Better Buildings®
U.S. DEPARTMENT OF ENERGY

Combined Heat and Power for Resiliency

May 11, 2016

Claudia Tighe
Moderator

CHP PACKAGED SYSTEM CHALLENGE

U.S. DOE CHP Deployment Program

- **Market Analysis and Tracking** – Supporting analyses of CHP market opportunities in diverse markets including industrial, federal, institutional, and commercial sectors.

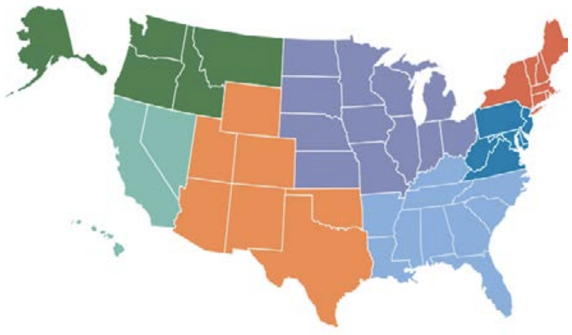
- **Technical Assistance through DOE's CHP Technical Assistance Partnerships (CHP TAPs)** – Promote and assist in transforming the market for CHP, waste heat to power, and district energy with CHP throughout the United States

- ***Just Launched* Combined Heat and Power (CHP) for Resiliency Accelerator -**

  Collaborating with Partners to support consideration of CHP and other distributed generation solutions for critical infrastructure resiliency planning at the state, local, and utility levels

- **Packaged CHP System Challenge (under development) -**

  Increase CHP deployment in underdeveloped markets with standardized, pre-approved and warrantied packaged CHP systems driven by strong end-user engagement via Market Mover Partners, such as cities, states, and utilities



www.energy.gov/chp

Bruce Hedman
Entropy Research

Emergence of Resiliency as a Policy Priority

Critical Infrastructure Resiliency is an Emerging Concern

- Connecticut establishes Microgrid Pilot Program in Response to the Two Storms Report (Hurricane Irene, Oct. 29, 2011 Snowstorm)
- New York Commission 2100 Report January 2013 calls for accelerated deployment of DG/Microgrids as component of future resiliency planning
- New Jersey established Resiliency Bank in response to Sandy

Business Continuity

- Business downtime, economic losses (beyond traditional CI definition)
- Cascading problems affecting transport (unavailability of gas in NJ post Sandy)

Emergency Preparedness & Planning

- Developers reporting inquiries from campuses looking to keep students sheltered
- Nursing homes, public housing, large multi-family buildings keeping people "safe-in-place"

Critical Infrastructure

"Critical infrastructure" refers to those assets, systems, and networks that, if incapacitated, would have a substantial negative impact on national security, national economic security, or national public health and safety."

Patriot Act of 2001 Section 1016 (e)

Applications:

- Hospitals and healthcare centers
- Water / wastewater treatment plants
- Police, fire, and public safety
- Centers of refuge (often schools or universities)
- Military/National Security
- Food distribution facilities
- Telecom and data centers

Economic Impact of Grid Outages

- Hurricane Sandy $70 Billion
- Hurricane Katrina $40 Billion
- 2003 Blackout $10 Billion
- Industrial and digital economy firms are losing about $45.7 billion per year due to power outages (EPRI)

CHP offers the opportunity to keep **critical facilities running** when the grid is impaired, enabling:

- Business Continuity
- Community Sustainability
- Disaster Preparedness

Why CHP for Resiliency and Business Continuity?

- CHP is a proven and effective energy option for facilities/buildings that can enhance electric reliability and provide for energy services before, during, and after an emergency situation.
- CHP provides users with financial benefits through energy savings **every day** rather than only during a grid outage, as with a standby generator.
- CHP is more reliable than a standby generator because it is typically better maintained and continuously operated.

CHP versus Backup Generation

	Backup Generator	CHP
System Performance	• Only used during emergencies	• Designed and maintained to run continuously • Improved performance reliability
Fuel Supply	• Limited by on-site storage	• Natural gas infrastructure typically not impacted by severe weather
Transition from Grid Power	• Lag time may impact critical system performance	• May be configured for "flicker-free" transfer from grid connection to "island mode"
Energy Supply	• Electricity	• Electricity • Thermal (heating, cooling, hot/chilled water)
Emissions	• Commonly use diesel fuel	• Typically natural gas fueled • Achieve greater system efficiencies (70+%) and lower emissions

Uninterrupted Operation Requirements

- **Black start capability**
  - Allows the system to start up independently from the grid
- **Generators capable of grid-independent operation**
  - The system must be able to operate without the grid power signal
- **Ample carrying capacity**
  - System size must match critical loads
- **Parallel utility interconnection and switchgear controls**
  - The system must be able to disconnect from the grid, support critical loads, and reconnect after an event

Designing CHP for Reliability

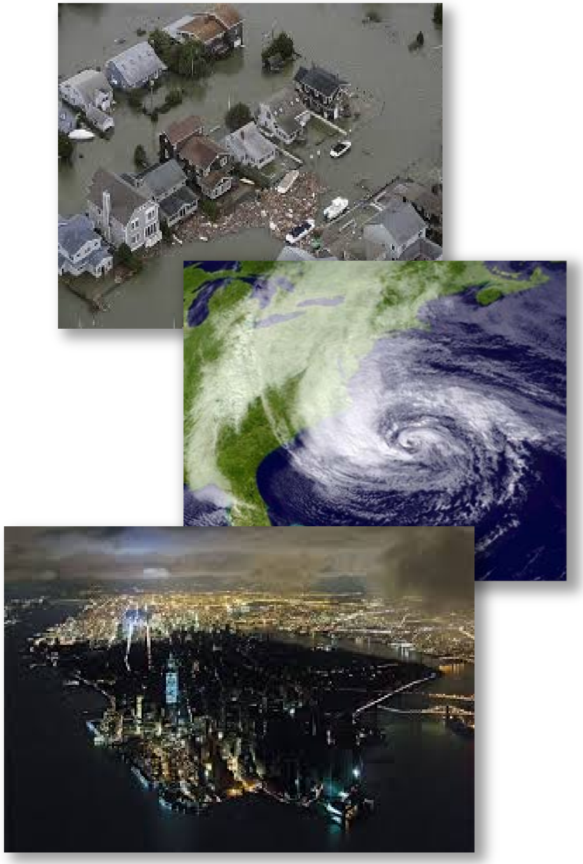
- CHP systems designed for reliability will incur additional costs on the order of 10% of installation costs ($45 - $170/kW depending on complexity of system)
- These additional costs however provide important reliability benefits to the site, and to the community at large
- Estimates of costs to U.S. industries due to electric network reliability problems range from $40 billion to over $150 billion per year

New Interest in Promoting CHP for Resiliency Benefits

- CHP increasingly recognized as an important tool to support critical infrastructure, emergency preparedness and provide for business continuity
- Appropriately designed, configured and operated CHP can offer significant social benefits, but with added costs to the site
- Policymakers are responding with a new commitment to CHP that recognizes the societal value of high reliability for important services

CHP Provides Energy Reliability and Resiliency Benefits

- Traditional backup generators do not always perform during emergencies, a system operating on a daily basis (CHP) is more reliable
- CHP provides continuous benefits to host facilities, rather than just during emergencies
- CHP systems kept running during Sandy:
  - South Oaks Hospital - Amityville, NY, 1.25 MW
  - The College of New Jersey - Ewing, NJ, 5.2 MW
  - Public Interest Data Center - New York, NY, 65 kW
  - Bergen County Wastewater Plant – Little Ferry, NJ
  - New York University – New York, NY
  - Sikorsky Aircraft Corporation – Stratford, CT



The Brevoort - Manhattan, NY

- Residential high rise with natural gas-powered CHP system
  - Four 100 kW CHP units powered all 290 apartments through Sandy
- Normal occupancy is 720 people. During Sandy, the Brevoort housed and provided power to 1,500 people through the storm.
- *"Powered by our CHP system, we were the only building on lower Fifth Avenue able to provide energy and full service to our residents."* - Diane Nardone, President of the Brevoort coop board
- The Brevoort was able to maintain power for central boilers, domestic water pumps, all elevators and all apartments.

South Oaks Hospital - Amityville, NY

- Hospital & Nursing Home campus with natural gas-powered CHP system
  - System consists of five 250 kW natural gas engines
- When the grid went down during Sandy, South Oaks transitioned to "island mode" with no interruption of power.
- The CHP System provided 100% of the facility's electricity, thermal and hot water demands for 15 days.
- In addition to meeting the hospital's needs, South Oaks admitted evacuated patients from nearby healthcare facilities, refrigerated medications, and housed hospital staff who had lost power.

New York Presbyterian Hospital Weill Cornell Medical Center, Manhattan, NY

- 7.5 MW natural gas-fired CHP system
- New York City's first hospital with grid-independent operating capability
- Maintained full service while the surrounding grid was shut down
- Due to its CHP system, New York Presbyterian not only cared for its own patients during the Sandy blackout, but was able to admit patients from nearby hospitals that had lost power during the storm

Resiliency Planning

- Mitigate the effects of natural disaster or other events that would shut down power supplies
- Develop secure, safe and more resilient electrical power infrastructure
- Ensure critical infrastructure remains operational



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Definitions of Resiliency

- Utility systems and grid infrastructure resiliency
- Infrastructure resiliency – upgrading aging infrastructure and supporting critical infrastructure
- Climate resiliency – coastal planning, storm damage mitigation
- Social resiliency – Economic development and social equity

CHP can support all of these objectives!

DOE's CHP for Resiliency Accelerator

Purpose

Combined Heat and Power can play a vital role in ensuring that emergency response services are available and critical infrastructure maintains needed electric and thermal energy services to remain operational during disasters.

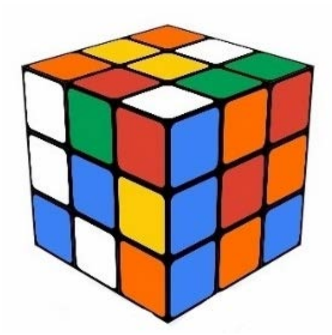
Offerings

- A forum for collaborating with other Partners to integrate CHP and other distributed generation into resiliency action plans where appropriate
- Direct technical support through DOE's CHP Technical Assistance Partnerships (CHP TAPs)
- Tools and templates to promote deployment of CHP/distributed generation in Critical Infrastructure
- Streamlined project development process with help from the *Packaged CHP Challenge*
- National recognition and visibility

Outcomes

- Integrated resiliency plans (local, state, utility)
- Template with collective lessons learned for replicability

Additional Information



Visit:
energy.gov/chp
or
send us an email at:
CHP@ee.doe.gov

Travis Sheehan
City of Boston

Benjamin Locke
Tecogen

U.S. DEPARTMENT OF
ENERGY

Tecogen

CHP For Savings + Resiliency

BENJAMIN LOCKE, C0-CEO

POINTS OF DISCUSSION

- Introduction to Tecogen
- Drivers for CHP
- Case Study: Hurricane Sandy
- Questions/Discussion

Tecogen
Advanced Modular
CHP Systems

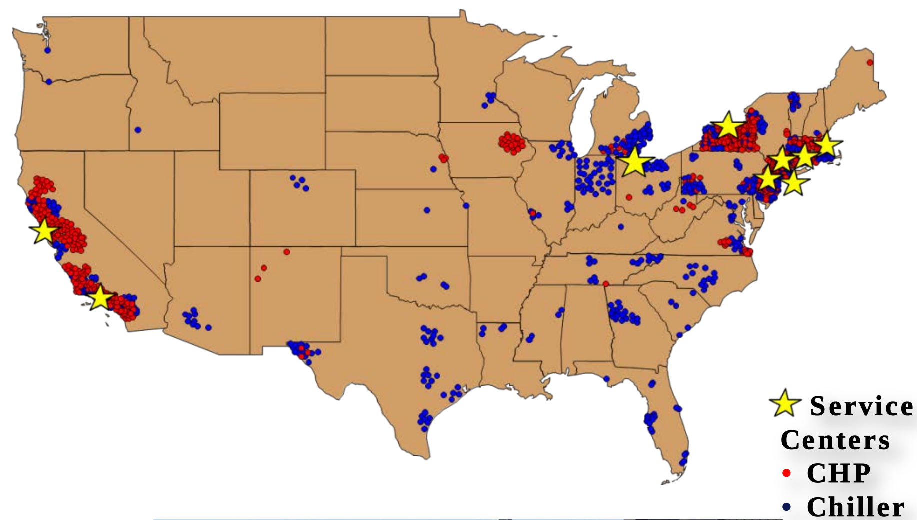
Tecogen Background

Origins

- Thermo Electron Research Center (now Thermo Fisher Scientific)
- Long associations with US natural gas industry and national labs

Key Stats

- Headquartered in Massachusetts
  - 30+ Years
- Nine service centers
  - Full staff, inventory, dispatch
- More units shipped than any other modular CHP manufacturer
  - 2000+ units shipped
  - >150 black-start units



TECOGEN HISTORY:
Leading Manufacturer of Clean Energy Solutions

Leading provider of cost efficient, clean and reliable products for power production, heating and cooling which, through patented technology, nearly eliminate criteria pollutants and significantly reduce a customer's carbon footprint. With over 2,300 units shipped, Tecogen technology is revolutionizing distributed generation for customers in the $40B small-to-mid size Combined Heat & Power ("CHP") market segment.

Open first FACTORY service office

First commercial sale of TGEN CHP module

1 million total operating hours logged on installed units

2nd Generation of standardized engine-driven screw chiller introduced

First two-stage catalytic converter units sold in California

"TecoNet" microprocessor controller upgrade improves interface capability

3rd Generation engine driven chiller introduced w/ R-134a

First engine-driven CHP units added to NY Dept of Public Utilities NYSIR list of Certified Interconnection Equipment

InVerde inverter based CHP unit introduced offering "seamless" interconnection

InVerde 100 first and only NYSIR certified engine-driven inverter based CHP module

Introduced Ilios an ultra high efficient water heating appliance (engine-driven heat pump)

Ultera Emissions technology patented

Released 2nd Generation InVerde e+ w/ UL 1741 & 2200 certification

1983 | 1987 | 1991 | 1995 | 1999 | 2003 | 2007 | 2011 | 2015 | 2019

Tecogen

Advanced Modular CHP Systems

CHP – DRIVERS

- ✓ Plentiful and affordable natural gas
- ✓ Electric tariffs remain high and generally increasing
- ✓ Clean technology
- ✓ Long-term pressure for Infrastructure Upgrades
- ✓ Good Incentives
- ✓ **Grid Resiliancy**

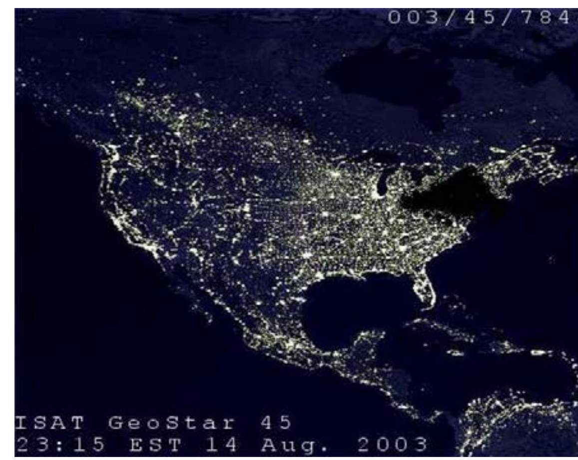

SPECIAL ★ ★ ★ ★ EDITION

DAILY NEWS

NEW YORK'S HOMETOWN NEWSPAPER

BLACKOUT

- 50 MILLION LOSE POWER
- CITY SWELTERS TO A HALT
- RUSH-HOUR CHAOS TODAY



Grid Resiliency in NYC

- Largest NYC Population of Microgrid Enabled Units
- Majority Unaffected by Hurricane
- Three Commissioned Sites Lost Power
  - ✓ Site 1 (6 Modules/warehouse)
  - ✓ Site 2 (4 Modules/ 400-Unit Condo)
  - ✓ Site 3 (4 Modules/ 400-Unit Condo)

Tecogen
Advanced Modular CHP Systems

Grid Resiliency

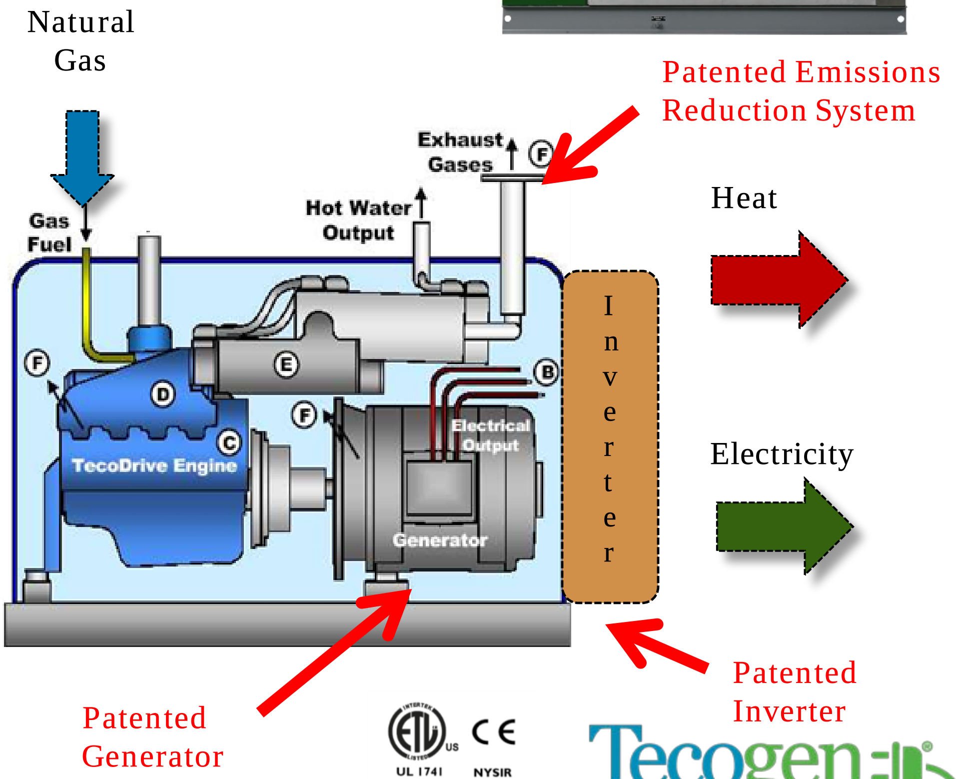
NOTE: The presentation we are bringing on a thumb drive has a 65 MB five minute video embedded in this slide. You can preview the video at: https://www.youtube.com/watch?v=-SIbcNG_cQY

TECOGEN TECHNOLOGY

InVerdẽ 100 e⁺: High Performance CHP

- New features include
  - ✓ **Best in class efficiency**
  - ✓ **10 second rapid start after blackout**
  - ✓ **Patented technology for turndown to 10 kW**
  - ✓ **Quiet operation**
  - ✓ **Integrated microgrid controls**
  - ✓ **125 kW peaking power**

- Qualifies for Demand Response Programs
- Remote monitoring service.
- Power converter certified as utility safe (UL 1741 and 2200)

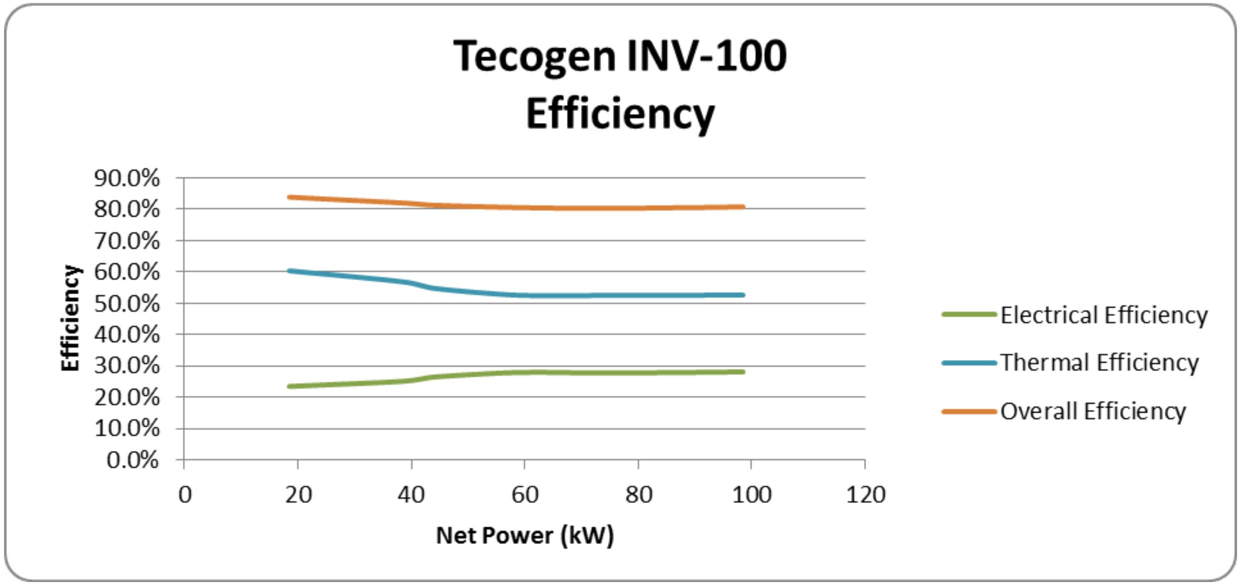


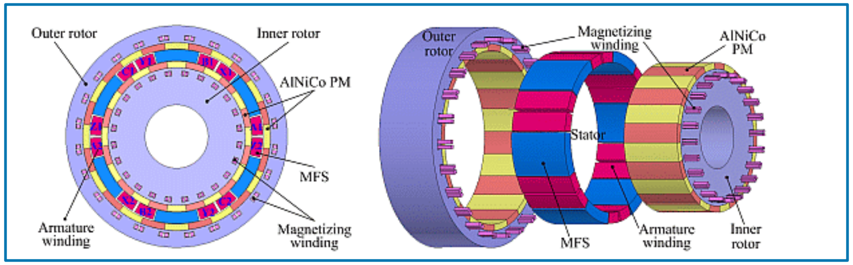
UL 1741 Compliant
NYSIR Certified

Advanced Modular CHP Systems

TECOGEN'S ADVANCED VARIABLE SPEED TECHNOLOGY

kW	Electrical Efficiency	Overall Efficiency
20	23.5%	83.9%
40	25.2%	82.0%
45	26.6%	81.3%
60	28.0%	80.6%
75	27.8%	80.3%
90	28.0%	80.6%
100	28.2%	80.8%





Tecogen

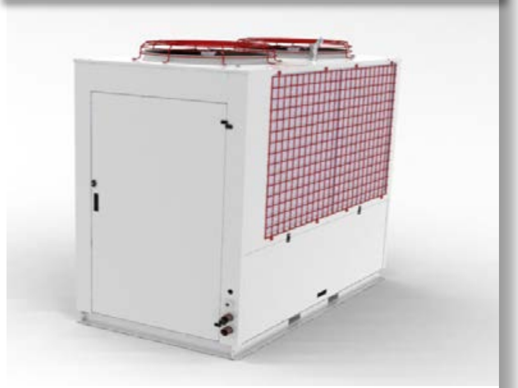
Advanced Modular CHP Systems

TECOGEN'S TECHNOLOGY

CHP Modules

Electricity & Heat

Ilios Water Heaters



3x Heat Efficiency

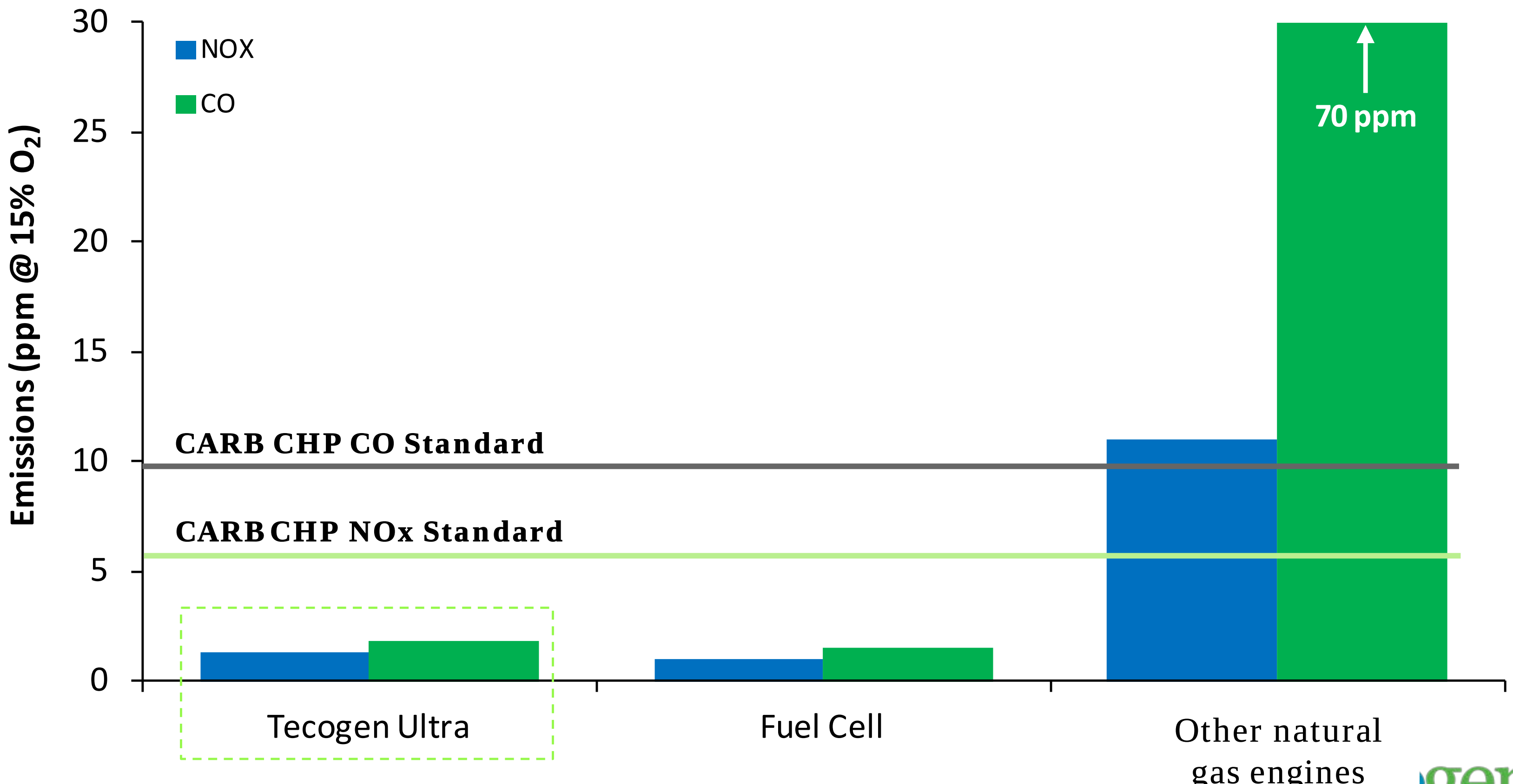
TECOCHILL Water Chillers

Cooling & Heat

Tecogen
Advanced Modular
CHP Systems

Clean Technology

Tecogen "Ultera" Low Emissions



Advanced Modular CHP Systems

Company Information

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Advanced Modular
CHP Systems

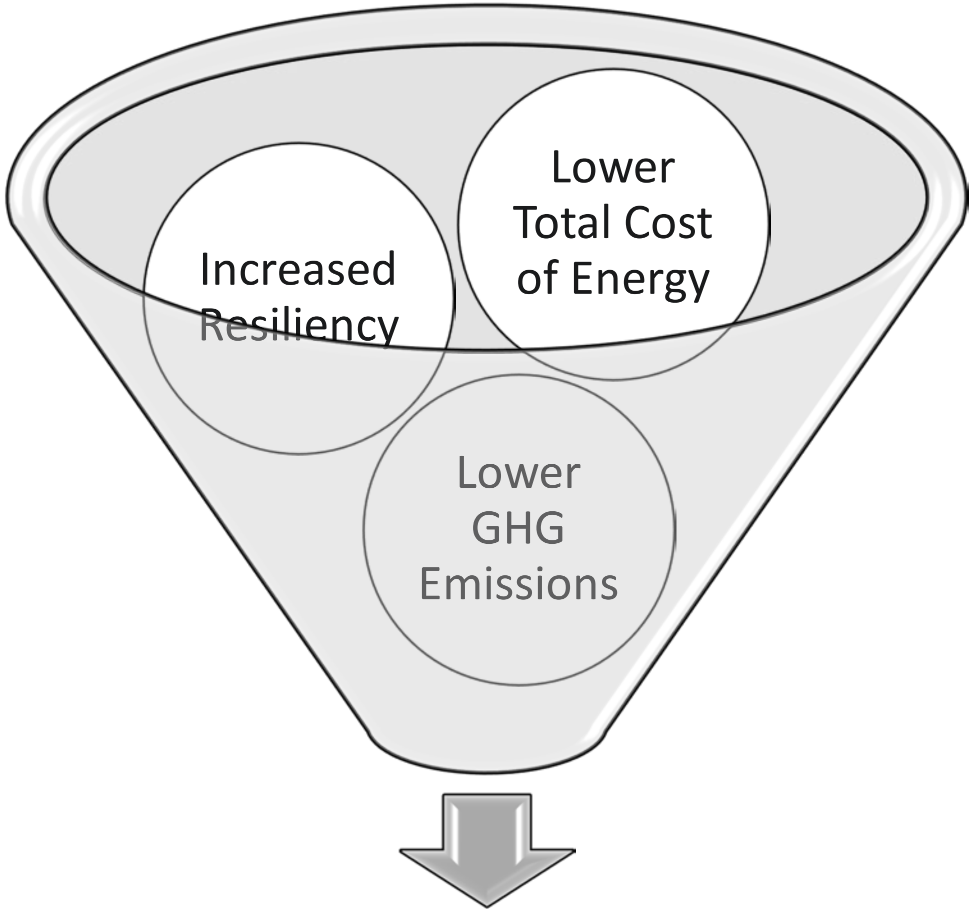
BOSTON REDEVELOPMENT AUTHORITY

GREENOVATE BOSTON

ENERGY SYSTEM PLANNING

Travis Sheehan

Presentation to the Better Buildings Initiative Conference - May 2016



Energy Investments

Resiliency for vulnerable populations and business continuity

Lower Total Cost of Energy makes the state attractive to all firms and residents

Energy Security make the state more attractive to hi-tech/ clean tech/ bio tech / advanced manufacturing

Local generation revenues keep capital local, investment potential to spark local industries

TRENDS IN URBAN ENERGY INFRASTRUCTURE

Superstorm Sandy

- NYU serves as safe haven, Hudson Yards

Energy Efficiency and Economics in Boston

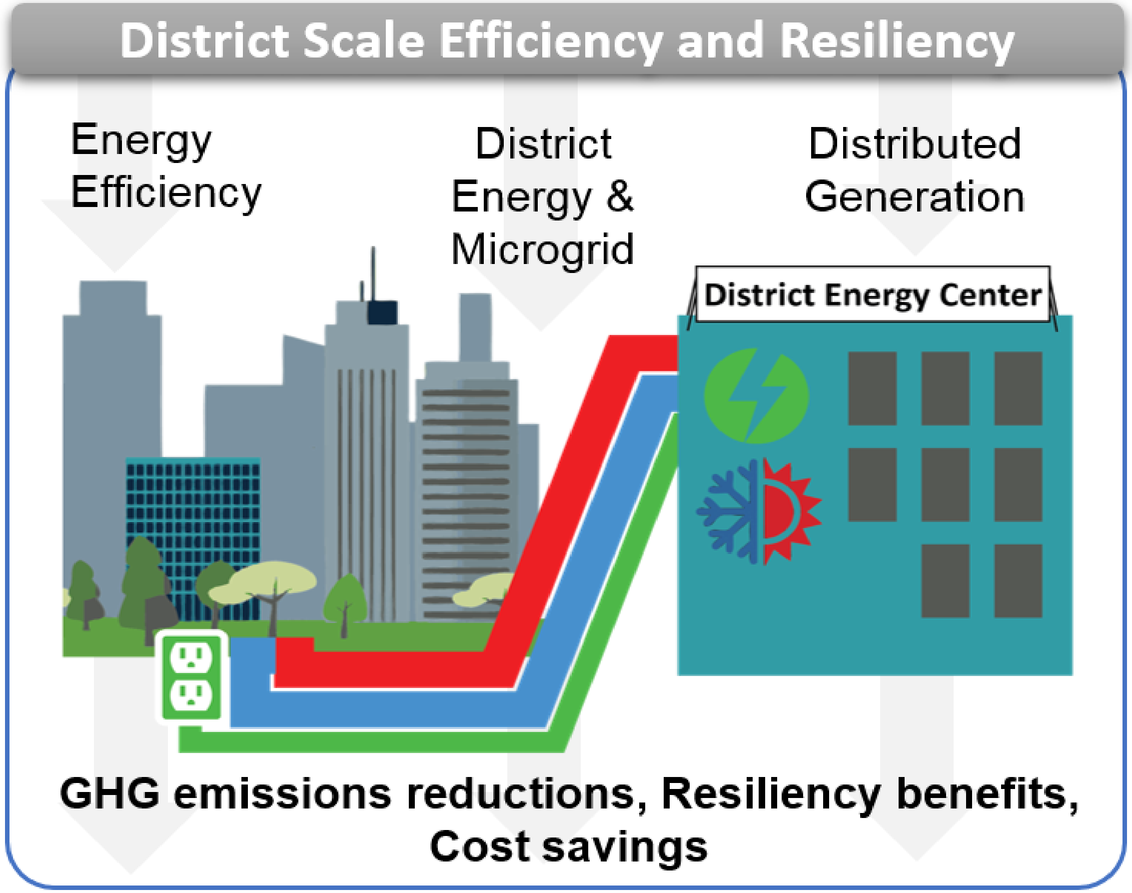
- Biogen Energy System- CHP Driven

City of "Meds and Eds" as case examples

- Harvard, MIT, MATEP- CHP Driven

CHP for Resilience:

- Seeking to transfer institutional models to commercial (multi user microgrids)
- Partnering with DOE TAP to perform community scale CHP assessments
- Partnering with Eversource Energy to promote CHP via Article 37 and Article 80

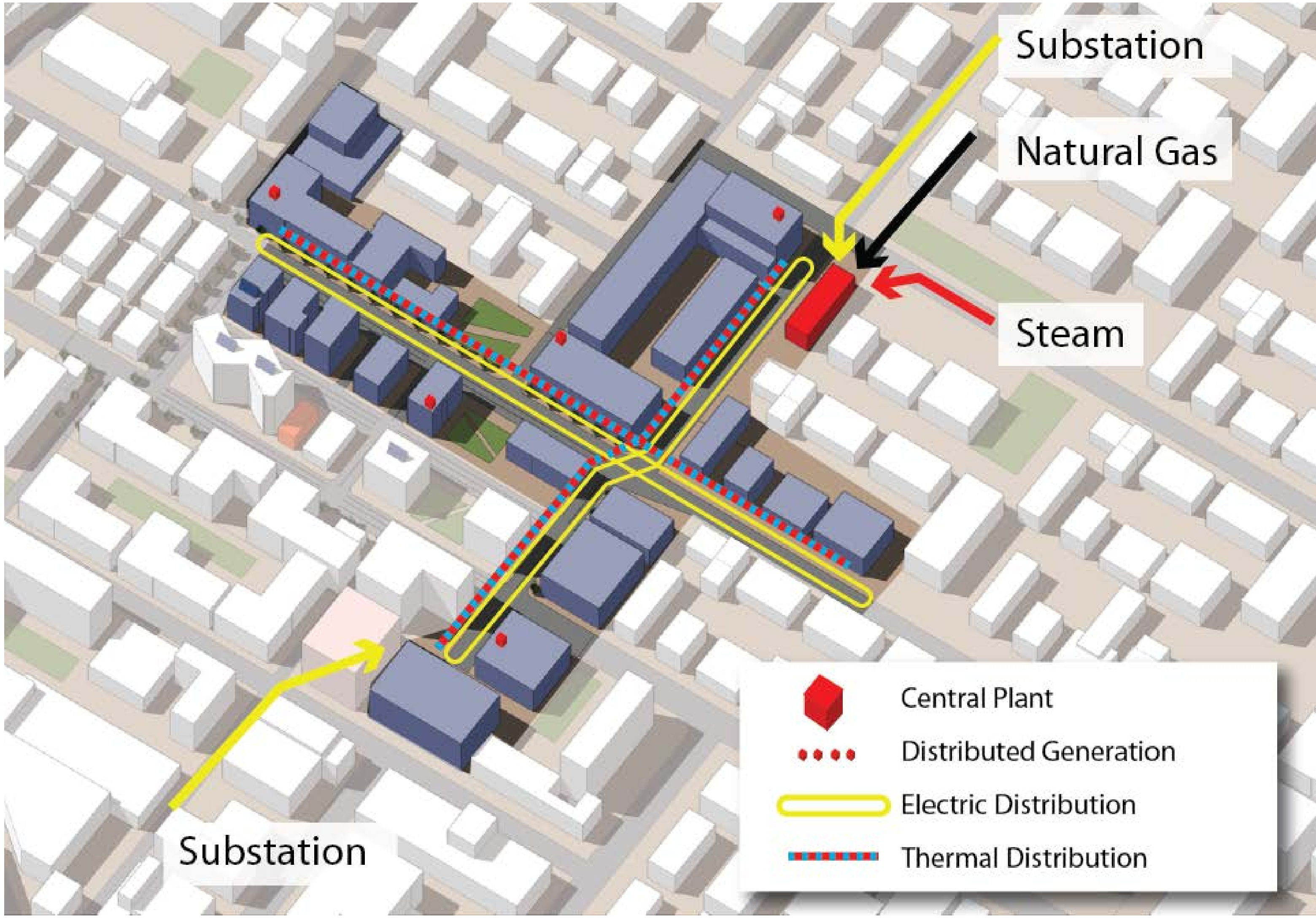


Source: City of Boston, Mayor's Office of Environment Energy and Open Space

MULTI USER MICROGRIDS

- Deploy local generation and storage
- Develop hot and cold water loops
- Deploy Smart Grid and smart building technologies
- Create islanding capability for critical loads
- Replace building boilers and chillers with central CHP (applied to new and old districts of the City)
- Pathway to Energy efficiency
- Challenges?

Illustration of a Multiuser Microgrid



ENERGY SYSTEM PLANNING

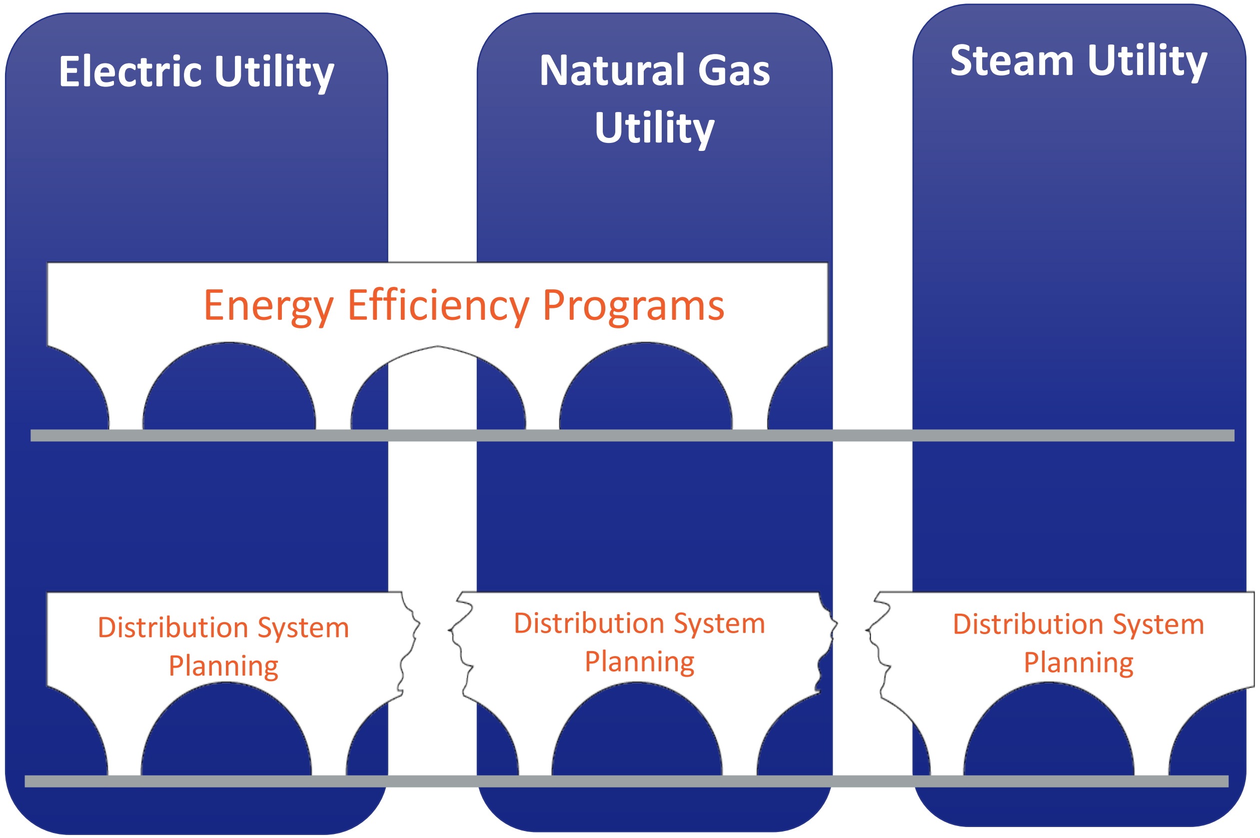
Why involve city government?

A policy of the Climate Action Plan

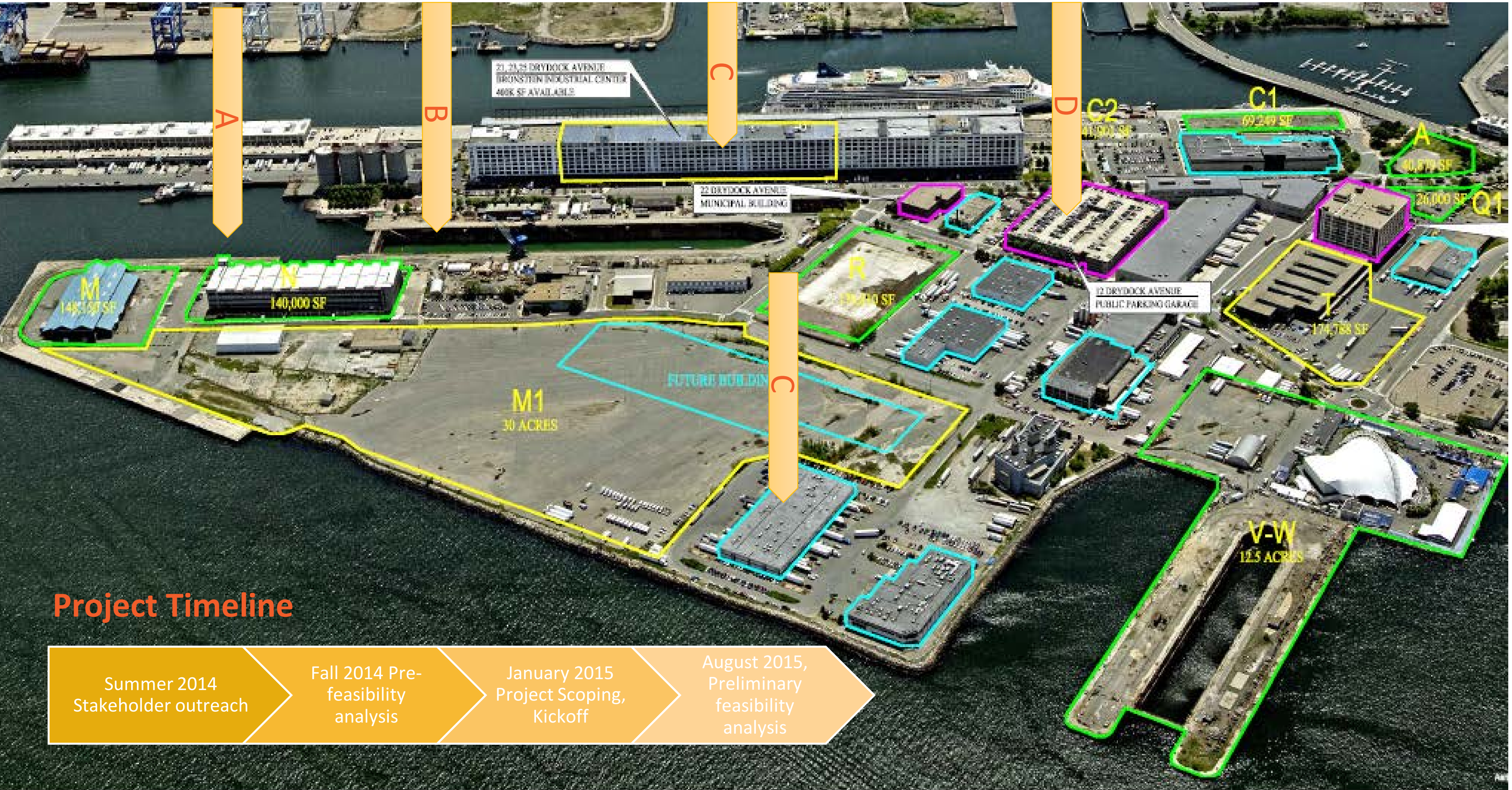
- Increased cogeneration, district energy, solar installation
- Lower total cost of energy, reduced GHG emissions, increased resiliency

Challenges

- Boston has many DE systems because campuses
- Vision: Campus-like technology in commercial buildings
- No business model



RAY FLYNN MARINE PARK



Project Timeline

Summer 2014 Stakeholder outreach → Fall 2014 Pre-feasibility analysis → January 2015 Project Scoping, Kickoff → August 2015, Preliminary feasibility analysis

Opportunities

A. Economic development

B. Cost sensitivity

C. Security & business continuity

D. Clean power

Challenges

1. Lacks business model
2. Perceived threat to utility business model
3. No regulatory / statutory support
4. Real estate developers unaware of opportunity
5. City government involvement not the norm in energy planning

BOSTON
REDEVELOPMENT
AUTHORITY

BUSINESS MODEL

Stage: Complete

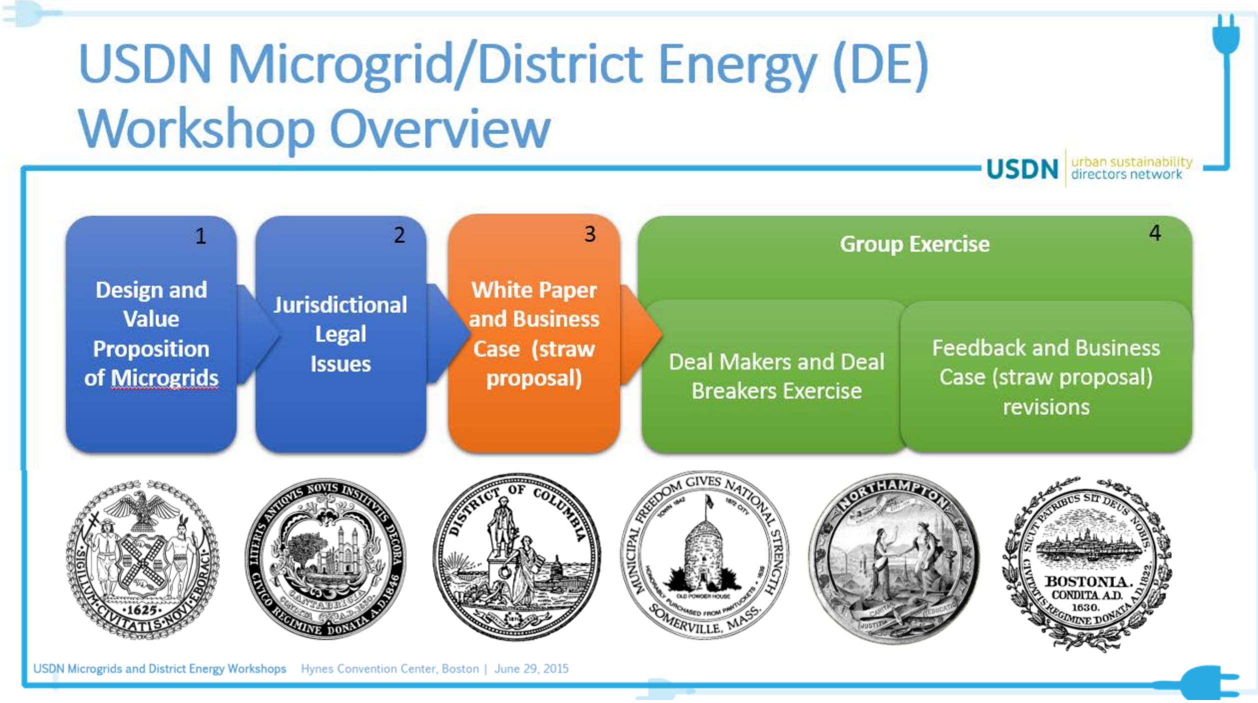
Boston on Forefront of Microgrid Policy and Business Case Development

Developed 3-part microgrid workshop series

- “Microgrids and District Energy for Critical Infrastructure and Multi-Users”
- Ultimately won microgrid development participation from MA utility Eversource

Convened Urban Sustainability Directors Network workshop 2015

- New York City, Washington DC , MA Communities : Somerville, Cambridge, Northampton
- Housed by International District Energy Association Conference with 950+ Attendees
- Technology and Policy innovations replicable



EVERSOURCE ENERGY | Pace Energy and Climate Center PACE LAW SCHOOL | MASSACHUSETTS CLEAN ENERGY CENTER | U.S. DEPARTMENT OF ENERGY | Homeland Security

BOSTON REDEVELOPMENT AUTHORITY

SUSTAINABLE DESIGN LAB

LINCOLN LABORATORY
Massachusetts Institute of Technology

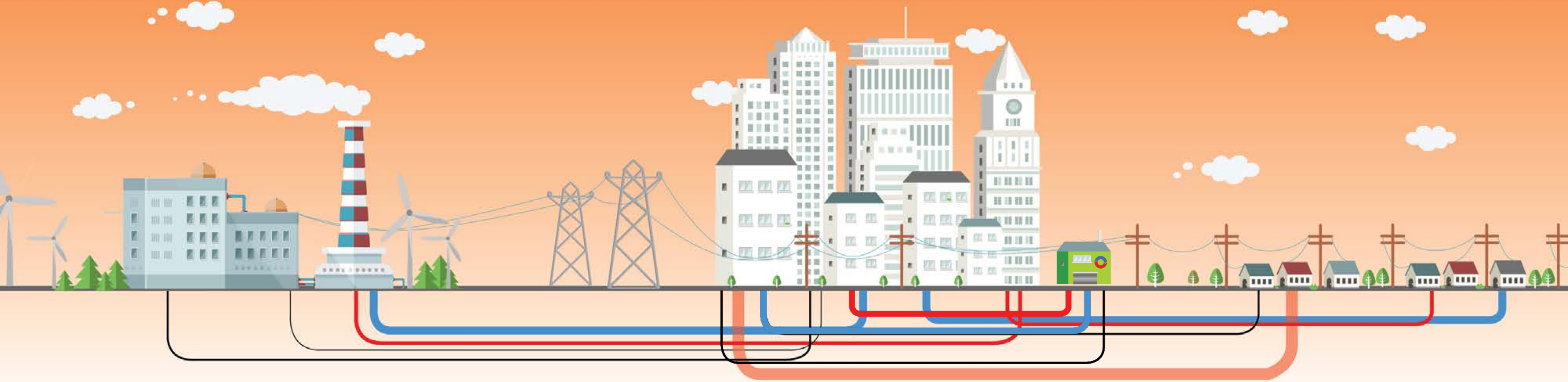
BOSTON
COMMUNITY ENERGY STUDY

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

2016

Presentation to the Zofnass Program Workshop - April 2016

INTRODUCTION



Boston's Climate Action Commitment

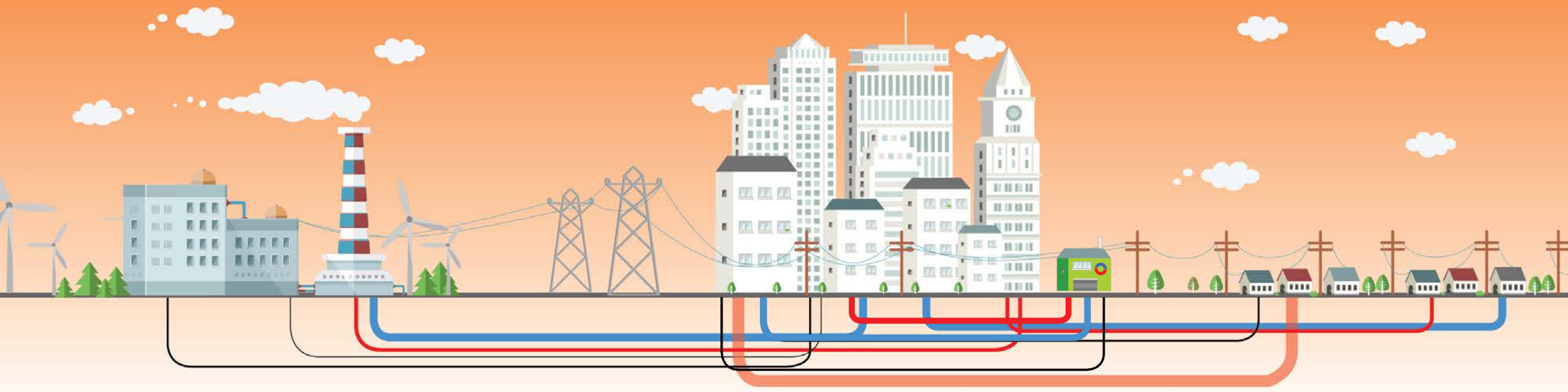
- Goals in 2014 Climate Action Plan Update
- Promote onsite CHP, renewables, district energy
- 2020 Supply Targets: 15 % energy use from cogeneration, 10 MW of commercial solar generation

Purpose of the Study

- identify districts where these technologies are most feasible,
- provide hypothetical engineering solutions as a starting point for community conversation, and
- quantify the overall benefits of Community Scale energy systems in Boston.

Image credit: Tajunique Thompson, Boston Redevelopment Authority, 2016

INTRODUCTION- COMMUNITY ENERGY SOLUTIONS



Local Generation and Storage

Photovoltaic / Solar Panels, Solar Thermal Panels, Combined Heat and Power (CHP) , Heat Storage, Cold Storage, Battery Storage, Absorption Chiller, Refrigeration, Air Source Heat Pump, Ground Source Heat Pump

Building owners use local generation and energy storage to reduce peak loads, energy costs , greenhouse gas emissions and to increase resiliency to power outages.

District Thermal Systems

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

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

Microgrids

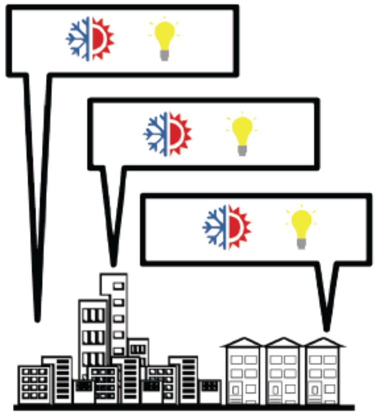
An electrical grid that can isolate a group of buildings and self-power with local generation.

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

Image credit: Tajunique Thompson, Boston Redevelopment Authority, 2016

STEP ONE
ENERGY-USE MAPPING

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

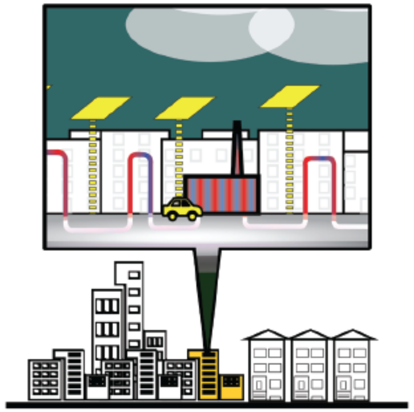


STEP TWO
LOCATING SUITABLE DISTRICTS

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

STEP THREE
ENGINEERING ANALYSIS

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



STEP FOUR
SUSTAINABLE RETURN ON INVESTMENT ANALYSIS

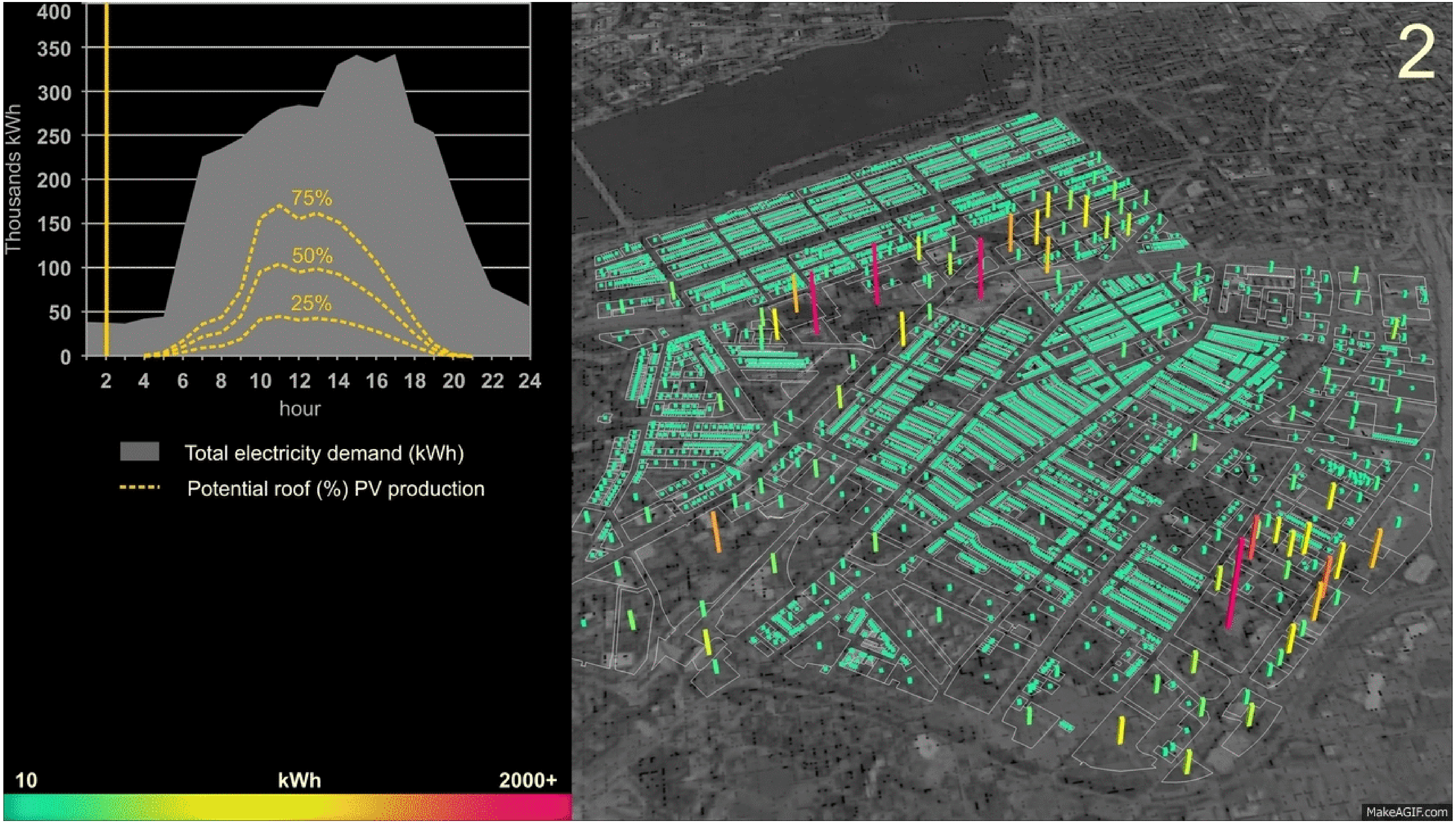
The Sustainable Return on Investment Analysis quantifies the benefits of this hypothetical infrastructure, if it were implemented. This economic model quantifies the monetary value of the infrastructure in operation over 25 years.

Image credit: Boston Redevelopment Authority, 2016

BOSTON REDEVELOPMENT AUTHORITY

MIT SUSTAINABLE DESIGN LAB

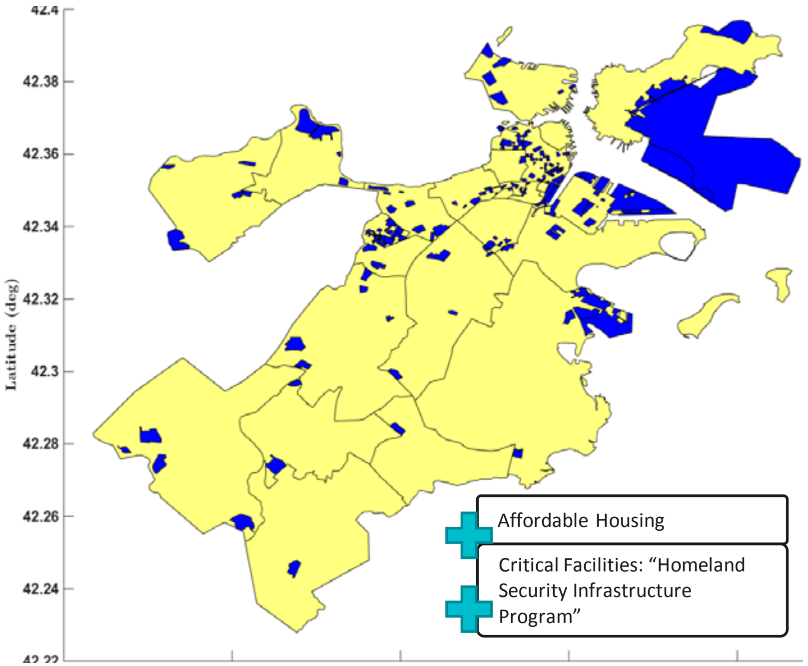
LINCOLN LABORATORY
MASSACHUSETTS INSTITUTE OF TECHNOLOGY



BOSTON REDEVELOPMENT AUTHORITY | MIT SUSTAINABLE DESIGN LAB | LINCOLN LABORATORY MASSACHUSETTS INSTITUTE OF TECHNOLOGY

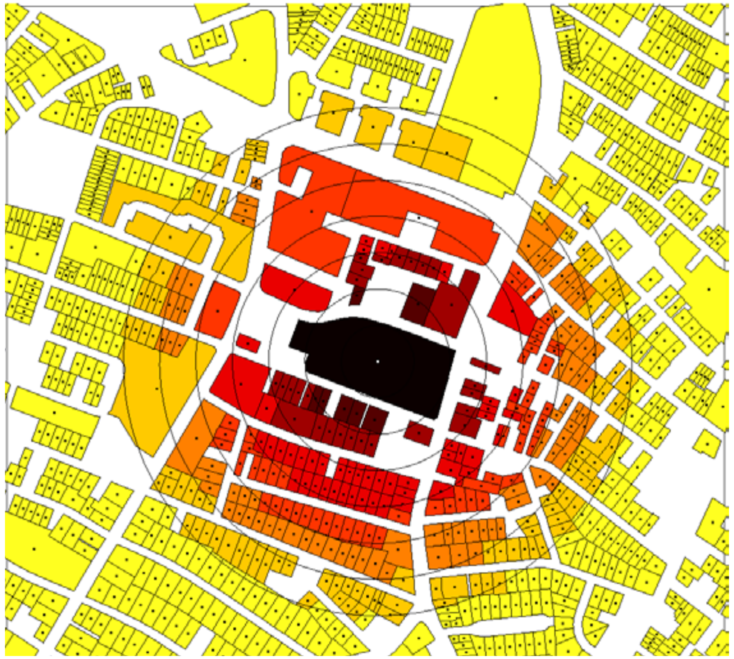
DISTRICT SUITABILITY ANALYSIS

Step 1: High energy use parcels



HSIP compiles geospatial data from federal agencies, commercial vendors, state, and local partners for common use by the Homeland Security; Homeland Defense; and Emergency Preparedness, Response, and Recovery communities. These datasets allow for nationwide infrastructure information access to assist decision makers in analyzing threats (whether natural or manmade) and modeling for emergencies and other missions.

Step 2: Local Analysis



Critical Facility Types:
AFFORDABLE HOUSING | EMERGENCY SHELTERS | GAS/ELECTRIC ASSETS (SUBSTATIONS, GAS STATIONS) | PHARMACIES | SUPERMARKETS | BOSTON CENTER FOR YOUTH AND FAMILIES FACILITIES HOTELS / MOTELS | LIBRARIES | MALLS | MUSEUMS | PUBLIC SCHOOLS | PUBLIC GOOD SHELTERS | HOMELESS SHELTERS, ETC) | FIRE STATIONS | POLICE STATIONS

Step 3: Final Identification

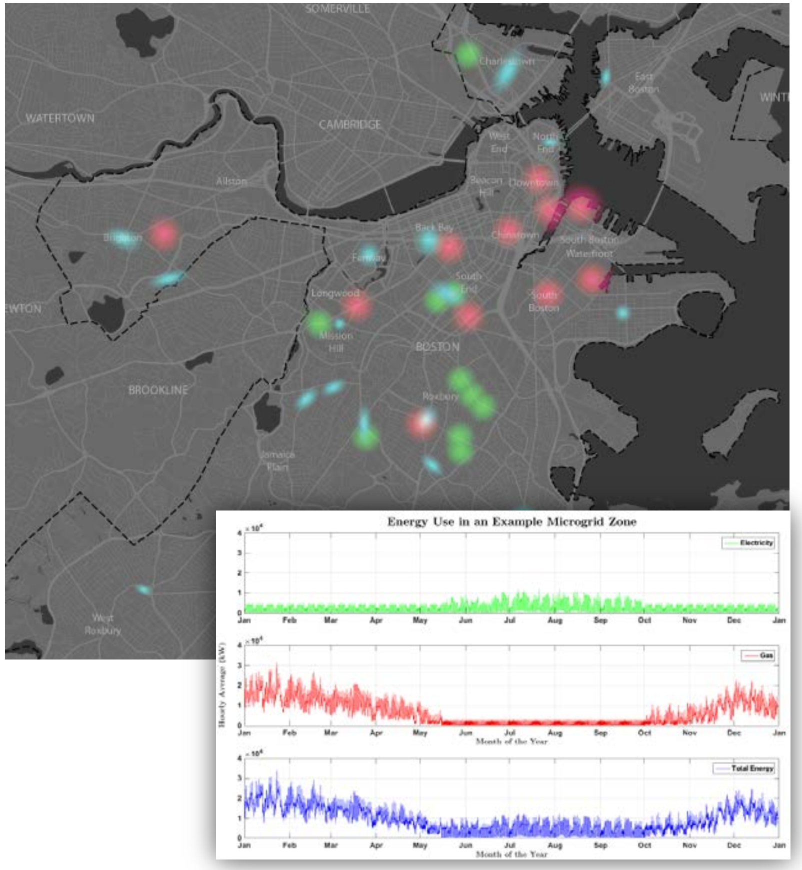
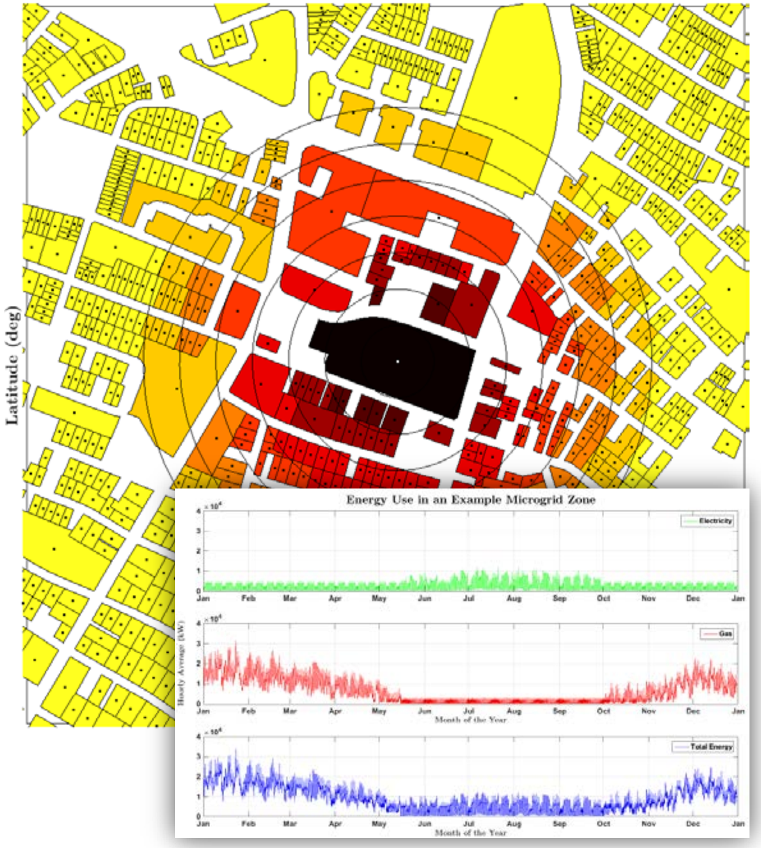


Image credits: "High Energy Use Parcels" and "Local Analysis" by Lincoln Laboratory. "Final Identification" by Boston Redevelopment Authority, 2016

ENGINEERING A DISTRICT SYSTEM

Step 1: Input Base Data



Step 2: Run DER-CAM

- Inputs: Local electric and gas prices
- Inputs: Weather normalization
- Operations: Can decide how and when to dispatch technologies
- Existing data: Capital costs for technologies

Step 3: Engineering Solution

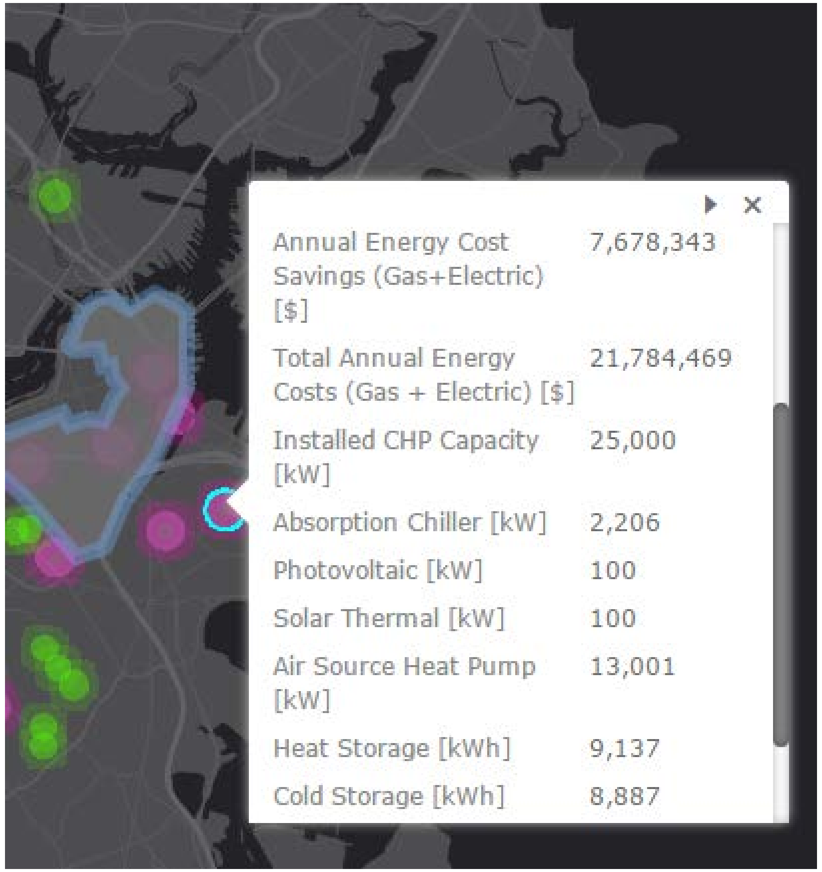


Image credits: (left) Lincoln Laboratory, 2015, (right) Boston Redevelopment Authority 2016

SUSTAINABLE RETURN ON INVESTMENT

MODEL INPUTS

The direct inputs for each scenario are as follows:

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

SUSTAINABLE RETURN ON INVESTMENT

COMPARISON OF FINANCIAL SAVINGS AND MONETIZED ENVIRONMENTAL BENEFITS

Analysis by Boston Redevelopment Authority, Research Division
2015

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

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

NEXT STEPS

City of Boston

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

Photo Courtesy of Medical Area Total Energy Plant (MATEP, LLC)