0	0	0	0	0	0	0
5590700	OLD COLONY AVENUE	0.03	Existing	0	0	177	0	0	0	0	0	0	0	0
5591400	OLD COLONY AVENUE	0.01	Existing	0	0	0	0	0	0	0	0	0	0	0
5843600	OLD COLONY AVENUE	0.04	Existing	0	0	193	0	0	0	0	0	0	0	0
47433800	OLD COLONY AVENUE	0.01	Existing	0	0	30	0	0	0	0	0	0	0	0
5699500	OLD COLONY AVENUE	0.05	Existing	0	0	0	0	0	0	0	0	0	0	0
5590600	OLD COLONY AVENUE	0.04	Existing	0	0	196	0	0	0	0	0	0	0	0
5590800	OLD COLONY AVENUE	0.03	Existing	0	0	136	0	0	0	0	0	0	0	0
5591000	OLD COLONY AVENUE	0.07	Existing	0	0	360	0	0	0	0	0	0	0	0
6261100	OLD COLONY AVENUE	0.05	Existing	0	0	264	0	0	0	0	0	0	0	0
6289100	OLD COLONY AVENUE	0.10	Existing	0	0	0	0	0	0	0	0	0	0	0
5590500	OLD COLONY AVENUE	0.03	Existing	0	0	159	0	0	0	0	0	0	0	0
5423900	OLD COLONY AVENUE	0.07	Existing	0	0	370	0	0	0	0	0	0	0	0
6248200	OLD COLONY AVENUE	0.12	Existing	0	0	649	0	0	0	0	0	0	0	0
6255700	OLD COLONY AVENUE	0.07	Existing	0	0	348	0	0	0	0	0	0	0	0
4560400	ORTON MOROTTA WAY	0.11	Existing	0	0	0	0	0	0	0	0	0	0	0
5834800	PATTERSON WAY	0.00	Existing	0	0	0	0	0	0	0	0	0	0	0
5555500	PLUMMER PLACE	0.02	Existing	0	0	0	0	0	0	0	0	0	0	0
5296600	PREBLE STREET	0.03	Existing	0	0	140	0	140	0	0	0	0	0	0
5296500	PREBLE STREET	0.02	Existing	0	0	120	0	120	0	0	0	0	0	0
4611500	PREBLE STREET	0.03	Existing	0	0	167	0	167	0	0	0	0	0	0
5296400	PREBLE STREET	0.01	Existing	0	0	75	0	75	0	0	0	0	0	0
5296300	PREBLE STREET	0.03	Existing	0	0	132	0	132	0	0	0	0	0	0

Segment ID	Street	Length (mi)	Year Constructed	Road	Water		Sewer		Electricity		Natural Gas		Telecom Fibers	
				New Const (ft.)	Mains (ft.)	Distr (ft.)	Mains (ft.)	Distr (ft.)	Mains (ft.)	Distr (ft.)	Mains (8") (ft.)	Distr (6") (ft.)	Gigabit Main (ft.)	Distr (ft.)
5699600	PREBLE STREET	0.04	Existing	0	0	223	0	223	0	0	0	0	0	0
4612100	PREBLE STREET	0.02	Existing	0	0	122	0	122	0	0	0	0	0	0
5844700	PREBLE STREET	0.03	Existing	0	0	182	0	182	0	0	0	0	0	0
47435500	REVEREND R A BURKE STREET	0.00	Existing	0	0	0	0	0	0	0	0	0	0	0
5395100	ROGERS STREET	0.07	Existing	0	0	351	0	351	0	0	0	0	0	0
5395000	ROGERS STREET	0.04	Existing	0	0	0	0	0	0	0	0	0	0	0
5558200	SAYWARD PLACE	0.02	Existing	0	0	0	0	0	0	0	0	0	0	0
6317400	SERGEANT ALEXANDER F PACUSKA CIRCLE	0.05	Existing	0	0	0	0	0	0	0	0	0	0	0
6317300	SERGEANT ALEXANDER F PACUSKA CIRCLE	0.04	Existing	0	0	0	0	0	0	0	0	0	0	0
5698702	SILVER STREET	0.07	Existing	0	0	0	0	0	0	0	0	0	0	0
4540800	SILVER STREET	0.08	Existing	0	0	0	0	0	0	0	0	0	0	0
5698700	SILVER STREET	0.02	Existing	0	0	0	0	0	0	0	0	0	0	0
5848600	SOUTHAMPTON STREET	0.11	Existing	0	0	0	0	561	0	561	0	561	0	561
5844500	SOUTHAMPTON STREET	0.07	Existing	0	0	0	0	371	0	371	0	371	0	371
4590800	TELEGRAPH STREET	0.05	Existing	0	0	0	0	0	0	0	0	0	0	0
5552100	TRANSIT STREET	0.02	Existing	0	0	0	0	0	0	0	0	0	0	0
4601100	TUCKERMAN STREET	0.07	Existing	0	0	0	0	393	0	0	0	0	0	0
47433700	TUCKERMAN STREET	0.01	Existing	0	0	29	0	29	0	0	0	0	0	0
5778000	VINTON STREET	0.12	Existing	0	0	634	0	634	0	0	0	0	0	0
5681300	WADLEIGH PLACE	0.03	Existing	0	0	0	0	0	0	0	0	0	0	0
5545700	WARD COURT	0.03	Existing	0	0	0	0	0	0	0	0	0	0	0
5360300	WARD STREET	0.04	Existing	0	0	0	0	0	0	0	0	0	0	0
5360400	WARD STREET	0.03	Existing	0	0	141	0	141	0	0	0	0	0	0
5800900	WARD STREET	0.02	Existing	0	0	104	0	104	0	0	0	0	0	0
5777800	WARD STREET	0.03	Existing	0	0	181	0	181	0	0	0	0	0	0

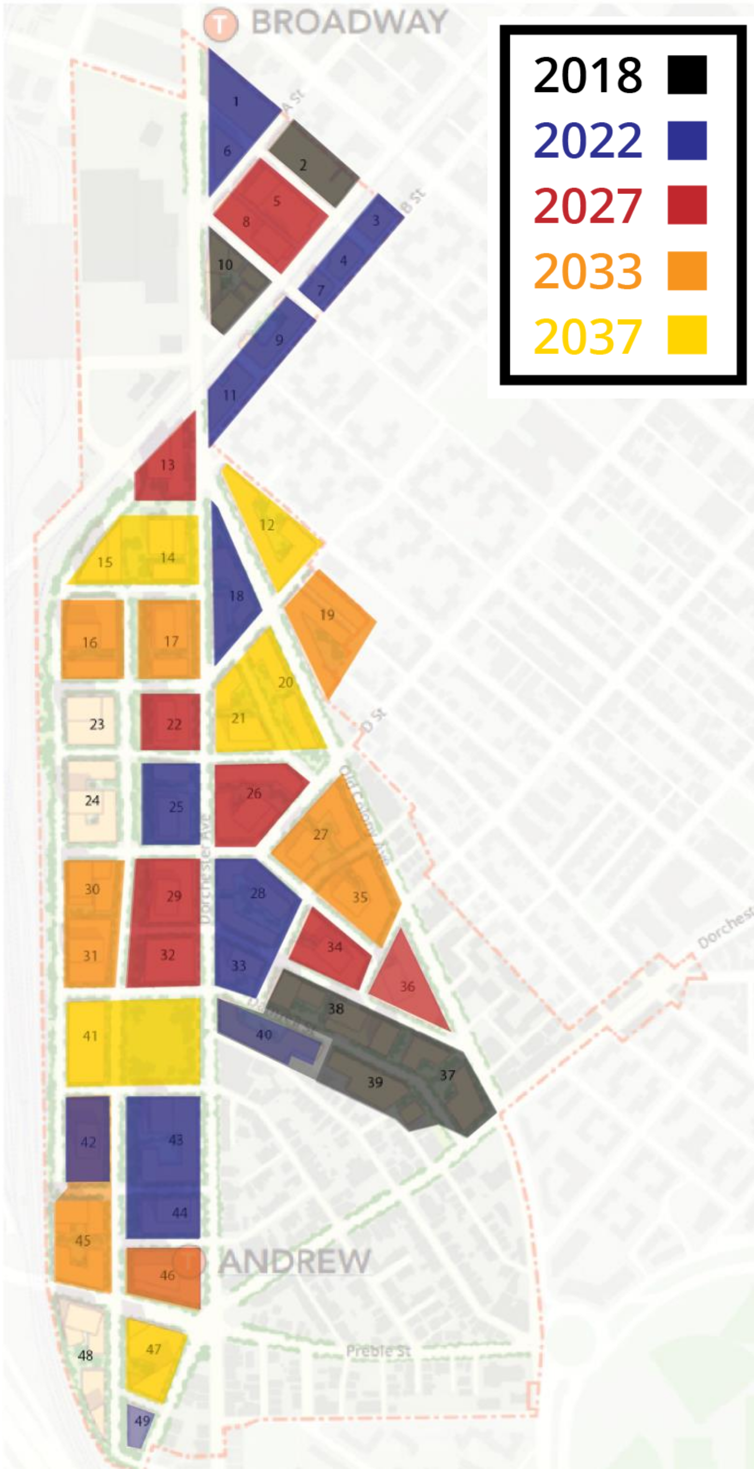
Segment ID	Street	Length (mi)	Year Constructed	Road	Water		Sewer		Electricity		Natural Gas		Telecom Fibers	
				New Const (ft.)	Mains (ft.)	Distr (ft.)	Mains (ft.)	Distr (ft.)	Mains (ft.)	Distr (ft.)	Mains (8") (ft.)	Distr (6") (ft.)	Gigabit Main (ft.)	Distr (ft.)
5554000	WENDELL PLACE	0.02	Existing	0	0	0	0	0	0	0	0	0	0	0
4614100	WENDELLER STREET	0.04	Existing	0	0	0	0	0	0	0	0	0	0	0
4574400	WEST EIGHTH STREET	0.05	Existing	0	0	0	0	0	0	0	0	0	0	0
4591100	WEST EIGHTH STREET	0.05	Existing	0	0	0	0	0	0	0	0	0	0	0
47434100	WEST EIGHTH STREET	0.01	Existing	0	0	0	0	0	0	0	0	0	0	0
5698502	WEST FIFTH STREET	0.02	Existing	0	0	0	0	0	0	0	0	0	0	0
5698501	WEST FIFTH STREET	0.01	Existing	0	0	0	0	0	0	0	0	0	0	0
5698500	WEST FIFTH STREET	0.07	Existing	0	0	0	0	0	0	0	0	0	0	0
5590002	WEST FOURTH STREET	0.06	Existing	0	0	342	0	0	0	0	0	0	0	0
4542500	WEST FOURTH STREET	0.04	Existing	0	0	212	0	0	0	0	0	0	0	0
5590001	WEST FOURTH STREET	0.01	Existing	0	0	0	0	0	0	0	0	0	0	0
5672301	WEST FOURTH STREET	0.07	Existing	0	0	0	0	0	0	0	0	0	0	0
5590000	WEST FOURTH STREET	0.02	Existing	0	0	0	0	0	0	0	0	0	0	0
46178300	WEST FOURTH STREET	0.01	Existing	0	0	0	0	0	0	0	0	0	0	0
5756500	WEST NINTH STREET	0.06	Existing	0	0	0	0	0	0	0	0	0	0	0
47434000	WEST NINTH STREET	0.01	Existing	0	0	0	0	0	0	0	0	0	0	0
5757100	WEST NINTH STREET	0.03	Existing	0	0	0	0	0	0	0	0	0	0	0
5843500	WEST SEVENTH STREET	0.11	Existing	0	0	0	0	0	0	0	0	0	0	0
47437000	WEST SEVENTH STREET	0.01	Existing	0	0	0	0	0	0	0	0	0	0	0
4553300	WEST SIXTH STREET	0.03	Existing	0	0	0	0	0	0	0	0	0	0	0
5777600	WOODWARD STREET	0.03	Existing	0	0	154	0	154	0	0	0	0	0	0
5369500	WOODWARD STREET	0.03	Existing	0	0	161	0	161	0	0	0	0	0	0
5369701	WOODWARD STREET	0.02	Existing	0	0	117	0	117	0	0	0	0	0	0
5369600	WOODWARD STREET	0.03	Existing	0	0	164	0	164	0	0	0	0	0	0

Segment ID	Street	Length (mi)	Year Constructed	Road	Water		Sewer		Electricity		Natural Gas		Telecom Fibers	
				New Const (ft.)	Mains (ft.)	Distr (ft.)	Mains (ft.)	Distr (ft.)	Mains (ft.)	Distr (ft.)	Mains (8") (ft.)	Distr (6") (ft.)	Gigabit Main (ft.)	Distr (ft.)
47433500	WOODWARD STREET	0.01	Existing	0	0	34	0	34	0	0	0	0	0	0
5369700	WOODWARD STREET	0.02	Existing	0	0	80	0	0	0	0	0	0	0	0
1	NEW	0.04	2033	200	0	200	0	200	0	0	0	0	0	0
2	NEW	0.04	2033	200	0	0	0	200	0	200	0	200	0	200
3	NEW	0.05	2033	250	0	0	0	250	0	250	0	250	0	250
4	NEW	0.05	2033	250	0	0	0	250	0	0	0	0	0	0
5	NEW	0.07	2033	350	0	350	0	350	0	0	0	0	0	0
6	NEW	0.04	2033	225	0	0	0	225	0	225	0	225	0	225
7	NEW	0.05	2033	250	0	0	0	250	0	250	0	250	0	250
8	NEW	0.04	2033	230	0	0	0	230	0	0	0	0	0	0
9	NEW	0.05	2033	240	0	240	0	240	0	0	0	0	0	0
10	NEW	0.04	2033	225	0	0	0	225	0	225	0	225	0	225
11	NEW	0.05	2033	250	0	0	0	250	0	250	0	250	0	250
12	NEW	0.07	2033	370	0	0	0	370	0	0	0	0	0	0
13	NEW	0.07	2033	350	0	350	0	350	0	0	0	0	0	0
14	NEW	0.04	2033	200	0	0	0	200	0	200	0	200	0	200
15	NEW	0.05	2022	250	0	0	0	250	0	250	0	250	0	250
16	NEW	0.09	2033	500	0	0	0	500	0	0	0	0	0	0
17	NEW	0.05	2033	280	0	280	0	280	0	0	0	0	0	0
18	NEW	0.05	2033	290	0	0	0	290	0	290	0	290	0	290
19	NEW	0.04	2033	210	0	210	0	210	0	0	0	0	0	0
20	NEW	0.04	2033	190	0	0	0	190	0	190	0	190	0	190
21	NEW	0.07	2033	360	0	0	0	360	0	0	0	0	0	0
22	NEW	0.07	2033	360	0	360	0	360	0	0	0	0	0	0
23	NEW	0.04	2022	190	0	0	0	190	0	190	0	190	0	190
24	NEW	0.06	2022	325	0	0	0	325	0	325	0	325	0	325
25	NEW	0.07	2033	350	0	0	0	350	0	0	0	0	0	0

Segment ID	Street	Length (mi)	Year Constructed	Road	Water		Sewer		Electricity		Natural Gas		Telecom Fibers	
				New Const (ft.)	Mains (ft.)	Distr (ft.)	Mains (ft.)	Distr (ft.)	Mains (ft.)	Distr (ft.)	Mains (8") (ft.)	Distr (6") (ft.)	Gigabit Main (ft.)	Distr (ft.)
26	NEW	0.07	2033	350	0	350	0	350	0	0	0	0	0	0
27	NEW	0.03	2033	150	0	150	0	150	0	0	0	0	0	0
28	NEW	0.03	2033	150	0	150	0	150	0	0	0	0	0	0
29	NEW	0.05	2022	280	0	280	0	280	0	280	0	280	0	280
30	NEW	0.07	2037	370	0	370	0	370	0	0	0	0	0	0
31	NEW	0.03	2022	140	0	0	0	140	0	140	0	140	0	140
32	NEW	0.05	2022	240	0	240	0	240	0	240	0	240	0	240
33	NEW	0.06	2018	325	0	0	0	325	0	325	0	325	0	325
34	NEW	0.03	2018	150	0	0	0	150	0	0	0	0	0	0
35	NEW	0.03	2018	140	0	0	0	140	0	0	0	0	0	0
36	NEW	0.03	2018	150	0	150	0	150	0	0	0	0	0	0
37	NEW	0.03	2018	150	0	0	0	150	0	0	0	0	0	0
38	NEW	0.11	2018	560	0	560	0	560	0	560	0	560	0	560

Appendix E Development Build-Out Schedule

The Development Build-out Schedule was used to estimate the phasing of the infrastructure build-out. The schedules are the same for both the high residential and high office/laboratory development



scenarios.

Appendix F Preliminary Smart Utility Technologies & Strategies

Best Practice	Description
Energy	
District Energy Microgrids	A local system of production and distribution of thermal energy to heat and cool buildings that also produces onsite electric generation for emergency power during a major grid outage.
Solar and Battery Microgrids	Microgrids are energy systems capable of operating independent of the main grid. These systems include transmission and generation resources and increase resilience of connected loads by ensuring the continuity of power during main grid outage events. Microgrids can also allow communities to lower energy costs using distributed resources while maintaining a connection to the main grid when additional power is need. Specifically, distributed solar technologies provide local energy to the community and can support the capacity of microgrids. Battery storage in association with distributed solar allows the storage of excess solar energy and increase the resilience of a system.
Smart/Resilient Grid	A smart grid includes smart switches, automatic, redundant infrastructure, and other technologies to facilitate two-way communication between the utility customer and the utility on the grid and increase resilience.
Advanced Metering Infrastructure - Energy	A component of a smart grid, advanced metering infrastructure allows two-way communication between the utility costumer and the utility. This allows the utility to remotely monitor electricity usage and manage loads more efficiently.
Advanced Metering Infrastructure - Gas	A component of a smart grid, advanced metering infrastructure allows two-way communication between the utility costumer and the utility. This allows the utility to remotely monitor gas usage and manage loads more efficiently.
Automatic Energy Outage Information	A component of a smart grid, this allows utilities to isolate the cause of an outage issue quickly and restore power sooner than they could with traditional methods.
Electric Vehicle Charging	Electric vehicle charging infrastructure includes both wired and wireless options to charge the batteries of battery electric vehicles.
Electrified Induction Roadway	Wireless electric charging technologies built into roadways wirelessly charges special vehicles as they drive the roadway. This eliminates the need to stop and charge vehicles.
Smart LED Streetlights	LED streetlight upgrades offer significant energy efficiency gains over traditional street lighting technologies. Coupling this with smart-ready technologies allows plug-and-play options for Smart City features.
Network Operations Center	A networked platform that allows utility and /or smart feature operator to see information on various market, operating, and customer usage information.
Vehicle-to-Grid Charging	Bi-directional electricity flow from the grid to a vehicle battery, allowing the grid to pull energy from the battery and the battery to pull energy from the grid.
Regenerative Braking	Captured kinetic energy from train braking is sent to the grid.

Best Practice	Description
Wireless Energy	Wireless charging capability for small devices through park benches, tables, etc. (technology availability depends on application)
Customer Energy Portal	Software portal that allows utility customers to see their live energy consumption and prices to adjust their power use accordingly.
Water & Wastewater	
Water Re-Use	Water re-use can include collection of rainwater or greywater for re-use. Rainwater collection involves the use of cisterns, typically on rooftops, to collect rainwater for use in landscape irrigation. Greywater, gently used water from bathroom sinks, showers, tubs, and washing machines, can be directed and collected using a plumbing system that is separate from the plumbing system used for wastewater. This water can be treated for use in toilets and for irrigation.
Space-Heating Generation	Using sewage waste-heat recovery to feed low-cost, no carbon heating to buildings
Green Infrastructure	A number of technologies including bio retention cells, bio retention swales, infiltration basins, planter boxes, rainwater capture, permeable pavement, dry wells, etc., that capture stormwater runoff, reducing flooding and providing various environmental and community benefits.
Advanced Metering Infrastructure - Water	A component of a smart grid, advanced metering infrastructure allows two-way communication between the utility costumer and the utility. This allows the utility to remotely monitor water usage and manage loads more efficiently.
Environmental Sensors	Sensors in the public realm that provide hyper-local information on weather, air quality, and stormwater levels
Smart Green Infrastructure Monitoring	A cloud-based package of sensors used to report on performance of green infrastructure.
Water Treatment Sensors	Chemical sensors that can detect chlorine and pH in drinking water can be applied to test for a variety of pollution issues. The sensors can communicate wirelessly to measure water quality.
Systems Management	Software systems can be used to prioritize upgrades to water supply infrastructure by analyzing data from smart meters and sensors to pinpoint emerging leaks and contamination.
Telecommunications	
Conduit	Adequate conduit space to support growth demands for fiber is needed.
Fiber	A robust fiber backbone necessary to meet growing demands for telecommunication services.
Wireless Hardware	New hardware solutions in R&D stages to support ever-growing bandwidth demands.
Public Wi-Fi	Public Wi-Fi to allow people to connect to wireless internet while out in the community. This can enable economic development and enhance community livability.
Public Data Sharing Platform	Connecting citizens with data from smart technology devices around the city creates transparency and allows citizens to benefit further from data-based decision making.

Best Practice	Description
Network As A Service (NAAS)	Cloud-based management of networks and security to enable specific services to be provided. (e.g. Virtual Private Network (VPN) services, Bandwidth on Demand (BOD), and Mobile Network Visualization)
Transportation	
Adaptive Signal Technology	Sensors that gather data on traffic patterns, allowing the optimization of traffic signals, routes, and detours. This increases traffic flow and reduces traffic jams.
Dynamic Traffic Lights	An active component of adaptive signal technology, dynamic traffic lights employ sensors to optimize timing and can be controlled via a central control center.
Autonomous Vehicles	Specific transportation infrastructure can be developed to support the use of autonomous vehicles. These included installing additional roadside devices that reduce glare and allow autonomous vehicle sensors and cameras to read traffic signals in all lighting conditions. Autonomous vehicles also rely on reading road markings with cameras. Restriping lane lines and other markings more frequently can ensure accurate lane sensing.
Electric Vehicles	Infrastructure to re-charge electric vehicles.
Shared Mobility	A network of shared transportation options such as Bike Share and Car Share that allow users access to different modes of transportation without personal ownership. *Currently exists in Boston with docks within the Project area.*
Flood Sensors	Sensors that automatically detect street flood, notify appropriate parties, and communicate to drivers what areas to avoid through an app and/or LED Smart Signs.
Smart Snow Removal	Sensors monitor snow levels and road temperatures to optimize snow removal and notify drivers of road conditions to reduce snow and ice-related traffic accidents.
Complete Streets	Designing, planning, and building streets accessible, efficient, and safe for all modes of transportation (e.g. Protected Bike Lanes).
Smart Pedestrian Safety	Sensors related to traffic management and crowd management optimize the flow of pedestrians across streets to reduce accidents.
Other	
Gunshot Notification	Sensors placed in the area detect the sound of a gunshot and automatically dispatch emergency services.
LED Smart Signage	LED smart signs display important announcements or information as well as advertising.
Air Quality Monitoring	Sensors collect data on air quality and push information to a mobile application to alert residents of potential health risks.
Real-time 311 Management & Response	Upgraded 311 System with real-time call tracking and smart phone apps to pinpoint calls and improve response time
Smart Waste Management	Dumpster-level sensors notify waste management organizations when waste needs to be collected, optimizing waste collection and reducing sanitation issues.

Appendix G Smart Technologies and Practices – Initial System Designs for Modeling

This section outlines initial designs for modeling. For final modeling designs, please refer to *Assessment of Smart Utility Technologies Costs & Benefits* and supporting modeling inputs provided to BPDA.

G.1 District Energy Strategy Assessment

The following energy supply strategies were assessed for their applicability for the development:

- Option A: Central Heating and Cooling
- Option B: Central Heating and Cooling using Wastewater Heat Recovery and Rejection
- Option C: Central Heating and Cooling with Tri-Generation

At this stage in the assessment process, the following assumptions were made for distribution (Table 13), systems (Table 14), and energy costs and emissions factors (Table 15):

Table 13: Distribution Assumptions

	Heating	Cooling
36” Pipe Length (ft)		10,200
28” Pipe Length (ft)	10,200	
12” Pipe Length (ft)		28,000
8” Pipe Length (ft)	28,000	
Distribution Losses (ft/ft)	0.04	0.04
Average Pipe Size (in)*	12	22
Total Pump Size (kW)*	1,000	1,800

*Average pipe size and total pump sizes were derived using a pipe sizing tool assuming 4 primary branches and peak demands consistent with those previously discussed.

Table 14: System Assumptions

	Heating	Cooling
Baseline System Efficiency*	0.84	6
Centralized System (Boiler and Chiller)	0.95	7.8**
Wastewater Heat Pump (where applicable)	5.3***	N/A
Combined Heat and Power and Absorption Chiller	0.47 Heating, 0.29 Electrical	1.3

*ASHRAE 2016 Baseline System Efficiency

**TRANE VRF Specification CTV-PRC007M-EN

***COP of heating derived from Sewage Sharc S-660 Data Sheet (http://www.sewageheatrecovery.com/wp-content/uploads/2014/11/SHARC-660-Information.pdf)

Table 15: Cost and Emission Assumptions

	Electricity	Gas
Energy Cost	$ 0.193 / kWh	$ 1.078 / therm
Carbon Emissions Factor	0.2893 MTCO2 / MWh	0.1847 MTCO2 / MWh

Capital costs used in this assessment were taken from previous project examples.

Option A: Central Heating and Cooling

This strategy assumes that all of the development's heating and cooling demand is met centrally by one or more central plants. This assumes that all heating demand is met by high efficiency gas-fired boilers and all cooling demand is met by high-efficiency water-cooled chillers.

Figure 4 isolates Scenario 1 heating demand on the peak winter and on a summer day.

Figure 14: Scenario 1 Peak Winter and Summer Heating Profiles

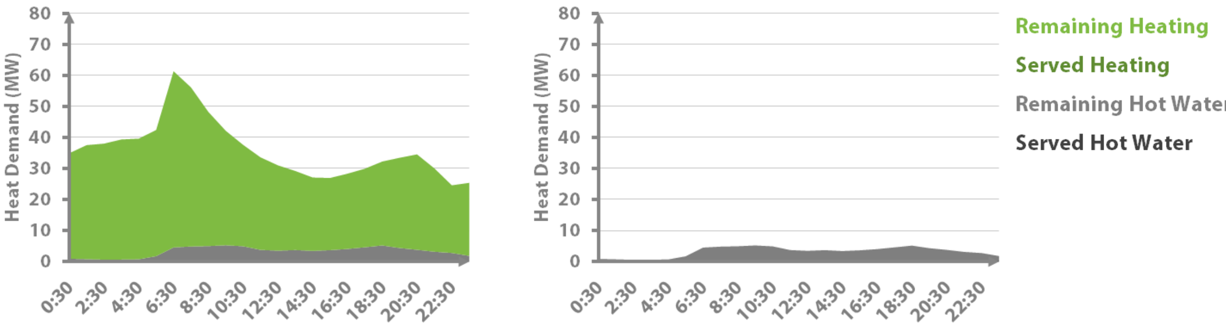
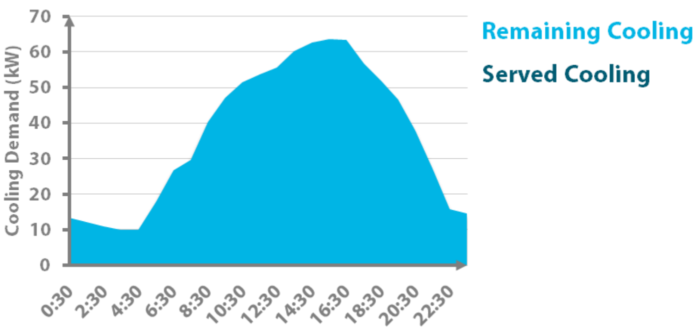


Figure 15: Scenario 1 Peak Summer Cooling Profile



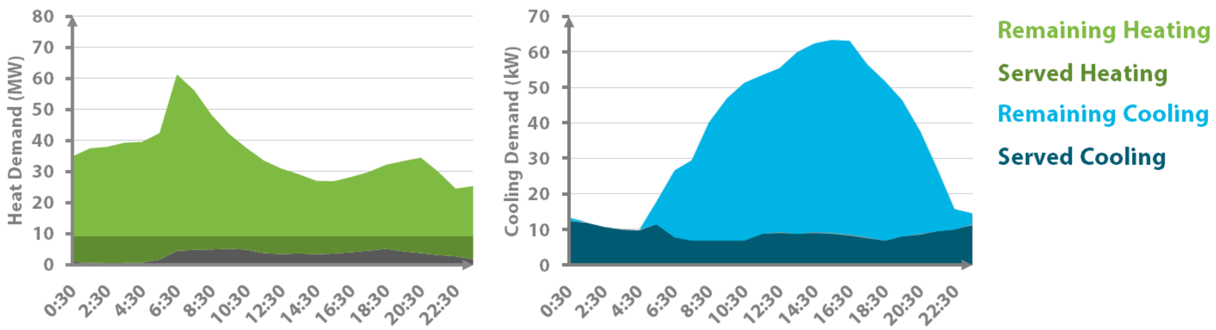
Option B: Central Heating and Cooling using Wastewater Heat Recovery and Rejection

This strategy is the same as Option A but adds a wastewater heat recovery system sized to the base heating demand (that which is consistent throughout the year), 5 MW.

Option C: Central Heating and Cooling with Tri-Generation

In Option C the central plant includes a 10 MW combined heat and power (CHP) turbine and absorption chillers. The turbine runs full-time, generating electricity and heat. The CHP turbine's heat is used to meet heating and hot water demands in the winter, and is used by absorption chillers to provide cooling when in the warmer months. Figure 6 shows how the CHP heat is used on both the peak winter, and peak summer day.

Figure 16: Scenario 1 Tri-generation Supply Profile



The energy savings associated with each district energy option are shown in Tables 4 and 5 below for development scenarios 1 and 2 respectively:

Table 16: District Energy Results Summary – Scenario 1

	Electricity (MWh/yr)	Gas (MWh/yr)	Water (kgal/yr)	Utility Cost ($/year)	Carbon (MTCO2/yr)	Cap Cost
Baseline	149,844	76,118	35,545	$31,790,383	57,416	$15,000,000*
Option A	150,370	72,072	35,545	$31,606,592	56,177	$79,000,000
Option B	155,457	57,881	35,545	$32,068,531	55,028	$88,000,000
Option C	133,468	102,730	35,545	$29,465,119	56,949	$103,00,000

*This is the cost of equipment no longer required if switching to a district energy system. It does not include building level distribution or the value of reduced plant space requirements in individual buildings (~3-5% TFA).

Table 17: District Energy Results Summary – Scenario 2

	Electricity (MWh/yr)	Gas (MWh/yr)	Water (kgal/yr)	Utility Cost ($/year)	Carbon (MTCO2/yr)	Cap Cost
Baseline	200,773	90,041	47,167	$42,155,657	74,724	$19,000,000*
Option A	201,294	84,383	47,167	$41,899,241	73,024	$97,000,000
Option B	206,598	69,587	47,167	$42,380,861	71,826	$104,000,000
Option C	183,643	116,535	47,167	$39,667,682	73,855	$112,000,000

*This is the cost of equipment no longer required if switching to a district energy system. It does not include building level distribution or the value of reduced plant space requirements in individual buildings (~3-5% TFA).

Summary

This high-level assessment of the potential of district energy suggests that site-wide system may not be financially viable at this point compared to a high-efficiency individual building systems.

The main detriment to district energy viability is the infrastructure cost; approximately 50% of the capital costs assessed are associated with the distribution. The large additional cost of infrastructures is generally not justified, with a best 'simple payback' estimated at over 30 years. While a district energy system does not seem to be financially viable at a site-level, but there may be localized opportunities where the distribution costs are lower.

G.2 Microgrid Strategy Assessment

The following microgrid strategies to support the entire development load were assessed for their applicability:

- Option A: Microgrid with Solar Photovoltaic (PV) and Battery Storage
- Option B: Microgrid with Solar Photovoltaic (PV) and Battery Storage and microturbines

These options can be combined with Distributed Energy options for further ability to support loads in island mode.

Option A: Microgrid with Solar Photovoltaic (PV) and Battery Storage

Table 18: Microgrid System Option A

Scenario 1 – High Residential Load	**51 MW Peak**			**Cost**		**Cost**
Demand Response	DR program	5.1	MW			
PV		7.64	MW			
Other Costs	Descriptions					
Load Management	Demand and supply management					$ 8,000,000
Interconnects						$ 12,000,000
						$ 20,000,000
O&M Costs						$ 100,092

Option B: Microgrid with Solar Photovoltaic (PV) and Battery Storage and Microturbines

Table 19: Solar PV Assumptions

Component	**Assumption**	**Unit**
Building Coverage	50	Acres
Building Coverage	43,560	sq.ft.
Est. PV Suitable	60%	
PV area	26,136	sq.ft.
Total PV Capacity	337.95	kW DC
Inverter Efficiency	96%	
Total PV Capacity	324.43	kW AC
Battery Storage	689	kWh
Battery Storage Cost	$350	per kWh
PV Cost	$3.00	per watt installed

Table 20: Microgrid System Option B

Scenario 1 – High Residential Load	**51 MW Peak**			**Cost**		**Cost**
Supporting Load	Microturbine	46	MW	$700-$1100	per kW	$ 47,618,763
Demand Response	DR program	5.1	MW			
PV		7.64	MW			
Other Costs	**Descriptions**					
SCADA and Software	Controller and software					$ 2,000,000
Load Management	Demand and supply management					$ 8,000,000
Interconnects						$ 12,000,000
						$ 69,618,763
O&M Costs						$ 679,300

G.3 Green Infrastructure

AECOM analyzed six Green Infrastructure strategies within the development area:

- Bioretention Basin on Parcels
- Permeable Pavement on Parcels
- Permeable Pavement on Right of Way
- Downspout Disconnection
- Detention Basins
- Bioretention Planters on Right of Way

These strategies were applied to specific street segments in the development area to calculate overall costs and impacts.

Table 21 Green Infrastructure Project Types

Street Description	Bioretention Basin (Parcel)	Permeable Pavement (Parcel)	Downspout Disconnection	Detention Basin	Bioretention Planter (ROW)	Permeable Pavement (ROW)
Downtown Mixed-Use					X	X
Neighborhood Main					X	X
Neighborhood Connector					X	X
Neighborhood Residential					X	X
Road + Linear Park		X	X	X		
Boulevard	X				X	X

All proposed new street segments were assumed to be built with Green Infrastructure. Additionally, the PLAN outlined two specific roadways for significant additions of Green Infrastructure: Ellery Street and D Street. A linear park is assumed to run parallel to the existing and proposed segments of Ellery Street and D Street will be made into a boulevard. Figure H-4 is a map that shows green infrastructure assumptions by street segment.

Figure 17 Green Infrastructure Assumptions

The following table shows the unit costs used to estimate the capital and O&M costs of this Green Infrastructure program.

Table 22 Green Infrastructure Unit Costs

GI Strategy	Unit Capital Costs (Loaded) ($/sf) ($/cf)	Unit Annualized O&M Costs ($/sf) ($/cf)
Bioretention Planter (ROW)	$80.40	$4.70
Bioretention Basin (Parcel)	$53.60	$3.97
Permeable Pavement (ROW)	$121.30	$0.12
Permeable Pavement (Parcel)	$75.30	$0.11
Detention Basin	$27.00	$2.37
Downspout Disconnection	$16.60	$0.40

G.4 Electric Vehicle Charging Assumptions

The costs and impacts of electric vehicle charging were analyzed under three scenarios of market penetration of electric vehicles:

- Option A: 30%
- Option B: 50%
- Option C: 80%

Charging stations are assumed to cost $1,200 each.

G.5 Water Reuse

This system includes collection piping and “purple piping” for on-site water re-use for treatment of greywater and black water for uses such as toilets, with an on-site storage tank. The following water reuse strategies were explored to support the development:

- Option A: Rainwater harvesting only
- Option B: Rainwater + Greywater
- Option C: Greywater + Blackwater

Capital Cost Assumptions		
Rainwater Harvesting/cistern	$3.75	per gal
Dual-Plumbing	$450	per toilet
On-site Reclamation System	$46.00	per GPD of installed Capacity
O&M Costs		
On-site reclamation	$3.50	per GPD of installed capacity
Rainwater Treatment	$0.16	per gallon capacity
Greywater Treatment	$1.11	per gallon capacity

G.6 Adaptive Signal Technology

For modeling, adaptive signal technology is assumed to include adaptive traffic signals and sensors for smart pedestrian safety. These were placed at twelve intersections around the Project area, the ten existing and two proposed. Adaptive traffic signals are assumed to cost $40,000 per unit and pedestrian safety sensors $16,000 per unit.

G.7 Autonomous Vehicles

Three options for supporting the use of autonomous vehicles were assessed for use in the development area. These include increased frequency of striping maintenance to facilitate easier detection of road lines by vehicle sensors, roadside devices to communicate with autonomous vehicles, and extra traffic signals and poles to reduce glare that inhibits sensor reading of traffic lights. Striping is assumed to cost $10 a linear foot and be done one extra time a year. Roadside equipment devices are assumed to cost $51,650 each. Extra traffic signals and poles are assumed to cost $5,000 each.

Benefit calculations for autonomous vehicles assume the following assumptions:

Assumptions	Value	Source
Autonomous Vehicle Market Penetration	10%	Boston Consulting Group & AECOM Analysis
Crash Rate Reduction (AV to Traditional)	24%	Virginia Tech
Average Annual Accidents – Project Area	23	Massachusetts Department of Transportation
Average Annual Accident Fatalities – Project Area	0.33	Massachusetts Department of Transportation
Average Annual Accidents – Citywide	3,978	Massachusetts Department of Transportation
Average Annual Accident Fatalities – Citywide	22	Massachusetts Department of Transportation

G.8 Public Wi-Fi

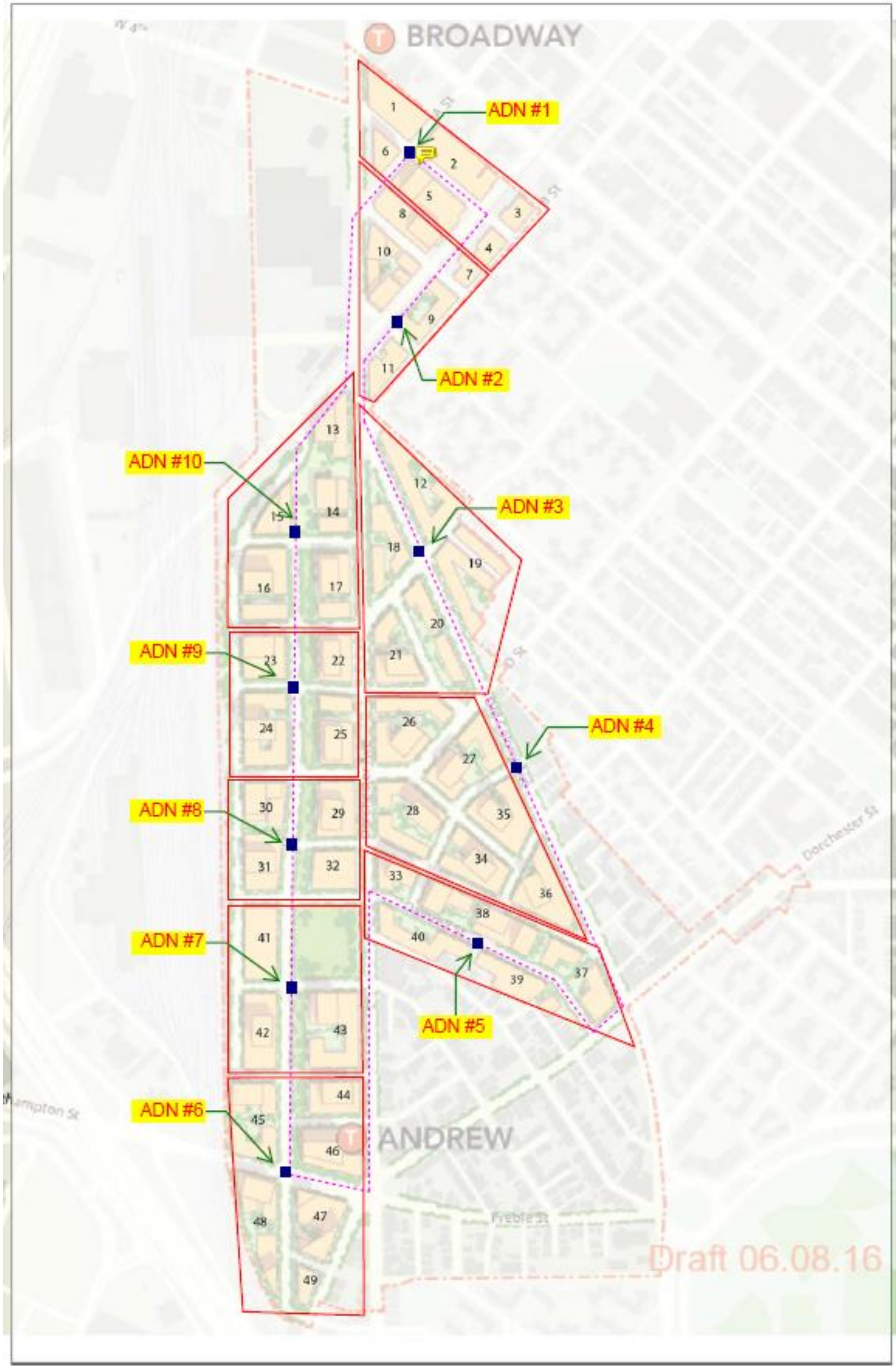
Boston has an existing public Wi-Fi system, Boston's Wicked Free Wi-Fi system. As this is already being carried out by the City through Annual Capital Planning, the Wi-Fi expansion can be seen as a "Business-as-Usual" buildout and is not going to be considered as a SUT.

Another option exists for adding public Wi-Fi to the area. This model mimics that of the NYClink program which installed street furniture (kiosks) that acted as Wi-Fi access points, portals for public information, and free charging stations. The added benefit of this system is the potential advertisement revenue from LED signage built into the streetscapes.

G.9 Looped Fiber System

Traditional trunk and branch design fiber systems can be improved by looping the system to increase resilience. A looped system allows service to continue in the event of an interruption to the system. The looped system design is in the following figure.

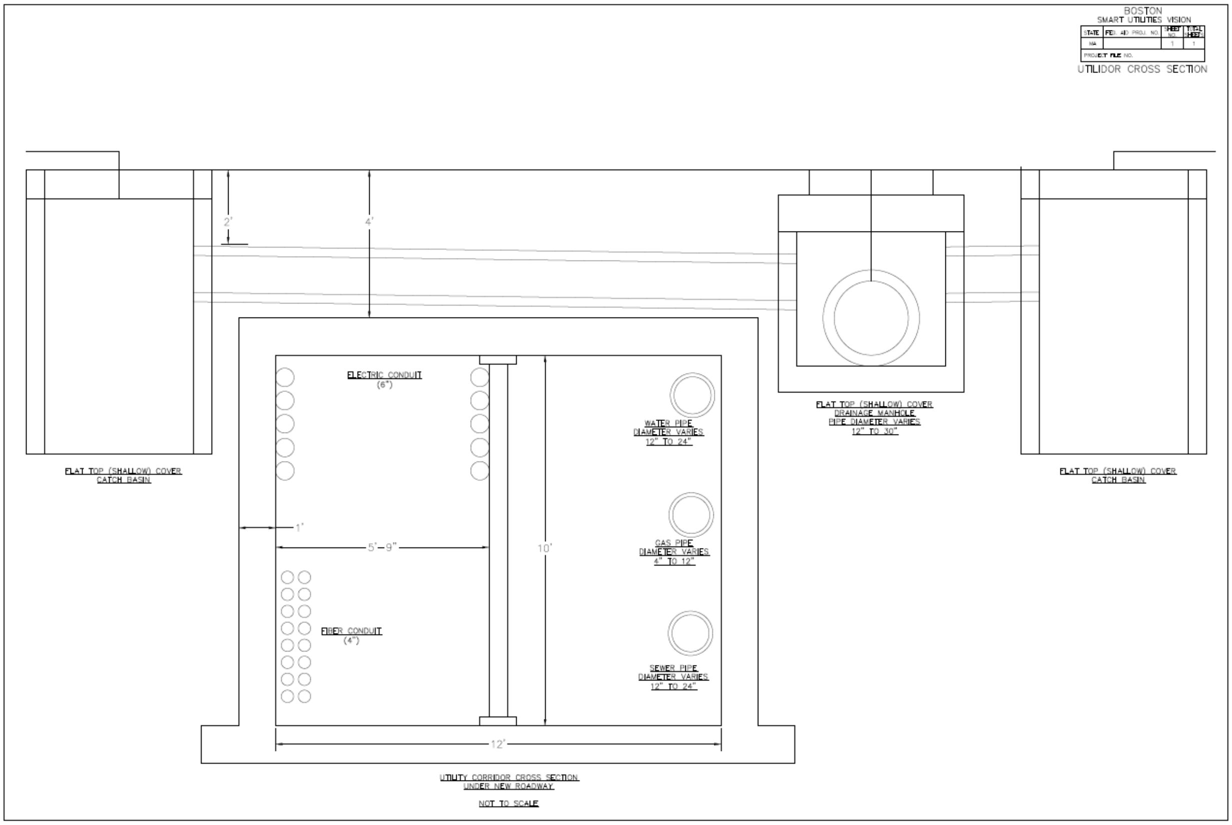
Figure 18 Resilient Fiber Loop System



G.10 Utilidor

The following utilidor design was conceptualized to capture the benefits from one main utility conduit with single access points. This reduces initial construction costs related to trenching and increase the efficiency of future maintenance or capacity expansions.

Figure 19 Utilidor Design



Appendix H Acronym List

Ac	Acre
App	Application (Mobile)
ASHRAE	American Society of Heating, Refrigerating and Air-Conditioning Engineers
BMP	Best Management Practice
BPDA	Boston Planning and Development Agency
BTD	Boston Transportation Department
BTU	British Thermal Unit
BWSC	Boston Water and Sewer Commission
CAD	Computer Aided Drafting
CHP	Combined Heat and Power; Cogeneration
CI	Cast Iron
CIP	Capital Improvement Program
CLEC	Competitive Local Exchange Carrier
COP	Coefficient of Performance
CS	Carbon Steel
DAS	Distributed Antenna System
DICL	Ductile Iron – Cement Lined
DOE	Department of Energy
DR	Demand Response
DU	Developed Unit
Eqv.	Equivalent
ERU	Residential Equivalent Unit
ESRI	Environmental Systems Research Institute
EUI	Energy Usage Intensity
Ft	Foot
FTE	Fulltime Equivalent
Gal	Gallon
GB	Gigabyte
GFA	Gross Floor Area
GIS	Geographical Information System
HH	Household

I.P.	Intermediate Pressure
ITE	Institute of Transportation Engineers
KV	Kilovolt
KWH	Kilowatt Hours
L.P.	Low Pressure
LED	Light Emitting Diode
LEED	Leadership in Energy and Environmental Design
MassDOT	Massachusetts Department of Transportation
MBTA	Massachusetts Bay Transportation Authority
Msf	Million Square Feet
MTCO2	Million Tons of Carbon Dioxide
MW	Megawatt
MWH	Million Watt Hours
MWRA	Massachusetts Water Resources Authority
NAAS	Network as a Service
O&M	Operations and Maintenance
PCI	Pit-Cast Iron (Lower strength material circa 1800's)
PDF	Portable Document Format
PL	Plastic
PSI	Pounds per Square Inch
PV	Photovoltaic
PWD	Public Works Department
RCP	Reinforced Concrete Pipe
SCADA	Supervisory Control and Data Acquisition
SDR	Standard Dimensional Ratio
sf	Square Foot
SSIM	Sustainable Systems Integration Model
SUT	Smart Utilities Technologies
T&D	Transmission and Distribution
TBL	Triple Bottom Line
Therm	Unit equal to 100,000 BTU
VMT	Vehicle Miles Traveled

VRF	Variable Refrigerant Flow
WI	Wrought Iron
Yr	Year