A GRCx Event: Decarbonizing Boston's District Energy Systems

GRCx is an interactive program series from the Boston Green Ribbon Commission designed to accelerate the implementation of the City's Climate Action Plan by providing high-quality, useful content on climate resilience and carbon mitigation to the Boston community.

GRCx

GREEN RIBBON COMMISSION
Climate Action Exchange

Introductions

Rebecca Hatchadorian
Associate Principal of Sustainability Consulting
Arup

Bill DiCroce
President and CEO
Vicinity Energy

Bob Biggio
SVP Facilities and Support Services
Boston Medical Center

Maria Cimilluca
Vice President of Facilities
Northeastern University

Brad Swing
Director of Energy Policy and Programs
City of Boston

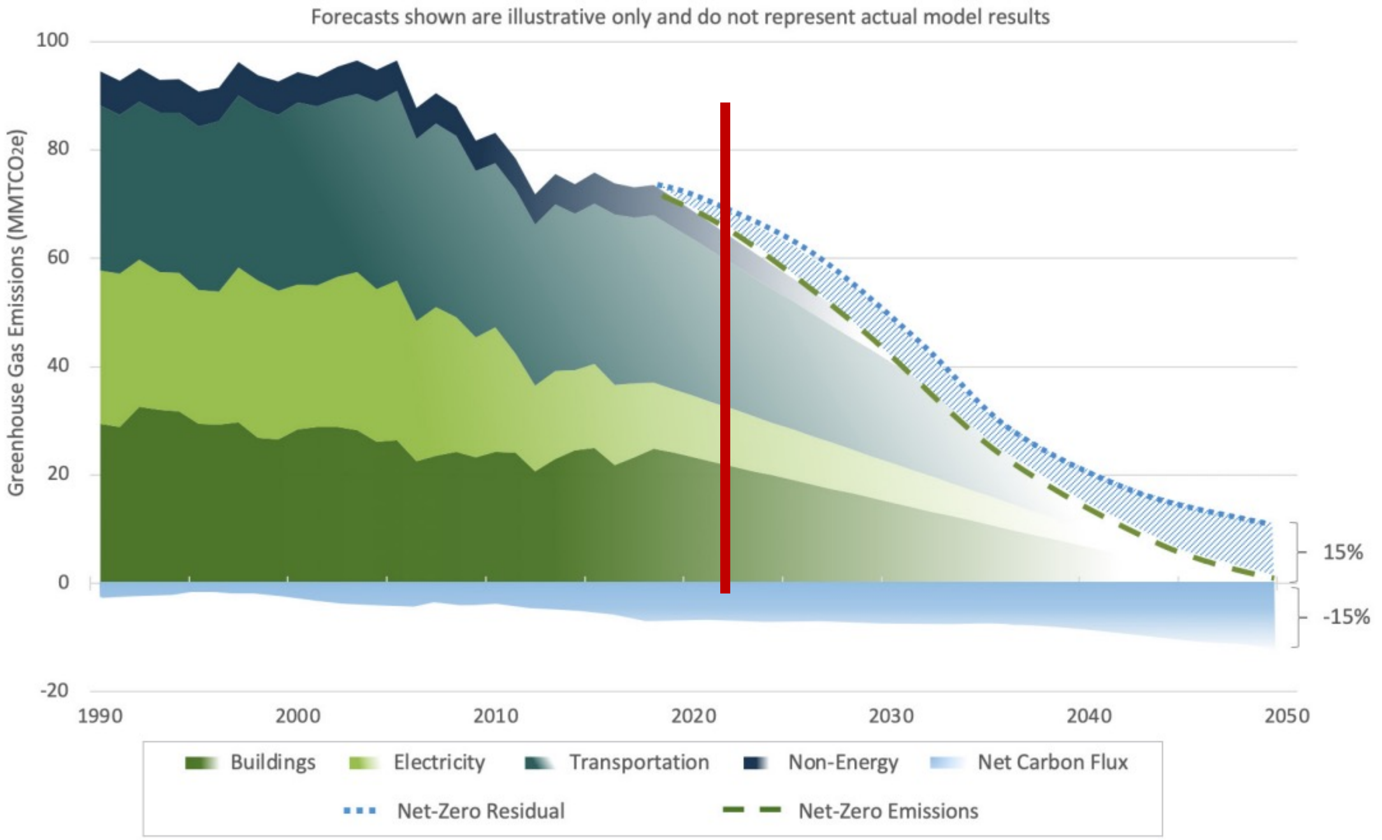
District Energy Systems & Decarbonization

Rebecca Hatchadorian

Why are we talking about district energy?

- Massachusetts and City of Boston have commitments to decarbonize at least 50% by 2030 and be carbon neutral by 2050

- District systems supply energy to buildings and have different challenges to decarbonize but great potential to realize emissions reductions at scale.

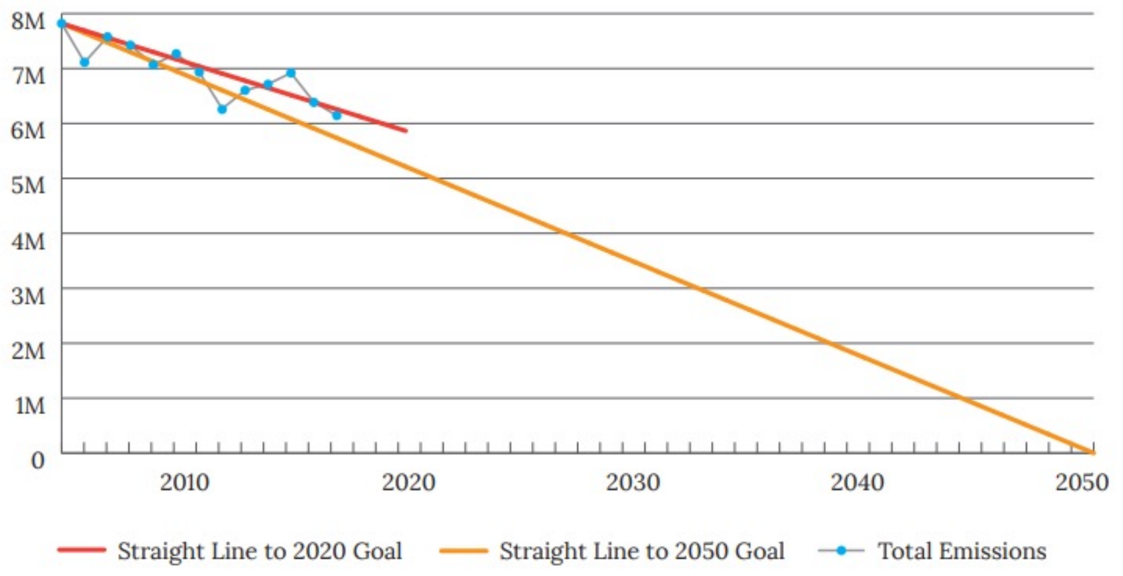


https://www.mass.gov/info-details/ma-decarbonization-roadmap

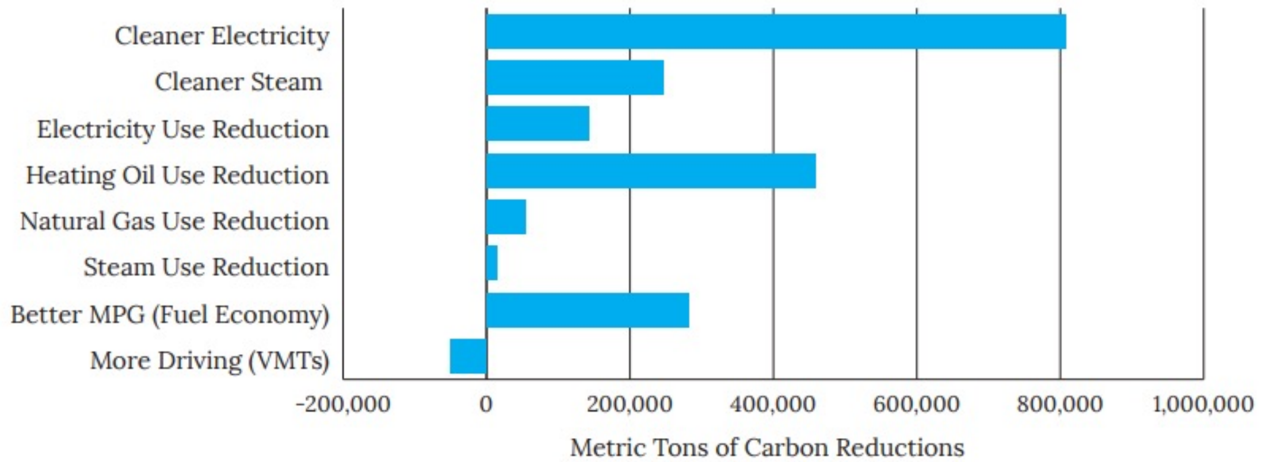
Why are we talking about district energy?

- City of Boston has a draft policy on BERDO building emissions performance standard proposed to go into effect in 2025.

Boston Community Carbon Emissions, 2005-2017, and Progress Towards Goals (in metric tons)



Source of Carbon Reductions, 2005-2017



https://www.boston.gov/sites/default/files/embed/file/2019-10/city_of_boston_2019_climate_action_plan_update_4.pdf

District Energy 101

- Centralized generation and consumption of any of the following:
  - Heating
  - Electricity
  - Cooling
- May be a microgrid
- These systems distribute to buildings in a campus/neighborhood/city

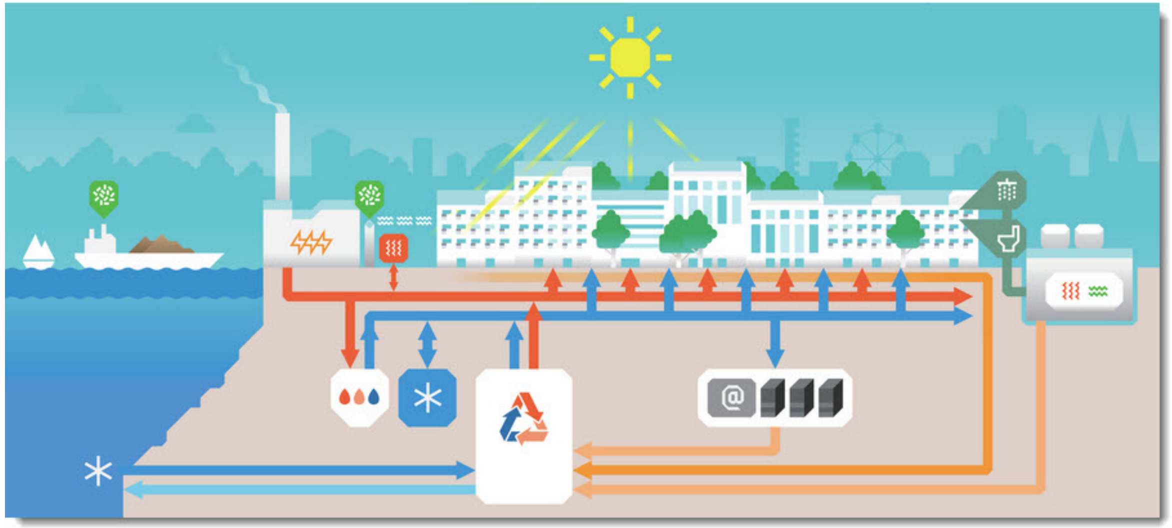
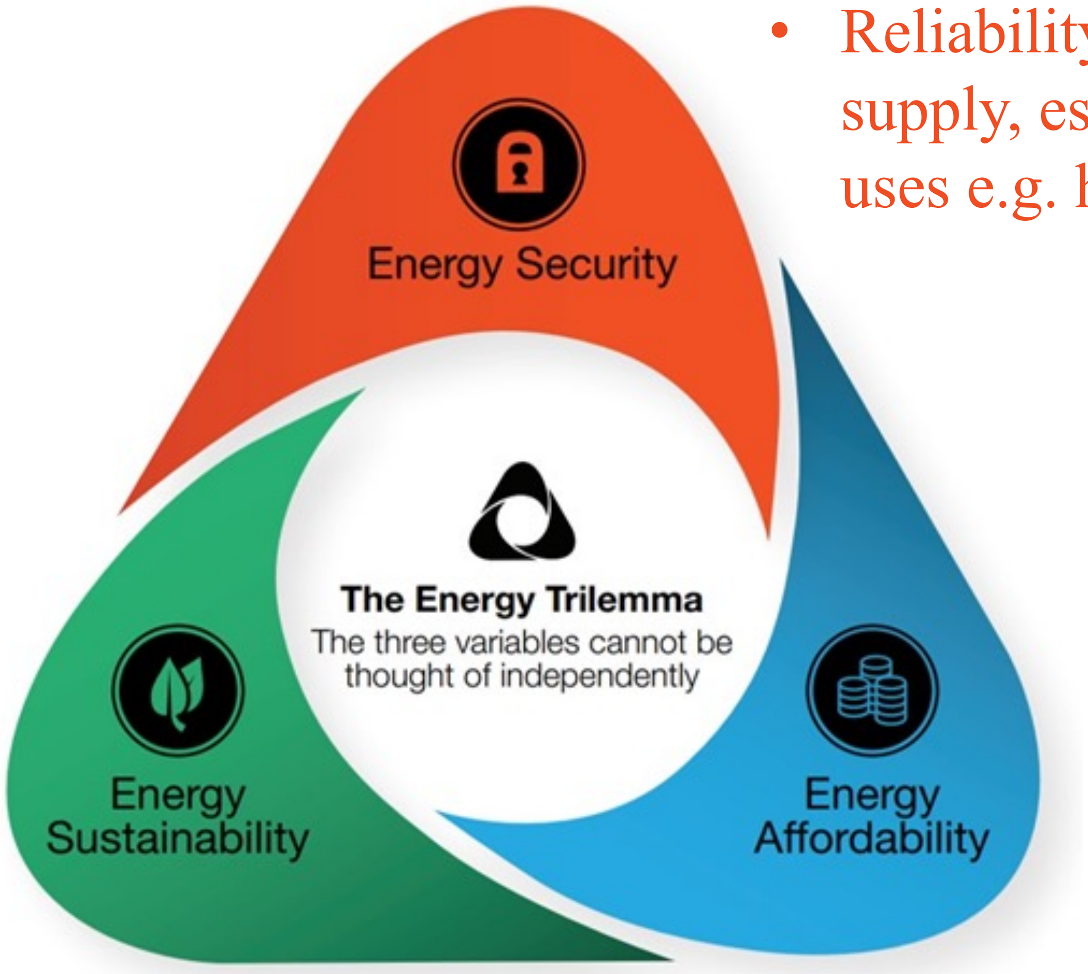


image courtesy of IDEA

Energy Trilemma

- Reliability & Resilience of supply, especially for critical uses e.g. hospitals and research

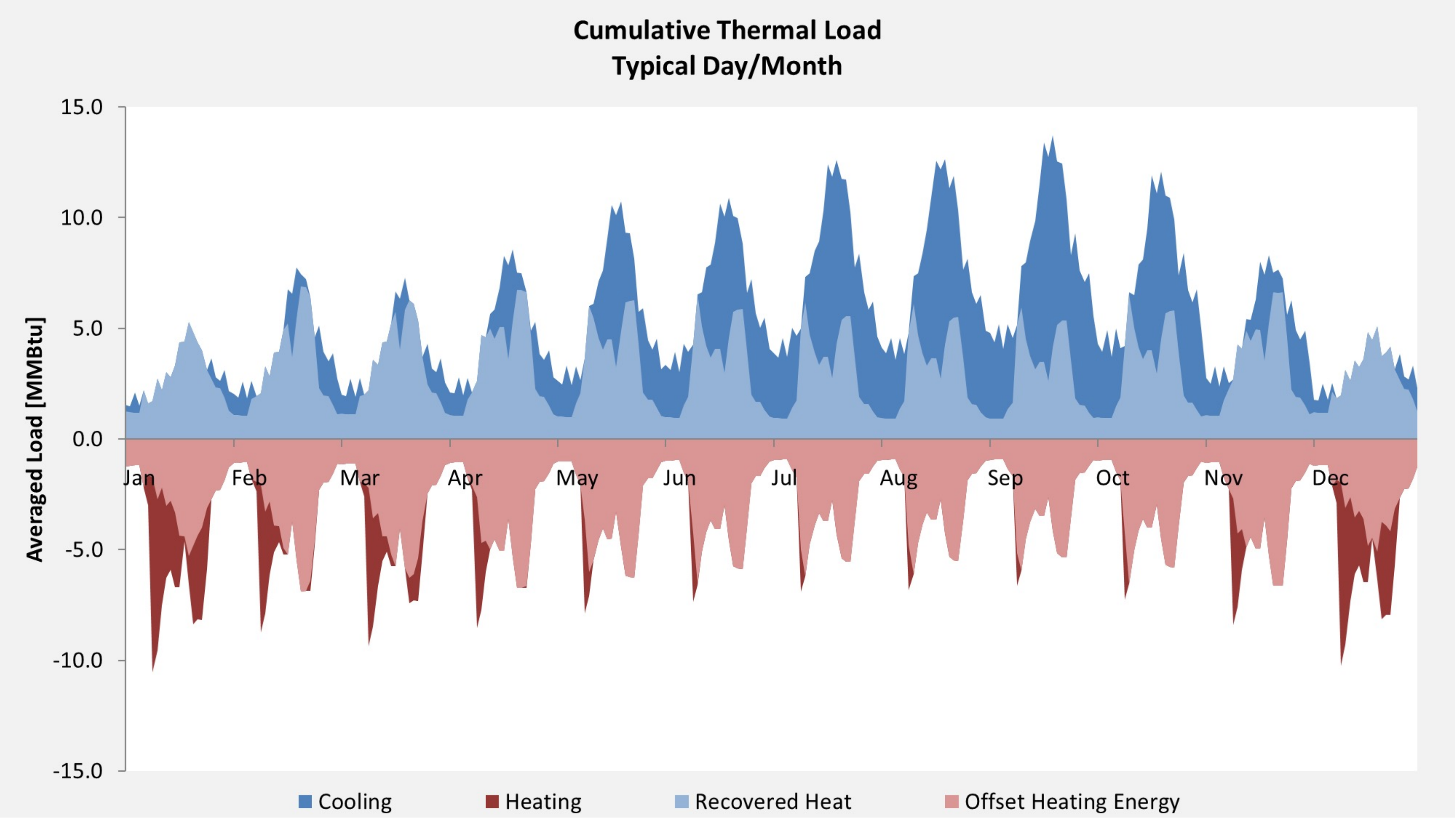


- GHG emissions & decarbonization
- Health & Air Quality

District Energy 101: Benefits

- Energy efficiency: Allows for thermal balancing,
  sharing & recovery

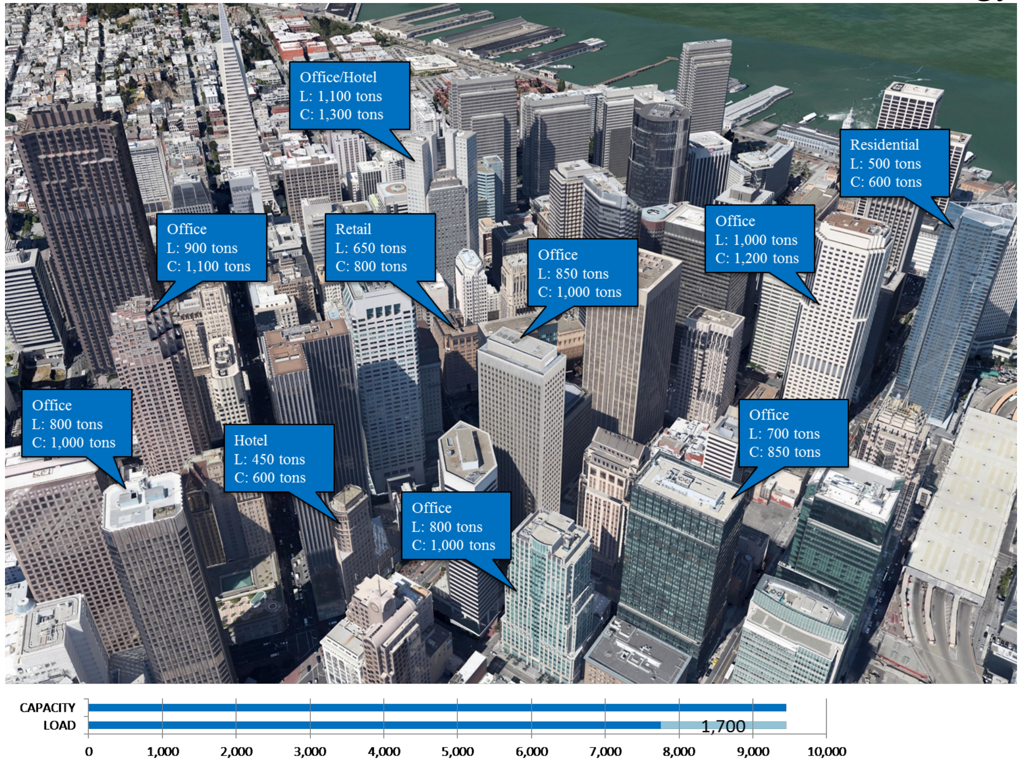
  Traditional power plants effectively convert only 40% of fuel energy into electricity, while 60% of energy is rejected or "wasted" as heat vented through a smokestack or released to a local body of water.



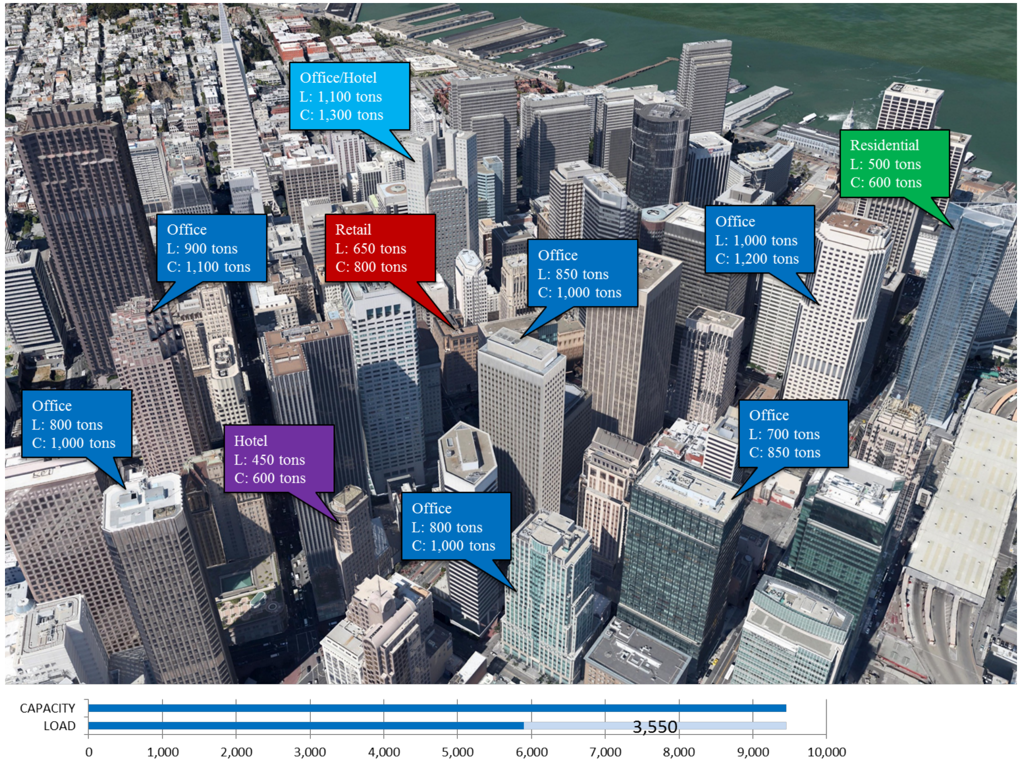
District Energy 101: Benefits

- Energy efficiency
- Lower total installed capacity

without District Energy



with District Energy



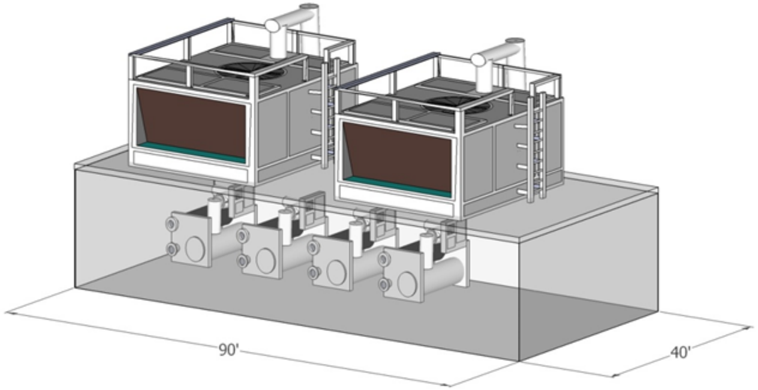
District Energy 101: Benefits

- Energy efficiency
- Lower total installed capacity
- Space & capital cost savings within individual buildings

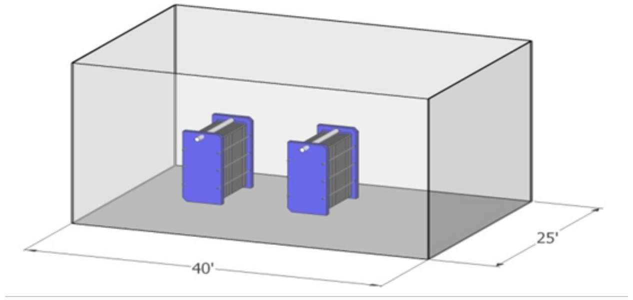
without District Energy

with District Energy

cooling



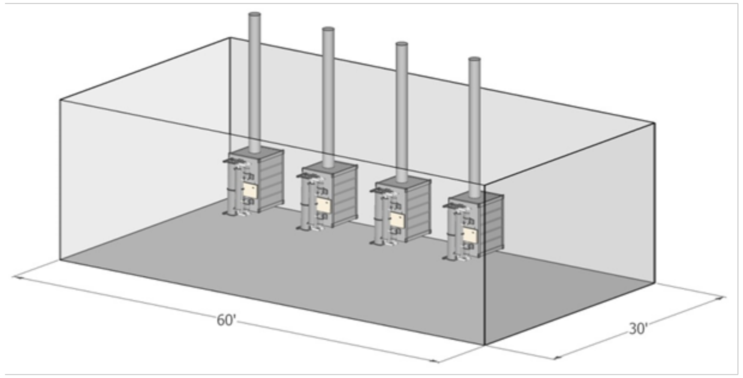
2,500 – 5,000 ft^2



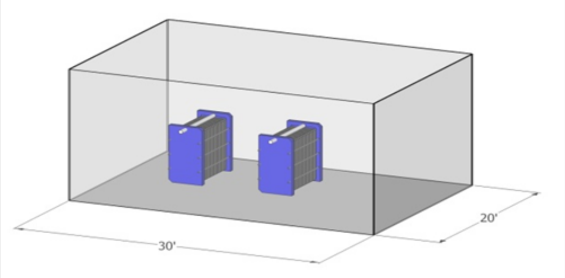
750 – 1,500 ft^2

(40% - 85% reduction)

heating



1,500 – 3,000 ft^2

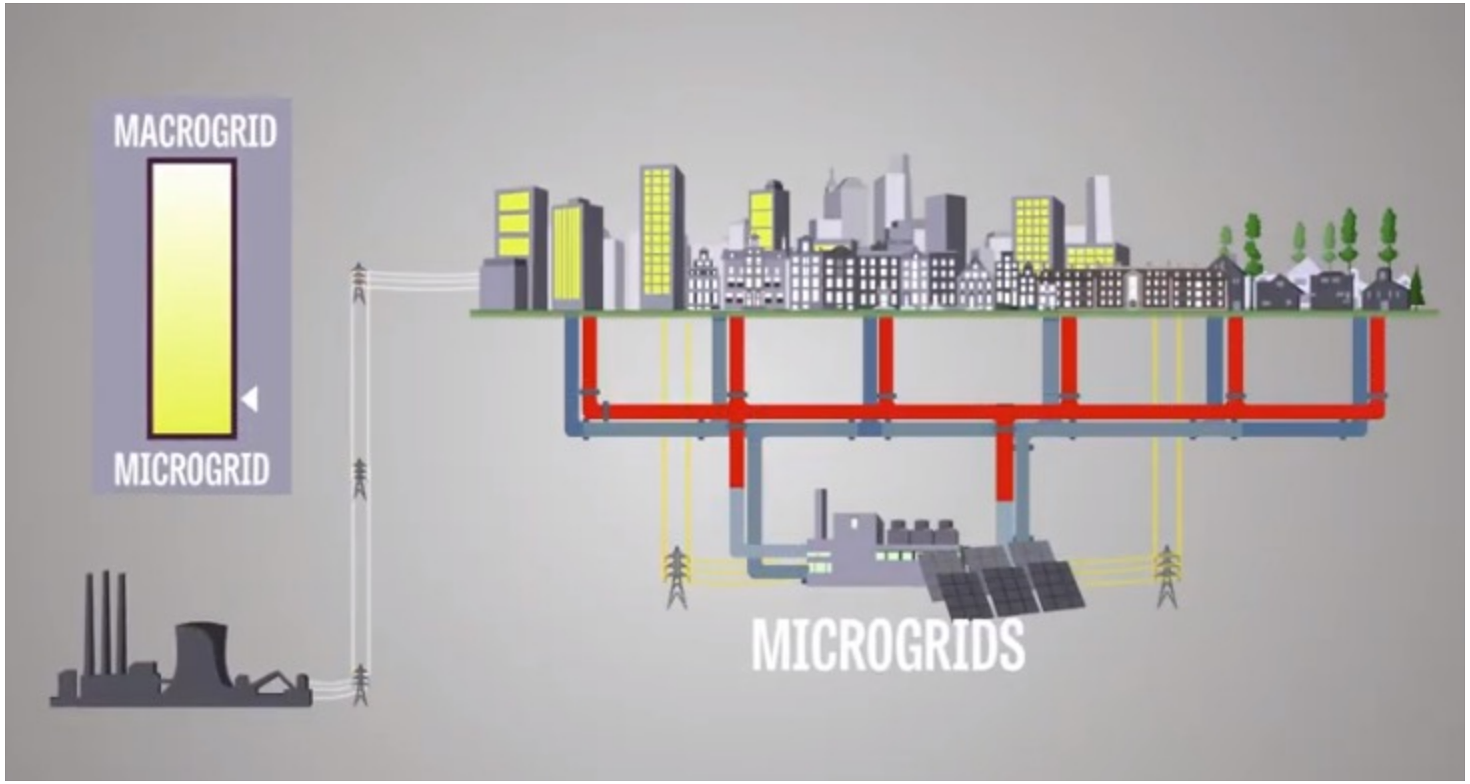


500 – 1,000 ft^2

(30% - 85% reduction)

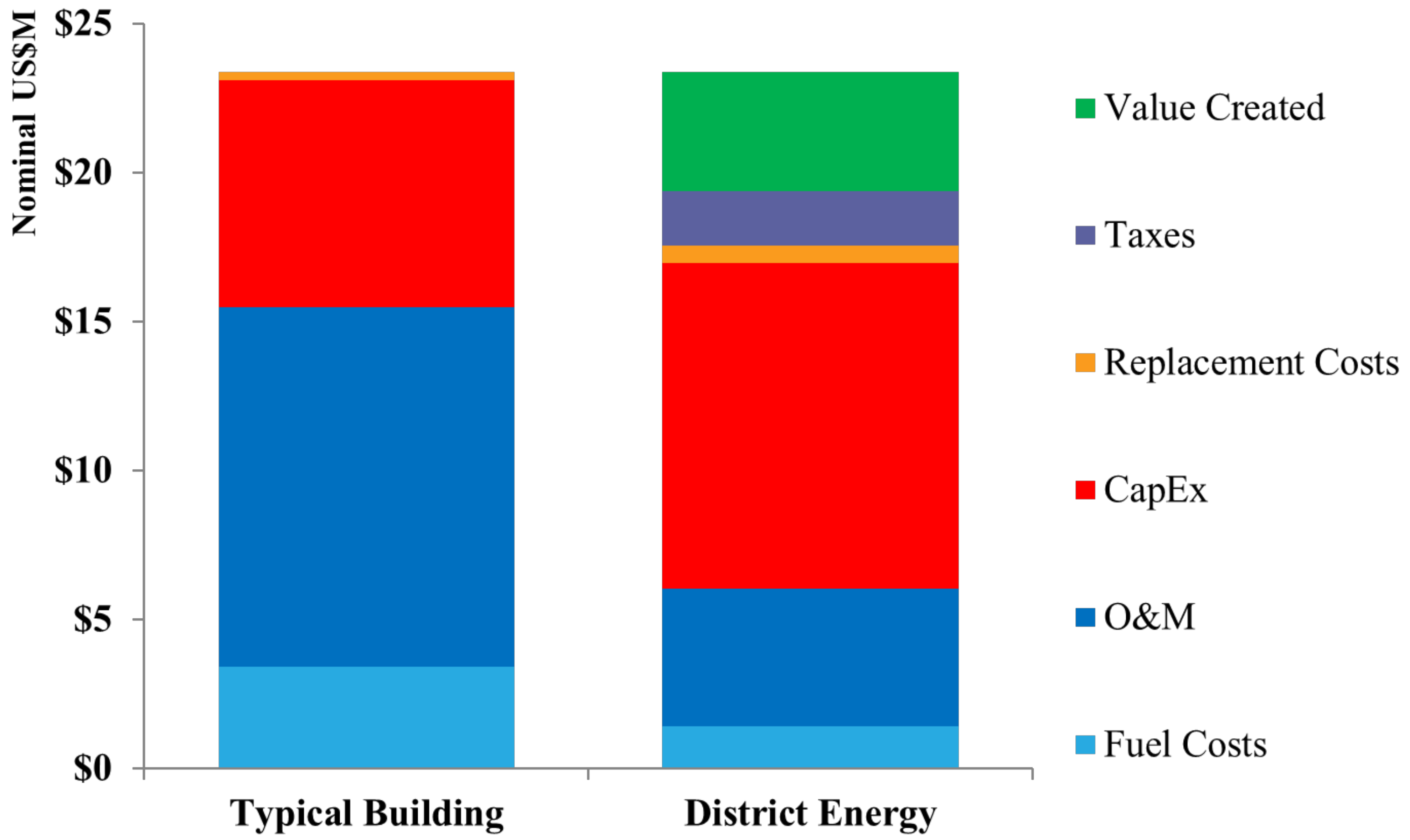
District Energy 101: Benefits

- Energy efficiency
- Lower total installed capacity
- Space & capital cost savings within individual buildings
- Resilience of energy supply
- Demand management & storage to reduce peak emissions

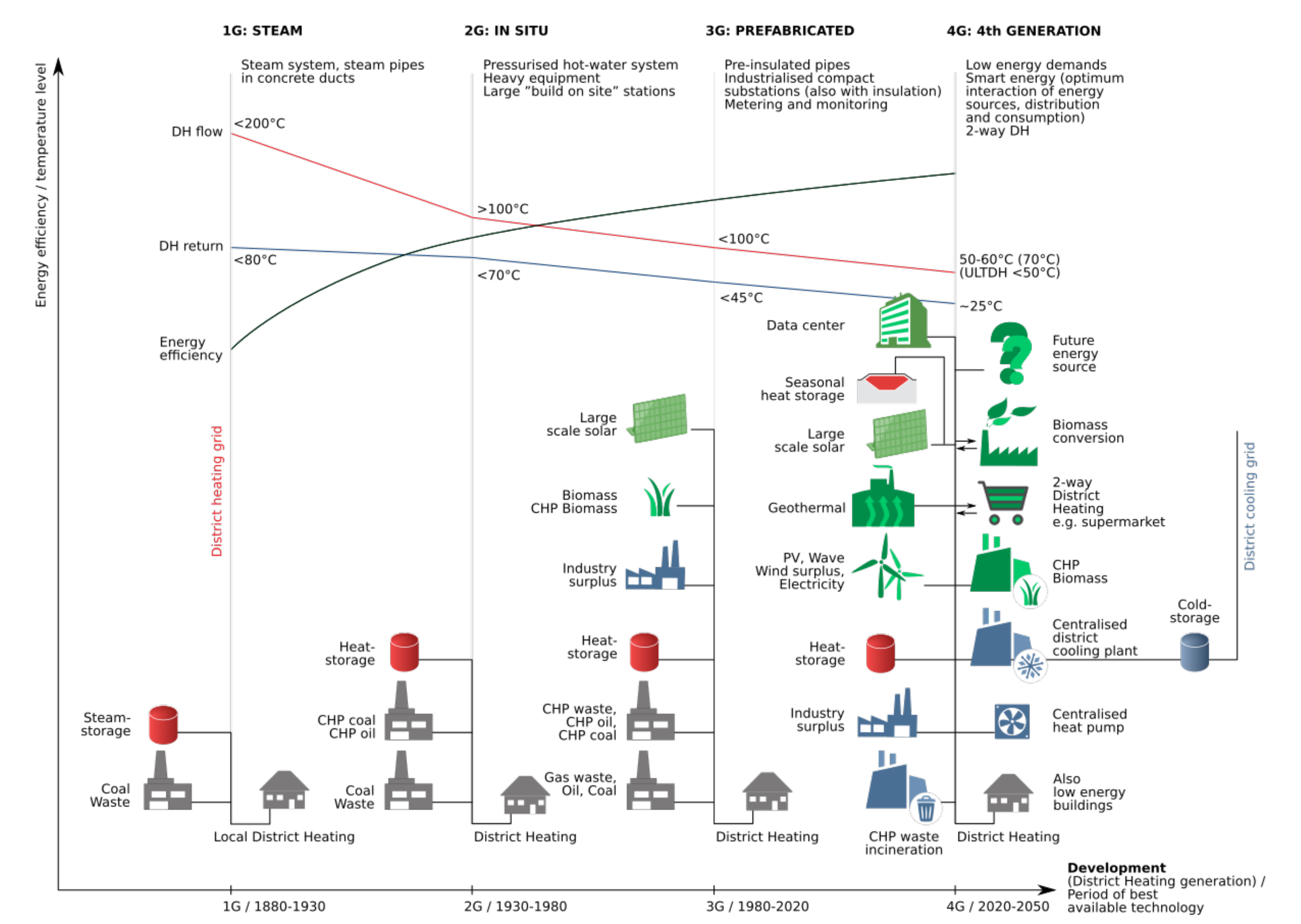


District Energy 101: Benefits

- Energy efficiency
- Lower total installed capacity
- Space & capital cost savings within individual buildings
- Resilience of energy supply
- Demand management & storage to reduce peak emissions
- Lower total cost of ownership



District Energy

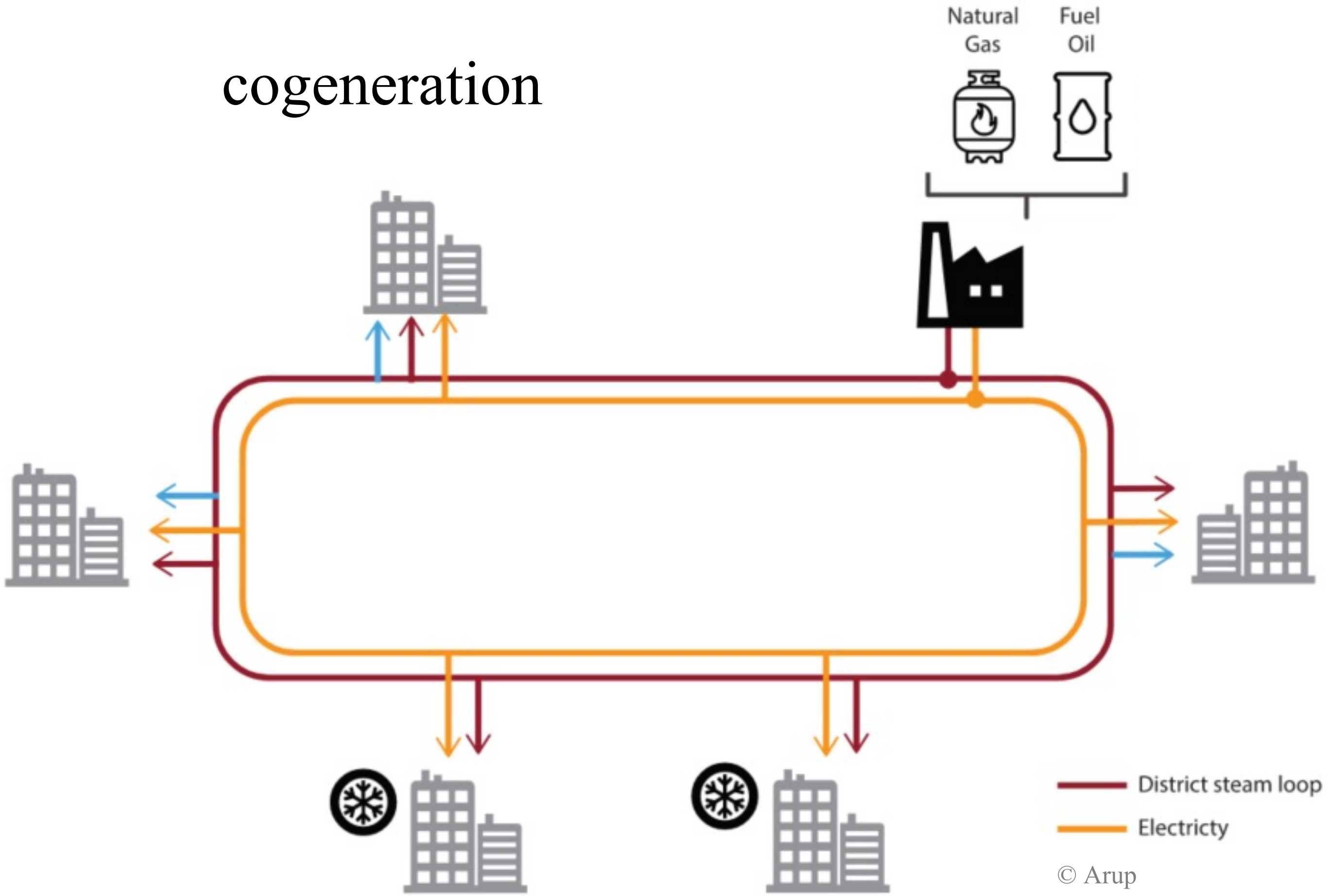


Source: Aalborg University

Combined heat + power (CHP)

also known as cogeneration or trigeneration, utilizes wasted heat from electric generation to increase the efficiency of power plants. Rejected heat is recovered to create steam, hot water, or chilled water to heat or cool a surrounding network of buildings through a district energy system.

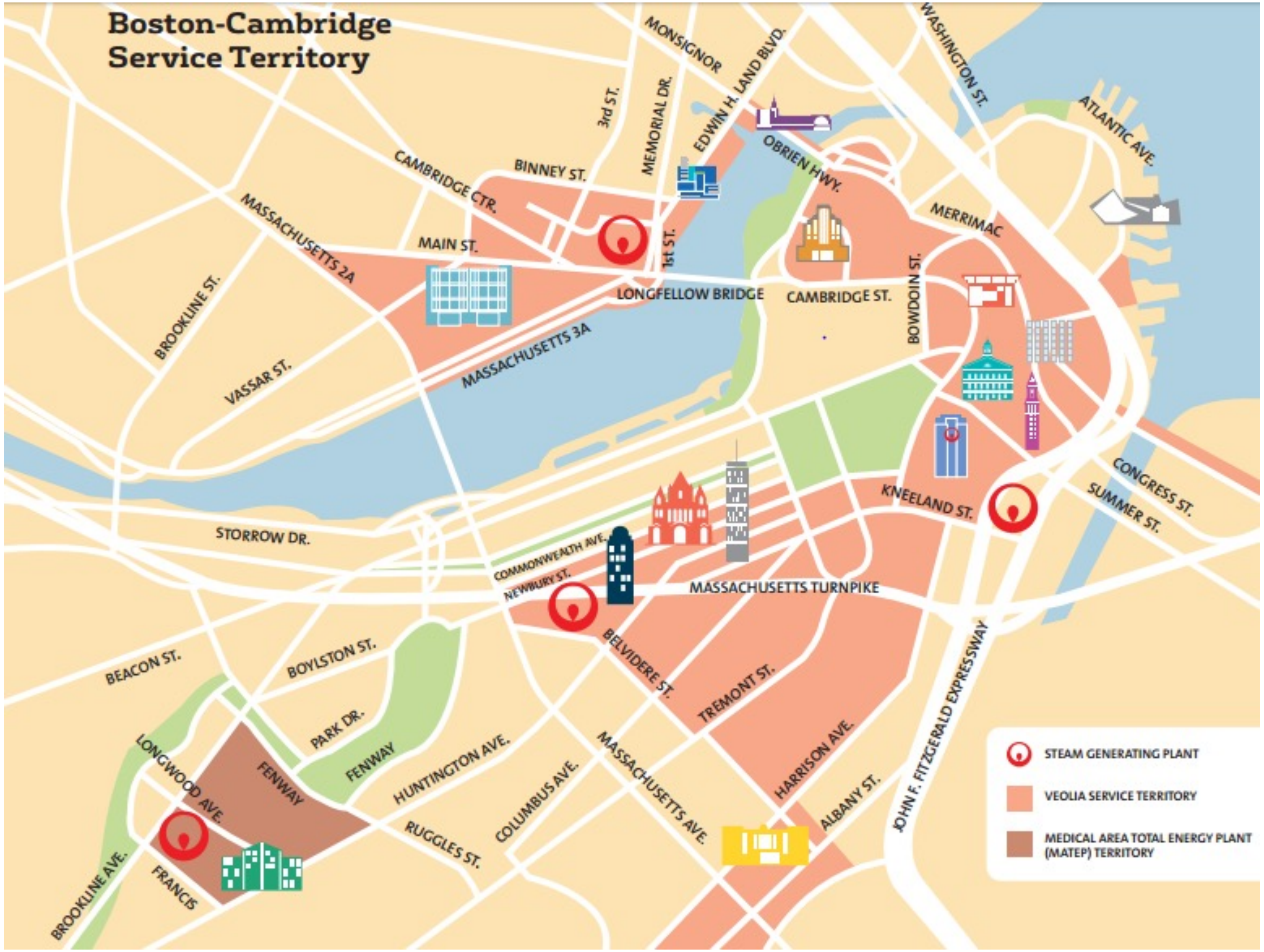
cogeneration



Vicinity

Vicinity is a combined heat and power (CHP) district energy system producing steam and electricity at Kendall + Kneeland Street plants

- Steam system serves 64M square feet in Boston & Cambridge.
- Electricity is produced to ISO grid, not distributed to customers



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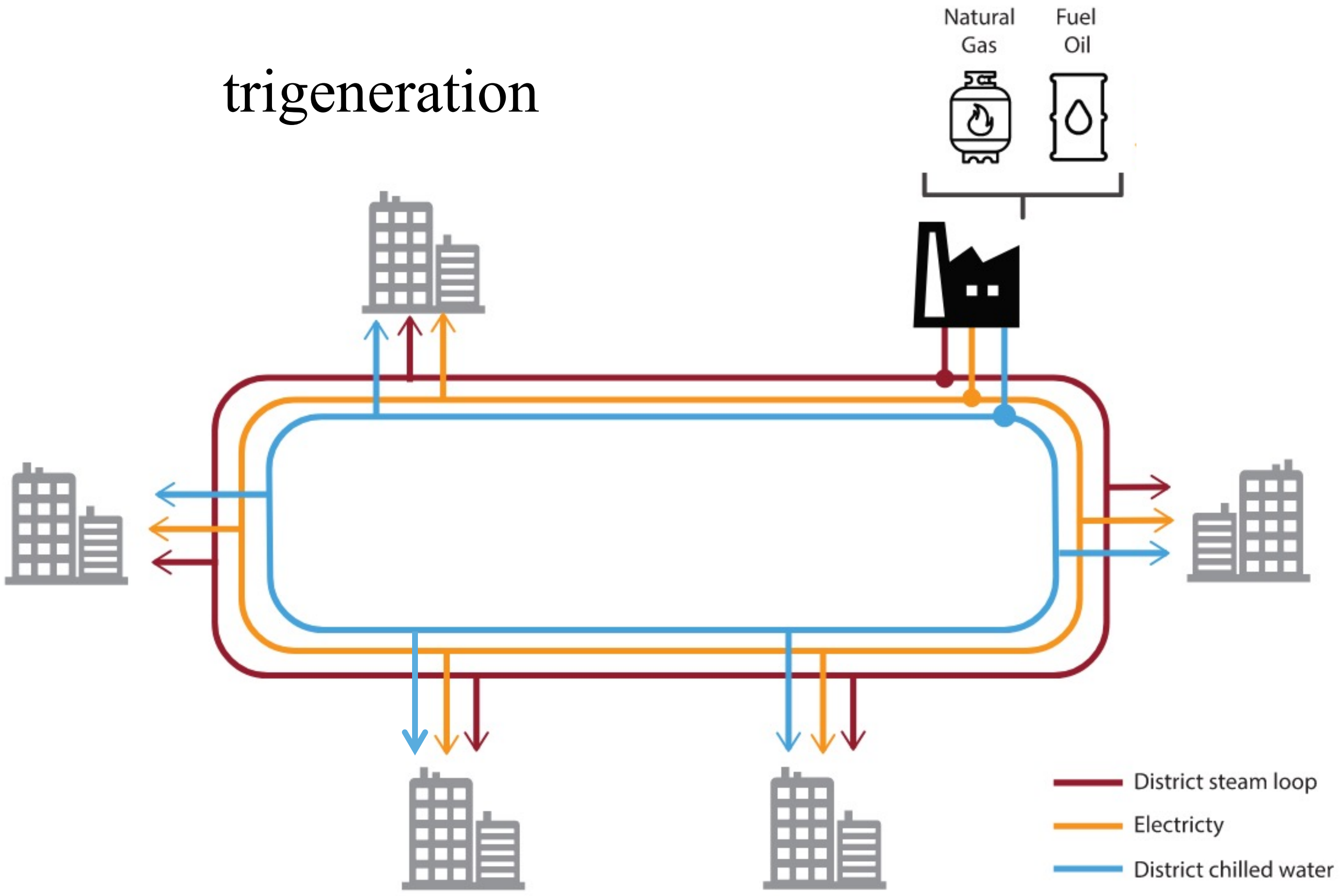
trigeneration



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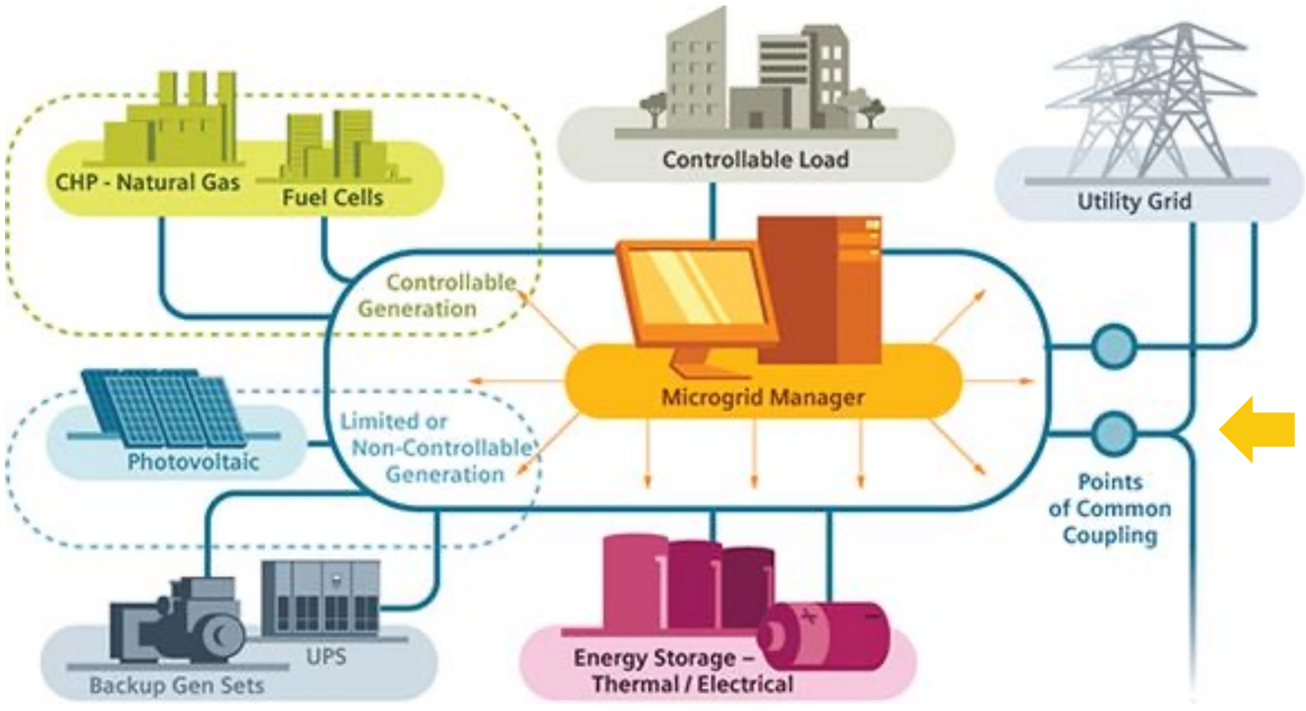
District Energy Microgrid

A microgrid is a group of interconnected loads and distributed energy resources within clearly defined electrical boundaries that acts as a single controllable entity with respect to the grid.

The power to isolate from the larger grid makes microgrids resilient, and the ability to conduct flexible, parallel operations permits delivery of services that make the grid more competitive



A microgrid can connect and disconnect from the grid to enable it to operate in both grid connected or "island" mode.

MATEP

MATEP is a combined cooling, heat and power (CCHP) or tri-generation district energy microgrid that provides electricity, steam and chilled water in the Longwood Medical Area

- 74 buildings & 12M square feet
- Microgrid means MATEP can operate independently of the electricity grid.

image credit: JOANNE RATHE/GLOBE STAFF/FILE

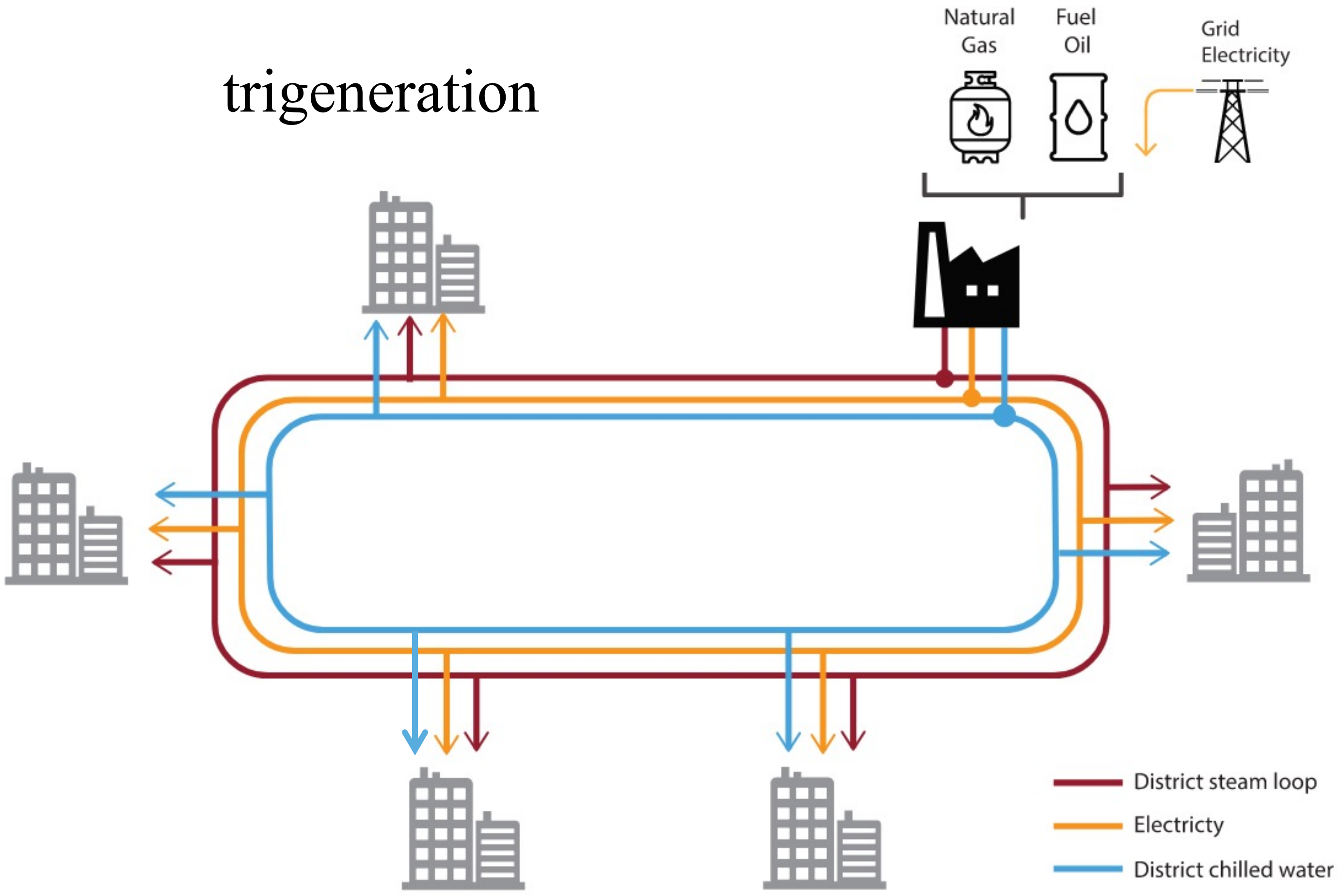
District energy & decarbonization

Currently fossil fuel-based systems

As electricity grid gets cleaner, generating electricity from natural gas becomes less appealing to customers

Steam needs for specialty uses harder to generate with the ‘traditional’ all-electric toolkit.

trigeneration



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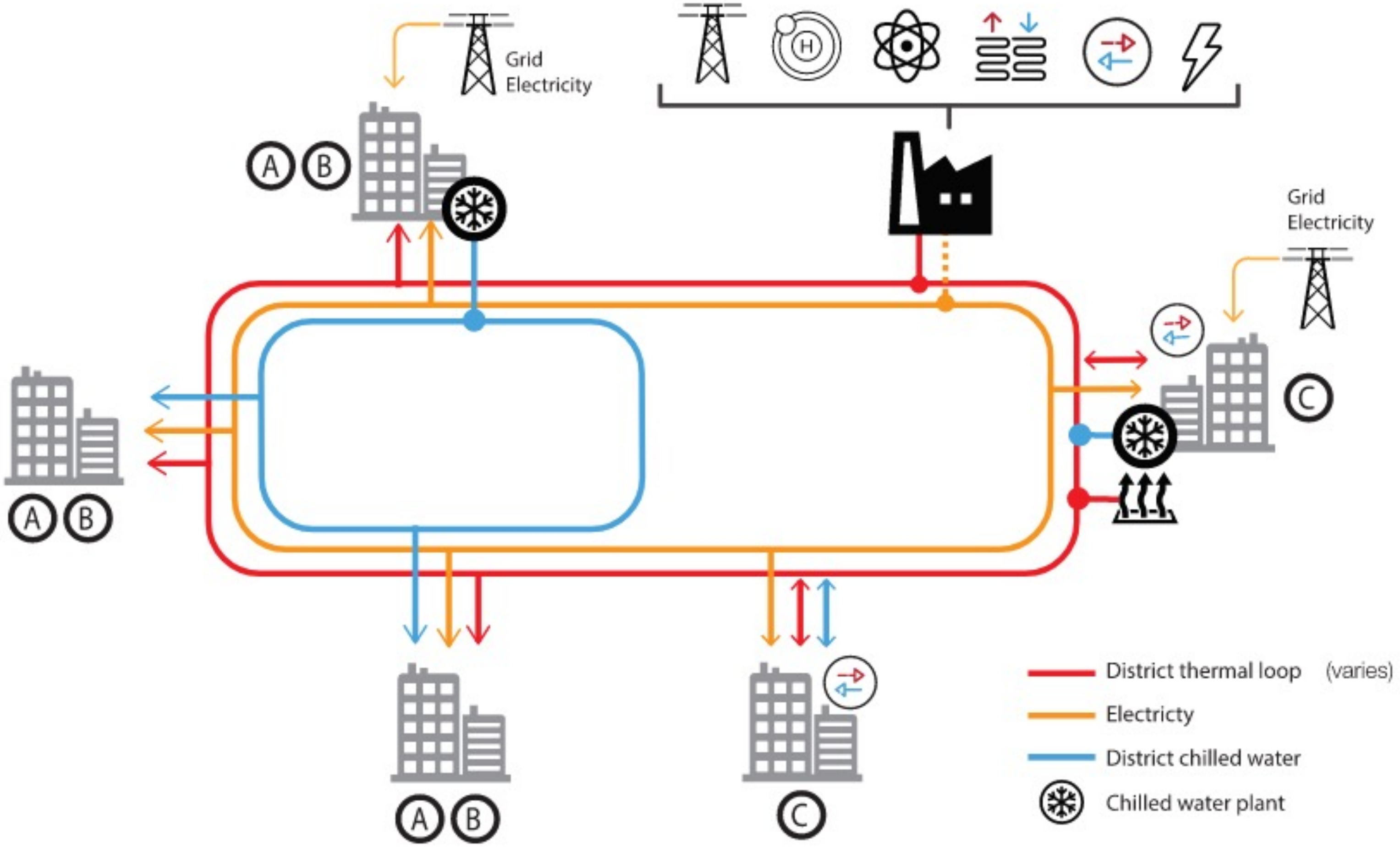
District Systems: Decarbonization Pathways



Ⓐ Steam decabonization

Fuel switch to maintain steam generation equipment with carbon free altneratives & maintain current distribution infrastructure

Hydrogen Boilers | Micronuclear Reactor

Ⓑ District hot water conversion

Retrofit steam distribution network to supply hot water to district buildings and maintain district chilled water infrastructure.

Hydrogen boilers | Micronuclear reactor | Ground source wells | Heat pumps (air/water) | Electric boilers

Ⓒ Thermal district / ambient loop

Eliminate steam generation and develop a thermal district utilizing ambient loop(s). Use existing chiller plants and new fossil-fuel free thermal systems to balance loop loads. Provide building-level heat pumps to transfer energy between buildings and loop.

Heat pumps (air/water) | Ground source wells | Waste-heat Recovery

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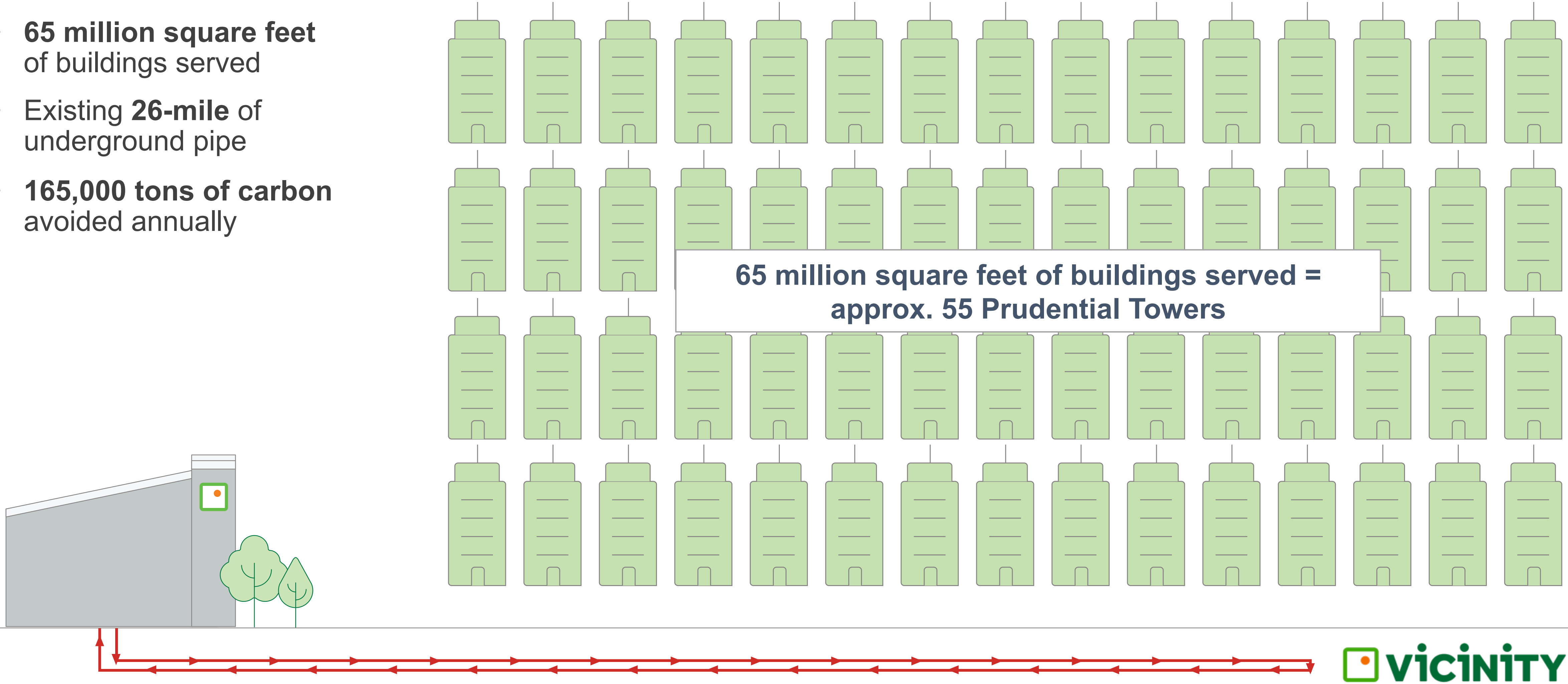
ARUP

Vicinity Energy's Roadmap for Decarbonization

Bill DiCroce, President and CEO, Vicinity Energy

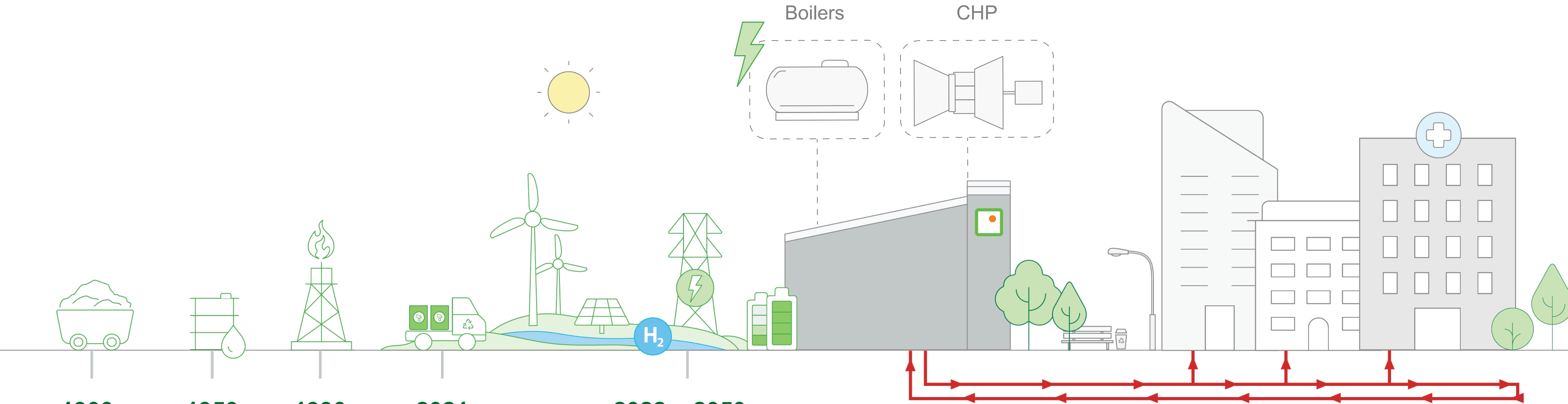
Major Hospitals, Campuses, Life Sciences, Hotels, Commercial Real Estate and City Buildings in MA Choose District Energy

- **65 million square feet** of buildings served
- Existing **26-mile** of underground pipe
- **165,000 tons of carbon** avoided annually



VICINITY

Vicinity's Net Zero Carbon Emissions Journey



~1900 Coal

~1950 Oil

~1990 Natural Gas

2021 Biogenic Fuel

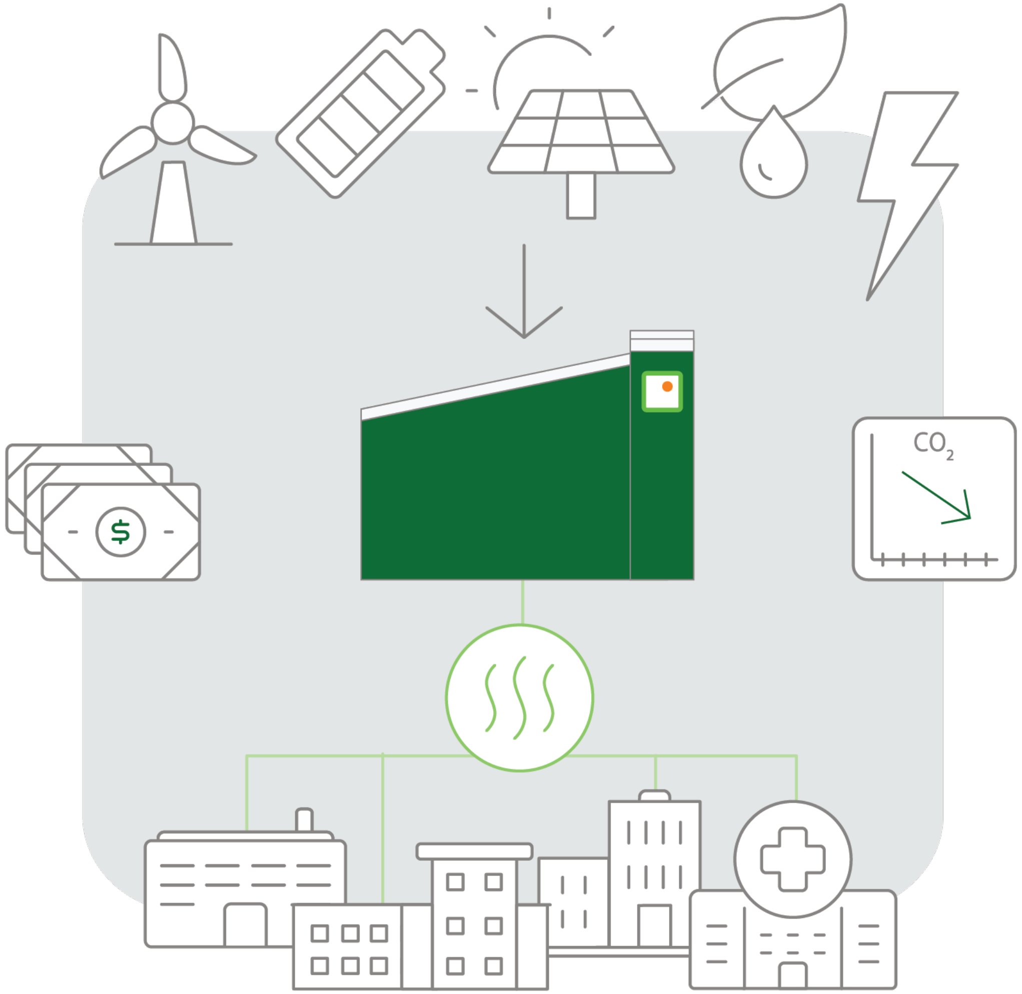
2022 – 2050 Electrification, industrial scale heat pumps, hydrogen and long-term battery storage for carbon dispatch

VICINITY

Plug and Play for Large-scale Decarbonization in Massachusetts

Plug and Play – existing 26-mile infrastructure for a low-cost, **ready to use**, solution for organizations to meet the City's climate goals

Save Money – no costly retrofits or infrastructure upgrades to meet new Massachusetts' regulations



A History of Change – adaptable fuel sources to decarbonize such as biogenic fuels, electrification, industrial-scale heat pumps, hydrogen and long-term battery storage for carbon dispatch

Resilient and Reliable – technology and systems provide **99.99% reliable distribution** with multiple redundancies in place for a climate uncertain future

VICINITY

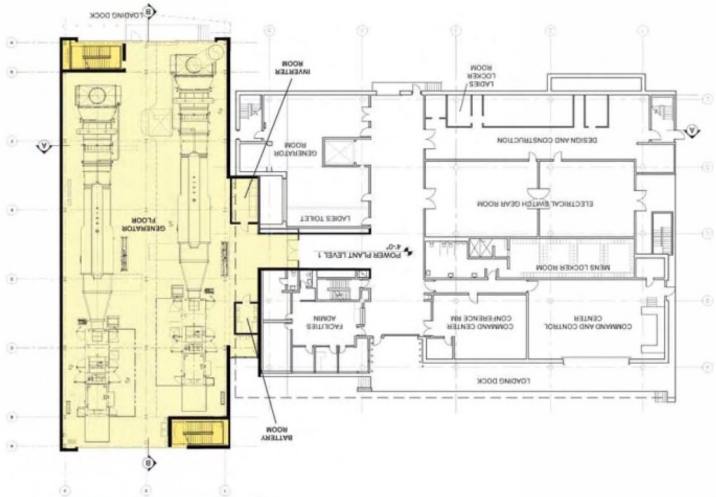
Thank You!

Greening Boston will require close collaboration with our utility partners

- For Boston to meet it decarbonization goals, it must solidly define for building owners what changes will be made at the utility level
  - Do I need to replace my steam supply through onsite investment, or can I bank on investments upstream that will green this energy source
- The ideal solutions will require investments both onsite, and upstream so as to create a high level of resiliency
  - If the electric grid or steam system go down, onsite backup will likely be required
  - In these scenarios, fuel diversity is an important factor, we should never count on one form of energy, and/or delivery system for critical facilities such as Boston Medical Center
- BMC started its journey towards a more efficient, sustainable, and resilient future over a decade ago, in partnership with Vicinity and Eversource

Back in 2010-2011, BMC was planning to build a large, utility scale cogen plant

- Project was proposed by the Boston University Medical Campus “Green Committee”
- 48,000 sf addition to BMC’s existing 120,000 sf power plant
  - To be built on 11,000 sf of BMC’s land
- 15 MW
  - To serve both BMC and BU Medical School
  - Generate 75% of the BUMC electricity and 95% of its steam
- $80-90 million price tag
  - $17.5 million investment by Veolia/ Vicinity
  - $52.5 million investment split by BMC and BU
- Project was fully designed, and DPIR approval process was underway

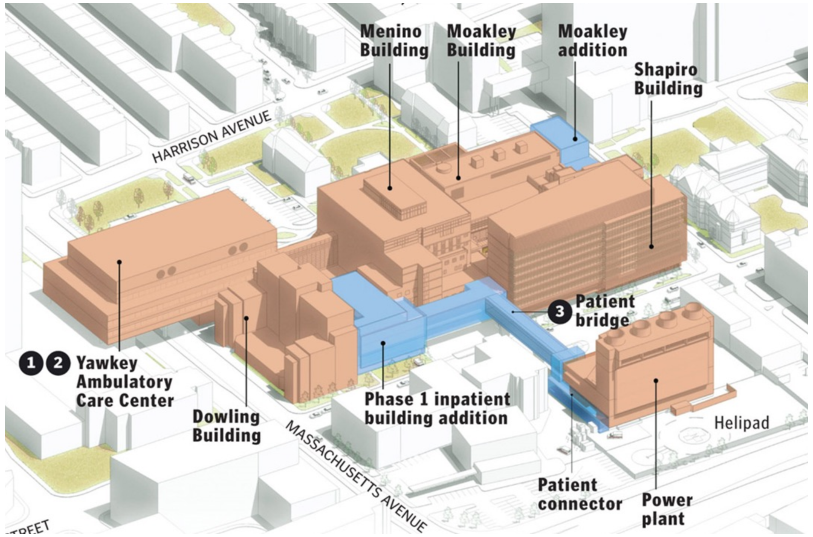


In 2011 the project was placed on hold

- BMC decided to take a step back to reassess it’s approach to greening the Campus
  - Evaluate the size of our campus and the efficient use of our square footage
  - What were the highest best uses for our real estate
  - Focus on right sizing our campus and driving deep energy efficiency, to determine what our energy loads can and should be

<u>Don’t make a large capital investment which simply fuels the existing inefficiencies that may already be in place.</u>

- In 2012, our vision for our Campus Redesign Project began to take shape
  - Consolidate our two campuses
  - Shed 300,000 sf of duplicative real estate
  - Monetize excess real estate to help fund the required investments
  - Invest heavily in energy efficiency to reduce energy consumption and associated costs
  - Create an efficient, resilient, and sustainable campus for the care of our community



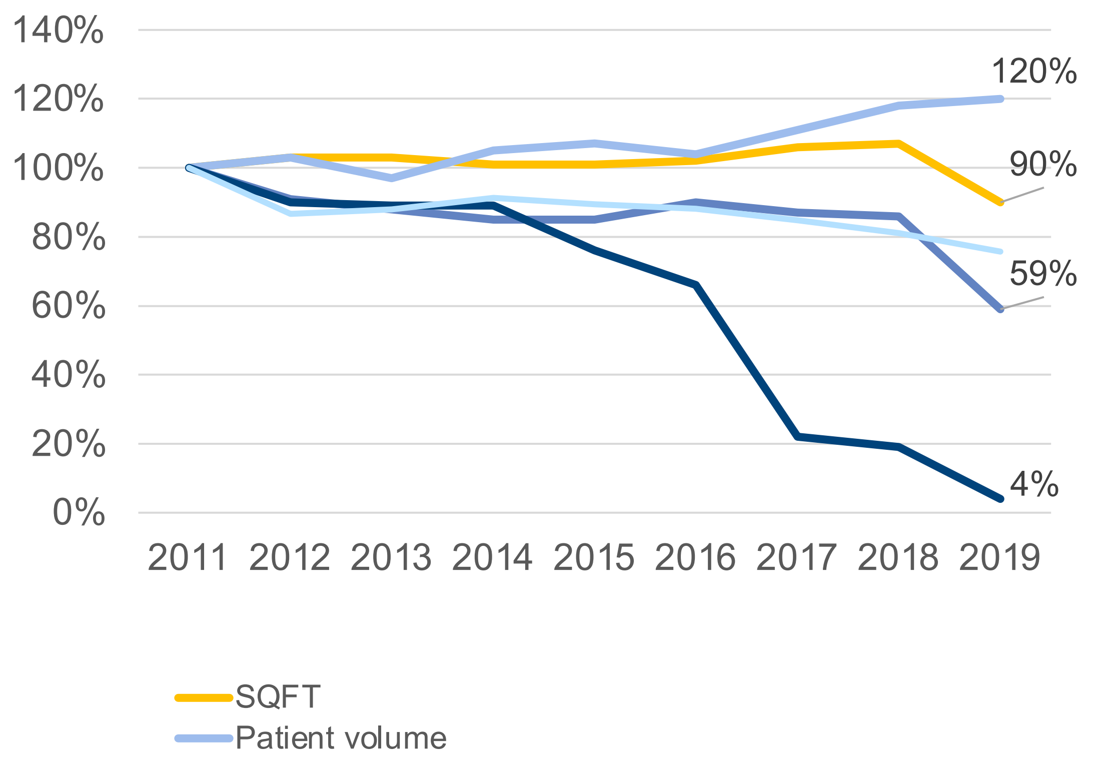
The renewed focus on efficiency versus fueling inefficiency paid dividends

- 10% reduction in total campus square footage
- ~40% reduction in electric consumption
- ~34% reduction in steam consumption
- 96% reduction in carbon emissions from energy
- ~$25 million of annual savings
- +20% increase in patient volume
- Completed over 30 individual energy efficiency projects between 2012-2018

Among the recurring benefits of the project are significant energy and carbon emissions reductions

Changes to energy costs, physical footprint and environmental impact since 2011

Indexed to 100; 2011 = 100%



And then…back to the cogen

Prior to installing our own cogen, the BMC campus was insufficiently resilient

Energy Type	Source of Current Supply	Issue	Reason for Concern
Steam	District steam system	Resiliency	• Single point of failure – our steam is supplied from the district steam system and we are at the end of the pipeline with no supply redundancy • In the event of failure, BMC requires temporary boilers to be set up in power plant parking lot, which takes days to complete
Electricity	Purchased from Eversource	Emergency Preparedness	• Emergency Generators provide backup power for the first 96 hours of power loss • In the event of a sustained disaster where fuel trucks could not reach BMC we would be completely without power, i.e. Hurricane Sandy

Lessons from Superstorm Sandy: Hospitals with CHP fared well, while others who relied on the grid struggled

Hospital	Type of System	SuperStorm Sandy Events
South Oaks Hospital	Five 250 kW natural gas-fired reciprocating engines for a max capacity of 1.25 MW.	• South Oaks isolated itself from the Long Island Power Authority (LIPA) grid on 10/28and remained disconnected from the grid for 15 days • South Oaks was able to provide critical services for 2 weeks relying solely on their CHP system • They admitted patients from other sites who had been displaced by the storm and offered refrigeration for vital medicines
Greenwich Hospital	Two 1,250 kW natural gas-fired reciprocating engines plus a 2,000 kW backup generator. The system runs 24 hrs/ day, 7 days/wk, except for routine maintenance	• The Greenwich area lost power for 7 days • When the hospital lost grid power, it went down for 7 sec before the backup generators kicked in • The CHP system shut down and restarted in island mode while power was supplied to the hospital by backup generators; the whole transition process took approximately 5 min. • Greenwich Hospital was able to continue normal operations throughout the storm

Islanding in the storm

- 2MW Cogeneration unit with **black start and islanding capability**
- Redundant source of heat and power for out inpatient campus
  - Generates 40% of electric consumption
  - Provides for 33% of total heating capacity needs
- Provides back up power for the City's emergency communications infrastructure
- When coupled with our energy efficiency work our loads off of the grid have reduced by ~70%

The project improved resiliency and provided additional financial benefits to BMC

	CHP Plant
Overview	• Self-contained Jennbacher 1980 kW HW cogen unit
Location	• Yawkey roof
What it will provide	• Electricity and hot water heat for entire Menino campus • Black start capability in event of a power outage
Rebates and Financial Benefits	• $1.5m to be paid at project completion from Eversource • $3.68m of state resiliency grant funds via City of Boston

Implementation Costs	
Construction	$15,000,000
Incentives	($5,165,000)
Total Implementation Cost	**$9,835,000**

- 8 year ROI
- 14.3% IRR
- $7.6 million NPV

Note: 7% discount rate

By prioritizing energy efficiency out of the gate…

- Reduce a $26m investment (BMC share of 16MW plant) to under $10 million
- Reduced the size of the cogen from 16MW to 2MW
- Reduced electric consumption by over 40%
- Reduce steam consumption by over 34%
- Achieve energy cost savings of over $8 million annually
- Liberate high value real estate for future growth of BMC (11,000sf power plant land parcel)
- Our partnership with both Vicinity and Eversource were critically important to the success of our work

Can building owners count on a transition to "Green Steam", renewable natural gas, and renewable electric power from its existing utility providers?

Decarbonizing Boston's District Energy Systems

Maria Cimilluca, Vice President for Facilities Management

Northeastern University

Decarbonization pathways for district energy systems require a commitment to near and long term goals to advance technologies and effect policy changes. It also requires collaboration as a community to achieve, greater impact that benefits our neighbors, the City of Boston and the world itself, especially given the urgency and scope of achieving **#CarbonFreeBoston**.

What is Happening

International, National, State, and Local

National:

- 2021 the United States back in the Paris Agreement
- A coalition of states and Cities pledge to the goals of the Paris
- Sub-national and private sector innovate to overcome large hurdles to generate subnational robust, cost-effective, and scalable policies, community resilience

State:

- March 26, 2021 Gob. Baker signs climate legislation to reduce greenhouse gas emissions, protect environmental justice communities
- February 7, 2019 Gov. Baker Testifies before a U.S. House committee and encouraging Congress follow Massachusetts lead in reducing greenhouse gases and building climate resiliency

Local:

- Reach carbon neutrality by 2050
- Climate change is not a narrow issue, but one that affects the social and economic vitality of our city
- Climate Ready Boston, 2016

#CarbonFreeBoston

LVX VERITAS VIRTVS

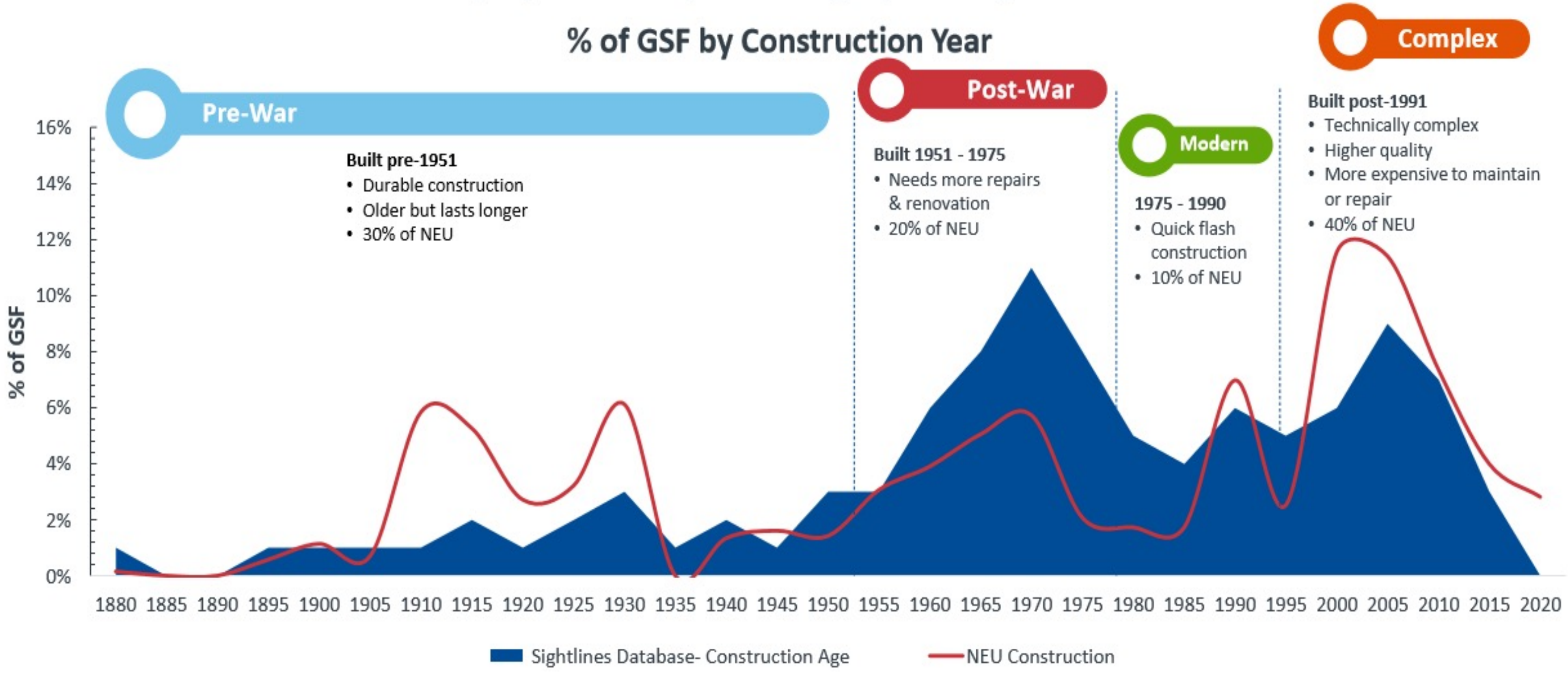
Northeastern

- Partnerships and Engagement
    - Globalization of Higher Education
    - Use Inspired Research
    - Experiential Learning
    - Innovation in Higher Education
- Stewardship: One of the largest property owners in Boston
    - Over 8M Gross Square Feet
- Advocacy: Be stewards and leaders on resiliency and sustainability
- Resiliency: Replicable model of success
    - Requires collaboration
    - How do we be a leader in this challenging time?
    - Educational institutions are ‘in-it’ for the long haul. What role can we play?

LVX
VERITAS
VIRTVS

What's Happening at Northeastern
Integrated Campus Stewardship

Northeastern's construction profile allows for strategic planning



Our Vision
Resiliency, Critical Infrastructure, and Microgrids

- NU's Climate commitment: Reduce 2005 Carbon Footprint by 80% by 2050
- Tangible actions to transform our current built environment to one that is more resilient and carbon neutral
    - Combined heat and power plant
        - Establish a microgrid
    - Energy conservation measures impacting close to 100% of our built environment
    - Alternative energy exploration and implementation on campus
        - Self generation
        - New technologies, battery storage, solar, wind, demand management all part of microgrid solution
        - Opportunity zones

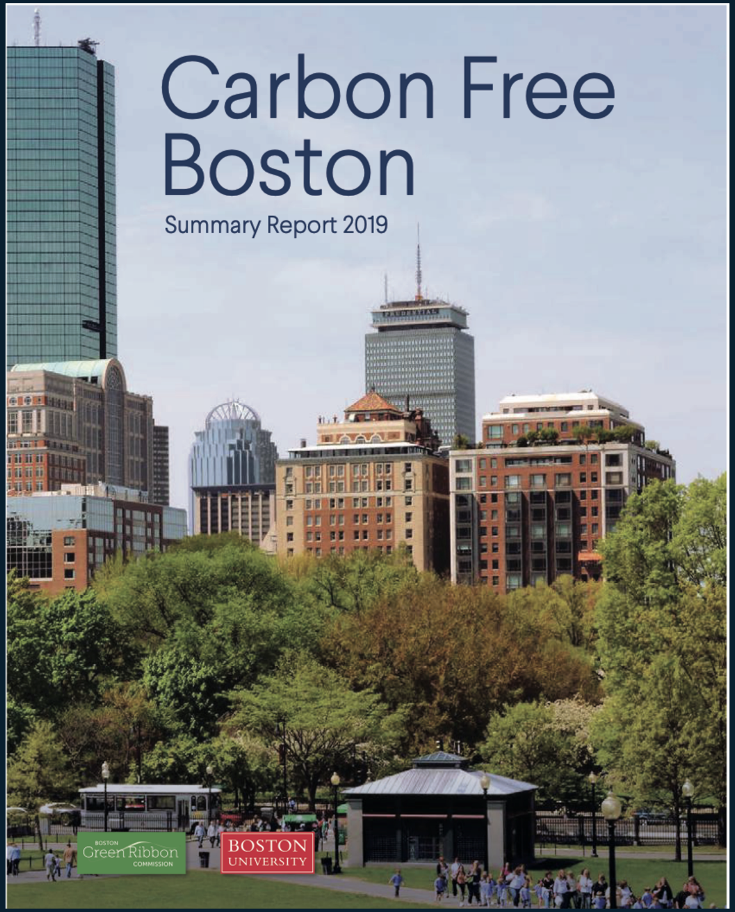
Thank You!

Northeastern University

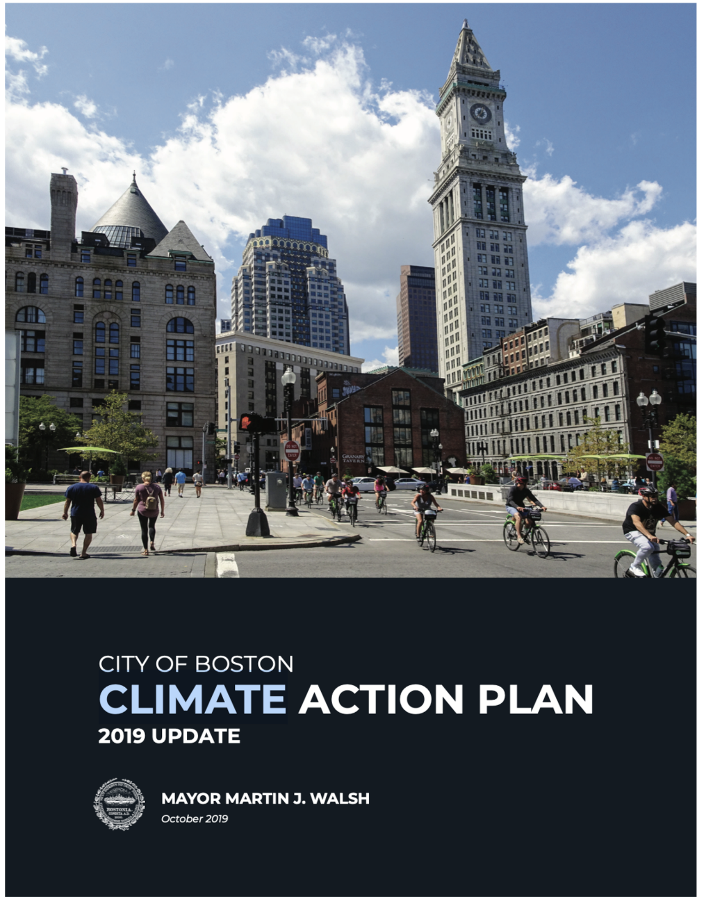
District Energy and the Emissions Performance Standard

Bradford Swing, Director of Energy Policy and Programs, City of Boston

Understanding what it takes to get to carbon neutrality...



... and detailing how we'll accelerate action in the next five years.



Climate Action Plan

NEW BUILDINGS & MAJOR RENOVATIONS

1. CONSTRUCT NEW MUNICIPAL BUILDINGS TO A ZERO NET CARBON STANDARD
2. ADOPT A ZERO NET CARBON STANDARD FOR CITY-FUNDED AFFORDABLE HOUSING IN BOSTON
3. STRENGTHEN GREEN BUILDING ZONING REQUIREMENTS TO A ZERO NET CARBON STANDARD

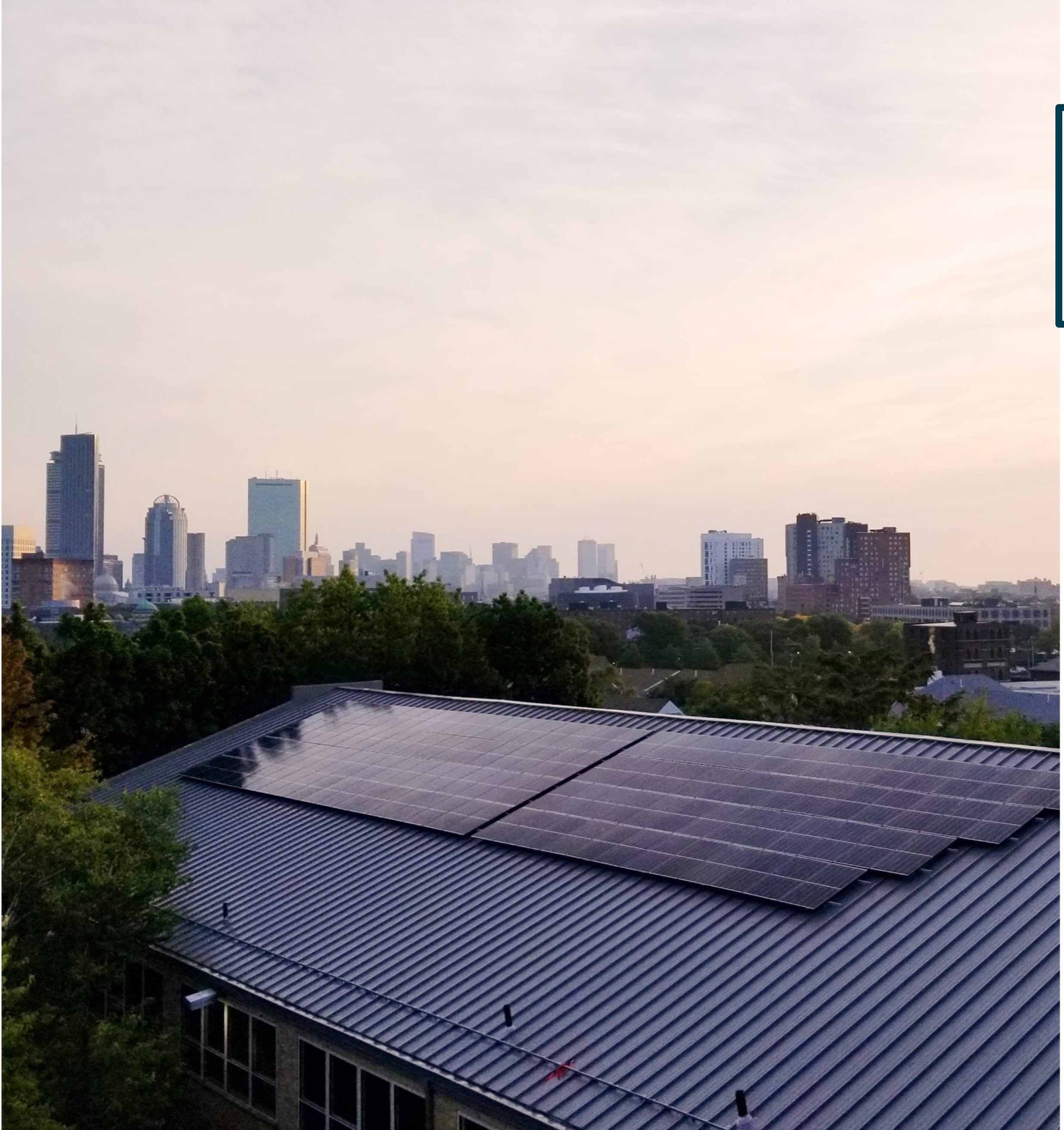
EXISTING BUILDINGS

4. INVEST IN ENERGY EFFICIENCY AND RENEWABLE ENERGY GENERATION IN MUNICIPAL BUILDINGS
5. DEVELOP A CARBON EMISSIONS PERFORMANCE STANDARD TO DECARBONIZE EXISTING LARGE BUILDINGS

ENABLING STRATEGIES

6. EXPAND WORKFORCE DEVELOPMENT PROGRAMS FOR BUILDING DECARBONIZATION
7. ADVOCATE FOR STATE BUILDING POLICIES THAT ALIGN WITH CARBON NEUTRALITY BY 2050

Climate Action Plan



13 IMPLEMENT AND EXPAND COMMUNITY CHOICE ENERGY

14 PLAN FOR THE DEPLOYMENT OF CARBON-NEUTRAL DISTRICT ENERGY MICROGRID SYSTEMS

15 SUPPORT STATE POLICIES AND PROGRAMS THAT FURTHER DECARBONIZE THE REGION'S AND BOSTON'S ENERGY SUPPLY

16 DECARBONIZE THE CONSUMPTION OF BOSTON RESIDENTS AND BUSINESSES

17 GREEN MUNICIPAL INVESTMENTS

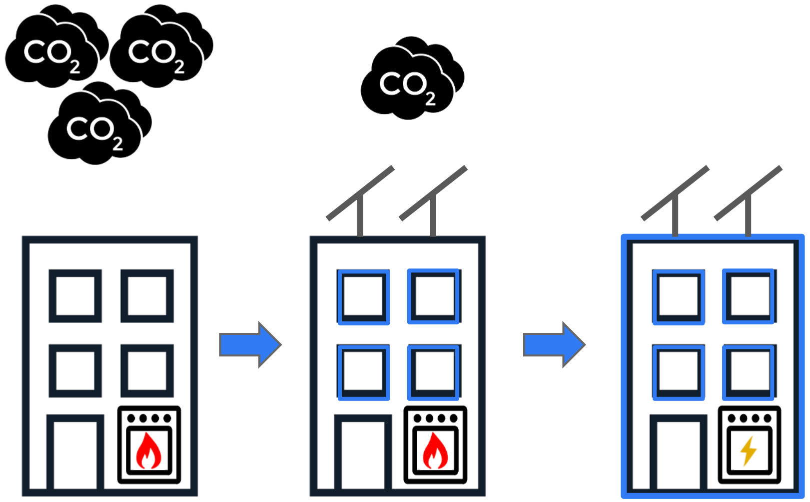
18 DEVELOP A VALUES-BASED FRAMEWORK FOR CARBON OFFSETS

BUILDING EMISSIONS PERFORMANCE STANDARD

A building performance standard sets carbon targets for existing large buildings that decrease over time.

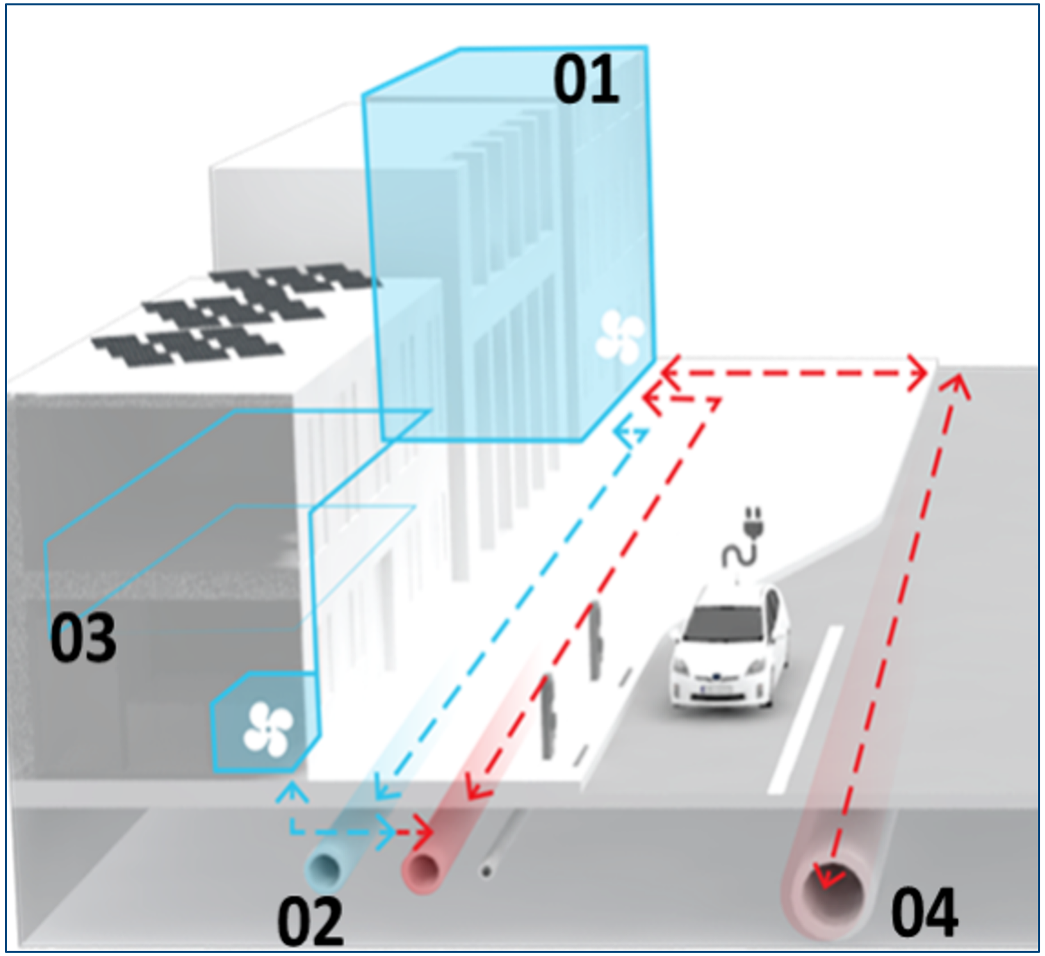
Why a building emissions performance standard?

- Directly targets our largest source of emissions
- Long planning horizons give flexibility in timing investments with financing cycles.



- Gives building owners flexibility in choosing how to meet the standard, selecting technologies and strategies that work for their particular building and its context.

SMART UTILITIES POLICY - DE MICROGRIDS



District Energy Microgrid

- Current threshold: **> 1.5 million SF, Feasibility Assessment;** if feasible, then **Master Plan** & District Energy Microgrid Ready design
- Description: **Energy system for clusters of buildings** that provides localized thermal and/or electrical services
- Benefits: Opportunity to **decrease GHG emissions**, **decrease energy and O&M costs**, and **increase** site energy **resilience**

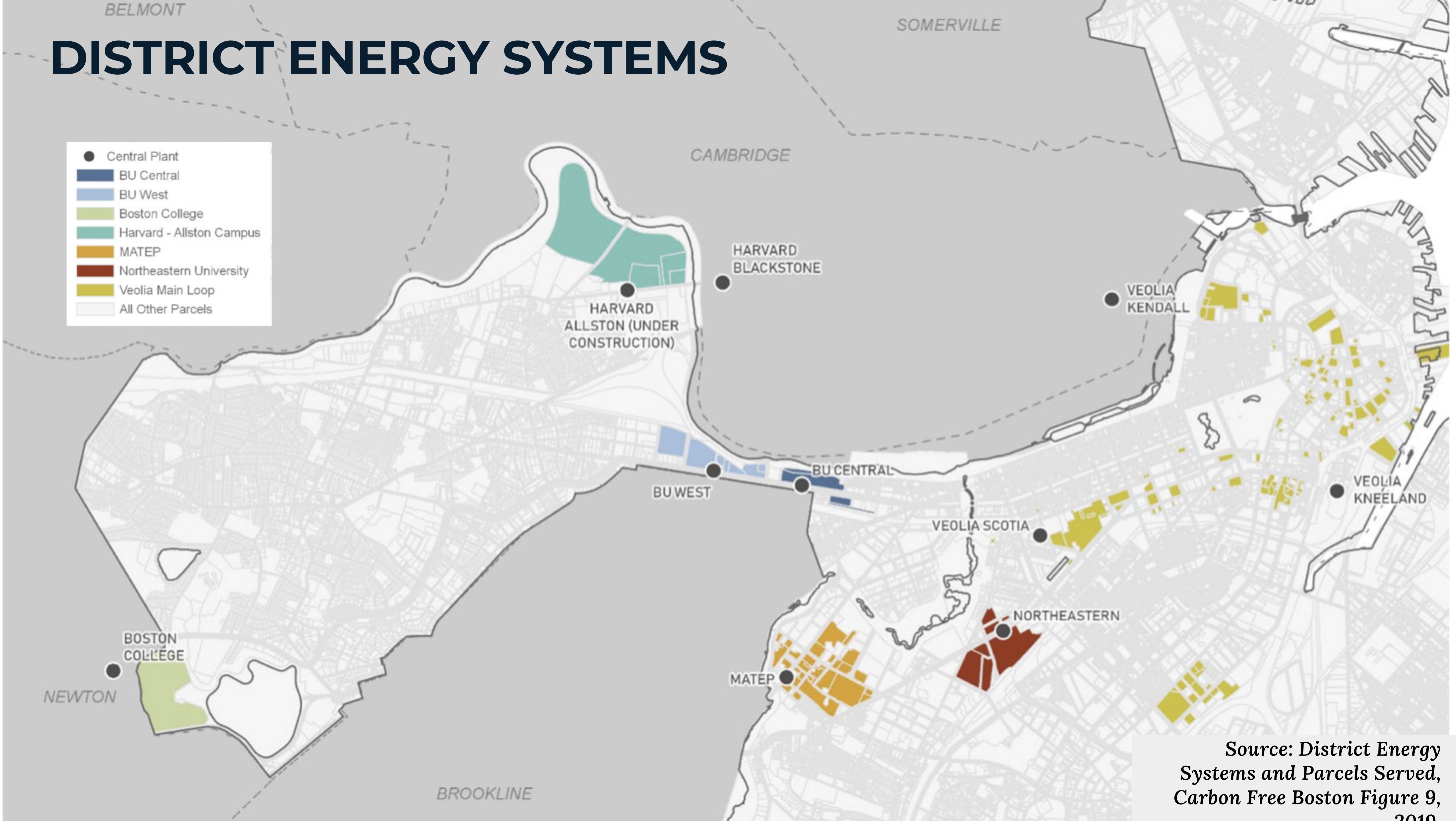
SMART UTILITIES POLICY - OCTOBER 2020 UPDATE

Data Sciences Center
Boston University

DE Microgrid Update

- **Continue to require Feasibility Assessment/Master Plan** review for > 1.5 million SF projects
- **Align with the Climate Action Plan** 2019 update and City's decarbonization goals
- **Prioritize fully decarbonized and carbon-neutral options**, including:
  - GSHP potential (including assessment of wells in the ROW)
  - Sewer heat recovery potential
  - PV+battery storage

DISTRICT ENERGY SYSTEMS



Source: District Energy Systems and Parcels Served, Carbon Free Boston Figure 9, 2019

DISTRICT ENERGY SYSTEMS

Table 7. Summary characteristics of existing district energy plants and systems in Boston.
Year Commissioned indicates year of central plant construction or conversion to district energy. Associated distribution systems may be older.

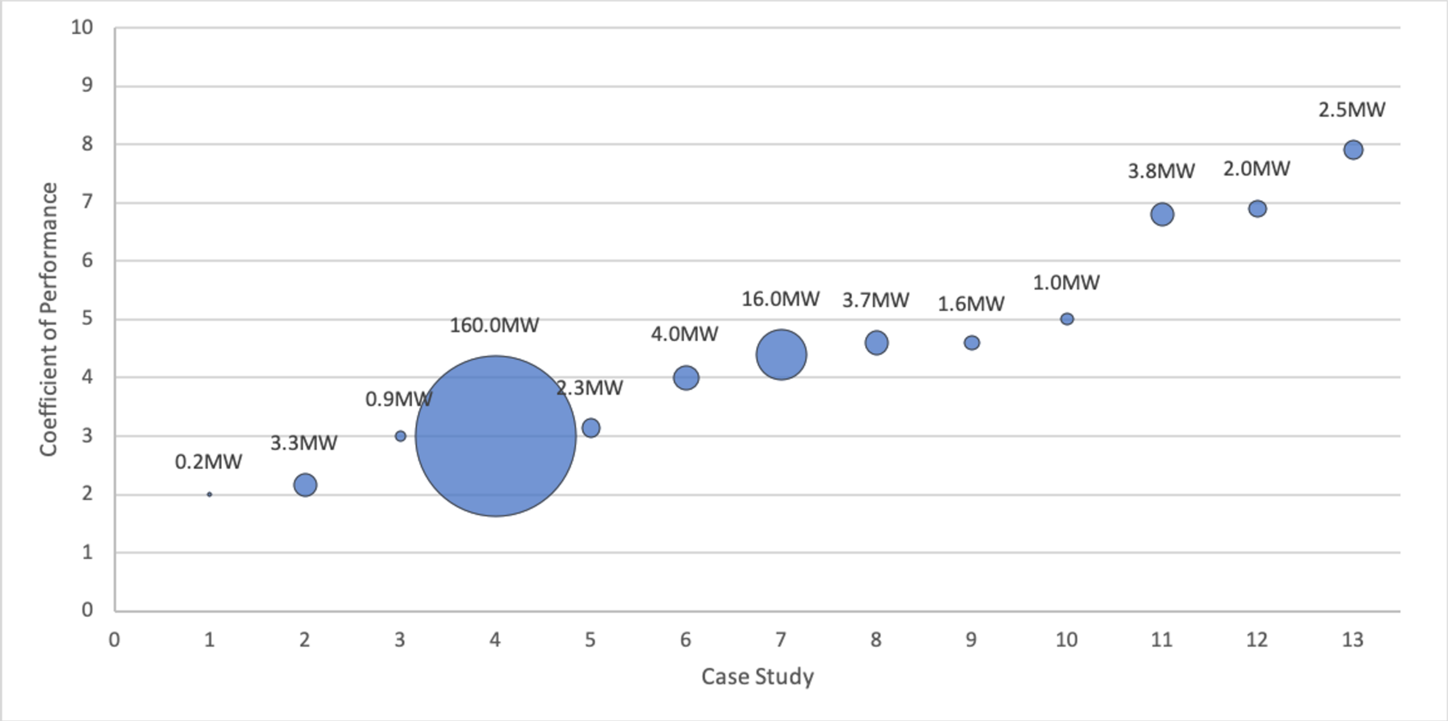
Central Plant *Linked-System*	Year Commissioned	Technology (Transfer fluid)	Approximate Million Sq. Ft. Served [41], [42]	Max Steam Capacity (Mlbs per Hour)	CHP Electricity Capacity (MW)	2015 CO_2 Emissions (t) [43]
Kendall* *Downtown* [44]	1949	CHP Cogeneration (Steam)	38.9	1,200	253.6	797,969
Kneeland *Downtown* [44]	1928	Large Boilers (Seasonal & Peak Steam)			N/A for Kneeland and Scotia	108,736 (Kneeland and Scotia)
Scotia *Downtown* [44]	1930	Large Boilers (Seasonal & Peak Steam)				
MATEP [44]	1986	Trigeneration (Steam and Chilled Water)	12.7	1,000	84	236,651
Boston College* [45]	1948	Large Boilers (Steam)	2.2	370	*N/A*	*21,403*
BU Central	1964	Large Boilers and Chillers (Steam and Chilled Water)	3.2	-	N/A	51,611
BU West	2000	Large Boilers and Chillers (Steam and Chilled Water)	3.4	-	N/A	
Harvard* [46]	1930's	CHP Cogeneration (Steam)	3.2	-	*12.5*	*71,028*
Northeastern [47]	1890s-1900s	Large Boilers (Low Pressure Steam and Hot Water)	4.8	145	N/A	31,967

*These plants are located outside the City of Boston. The service area reflects only the buildings served within the City of Boston. The capacities and emissions represent the entire facilities.

Decarbonization of District Energy Systems

- Numerous systems in Northern Europe demonstrate cold climate strategies for district heating
- These 13 case studies indicate a range of sizes and performance for existing heat pump-based district systems

Low-carbon district energy systems in Northern Europe & North America




Thank You

Thank You!

Join Our Next GRCx Program:

Accelerating Decarbonization of the Wholesale Energy Market

June 4th, 2021, 8:30 am – 10:00 am

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