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U.S. Energy Information Administration

U.S. District Energy Services Market Characterization

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U.S. District Energy Services Market Characterization

In a district energy system, a central plant or plants produce steam, hot water, or chilled water, which is then pumped through a network of insulated pipes to provide space heating, cooling, and/or hot water for nearby connected customer buildings. The U.S. Energy Information Administration (EIA) contracted this report from ICF L.L.C. to inform modeling and analysis of domestic district energy systems.

District energy allows customers to save space and expenses by avoiding individual installation, operation, and maintenance of in-building heating, cooling, and water-heating equipment. Using economies of scale, district energy systems often distribute heat generated by combined heat and power (CHP) systems to use thermal energy that is produced more efficiently. District energy systems are more commonly found in commercial clusters of buildings such as colleges, hospitals, downtowns, healthcare, and government campuses.

ICF worked with the International District Energy Association's (IDEA) database of 660 existing district energy systems operating in the United States. In 2012, an estimated 5.5 billion square feet of heating floorspace and 1.9 billion square feet of cooling floorspace were serviced by district energy. District energy characteristics are provided by Census division (Table 1) and by fuel type (Table 2).

Table 1. Share of U.S. district energy by Census division

Census division	Heating gross square footage served	Cooling gross square footage served
New England	350,911,392	95,141,891
Middle Atlantic	1,497,478,221	200,603,217
East North Central	991,553,018	395,790,579
West North Central	570,177,893	158,611,465
South Atlantic	813,768,087	288,977,364
East South Central	158,622,454	94,156,827
West South Central	359,938,693	316,360,508
Mountain	188,521,265	117,605,771
Pacific	520,343,083	210,321,556
Total	**5,451,314,105**	**1,877,569,178**

* Note that heating and cooling gross square footage overlap for many systems, so the regional amounts are not additive.

Table 2. Share of U.S. district energy fuel use by fuel type

Fuel	Non-CHP heating (MMBtu)	Non-CHP cooling (MMBtu)	CHP (MMBtu)	Total (MMBtu)	Percent of total fuel use
Coal	58,998,023	0	97,000,378	155,998,401	16%
Electricity	0	14,238,482	0	14,238,482	1%
Natural gas	372,251,735	6,049,694	342,242,633	720,544,063	74%
Oil	11,160,227	13,135	13,980,363	25,153,725	3%
Other (Biomass)	19,729,303	0	42,209,336	61,938,639	6%
Total	**462,139,288**	**20,301,311**	**495,432,710**	**977,873,309**	**100%**

When referencing the contract report, it should be cited as a report by ICF L.L.C. and the International District Energy Association prepared for the U.S. Energy Information Administration.

APPENDIX

U.S. District Energy Services Market Characterization

Commercial Data Analysis for EIA's National Energy Modeling System (NEMS)

January
2018

Prepared for: U.S. Energy Information Administration

ICF
IDEA

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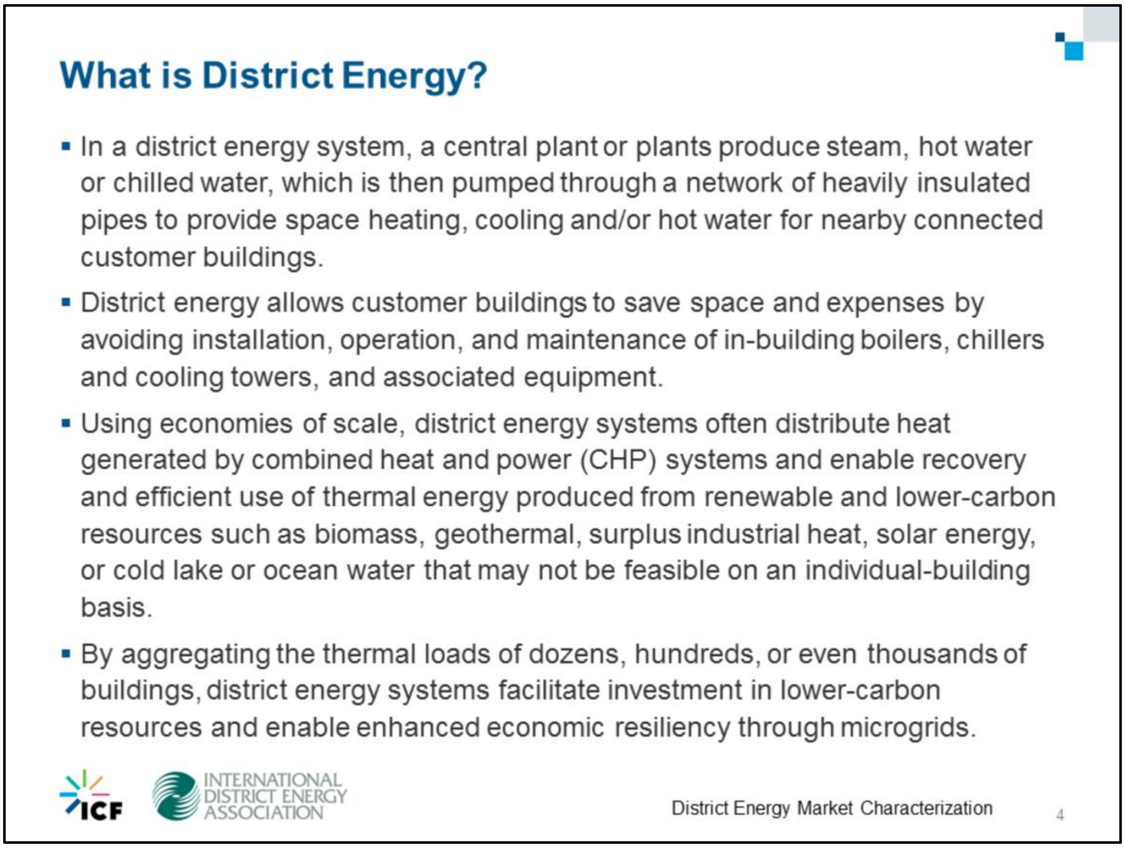
Introduction

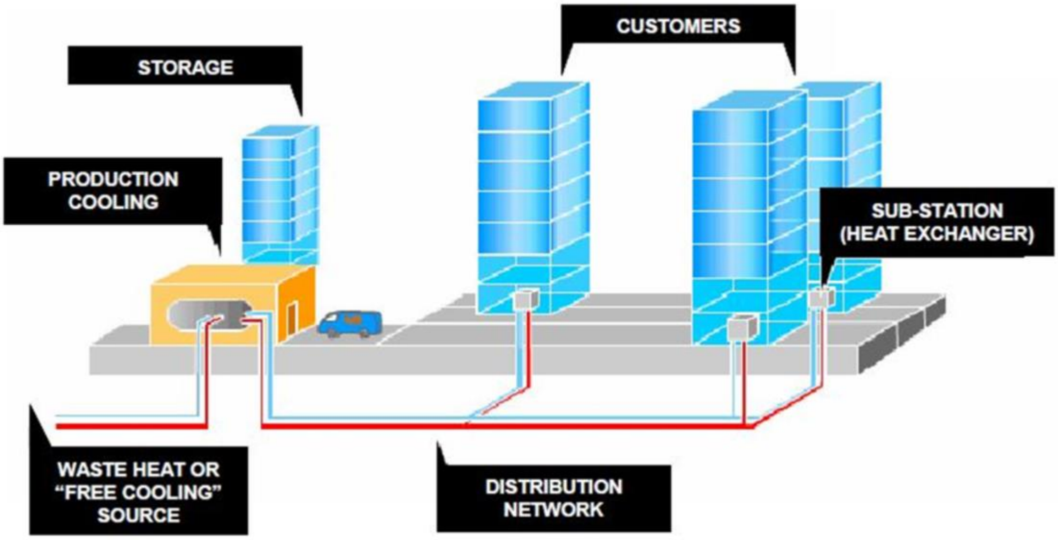
- The purpose of this work is to analyze and update the characterization of the district energy market that serves the U.S. commercial sector and develop fuel-specific estimates of energy consumed in 2012 to provide district energy services in the form of steam, hot water, and chilled water.
- The outcome of the analysis is data that provide the following:
  - Characterization of U.S. district energy services market, including estimates for current energy use for district energy services
  - Review of technology and market trends for district energy systems
  - Projected evolution of trends and district energy services through 2050

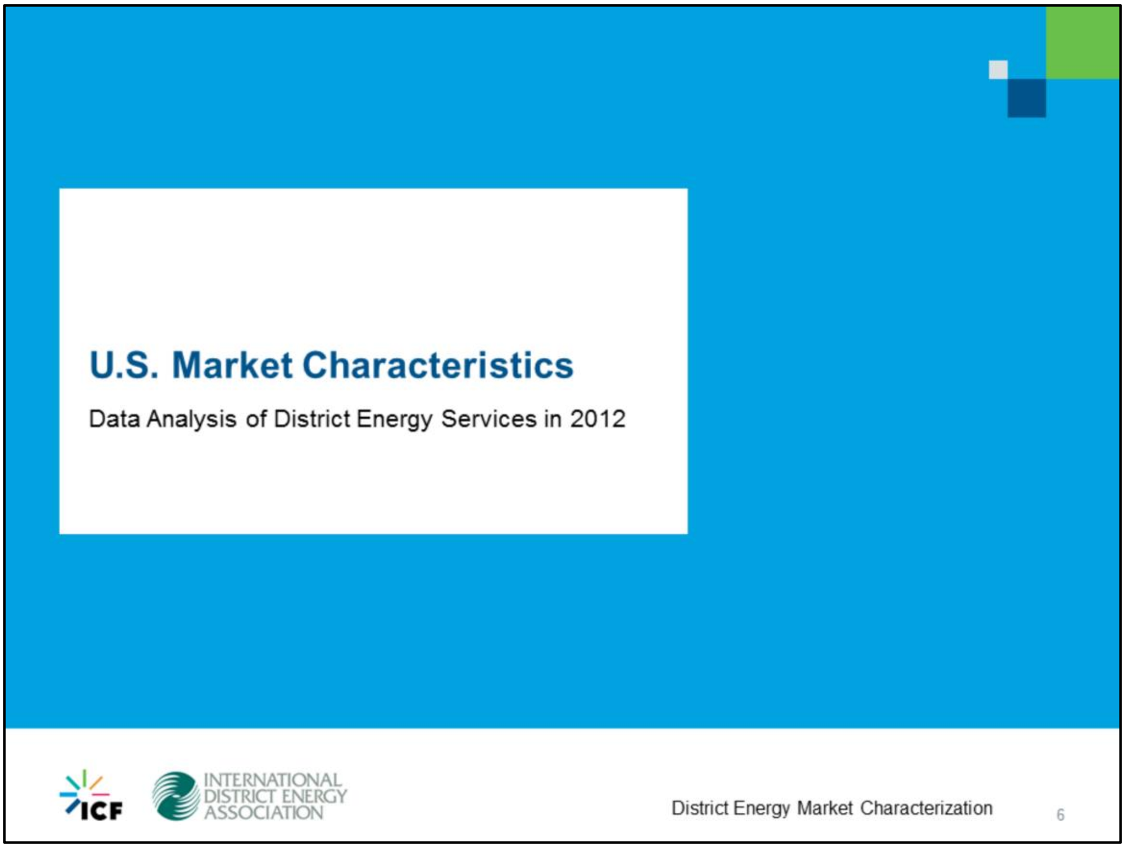


What is District Energy?

- In a district energy system, a central plant or plants produce steam, hot water or chilled water, which is then pumped through a network of heavily insulated pipes to provide space heating, cooling and/or hot water for nearby connected customer buildings.
- District energy allows customer buildings to save space and expenses by avoiding installation, operation, and maintenance of in-building boilers, chillers and cooling towers, and associated equipment.
- Using economies of scale, district energy systems often distribute heat generated by combined heat and power (CHP) systems and enable recovery and efficient use of thermal energy produced from renewable and lower-carbon resources such as biomass, geothermal, surplus industrial heat, solar energy, or cold lake or ocean water that may not be feasible on an individual-building basis.
- By aggregating the thermal loads of dozens, hundreds, or even thousands of buildings, district energy systems facilitate investment in lower-carbon resources and enable enhanced economic resiliency through microgrids.

What is District Energy?





U.S. Market Characteristics

Data Analysis of District Energy Services in 2012

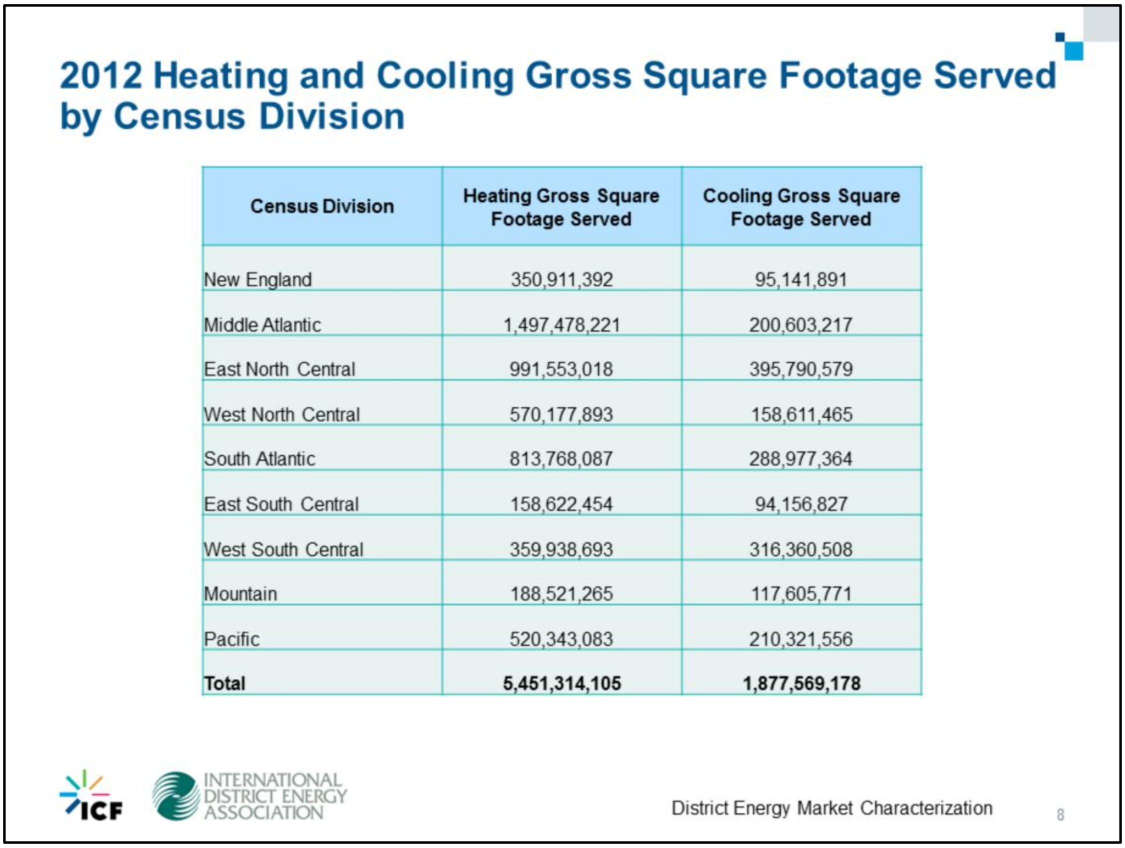
District Energy Systems Operate in Every State

2012 Installed Capacity is based on data reported by approximately 660 systems serving:

Heating: 5,451,314,105 sq ft
Cooling: 1,877,569,178 sq ft

Total Installed Capacity in 2012	
District Heating - Steam (lb/hr)	187,809,312
District Heating – Hot Water (MMBtu/hr)	5,386
Electricity Generation – CHP (MW)	6,744
District Cooling – Chilled Water (tons)	4,404,776

Source: IDEA



2012 Heating and Cooling Gross Square Footage Served by Census Division

Census Division	Heating Gross Square Footage Served	Cooling Gross Square Footage Served
New England	350,911,392	95,141,891
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Total	**5,451,314,105**	**1,877,569,178**

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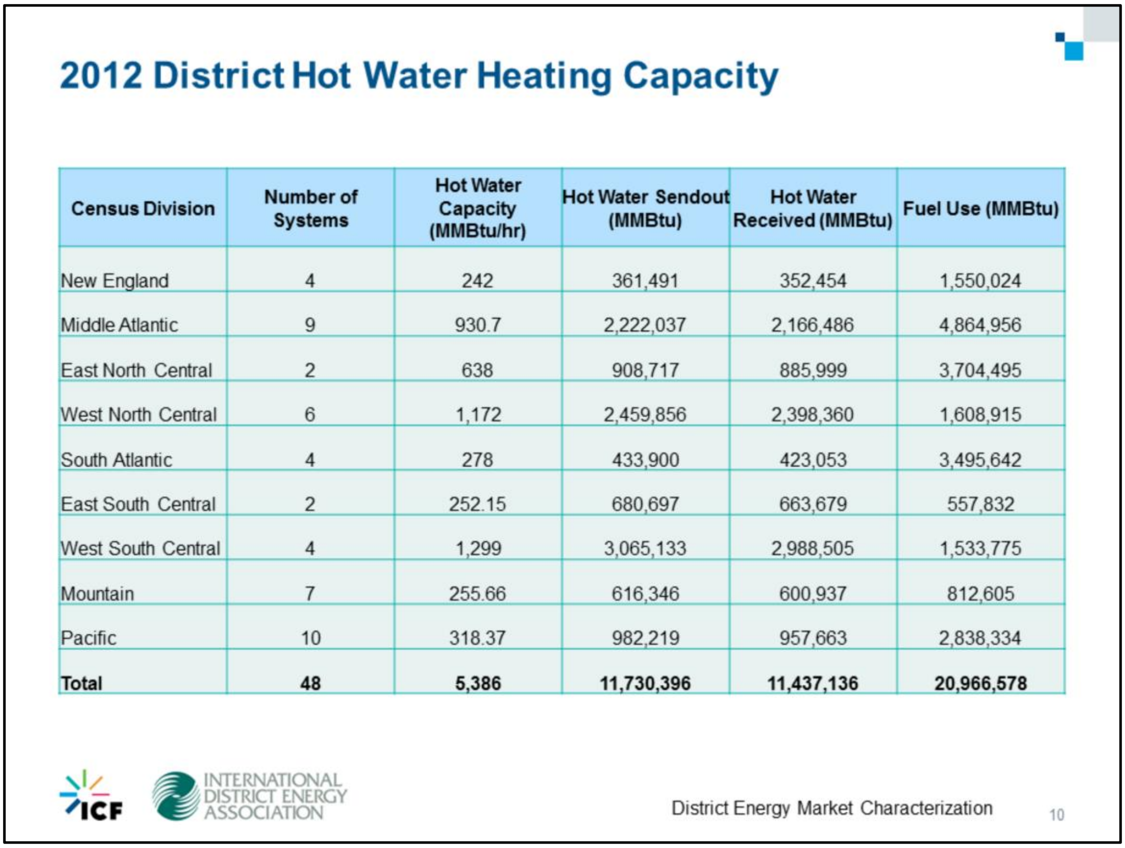
*Note that many district energy systems provide both heating and cooling services to the same buildings, therefore the GSFs for heating and cooling in the table above contain some overlap and are not additive.

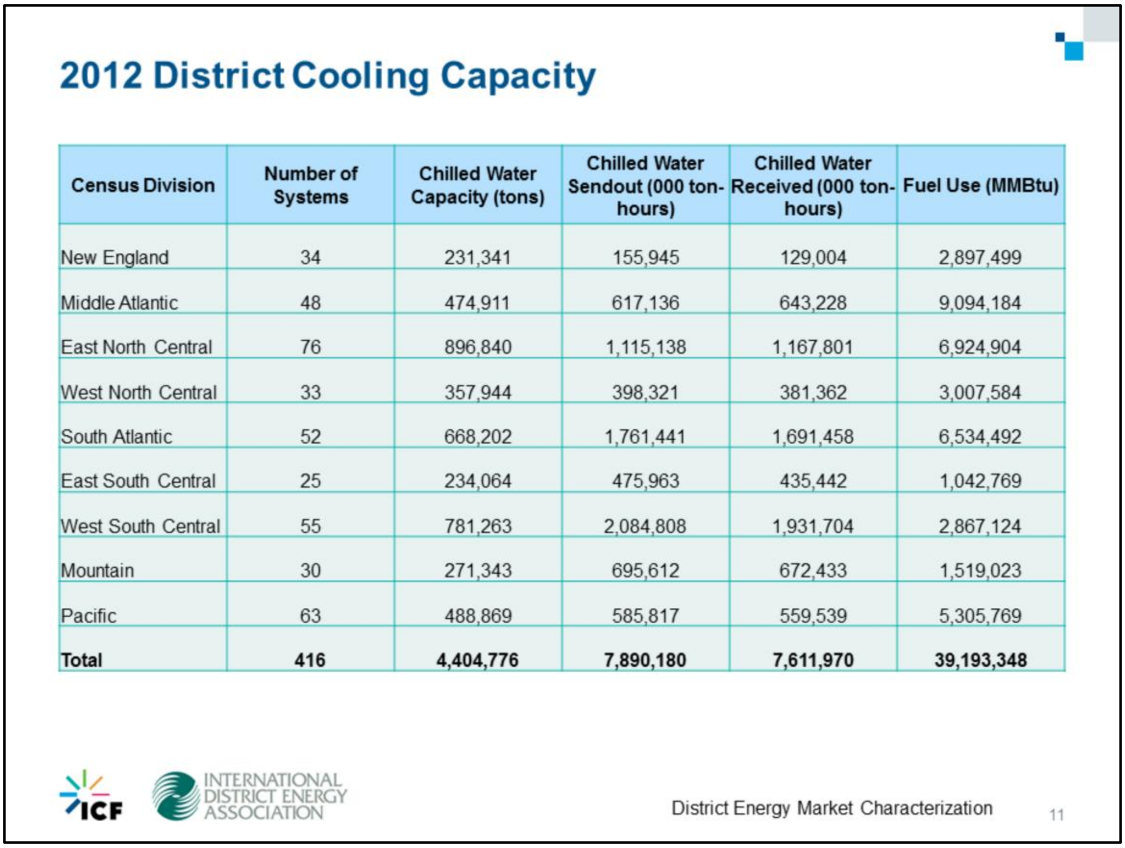
2012 District Steam Heating Capacity

Census Division	Number of Systems	Steam Capacity (lb/hr)	Steam Sendout (MMBtu)	Steam Received (MMBtu)	Fuel Use (MMBtu)
New England	55	12,615,394	33,107,119	30,624,085	67,845,023
Middle Atlantic	83	43,862,697	115,765,401	107,082,996	212,940,580
East North Central	99	32,999,448	89,168,866	82,481,201	162,146,836
West North Central	49	17,099,893	42,565,512	39,373,099	70,422,679
South Atlantic	93	32,736,773	96,198,708	88,983,805	153,005,313
East South Central	31	6,216,677	15,785,231	14,601,338	24,416,469
West South Central	57	13,395,924	34,714,492	32,110,905	67,133,787
Mountain	38	7,648,163	21,742,353	20,111,677	35,567,965
Pacific	89	21,234,344	68,629,243	63,482,049	124,234,732
Total	**594**	**187,809,312**	**517,676,925**	**478,851,156**	**917,713,383**



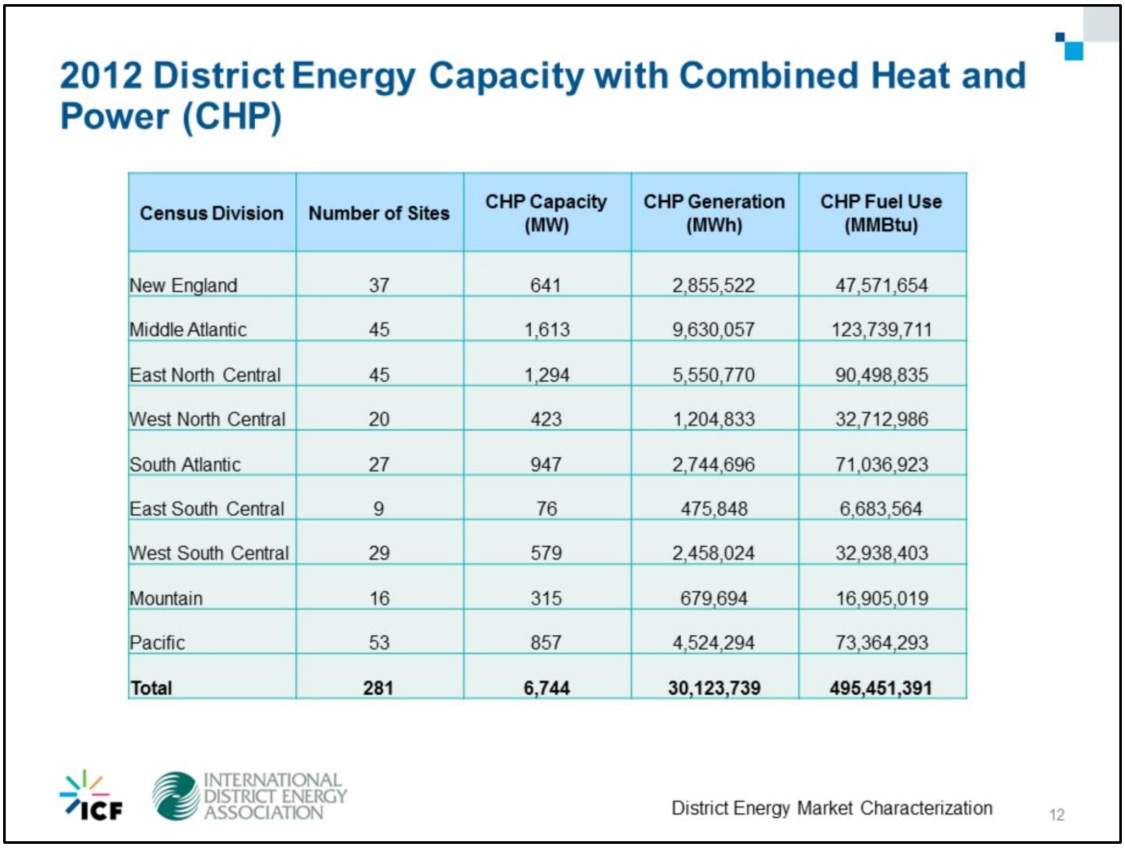
2012 District Hot Water Heating Capacity

Census Division	Number of Systems	Hot Water Capacity (MMBtu/hr)	Hot Water Sendout (MMBtu)	Hot Water Received (MMBtu)	Fuel Use (MMBtu)
New England	4	242	361,491	352,454	1,550,024
Middle Atlantic	9	930.7	2,222,037	2,166,486	4,864,956
East North Central	2	638	908,717	885,999	3,704,495
West North Central	6	1,172	2,459,856	2,398,360	1,608,915
South Atlantic	4	278	433,900	423,053	3,495,642
East South Central	2	252.15	680,697	663,679	557,832
West South Central	4	1,299	3,065,133	2,988,505	1,533,775
Mountain	7	255.66	616,346	600,937	812,605
Pacific	10	318.37	982,219	957,663	2,838,334
Total	**48**	**5,386**	**11,730,396**	**11,437,136**	**20,966,578**



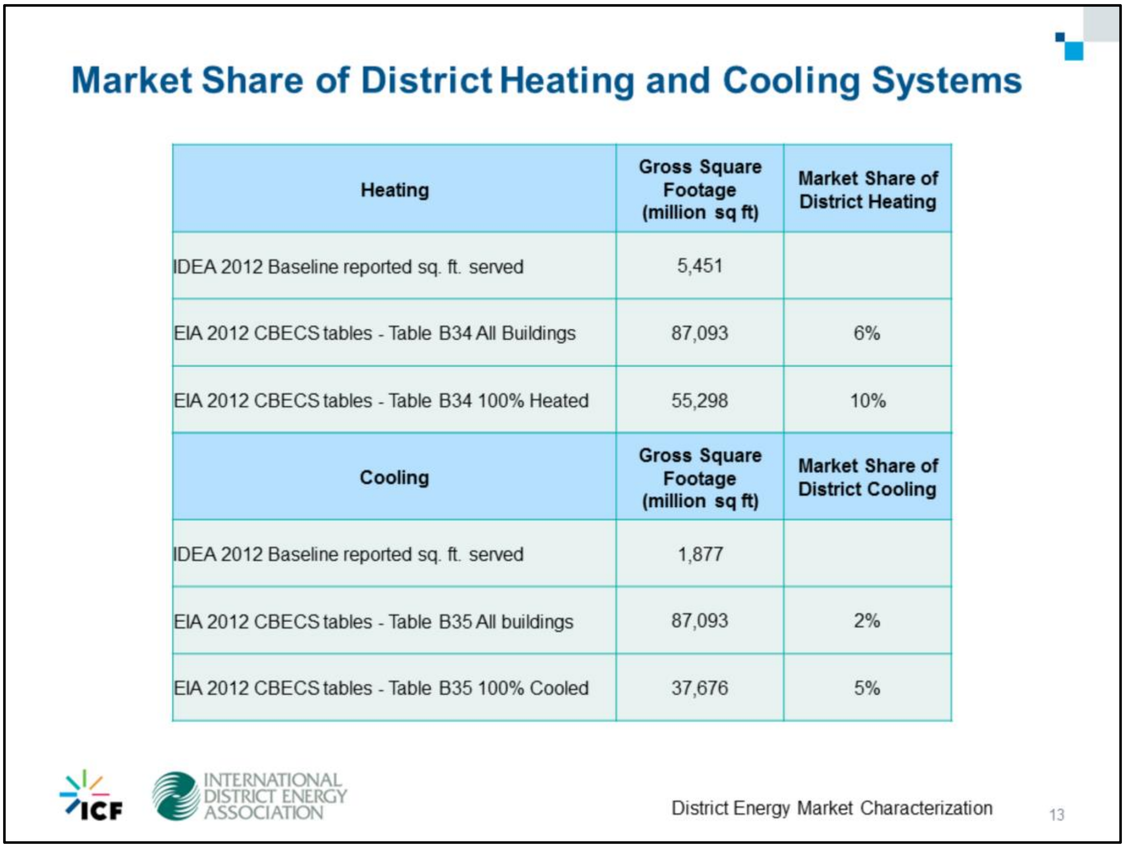
2012 District Cooling Capacity

Census Division	Number of Systems	Chilled Water Capacity (tons)	Chilled Water Sendout (000 ton-hours)	Chilled Water Received (000 ton-hours)	Fuel Use (MMBtu)
New England	34	231,341	155,945	129,004	2,897,499
Middle Atlantic	48	474,911	617,136	643,228	9,094,184
East North Central	76	896,840	1,115,138	1,167,801	6,924,904
West North Central	33	357,944	398,321	381,362	3,007,584
South Atlantic	52	668,202	1,761,441	1,691,458	6,534,492
East South Central	25	234,064	475,963	435,442	1,042,769
West South Central	55	781,263	2,084,808	1,931,704	2,867,124
Mountain	30	271,343	695,612	672,433	1,519,023
Pacific	63	488,869	585,817	559,539	5,305,769
Total	**416**	**4,404,776**	**7,890,180**	**7,611,970**	**39,193,348**



2012 District Energy Capacity with Combined Heat and Power (CHP)

Census Division	Number of Sites	CHP Capacity (MW)	CHP Generation (MWh)	CHP Fuel Use (MMBtu)
New England	37	641	2,855,522	47,571,654
Middle Atlantic	45	1,613	9,630,057	123,739,711
East North Central	45	1,294	5,550,770	90,498,835
West North Central	20	423	1,204,833	32,712,986
South Atlantic	27	947	2,744,696	71,036,923
East South Central	9	76	475,848	6,683,564
West South Central	29	579	2,458,024	32,938,403
Mountain	16	315	679,694	16,905,019
Pacific	53	857	4,524,294	73,364,293
Total	**281**	**6,744**	**30,123,739**	**495,451,391**



Market Share of District Heating and Cooling Systems

Heating	Gross Square Footage (million sq ft)	Market Share of District Heating
IDEA 2012 Baseline reported sq. ft. served	5,451	
EIA 2012 CBECS tables - Table B34 All Buildings	87,093	6%
EIA 2012 CBECS tables - Table B34 100% Heated	55,298	10%
Cooling	**Gross Square Footage (million sq ft)**	**Market Share of District Cooling**
IDEA 2012 Baseline reported sq. ft. served	1,877	
EIA 2012 CBECS tables - Table B35 All buildings	87,093	2%
EIA 2012 CBECS tables - Table B35 100% Cooled	37,676	5%

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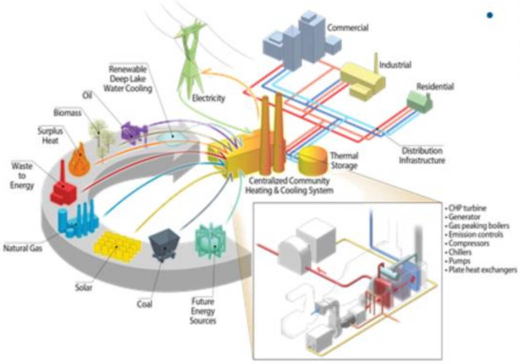
This slide is intended to show background data on market share.

References:
https://www.eia.gov/consumption/commercial/data/2012/bc/cfm/b34.php
https://www.eia.gov/consumption/commercial/data/2012/bc/cfm/b35.php

Features of District Energy Systems

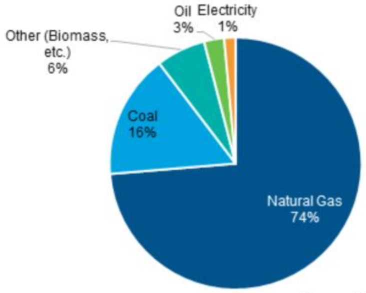
Fueling US District Energy Systems



- District energy systems were powered by more than 16 different types of fuel inputs in 2012, including:
  - Natural gas
  - Biomass
  - Municipally-sourced solid waste
  - Landfill gas
  - Purchased steam
  - Recovered heat
  - Geothermal
  - Solar thermal
  - Electricity
  - Distillate fuel oil
  - No. 2 fuel oil
  - No. 6 fuel oil
  - Coal
  - Wood waste
  - Biogas
  - Renewable cooling (lake or seawater)

- Most U.S. district heating systems are fossil-based, with nearly three-fourths of systems fueled by natural gas.
- Most district cooling systems utilize electric and/or hybrid chiller plants, often coupled with thermal storage.

2012 District Energy Fuel Use Breakdown



Source: IDEA and ICF

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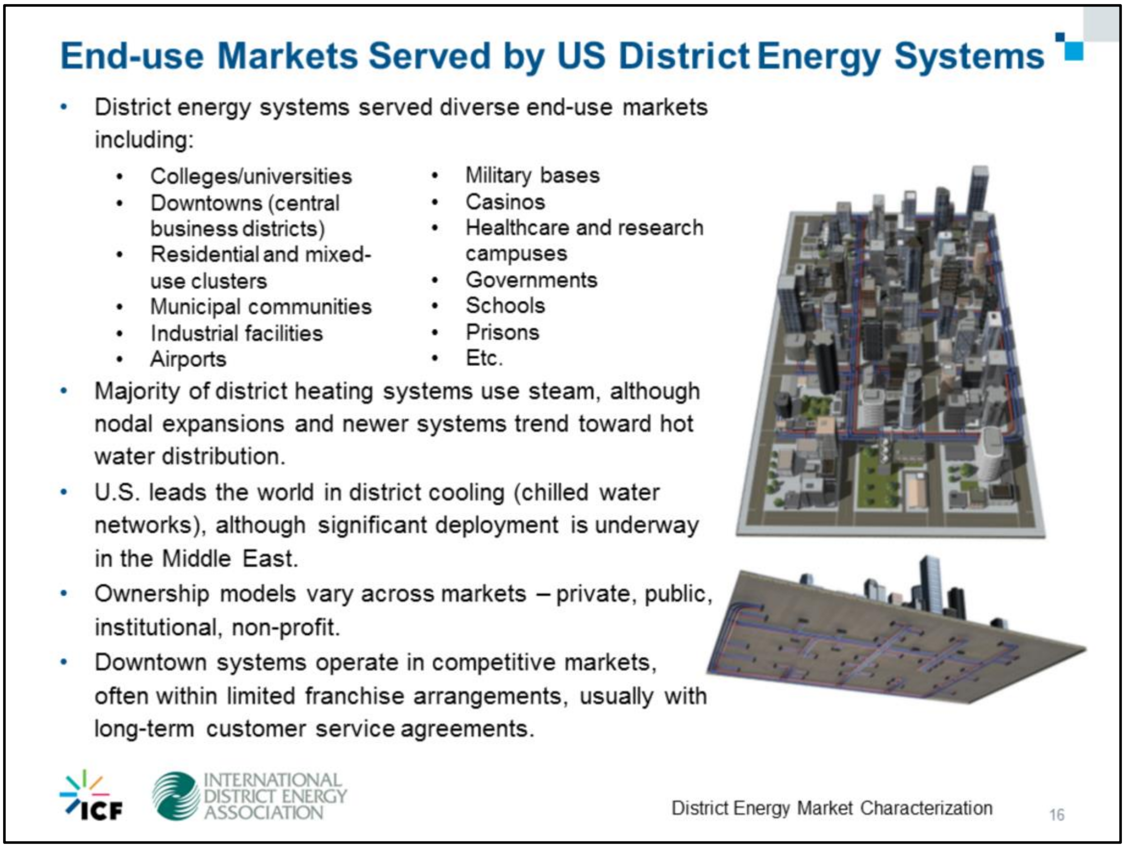
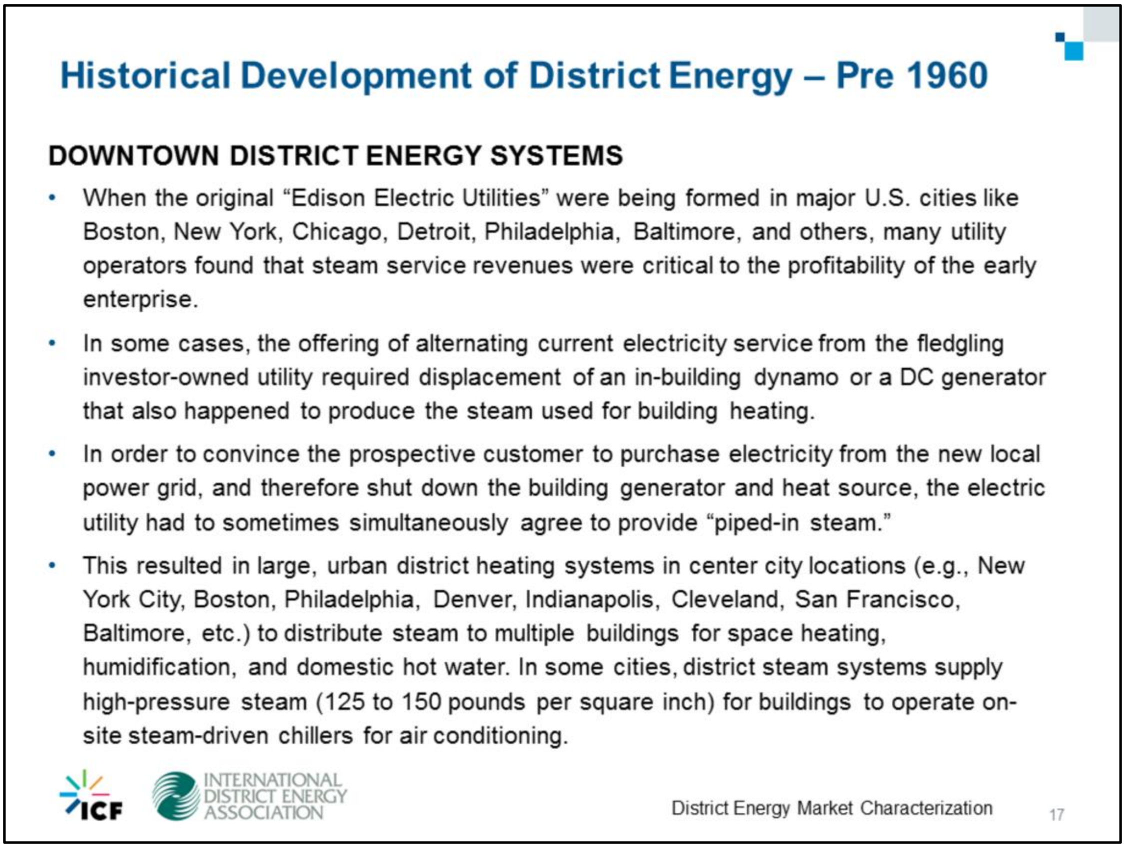


End-use Markets Served by US District Energy Systems

- District energy systems served diverse end-use markets including:
  - Colleges/universities
  - Downtowns (central business districts)
  - Residential and mixed-use clusters
  - Municipal communities
  - Industrial facilities
  - Airports
  - Military bases
  - Casinos
  - Healthcare and research campuses
  - Governments
  - Schools
  - Prisons
  - Etc.
- Majority of district heating systems use steam, although nodal expansions and newer systems trend toward hot water distribution.
- U.S. leads the world in district cooling (chilled water networks), although significant deployment is underway in the Middle East.
- Ownership models vary across markets – private, public, institutional, non-profit.
- Downtown systems operate in competitive markets, often within limited franchise arrangements, usually with long-term customer service agreements.

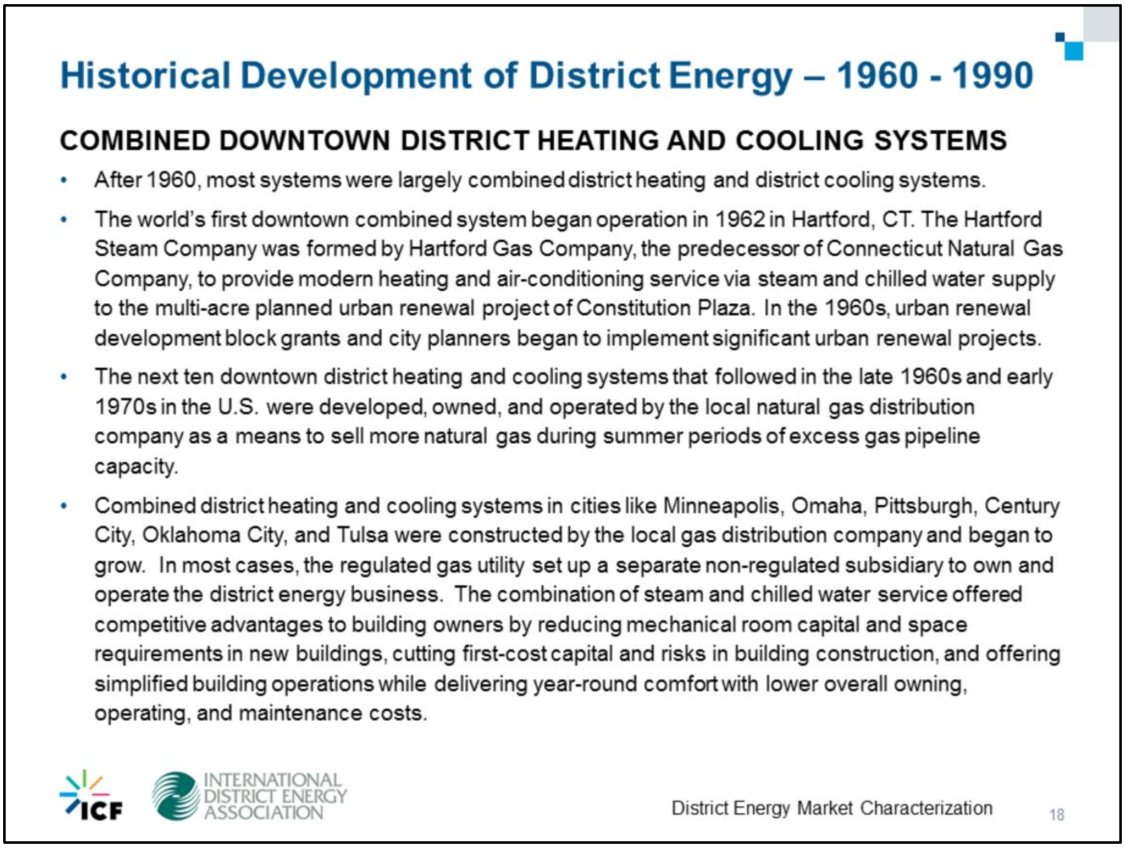
Middle East growth: https://www.gminsights.com/industry-analysis/middle-east-district-cooling-market



Historical Development of District Energy – Pre 1960

DOWNTOWN DISTRICT ENERGY SYSTEMS

- When the original “Edison Electric Utilities” were being formed in major U.S. cities like Boston, New York, Chicago, Detroit, Philadelphia, Baltimore, and others, many utility operators found that steam service revenues were critical to the profitability of the early enterprise.
- In some cases, the offering of alternating current electricity service from the fledgling investor-owned utility required displacement of an in-building dynamo or a DC generator that also happened to produce the steam used for building heating.
- In order to convince the prospective customer to purchase electricity from the new local power grid, and therefore shut down the building generator and heat source, the electric utility had to sometimes simultaneously agree to provide “piped-in steam.”
- This resulted in large, urban district heating systems in center city locations (e.g., New York City, Boston, Philadelphia, Denver, Indianapolis, Cleveland, San Francisco, Baltimore, etc.) to distribute steam to multiple buildings for space heating, humidification, and domestic hot water. In some cities, district steam systems supply high-pressure steam (125 to 150 pounds per square inch) for buildings to operate on-site steam-driven chillers for air conditioning.



Historical Development of District Energy – 1960 - 1990

COMBINED DOWNTOWN DISTRICT HEATING AND COOLING SYSTEMS

- After 1960, most systems were largely combined district heating and district cooling systems.
- The world's first downtown combined system began operation in 1962 in Hartford, CT. The Hartford Steam Company was formed by Hartford Gas Company, the predecessor of Connecticut Natural Gas Company, to provide modern heating and air-conditioning service via steam and chilled water supply to the multi-acre planned urban renewal project of Constitution Plaza. In the 1960s, urban renewal development block grants and city planners began to implement significant urban renewal projects.
- The next ten downtown district heating and cooling systems that followed in the late 1960s and early 1970s in the U.S. were developed, owned, and operated by the local natural gas distribution company as a means to sell more natural gas during summer periods of excess gas pipeline capacity.
- Combined district heating and cooling systems in cities like Minneapolis, Omaha, Pittsburgh, Century City, Oklahoma City, and Tulsa were constructed by the local gas distribution company and began to grow. In most cases, the regulated gas utility set up a separate non-regulated subsidiary to own and operate the district energy business. The combination of steam and chilled water service offered competitive advantages to building owners by reducing mechanical room capital and space requirements in new buildings, cutting first-cost capital and risks in building construction, and offering simplified building operations while delivering year-round comfort with lower overall owning, operating, and maintenance costs.

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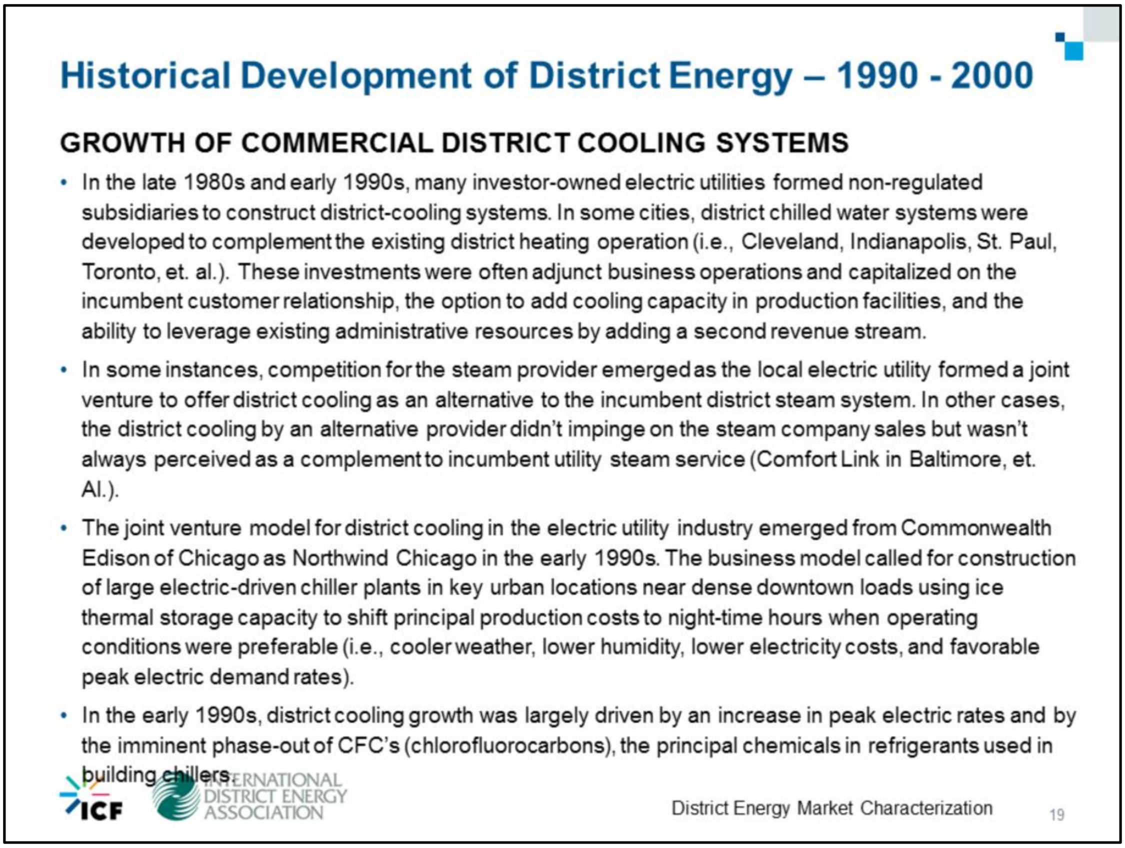
Hartford Constitution Plaza: http://www.scrapmonster.com/company/hartford-steam-co/45876



Historical Development of District Energy – 1990 - 2000

GROWTH OF COMMERCIAL DISTRICT COOLING SYSTEMS

- In the late 1980s and early 1990s, many investor-owned electric utilities formed non-regulated subsidiaries to construct district-cooling systems. In some cities, district chilled water systems were developed to complement the existing district heating operation (i.e., Cleveland, Indianapolis, St. Paul, Toronto, et. al.). These investments were often adjunct business operations and capitalized on the incumbent customer relationship, the option to add cooling capacity in production facilities, and the ability to leverage existing administrative resources by adding a second revenue stream.
- In some instances, competition for the steam provider emerged as the local electric utility formed a joint venture to offer district cooling as an alternative to the incumbent district steam system. In other cases, the district cooling by an alternative provider didn't impinge on the steam company sales but wasn't always perceived as a complement to incumbent utility steam service (Comfort Link in Baltimore, et. Al.).
- The joint venture model for district cooling in the electric utility industry emerged from Commonwealth Edison of Chicago as Northwind Chicago in the early 1990s. The business model called for construction of large electric-driven chiller plants in key urban locations near dense downtown loads using ice thermal storage capacity to shift principal production costs to night-time hours when operating conditions were preferable (i.e., cooler weather, lower humidity, lower electricity costs, and favorable peak electric demand rates).
- In the early 1990s, district cooling growth was largely driven by an increase in peak electric rates and by the imminent phase-out of CFC's (chlorofluorocarbons), the principal chemicals in refrigerants used in building chillers.

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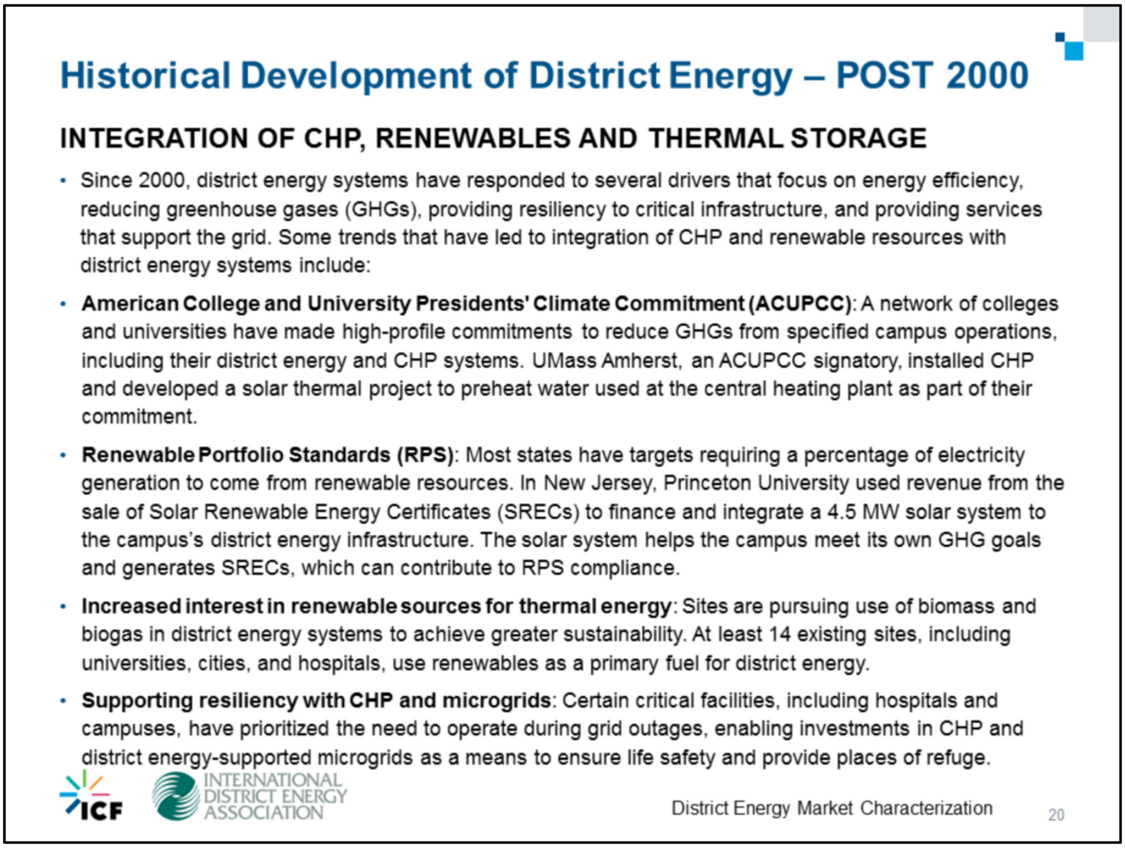
- Cleveland: http://www.corix.com/cleveland-thermal/district-energy
- Minneapolis: http://www.nrg.com/business/large-business/thermal/projects/minneapolis/
- St Paul: http://www.districtenergy.com/
- Toronto: http://enwave.com/locations/toronto/
- Comfortlink, Baltimore (purchased by Veolia): http://www.environmentalleader.com/2010/02/veolia-buys-comfort-link-enters-ice-thermal-storage-biz/; https://www.veolianorthamerica.com/en/case-studies/baltimore-md-district-heating-and-cooling

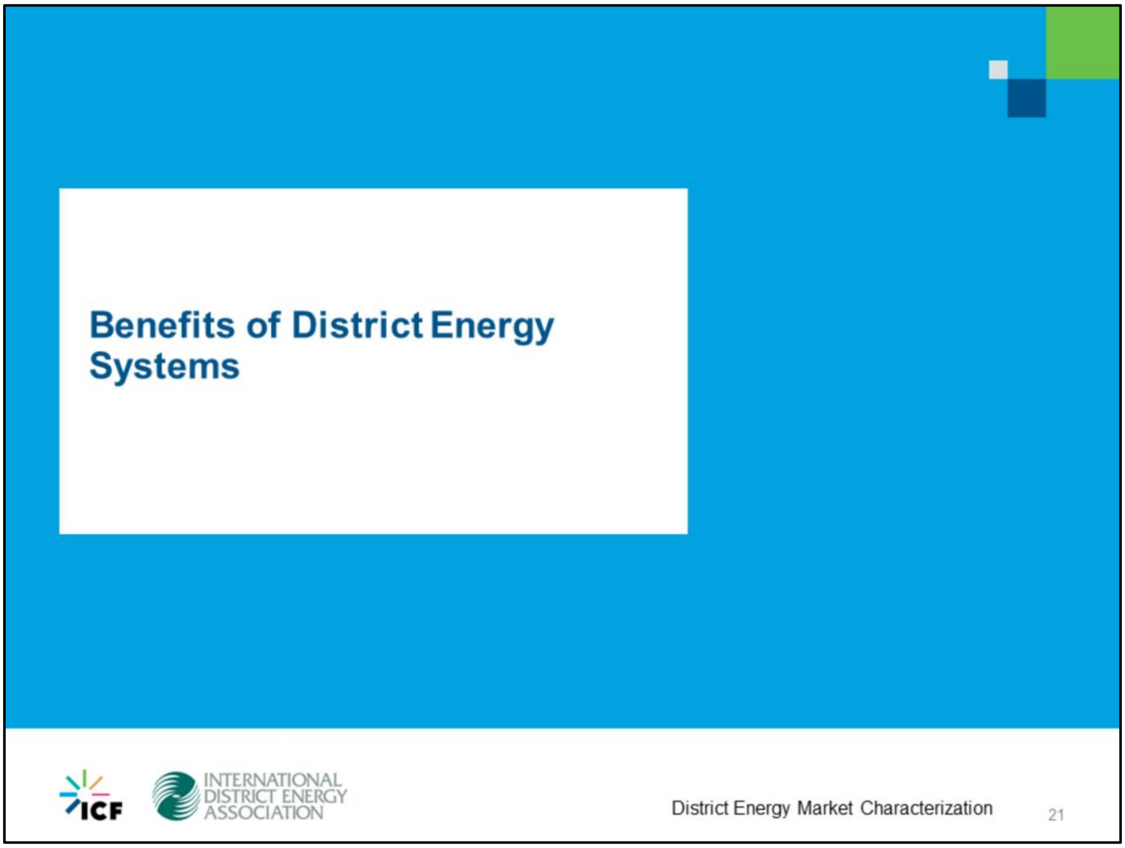


Historical Development of District Energy – POST 2000

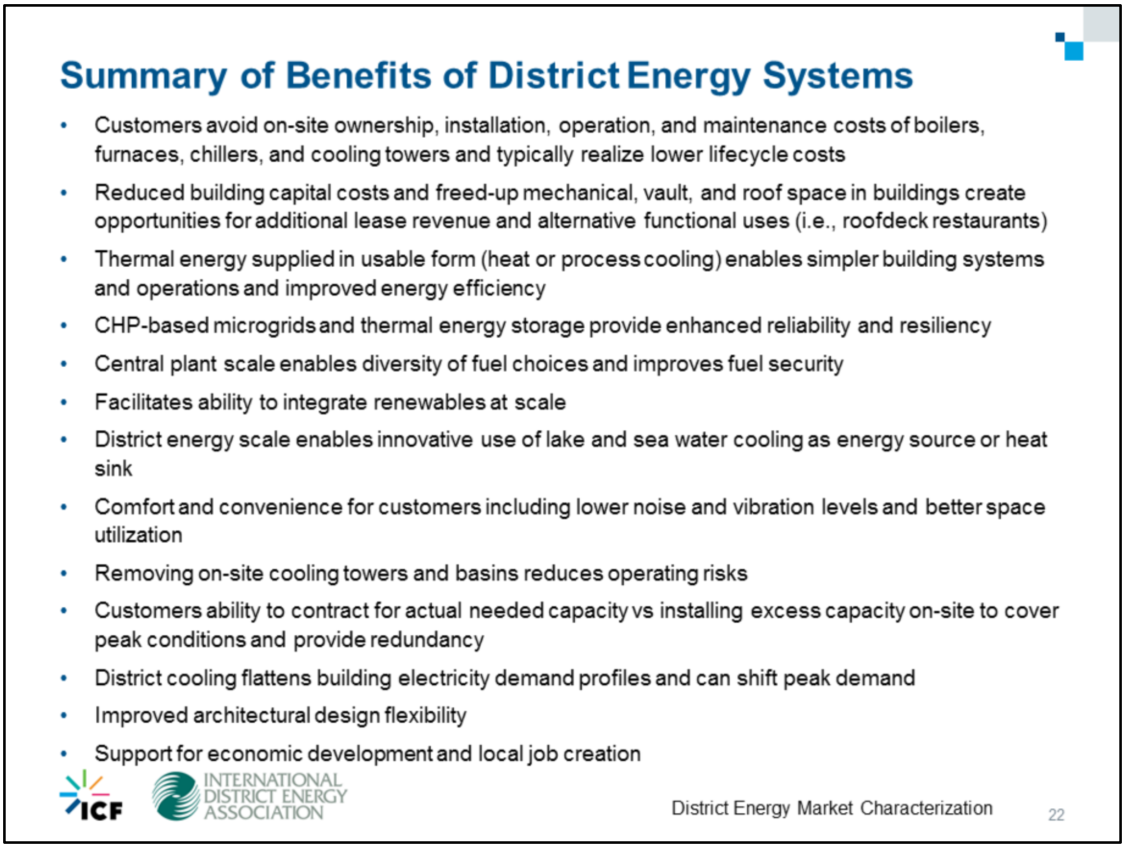
INTEGRATION OF CHP, RENEWABLES AND THERMAL STORAGE

- Since 2000, district energy systems have responded to several drivers that focus on energy efficiency, reducing greenhouse gases (GHGs), providing resiliency to critical infrastructure, and providing services that support the grid. Some trends that have led to integration of CHP and renewable resources with district energy systems include:
- **American College and University Presidents' Climate Commitment (ACUPCC)**: A network of colleges and universities have made high-profile commitments to reduce GHGs from specified campus operations, including their district energy and CHP systems. UMass Amherst, an ACUPCC signatory, installed CHP and developed a solar thermal project to preheat water used at the central heating plant as part of their commitment.
- **Renewable Portfolio Standards (RPS)**: Most states have targets requiring a percentage of electricity generation to come from renewable resources. In New Jersey, Princeton University used revenue from the sale of Solar Renewable Energy Certificates (SRECs) to finance and integrate a 4.5 MW solar system to the campus's district energy infrastructure. The solar system helps the campus meet its own GHG goals and generates SRECs, which can contribute to RPS compliance.
- **Increased interest in renewable sources for thermal energy**: Sites are pursuing use of biomass and biogas in district energy systems to achieve greater sustainability. At least 14 existing sites, including universities, cities, and hospitals, use renewables as a primary fuel for district energy.
- **Supporting resiliency with CHP and microgrids**: Certain critical facilities, including hospitals and campuses, have prioritized the need to operate during grid outages, enabling investments in CHP and district energy-supported microgrids as a means to ensure life safety and provide places of refuge.

- American College and University Presidents' Climate Commitment: http://secondnature.org/wp-content/uploads/Carbon-Commitment_Charter-Signatories.pdf
- UMass Amherst: http://scholarworks.umass.edu/cgi/viewcontent.cgi?article=1001&context=csi&_ga=2.51931179.380859945.1515006481-747043175.1515006481
- Princeton: https://facilities.princeton.edu/node/1471; https://www.princeton.edu/news/2011/02/02/princeton-install-powerful-solar-collector-field



Benefits of District Energy Systems



Summary of Benefits of District Energy Systems

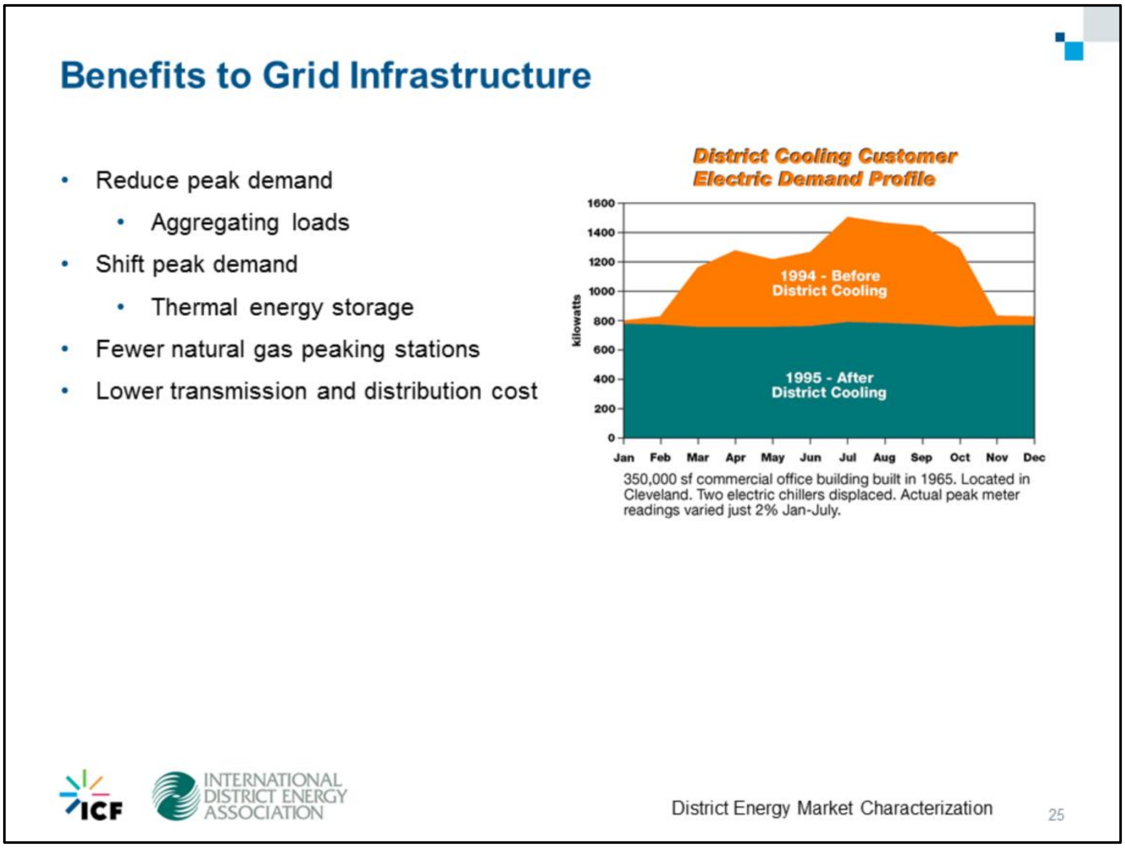
- Customers avoid on-site ownership, installation, operation, and maintenance costs of boilers, furnaces, chillers, and cooling towers and typically realize lower lifecycle costs
- Reduced building capital costs and freed-up mechanical, vault, and roof space in buildings create opportunities for additional lease revenue and alternative functional uses (i.e., roofdeck restaurants)
- Thermal energy supplied in usable form (heat or process cooling) enables simpler building systems and operations and improved energy efficiency
- CHP-based microgrids and thermal energy storage provide enhanced reliability and resiliency
- Central plant scale enables diversity of fuel choices and improves fuel security
- Facilitates ability to integrate renewables at scale
- District energy scale enables innovative use of lake and sea water cooling as energy source or heat sink
- Comfort and convenience for customers including lower noise and vibration levels and better space utilization
- Removing on-site cooling towers and basins reduces operating risks
- Customers ability to contract for actual needed capacity vs installing excess capacity on-site to cover peak conditions and provide redundancy
- District cooling flattens building electricity demand profiles and can shift peak demand
- Improved architectural design flexibility
- Support for economic development and local job creation

Benefits to Customers

- Improved energy efficiency/lower lifecycle cost; 50% power reduction/manage peaks
- Enhanced environmental protection
- Lower building costs; no chillers, A/C
- Easier building operation and maintenance
- Building architectural design flexibility, less noise and vibration
- Scale allows industrial-grade equipment not economical in buildings
- Reliability
- Fuel flexibility through electricity, absorption, CHP, renewable fuels, and integration of renewable resources

Benefits to Cities and Communities

- Available thermal energy supply reduces first costs for new development
- District energy systems can use local or regional fuel sources (i.e., wood waste, biomass, surplus heat, etc.) that keep energy dollars recirculating in local economy
- Roofs free of mechanical equipment provide architectural and aesthetic advantages
- Central plant scale allows use of grey water/treated sewage effluent for condenser water, conserving potable water for consumption
- District energy/CHP can serve as primary capacity for community microgrid to enhance resiliency and reduce regional greenhouse gas emissions



Benefits to Grid Infrastructure

- Reduce peak demand
  - Aggregating loads
- Shift peak demand
  - Thermal energy storage
- Fewer natural gas peaking stations
- Lower transmission and distribution cost

District Cooling Customer Electric Demand Profile

350,000 sf commercial office building built in 1965. Located in Cleveland. Two electric chillers displaced. Actual peak meter readings varied just 2% Jan-July.

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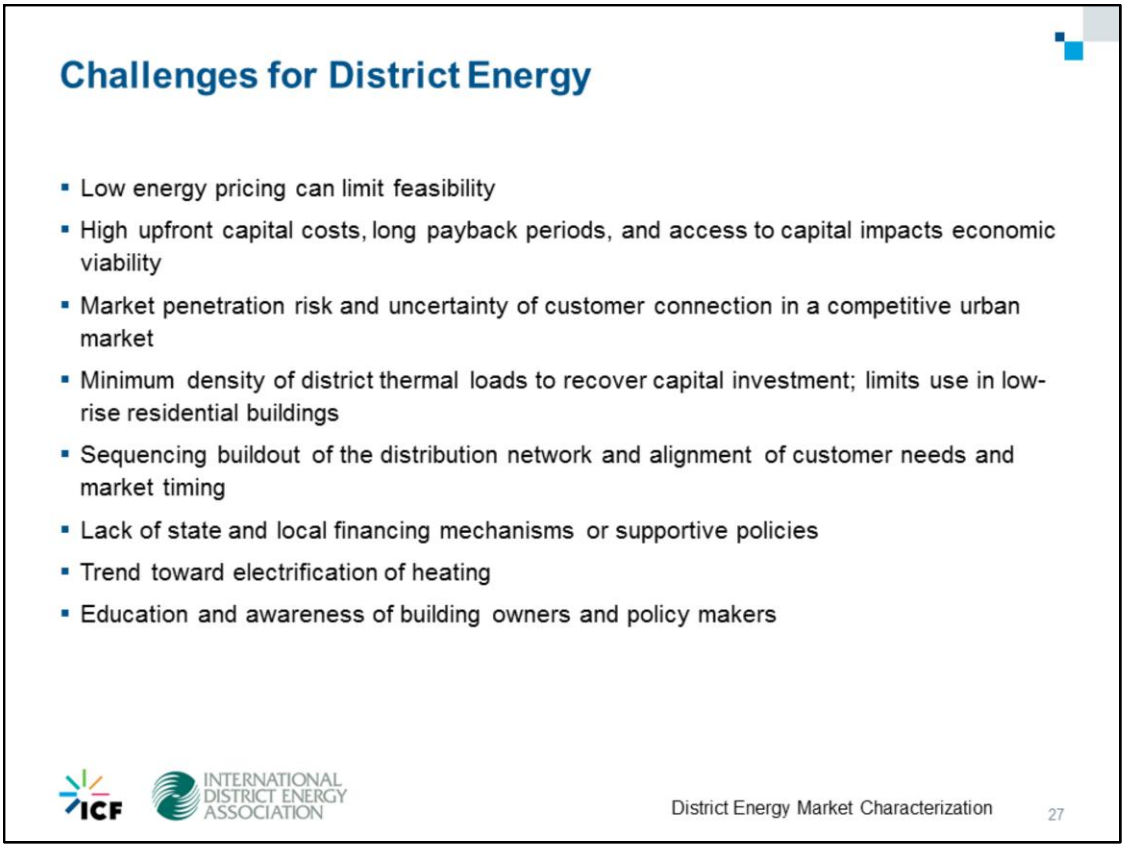
District Energy Market Characterization

District cooling systems provide chilled water service to customer buildings for air conditioning. This allows the customer to have a flatter load profile year round and to substantially reduce peak power demand from onsite equipment like chillers and cooling tower pumps and fans. Cutting demand for expensive peak power during high summer load condition reduces strain on the local power grid and improves system reliability and load factor for the local electricity provider. District cooling systems are also able to provide cooling via thermal storage, heat-based chilling, or renewable cooling sources like lakes, oceans, or rivers that would otherwise not be feasible on an individual building basis.

Benefits to the Environment

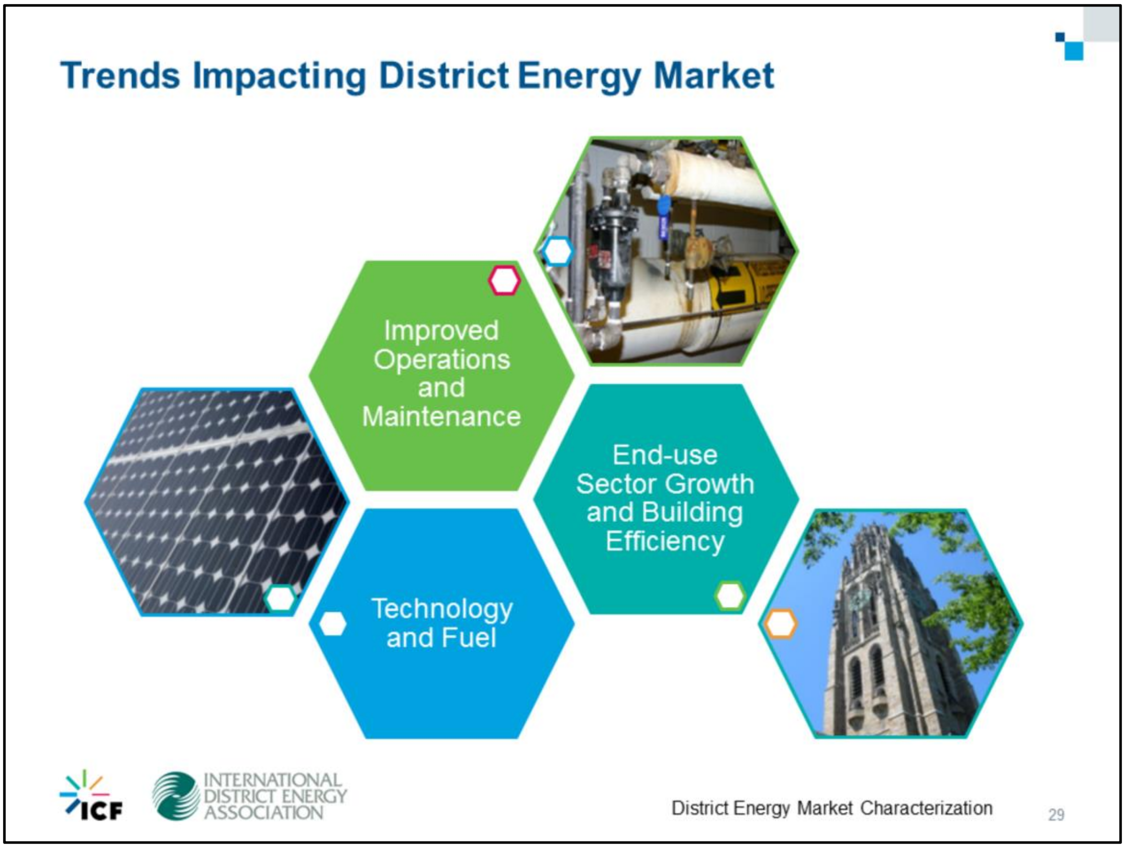
- Using less electricity during peak demand with district energy can result in greenhouse gas reductions.
- Fuel efficiency of district energy systems combined with CHP is greater compared to conventional heat and power, which results in less pollution.
- District energy facilitates ability to integrate renewables at scale, which replaces higher emitting central station generation with low- and zero-emitting technologies.
- Phase-out of chlorofluorocarbons has resulted in the use of low global warming-potential refrigerants for district cooling.
- District energy frees roof space and can enable the application of low-impact storm water management strategies and help prevent excessive runoff.



Challenges for District Energy

- Low energy pricing can limit feasibility
- High upfront capital costs, long payback periods, and access to capital impacts economic viability
- Market penetration risk and uncertainty of customer connection in a competitive urban market
- Minimum density of district thermal loads to recover capital investment; limits use in low-rise residential buildings
- Sequencing buildout of the distribution network and alignment of customer needs and market timing
- Lack of state and local financing mechanisms or supportive policies
- Trend toward electrification of heating
- Education and awareness of building owners and policy makers

Trends Impacting the District Energy Market



Trends Impacting District Energy Market

Improved Operations and Maintenance

End-use Sector Growth and Building Efficiency

Technology and Fuel

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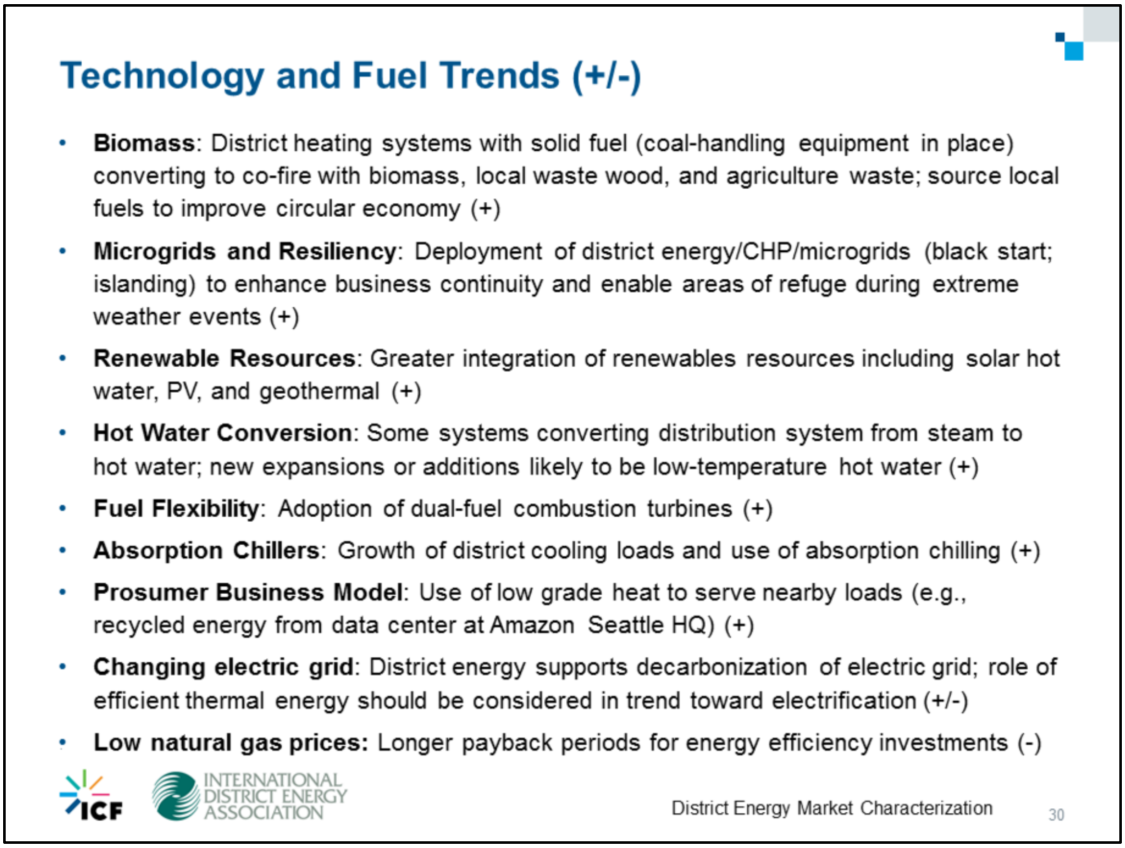


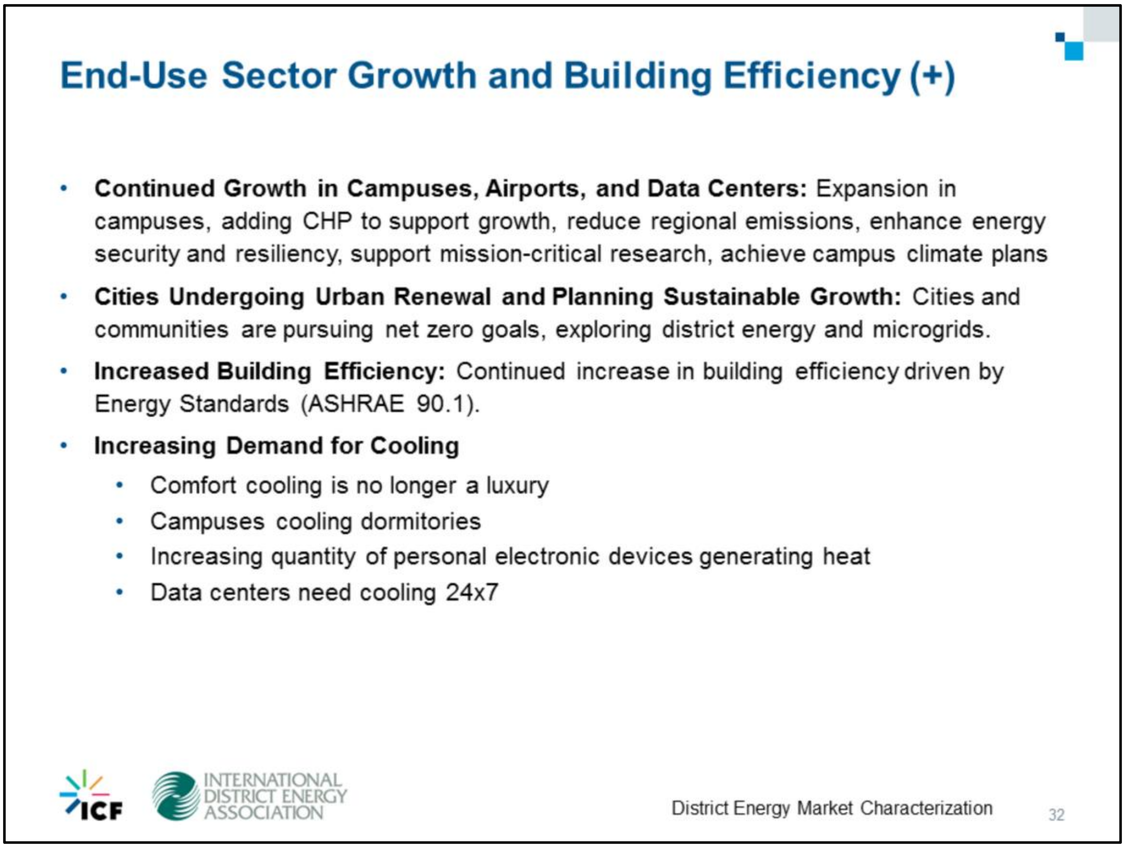
Technology and Fuel Trends (+/-)

- **Biomass**: District heating systems with solid fuel (coal-handling equipment in place) converting to co-fire with biomass, local waste wood, and agriculture waste; source local fuels to improve circular economy (+)
- **Microgrids and Resiliency**: Deployment of district energy/CHP/microgrids (black start; islanding) to enhance business continuity and enable areas of refuge during extreme weather events (+)
- **Renewable Resources**: Greater integration of renewables resources including solar hot water, PV, and geothermal (+)
- **Hot Water Conversion**: Some systems converting distribution system from steam to hot water; new expansions or additions likely to be low-temperature hot water (+)
- **Fuel Flexibility**: Adoption of dual-fuel combustion turbines (+)
- **Absorption Chillers**: Growth of district cooling loads and use of absorption chilling (+)
- **Prosumer Business Model**: Use of low grade heat to serve nearby loads (e.g., recycled energy from data center at Amazon Seattle HQ) (+)
- **Changing electric grid**: District energy supports decarbonization of electric grid; role of efficient thermal energy should be considered in trend toward electrification (+/-)
- **Low natural gas prices:** Longer payback periods for energy efficiency investments (-)

Trends with a plus sign are considered to be positive (+)
Trends with a minus sign are considered to be negative (-)
Trends with a plus and minus signs are neutral (+/-)

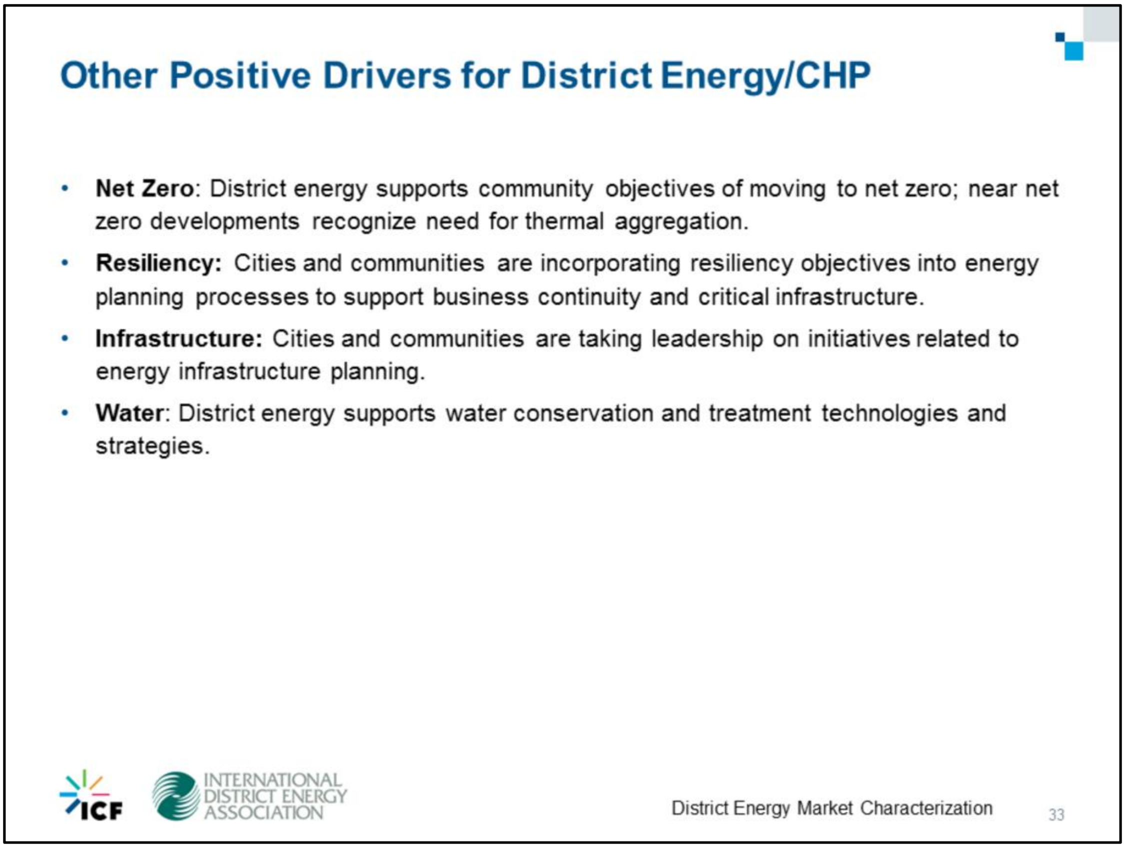
Improved Operations and Maintenance (+)

- **Heat Recovery:** Flue gas heat recovery systems are cost-effective method for reducing water and fuel usage
- **Reducing distribution losses through re-insulation:** Steam trap audits and replacement, manhole insulation upgrades, steam pipe restoration, insulating condensate receivers
- **Variable Speed Drives (VSD):** Implementing VSDs on chiller compressors cuts energy use
- **Metering, Monitoring, and Optimization:** Monitoring building performance with communications-enabled metering that optimize systems and increase efficiency
- **Plant Control Upgrades:** Upgrading plant controls and addressing cybersecurity
- **Economic Dispatch:** Improving economic efficiency with flexible operation of central plant assets
- **System Renewal:** Replacing boilers, chillers and cooling towers with greater efficiency
- **System Ownership Consolidation:** Private companies may bring greater expertise and/or resources from experience operating a range of diverse systems
- **Public-Private Partnerships for O&M**: Colleges/universities opting for third-party energy provider concession agreements



End-Use Sector Growth and Building Efficiency (+)

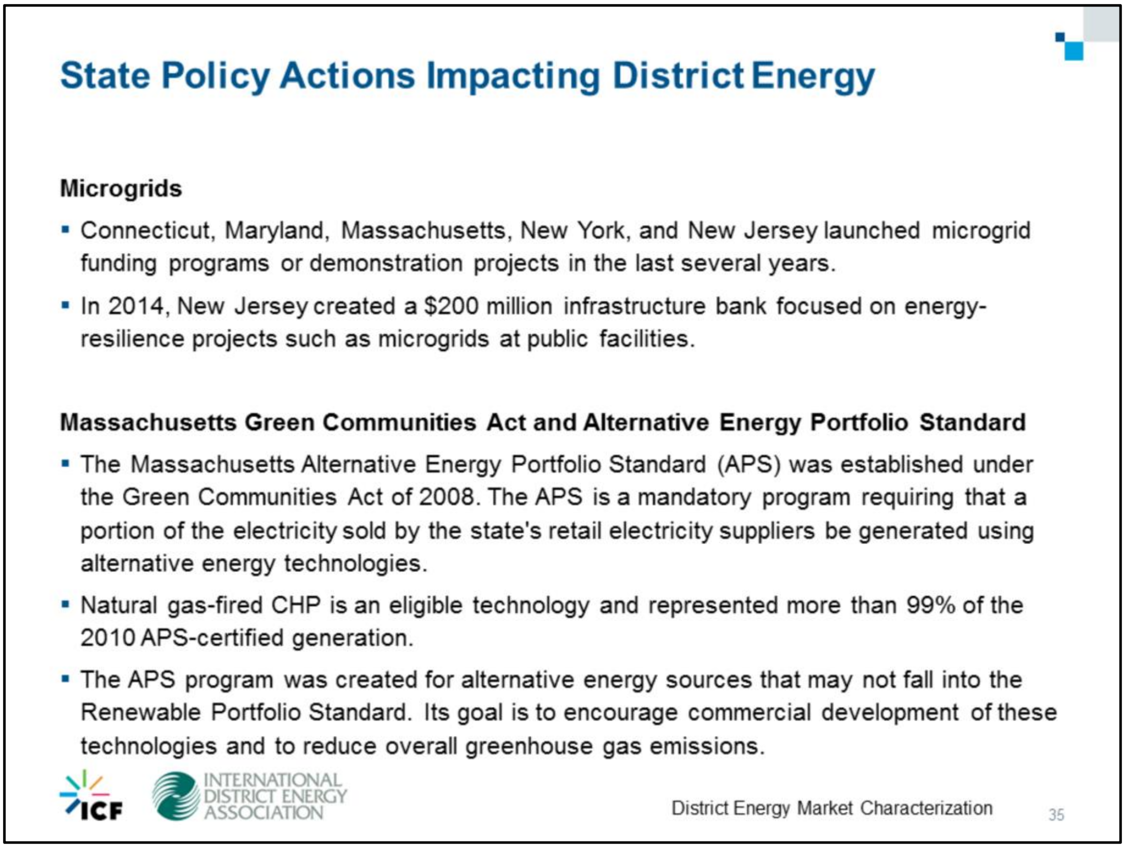
- **Continued Growth in Campuses, Airports, and Data Centers:** Expansion in campuses, adding CHP to support growth, reduce regional emissions, enhance energy security and resiliency, support mission-critical research, achieve campus climate plans
- **Cities Undergoing Urban Renewal and Planning Sustainable Growth:** Cities and communities are pursuing net zero goals, exploring district energy and microgrids.
- **Increased Building Efficiency:** Continued increase in building efficiency driven by Energy Standards (ASHRAE 90.1).
- **Increasing Demand for Cooling**
  - Comfort cooling is no longer a luxury
  - Campuses cooling dormitories
  - Increasing quantity of personal electronic devices generating heat
  - Data centers need cooling 24x7



Other Positive Drivers for District Energy/CHP

- **Net Zero**: District energy supports community objectives of moving to net zero; near net zero developments recognize need for thermal aggregation.
- **Resiliency:** Cities and communities are incorporating resiliency objectives into energy planning processes to support business continuity and critical infrastructure.
- **Infrastructure:** Cities and communities are taking leadership on initiatives related to energy infrastructure planning.
- **Water**: District energy supports water conservation and treatment technologies and strategies.

Trends in Policies and Standards



State Policy Actions Impacting District Energy

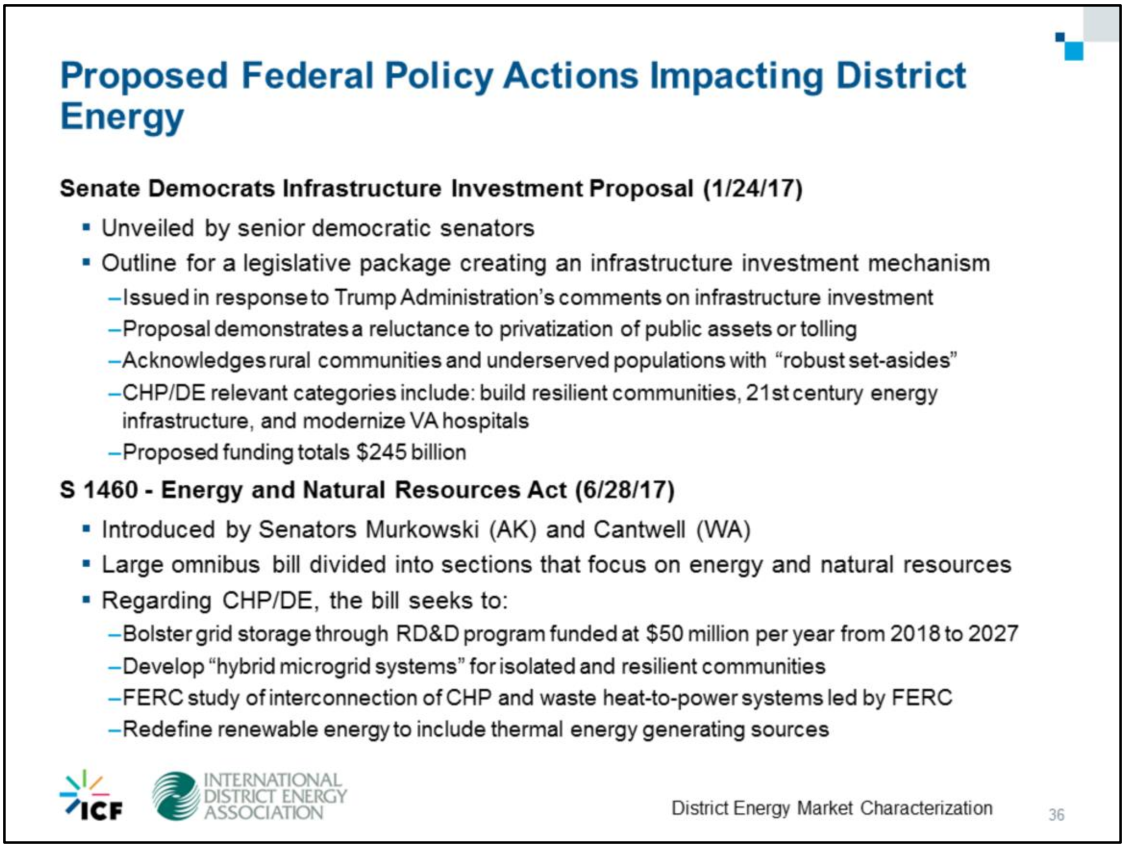
Microgrids

- Connecticut, Maryland, Massachusetts, New York, and New Jersey launched microgrid funding programs or demonstration projects in the last several years.
- In 2014, New Jersey created a $200 million infrastructure bank focused on energy-resilience projects such as microgrids at public facilities.

Massachusetts Green Communities Act and Alternative Energy Portfolio Standard

- The Massachusetts Alternative Energy Portfolio Standard (APS) was established under the Green Communities Act of 2008. The APS is a mandatory program requiring that a portion of the electricity sold by the state's retail electricity suppliers be generated using alternative energy technologies.
- Natural gas-fired CHP is an eligible technology and represented more than 99% of the 2010 APS-certified generation.
- The APS program was created for alternative energy sources that may not fall into the Renewable Portfolio Standard. Its goal is to encourage commercial development of these technologies and to reduce overall greenhouse gas emissions.

- MA Green Communities Act: https://malegislature.gov/Laws/SessionLaws/Acts/2008/Chapter169
- Alternative Portfolio Standard: https://www.mass.gov/service-details/program-summaries



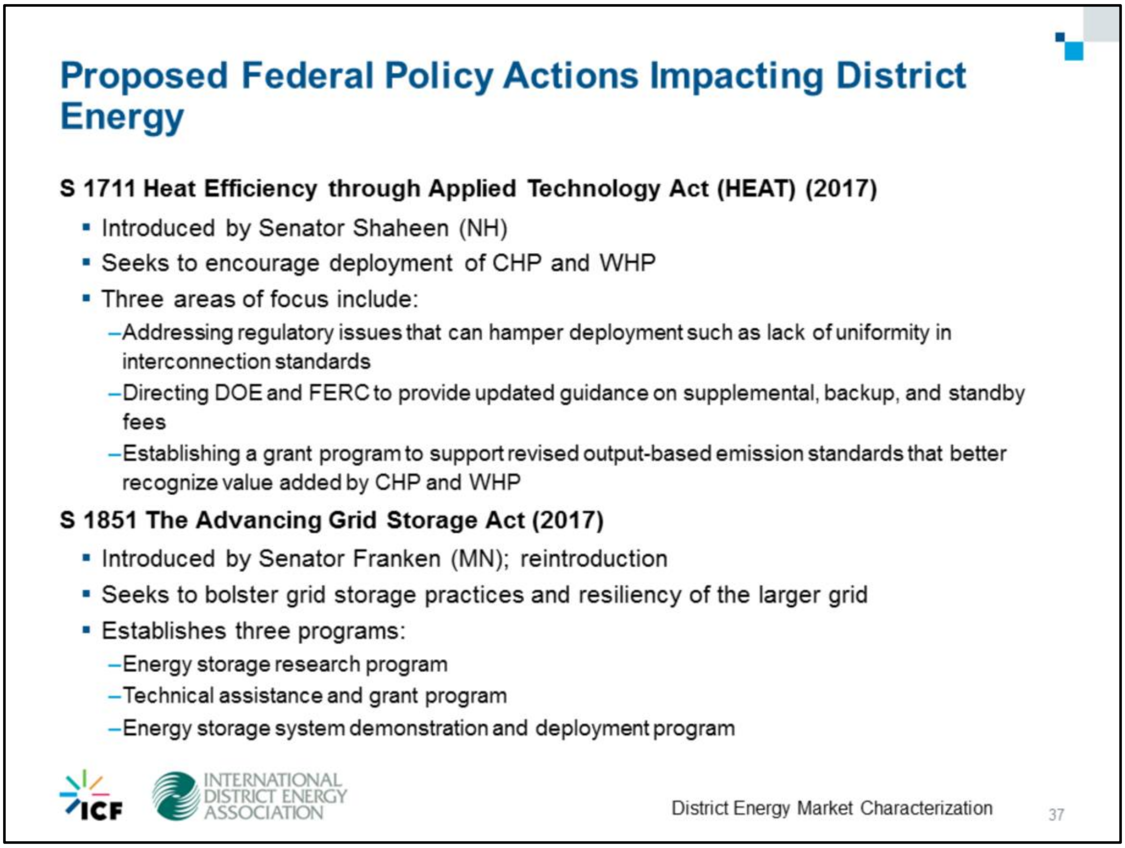
Proposed Federal Policy Actions Impacting District Energy

Senate Democrats Infrastructure Investment Proposal (1/24/17)

- Unveiled by senior democratic senators
- Outline for a legislative package creating an infrastructure investment mechanism
  - Issued in response to Trump Administration's comments on infrastructure investment
  - Proposal demonstrates a reluctance to privatization of public assets or tolling
  - Acknowledges rural communities and underserved populations with "robust set-asides"
  - CHP/DE relevant categories include: build resilient communities, 21st century energy infrastructure, and modernize VA hospitals
  - Proposed funding totals $245 billion

S 1460 - Energy and Natural Resources Act (6/28/17)

- Introduced by Senators Murkowski (AK) and Cantwell (WA)
- Large omnibus bill divided into sections that focus on energy and natural resources
- Regarding CHP/DE, the bill seeks to:
  - Bolster grid storage through RD&D program funded at $50 million per year from 2018 to 2027
  - Develop "hybrid microgrid systems" for isolated and resilient communities
  - FERC study of interconnection of CHP and waste heat-to-power systems led by FERC
  - Redefine renewable energy to include thermal energy generating sources



Proposed Federal Policy Actions Impacting District Energy

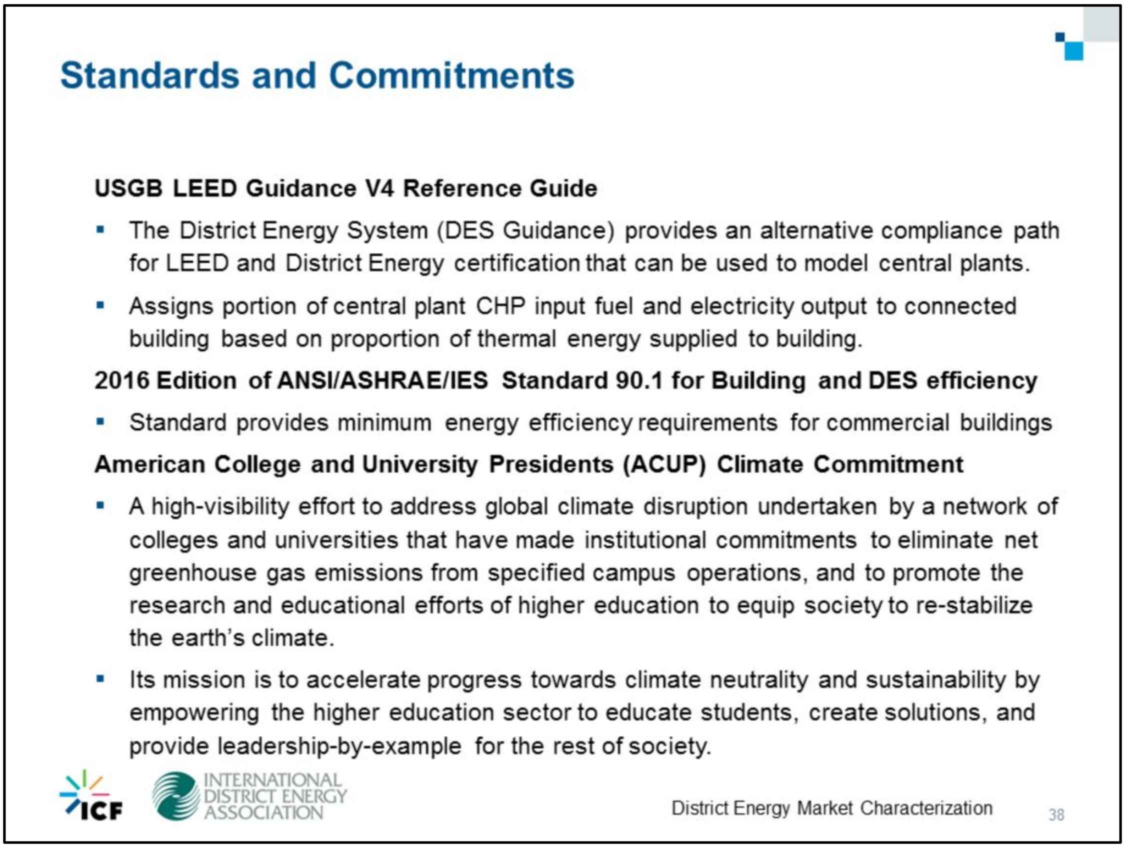
S 1711 Heat Efficiency through Applied Technology Act (HEAT) (2017)

- Introduced by Senator Shaheen (NH)
- Seeks to encourage deployment of CHP and WHP
- Three areas of focus include:
  - Addressing regulatory issues that can hamper deployment such as lack of uniformity in interconnection standards
  - Directing DOE and FERC to provide updated guidance on supplemental, backup, and standby fees
  - Establishing a grant program to support revised output-based emission standards that better recognize value added by CHP and WHP

S 1851 The Advancing Grid Storage Act (2017)

- Introduced by Senator Franken (MN); reintroduction
- Seeks to bolster grid storage practices and resiliency of the larger grid
- Establishes three programs:
  - Energy storage research program
  - Technical assistance and grant program
  - Energy storage system demonstration and deployment program

- HEAT Act: https://www.congress.gov/bill/115th-congress/senate-bill/1711/text?r=1
- Grid Storage Act: https://www.govtrack.us/congress/bills/115/s1851



Standards and Commitments

USGB LEED Guidance V4 Reference Guide

- The District Energy System (DES Guidance) provides an alternative compliance path for LEED and District Energy certification that can be used to model central plants.
- Assigns portion of central plant CHP input fuel and electricity output to connected building based on proportion of thermal energy supplied to building.

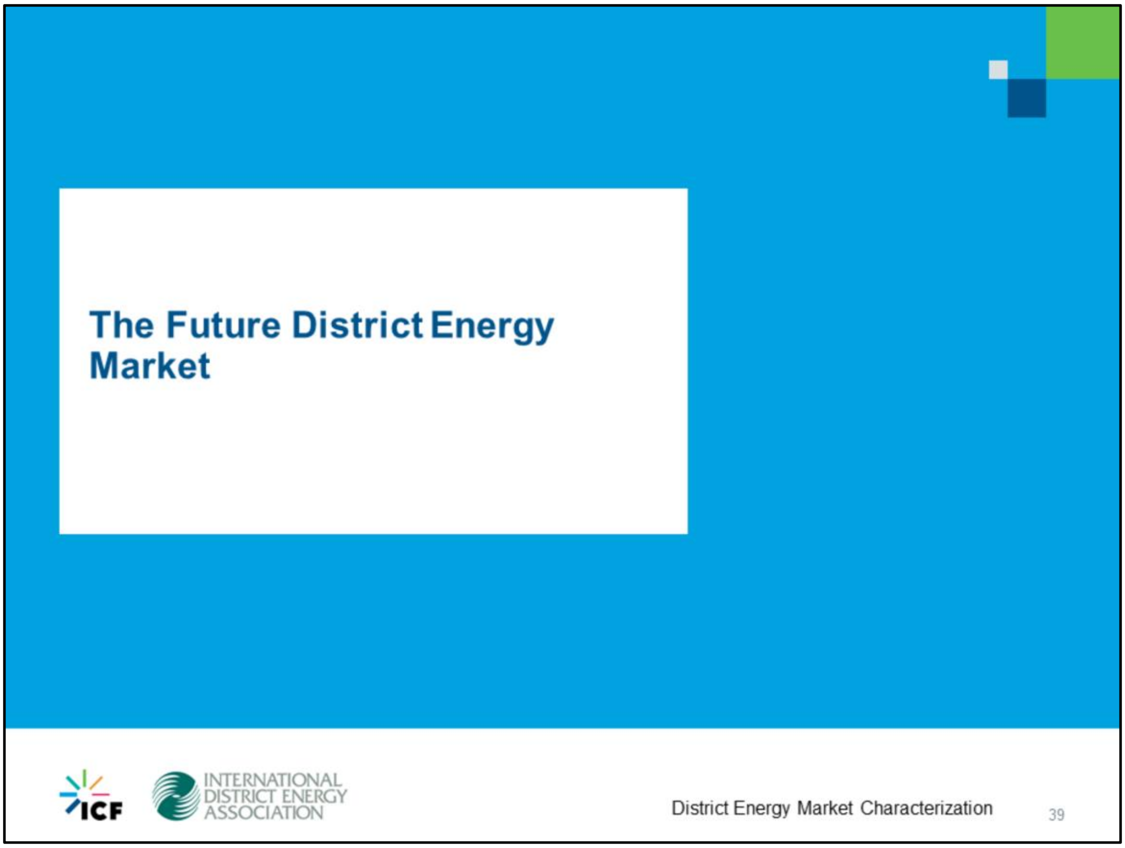
2016 Edition of ANSI/ASHRAE/IES Standard 90.1 for Building and DES efficiency

- Standard provides minimum energy efficiency requirements for commercial buildings

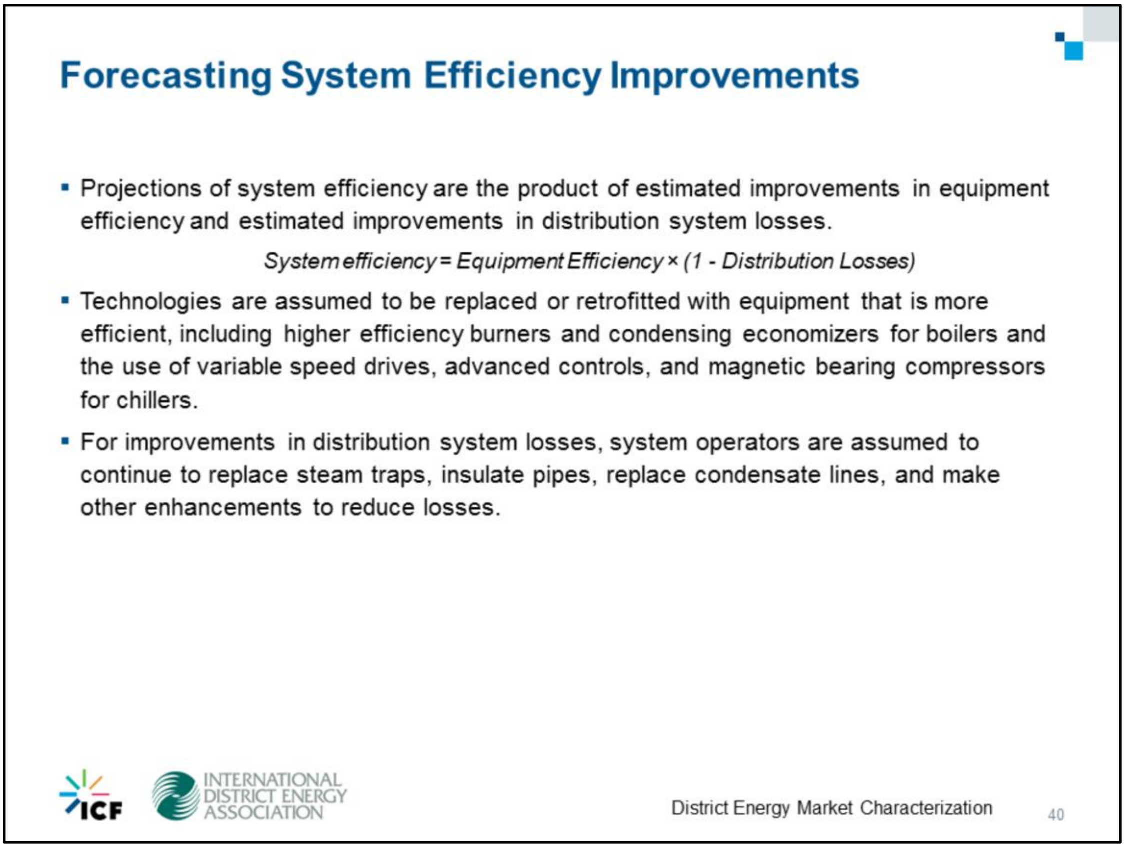
American College and University Presidents (ACUP) Climate Commitment

- A high-visibility effort to address global climate disruption undertaken by a network of colleges and universities that have made institutional commitments to eliminate net greenhouse gas emissions from specified campus operations, and to promote the research and educational efforts of higher education to equip society to re-stabilize the earth's climate.
- Its mission is to accelerate progress towards climate neutrality and sustainability by empowering the higher education sector to educate students, create solutions, and provide leadership-by-example for the rest of society.

- Treatment of District or Campus Thermal Energy in LEEDV2 and LEED 2009 – Design & Construction: https://www.usgbc.org/sites/default/files/DES%20Guidance.pdf
- CHP- Equipped District Energy: A Winning Strategy for LEED® and PEER: https://www.epa.gov/sites/production/files/2017-01/documents/chp-equipped-district-energy.pdf



The Future District Energy Market



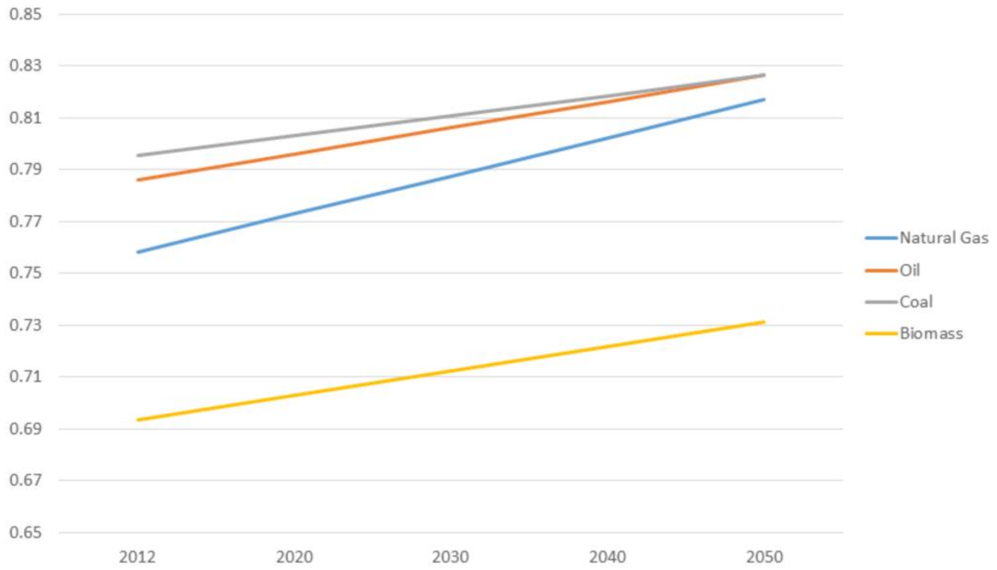
Forecasting System Efficiency Improvements

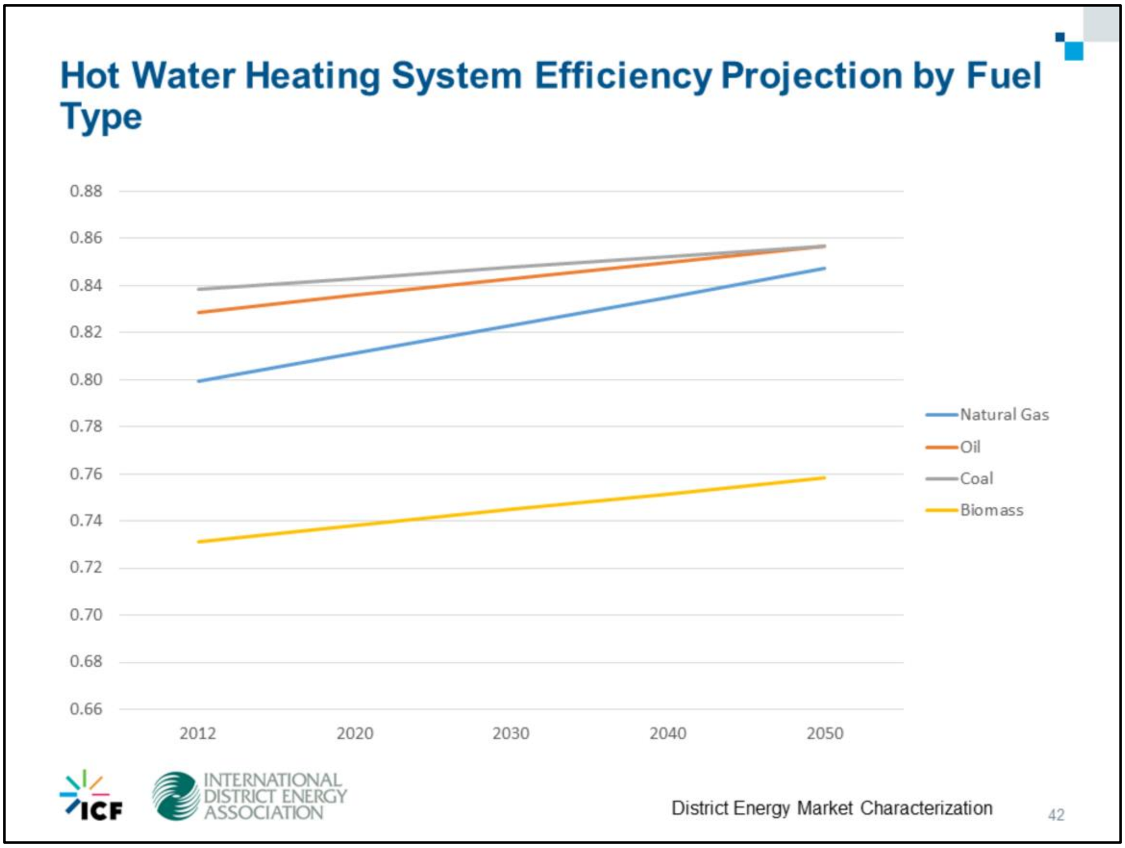
- Projections of system efficiency are the product of estimated improvements in equipment efficiency and estimated improvements in distribution system losses.

System efficiency = Equipment Efficiency × (1 - Distribution Losses)

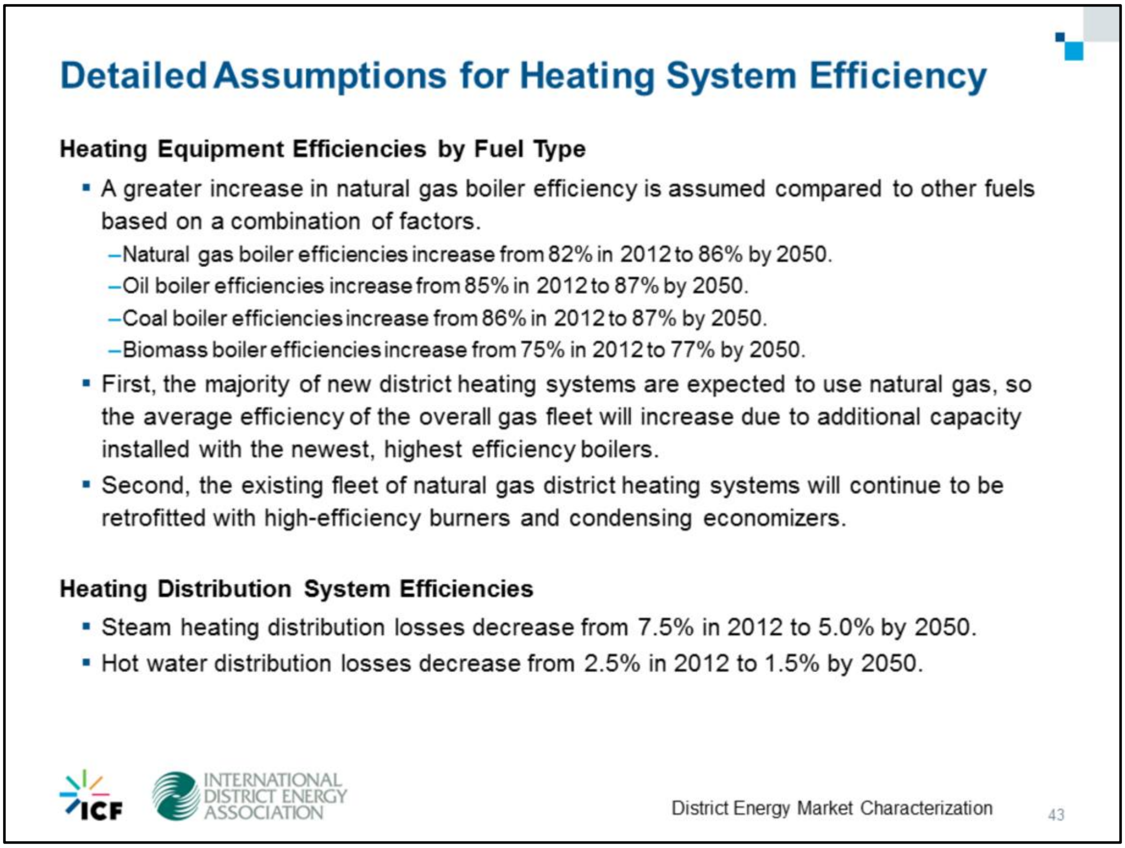
- Technologies are assumed to be replaced or retrofitted with equipment that is more efficient, including higher efficiency burners and condensing economizers for boilers and the use of variable speed drives, advanced controls, and magnetic bearing compressors for chillers.
- For improvements in distribution system losses, system operators are assumed to continue to replace steam traps, insulate pipes, replace condensate lines, and make other enhancements to reduce losses.

Steam Heating System Efficiency Projection by Fuel Type





Hot Water Heating System Efficiency Projection by Fuel Type



Detailed Assumptions for Heating System Efficiency

Heating Equipment Efficiencies by Fuel Type

- A greater increase in natural gas boiler efficiency is assumed compared to other fuels based on a combination of factors.
  - –Natural gas boiler efficiencies increase from 82% in 2012 to 86% by 2050.
  - –Oil boiler efficiencies increase from 85% in 2012 to 87% by 2050.
  - –Coal boiler efficiencies increase from 86% in 2012 to 87% by 2050.
  - –Biomass boiler efficiencies increase from 75% in 2012 to 77% by 2050.
- First, the majority of new district heating systems are expected to use natural gas, so the average efficiency of the overall gas fleet will increase due to additional capacity installed with the newest, highest efficiency boilers.
- Second, the existing fleet of natural gas district heating systems will continue to be retrofitted with high-efficiency burners and condensing economizers.

Heating Distribution System Efficiencies

- Steam heating distribution losses decrease from 7.5% in 2012 to 5.0% by 2050.
- Hot water distribution losses decrease from 2.5% in 2012 to 1.5% by 2050.

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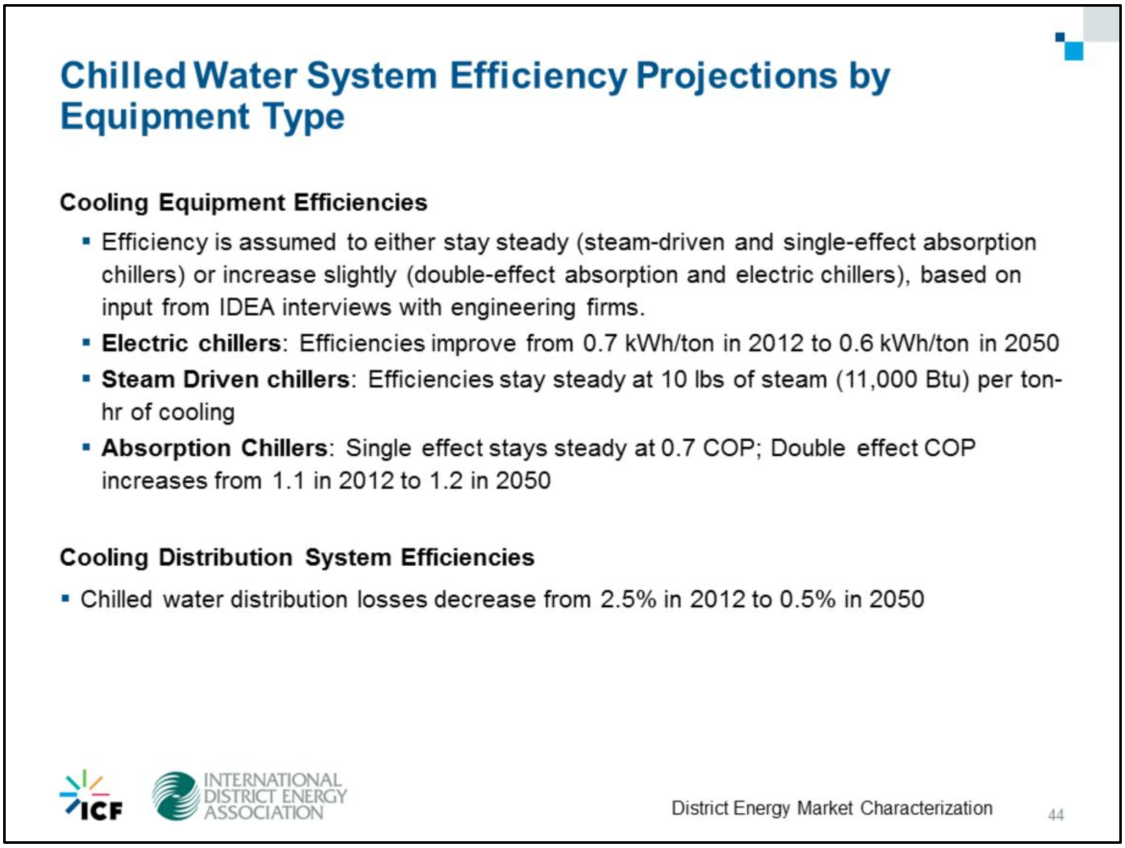
- Assumptions for oil and coal are based on relative positioning compared to natural gas in US DOE EERE Energy Tip sheet #15 “Benchmark the Fuel Cost of Steam Generation:” https://energy.gov/eere/amo/tip-sheets-system
- Assumptions for biomass are based on input from IDEA interviews with engineering firms.
- Assumptions for heating distribution losses in 2012 are based on EPA Energy Star Portfolio Manager Technical Reference on Source Energy: https://portfoliomanager.energystar.gov/pdf/reference/Source%20Energy.pdf
- Estimates on distribution system improvements over time are based on interviews with engineering firms and district energy system operators.



Chilled Water System Efficiency Projections by Equipment Type

Cooling Equipment Efficiencies

- Efficiency is assumed to either stay steady (steam-driven and single-effect absorption chillers) or increase slightly (double-effect absorption and electric chillers), based on input from IDEA interviews with engineering firms.
- **Electric chillers**: Efficiencies improve from 0.7 kWh/ton in 2012 to 0.6 kWh/ton in 2050
- **Steam Driven chillers**: Efficiencies stay steady at 10 lbs of steam (11,000 Btu) per ton-hr of cooling
- **Absorption Chillers**: Single effect stays steady at 0.7 COP; Double effect COP increases from 1.1 in 2012 to 1.2 in 2050

Cooling Distribution System Efficiencies

- Chilled water distribution losses decrease from 2.5% in 2012 to 0.5% in 2050

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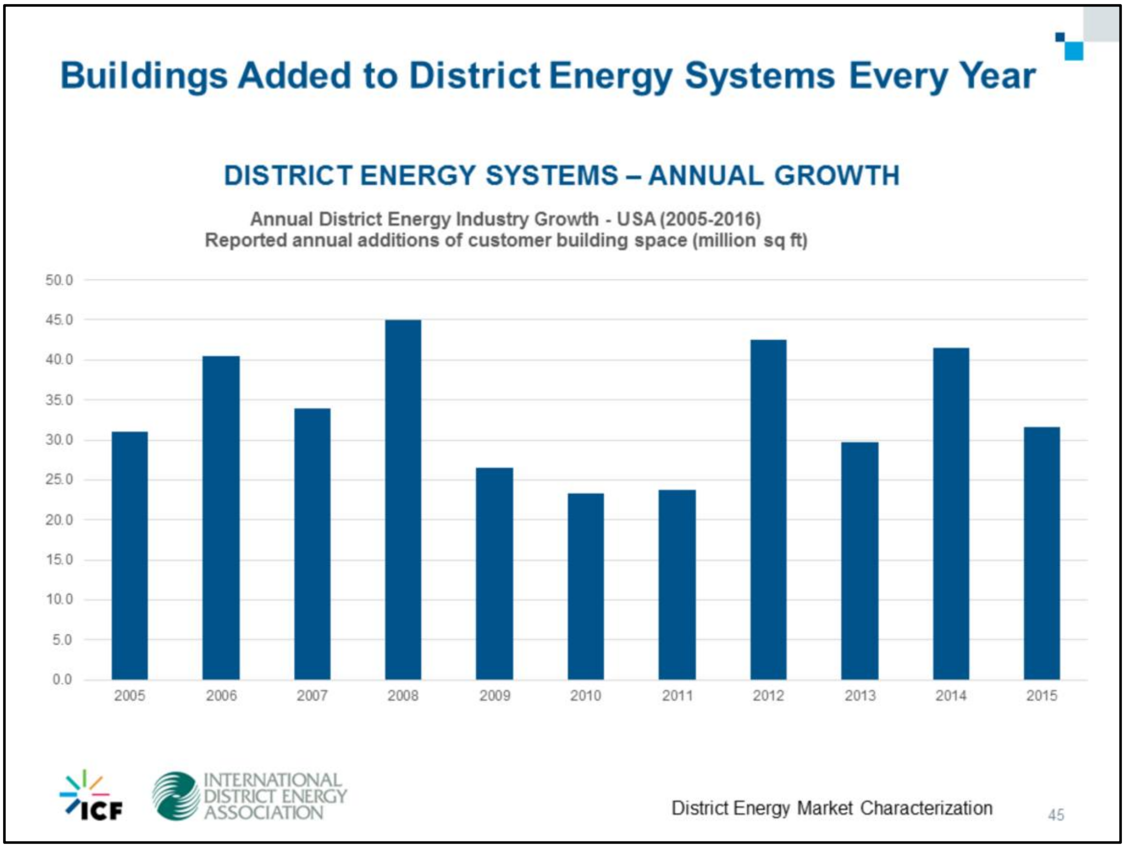
Magnetic bearing chiller compressors: https://energy.gov/eere/femp/magnetic-bearing-chiller-compressors



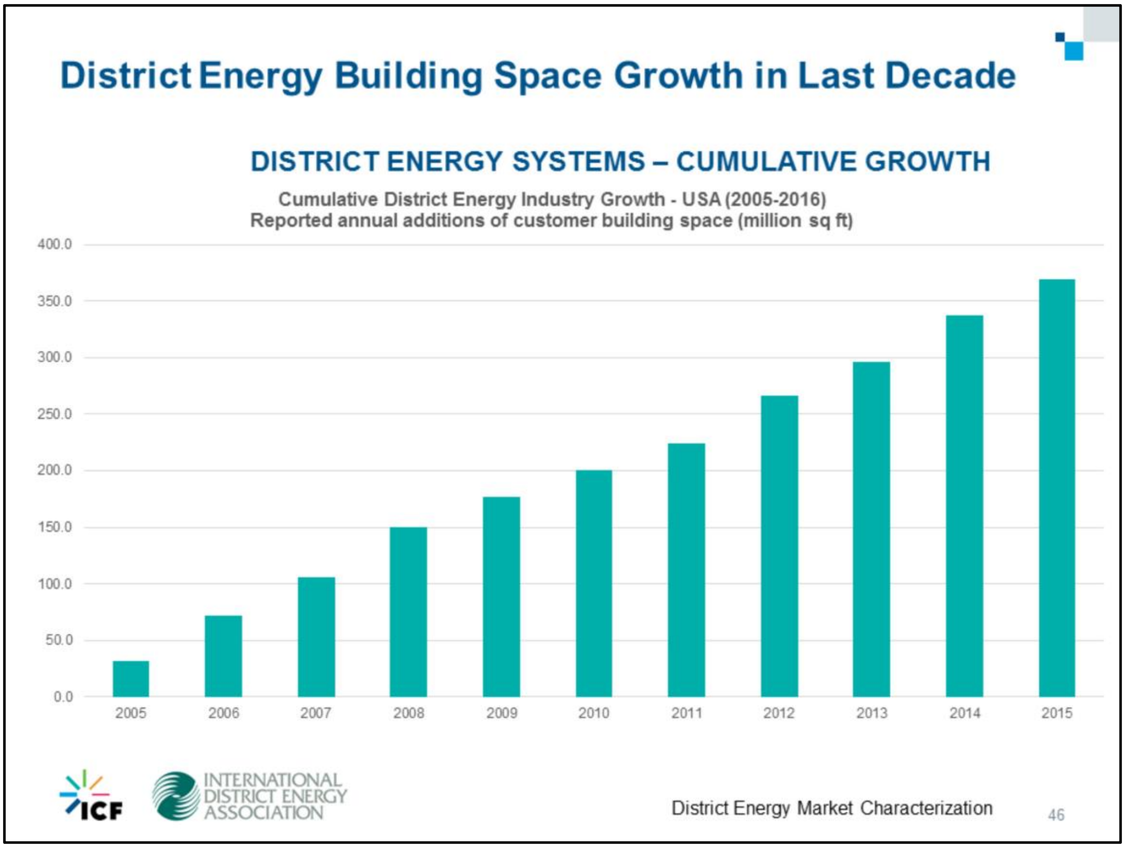
Buildings Added to District Energy Systems Every Year

DISTRICT ENERGY SYSTEMS – ANNUAL GROWTH

Annual District Energy Industry Growth - USA (2005-2016)
Reported annual additions of customer building space (million sq ft)

District Energy Market Characterization

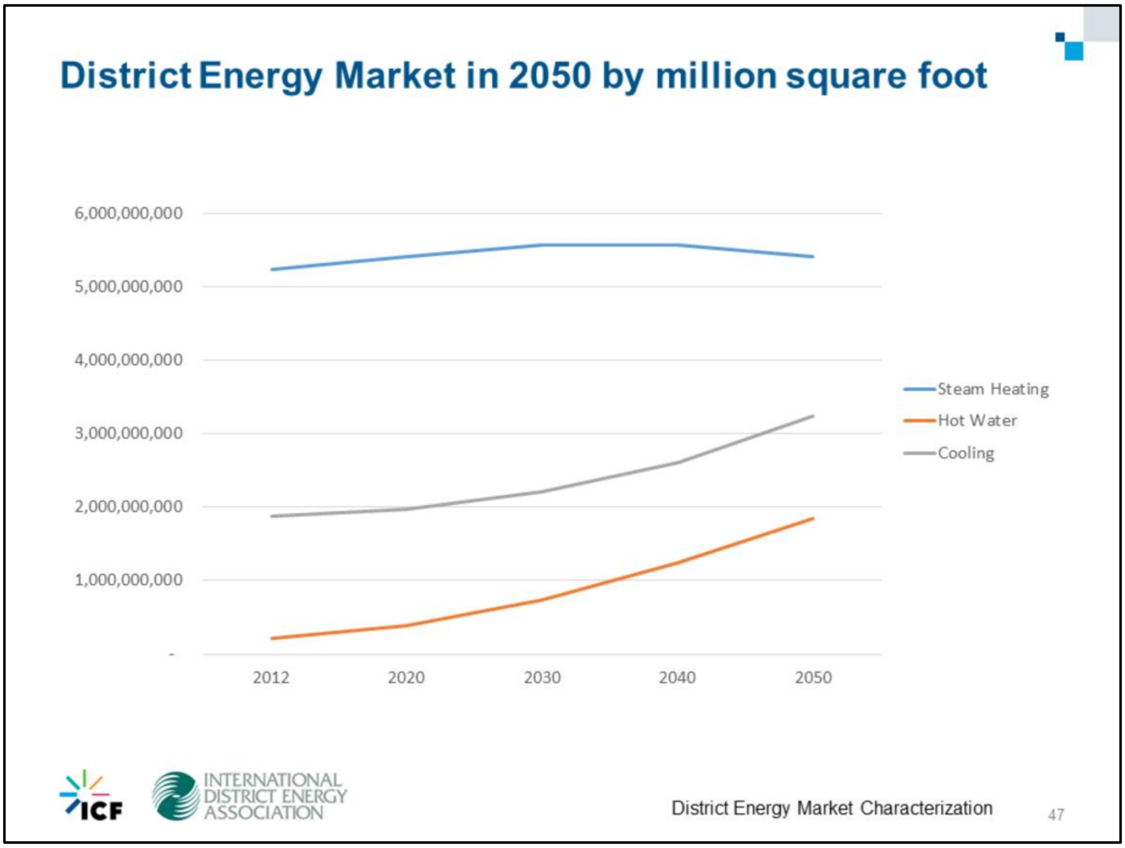
Industry-reported data on annual additions of customer building space since 2005 shows continued growth. Average annual growth (2012 – 2016) = 37.2 million sq ft. or approximately 0.65% growth per year.



District Energy Building Space Growth in Last Decade

DISTRICT ENERGY SYSTEMS – CUMULATIVE GROWTH

Cumulative District Energy Industry Growth - USA (2005-2016)
Reported annual additions of customer building space (million sq ft)



District Energy Market in 2050 by million square foot

District Energy Market Characterization

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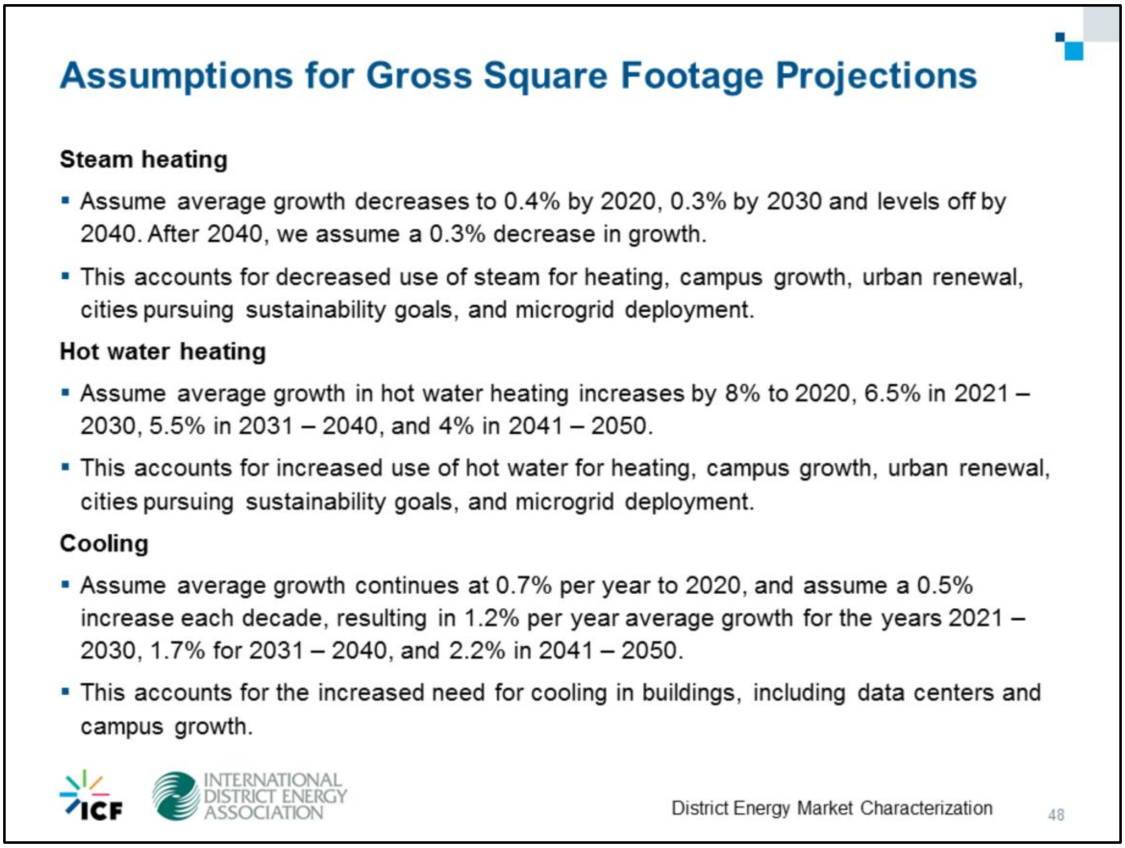
- Projections of gross square footage are based on an estimated average annual increase in square footage using data reported to IDEA during the most recent five year period (2012-2016), which resulted in 37.2 million square feet of average growth overall.
- With that estimate and an estimate of the total square footage served in 2012, we derive a baseline growth rate of 0.65% per year to use as the starting point for projections.
- Next, we estimate total square footage steam heating, hot water, and cooling capacity in the year 2012 and apply estimated percent annual increases for ten year periods up to 2020, 2030, 2040, and 2050 based on trends for steam, hot water, and cooling capacity identified by ICF and IDEA in conversations with district energy stakeholders.
- In general, trends reflect modest growth in square footage served by district energy, with a gradual transition from steam to hot water heating systems and a steady increase in cooling capacity.
- For more information on the technology developments, improvements in operations and maintenance, end-use sector growth, and the policy landscape that informed these forecasts, see earlier section, “Trends Impacting the District Energy Market.”
- *Note that the majority of cooling square footage is in shared systems (87%) and includes some of the same space as steam heating. Our estimate of total square footage includes total steam heating and hot water square footage and an estimate of square footage used ONLY for cooling to avoid double counting of square footage in shared systems.



Assumptions for Gross Square Footage Projections

Steam heating

- Assume average growth decreases to 0.4% by 2020, 0.3% by 2030 and levels off by 2040. After 2040, we assume a 0.3% decrease in growth.
- This accounts for decreased use of steam for heating, campus growth, urban renewal, cities pursuing sustainability goals, and microgrid deployment.

Hot water heating

- Assume average growth in hot water heating increases by 8% to 2020, 6.5% in 2021 – 2030, 5.5% in 2031 – 2040, and 4% in 2041 – 2050.
- This accounts for increased use of hot water for heating, campus growth, urban renewal, cities pursuing sustainability goals, and microgrid deployment.

Cooling

- Assume average growth continues at 0.7% per year to 2020, and assume a 0.5% increase each decade, resulting in 1.2% per year average growth for the years 2021 – 2030, 1.7% for 2031 – 2040, and 2.2% in 2041 – 2050.
- This accounts for the increased need for cooling in buildings, including data centers and campus growth.

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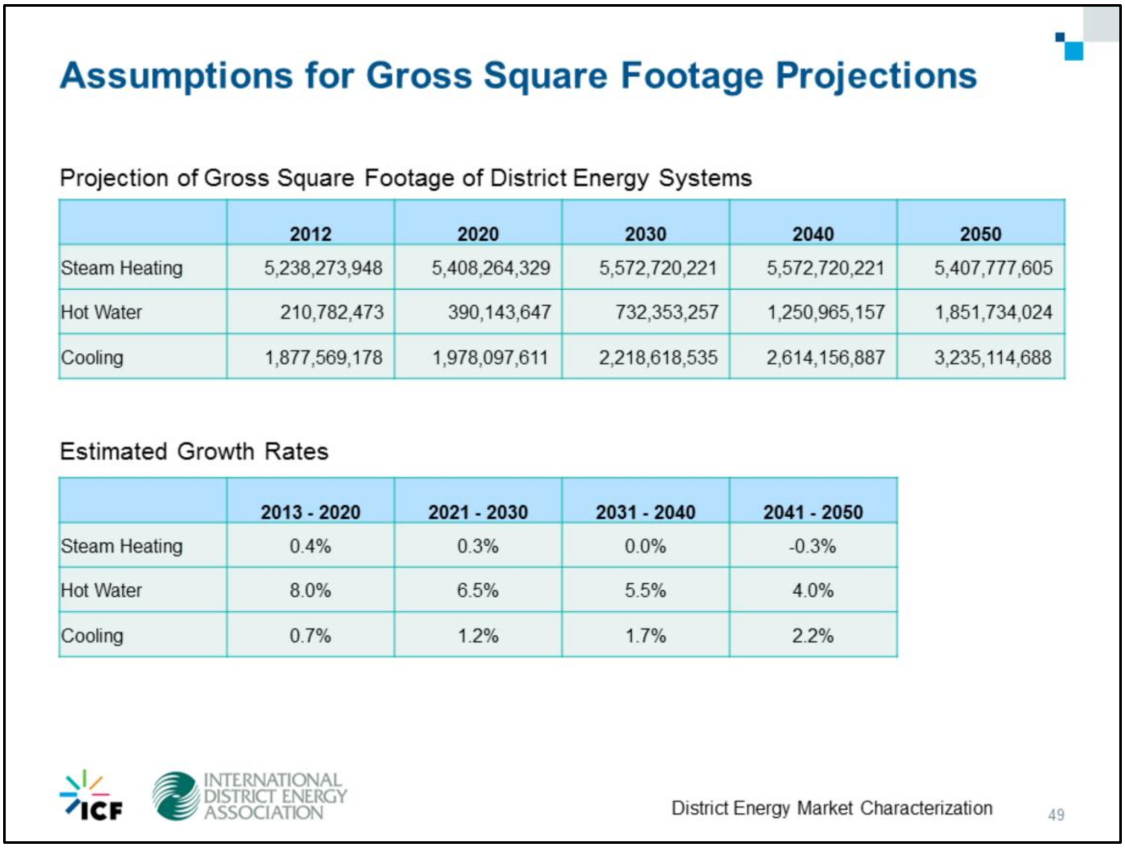
For more information on the technology trends and improvements in operations and maintenance that informed these forecasts, see earlier section, “Trends Impacting the District Energy Market.”



Assumptions for Gross Square Footage Projections

Projection of Gross Square Footage of District Energy Systems

	2012	2020	2030	2040	2050
Steam Heating	5,238,273,948	5,408,264,329	5,572,720,221	5,572,720,221	5,407,777,605
Hot Water	210,782,473	390,143,647	732,353,257	1,250,965,157	1,851,734,024
Cooling	1,877,569,178	1,978,097,611	2,218,618,535	2,614,156,887	3,235,114,688

Estimated Growth Rates

	2013 - 2020	2021 - 2030	2031 - 2040	2041 - 2050
Steam Heating	0.4%	0.3%	0.0%	-0.3%
Hot Water	8.0%	6.5%	5.5%	4.0%
Cooling	0.7%	1.2%	1.7%	2.2%

For more information on the technology trends and improvements in operations and maintenance that informed these forecasts, see earlier section, “Trends Impacting the District Energy Market.”

System Sketches: Technology and Fuel Trends

Microgrids

Institutions implementing district energy/CHP/microgrids to enhance business continuity and enable areas of refuge during extreme weather events.

Shands South Energy Center (Gainesville, FL)

- The CHP-based microgrid is a partnership between University of Florida Shands Cancer Hospital and Gainesville Regional Utilities, a municipal utility. It involved the integration and control of multiple local generation and storage assets (diesel generators, combustion turbine) to provide multiple levels of redundancy. The increased reliability and the ability to island have had immeasurable benefits in the storm-prone area.

Portsmouth Naval Shipyard (Kittery, ME)

- The U.S. Army Corps of Engineers and the U.S. Navy installed a microgrid to demonstrate islanding capabilities, which eliminates downtime during a loss of the electric public utility at Portsmouth Naval Shipyard in Kittery, Maine. The project included extensive upgrades to the shipyard's steam, power and control systems.

Princeton University (Princeton, NJ)

- Princeton's advanced microgrid uses multiple fuel sources, multiple power-generating assets, thermal energy storage, and modern digital controls to optimize and operate with an awareness of the real-time commodity costs of fuel and electricity. Princeton's gas-fueled CHP plant produced the heating, cooling, and electricity for the campus during Hurricane Sandy, keeping the university up and running when much of the state was dark.

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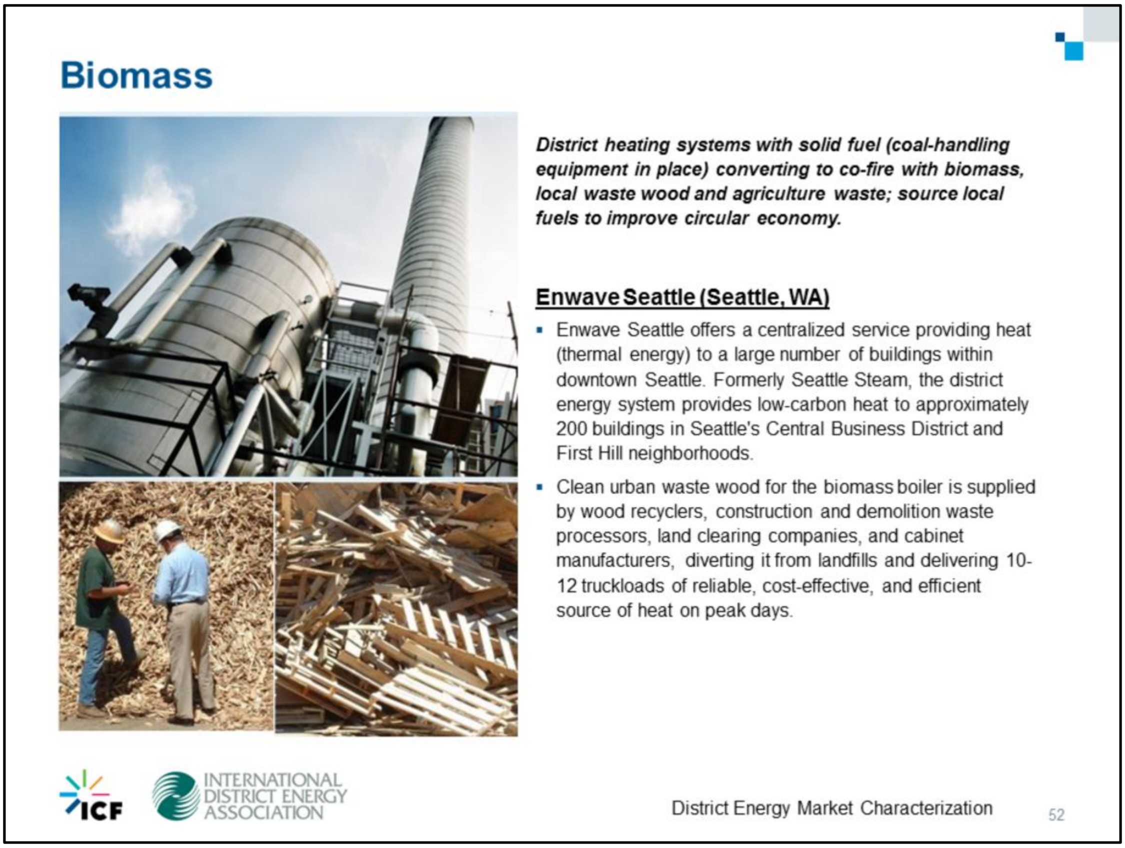
- Shands: http://relaymagazine.org/gru-serves-shands-cancer-center-reliable-microgrid
- Shipyard: http://www.ameresco.com/portfolio-item/portsmouth-naval-shipyard/
- Princeton: https://facilities.princeton.edu/news/the-princeton-energy-plant



Biomass

District heating systems with solid fuel (coal-handling equipment in place) converting to co-fire with biomass, local waste wood and agriculture waste; source local fuels to improve circular economy.

Enwave Seattle (Seattle, WA)

- Enwave Seattle offers a centralized service providing heat (thermal energy) to a large number of buildings within downtown Seattle. Formerly Seattle Steam, the district energy system provides low-carbon heat to approximately 200 buildings in Seattle's Central Business District and First Hill neighborhoods.
- Clean urban waste wood for the biomass boiler is supplied by wood recyclers, construction and demolition waste processors, land clearing companies, and cabinet manufacturers, diverting it from landfills and delivering 10-12 truckloads of reliable, cost-effective, and efficient source of heat on peak days.

Enwave Seattle: http://enwaveseattle.com/

Renewable Resource Integration

Princeton University (Princeton, NJ): Princeton's campus includes a 4.5 MW solar PV farm and a 15 MW CHP plant. Because of space considerations, the 27-acre solar PV installation is located off-campus, and electricity is delivered via a 13 KV cable. 5 - 6% of the campus's annual electricity consumption is produced at the solar farm.

Massachusetts Institute of Technology (Cambridge, MA)

Arizona State University: ASU has 21 MW of PV installed across its four campuses and the ASU Research Park.

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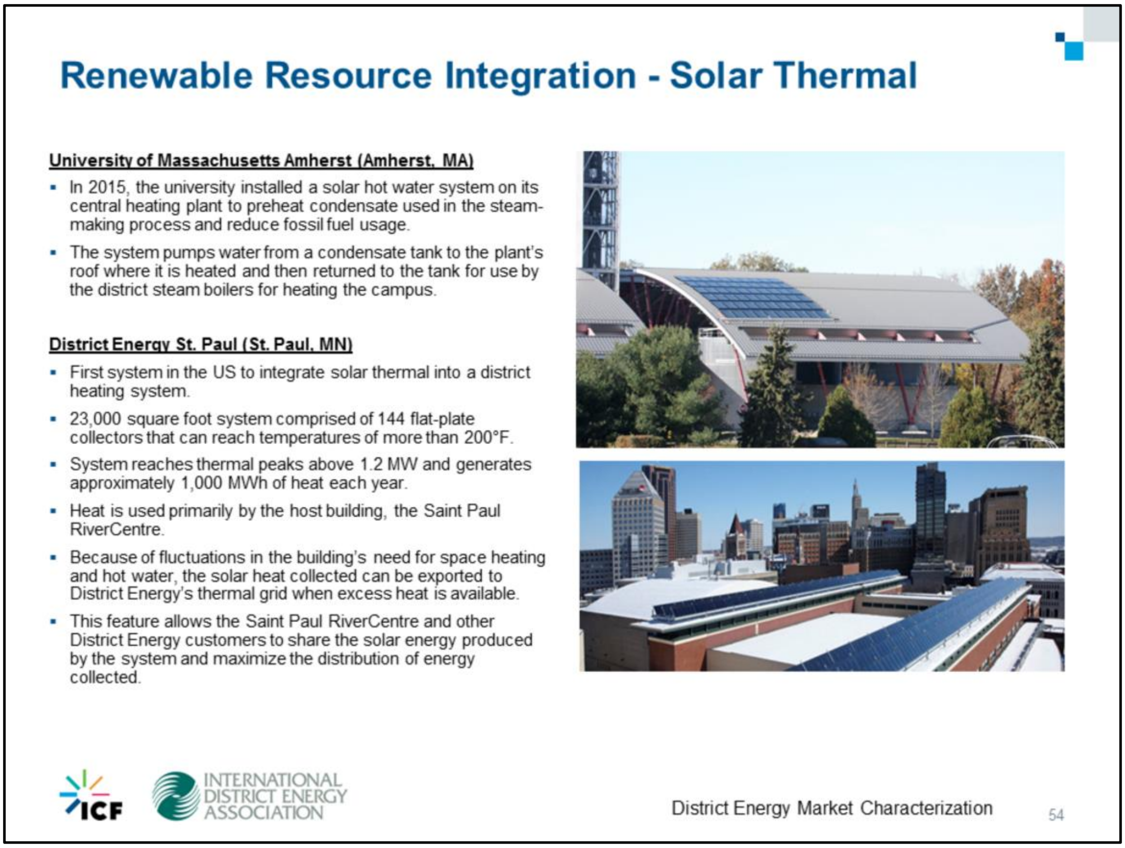
- Campus Solar: http://www.energydigital.com/top-10/top-10-which-campuses-take-cake-solar-energy
- Princeton: https://facilities.princeton.edu/news/the-princeton-energy-plant
- MIT: http://web.mit.edu/facilities/environmental/beep.html#renewables; http://web.mit.edu/facilities/about/maint-util/utilities/index.html
- ASU: https://wikivisually.com/wiki/Az_state_university; https://asunow.asu.edu/content/sun-devils-soak-solar-power



Renewable Resource Integration - Solar Thermal

University of Massachusetts Amherst (Amherst, MA)

- In 2015, the university installed a solar hot water system on its central heating plant to preheat condensate used in the steam-making process and reduce fossil fuel usage.
- The system pumps water from a condensate tank to the plant's roof where it is heated and then returned to the tank for use by the district steam boilers for heating the campus.

District Energy St. Paul (St. Paul, MN)

- First system in the US to integrate solar thermal into a district heating system.
- 23,000 square foot system comprised of 144 flat-plate collectors that can reach temperatures of more than 200°F.
- System reaches thermal peaks above 1.2 MW and generates approximately 1,000 MWh of heat each year.
- Heat is used primarily by the host building, the Saint Paul RiverCentre.
- Because of fluctuations in the building's need for space heating and hot water, the solar heat collected can be exported to District Energy's thermal grid when excess heat is available.
- This feature allows the Saint Paul RiverCentre and other District Energy customers to share the solar energy produced by the system and maximize the distribution of energy collected.

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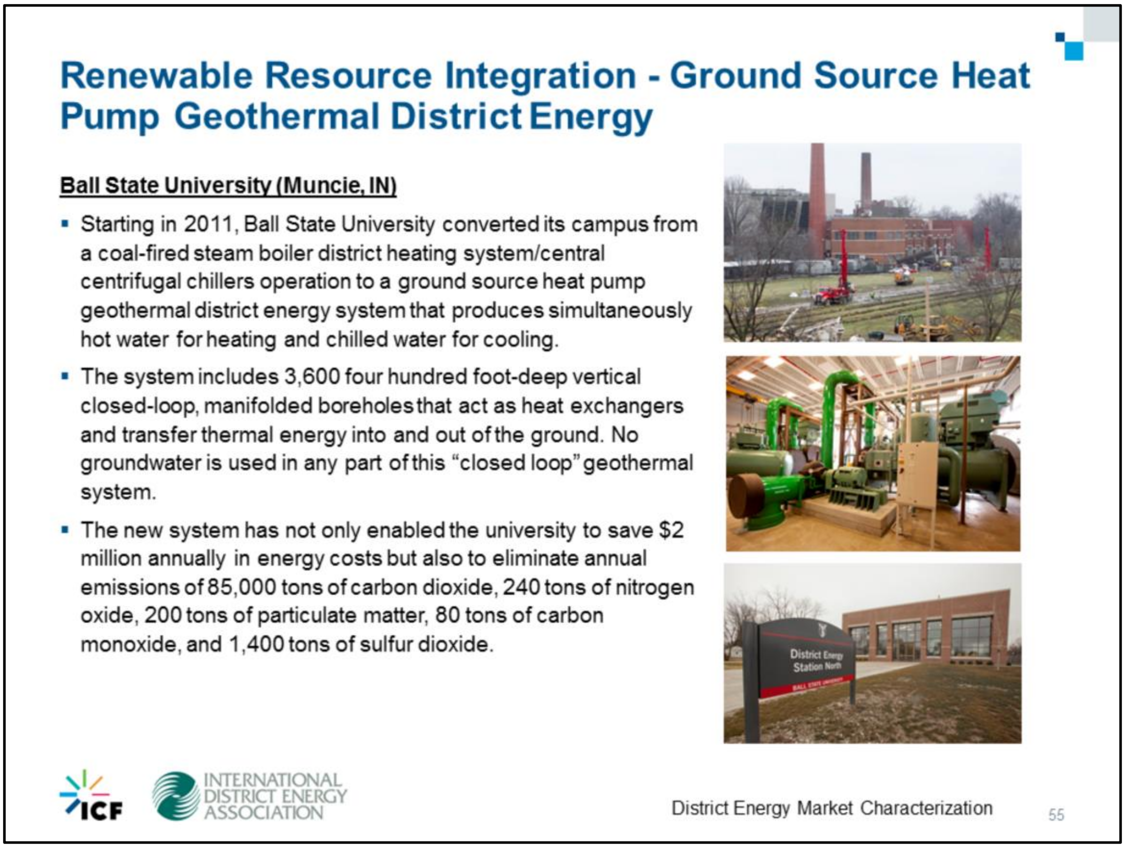
- UMass Amherst Solar Hot Water: https://www.umass.edu/sustainability/climate-change-energy/solar/central-heating-plants-solar-hot-water-system
- DE St. Paul: http://www.districtenergy.com/technologies/solar-thermal/



Renewable Resource Integration - Ground Source Heat Pump Geothermal District Energy

Ball State University (Muncie, IN)

- Starting in 2011, Ball State University converted its campus from a coal-fired steam boiler district heating system/central centrifugal chillers operation to a ground source heat pump geothermal district energy system that produces simultaneously hot water for heating and chilled water for cooling.
- The system includes 3,600 four hundred foot-deep vertical closed-loop, manifolded boreholes that act as heat exchangers and transfer thermal energy into and out of the ground. No groundwater is used in any part of this "closed loop" geothermal system.
- The new system has not only enabled the university to save $2 million annually in energy costs but also to eliminate annual emissions of 85,000 tons of carbon dioxide, 240 tons of nitrogen oxide, 200 tons of particulate matter, 80 tons of carbon monoxide, and 1,400 tons of sulfur dioxide.

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District Energy Market Characterization 55

Ball State: http://cms.bsu.edu/about/geothermal; http://www.districtenergy-digital.org/districtenergy/2017q4?search_term=ball%20state&doc_id=-1&search_term=ball%20state&pg=16#pg16

Renewable Resource Integration - Municipal Solid Waste

Detroit Thermal, Detroit, MI

- Provides space heating, hot water, and cooling for more than 100 buildings in the downtown area, totaling over 30 million square feet of office, medical, industrial, and assembly space.
- Receives majority of steam needs from sister company Detroit Renewable Power through their waste heat recovery process.
- Detroit Renewable Power operates a waste-to-energy plant that can convert up to 3,300 tons of municipal solid waste to generate up to 68 MW of electricity and provide 550,000 lbs/hr of steam.
- City of Detroit reduces its waste volume by 90% and delivers thermal services from renewable sources.

Detroit Thermal MSW: http://detroitthermal.com/renewable-energy/

Absorption Chillers

MARINE CORPS AIR GROUND COMBAT CENTER (TWENTYNINE PALMS, CA)

- Onsite 7.2 MW dual-fueled CHP system (natural gas and diesel)
- Hot turbine exhaust is captured in a heat-recovery generator to supply the base's high-temperature hot water system and to power a 200-ton absorption chiller for turbine inlet air cooling and turbine hall space conditioning.
- The turbine will provide approximately 30 to 35 MMBtu per hour of high-temperature hot water through the heat-recovery hot-water generator.
- During summer, the high-temperature hot water to power three new absorption chillers, one in each new chiller plant (approximately 1,650 tons of cooling).

HUDSON YARDS (NEW YORK CITY, NY)

- Hudson Yards is the largest private real estate development in the US and the largest development in New York City since Rockefeller Center.
- The site will include more than 18 million square feet of commercial and residential space, state-of-the-art office towers, more than 100 shops, and approximately 4,000 residences.
- Four multi-energy Thermax absorption chillers will provide chilled and hot water for air conditioning.
- Each chiller is designed for 664 tons of cooling and 4,280 thousand Btu/hr of heating, driven by exhaust gases and heat from jacket water coming from 3.3 MW GE Jenbacher natural gas engines that generate electricity for the buildings.

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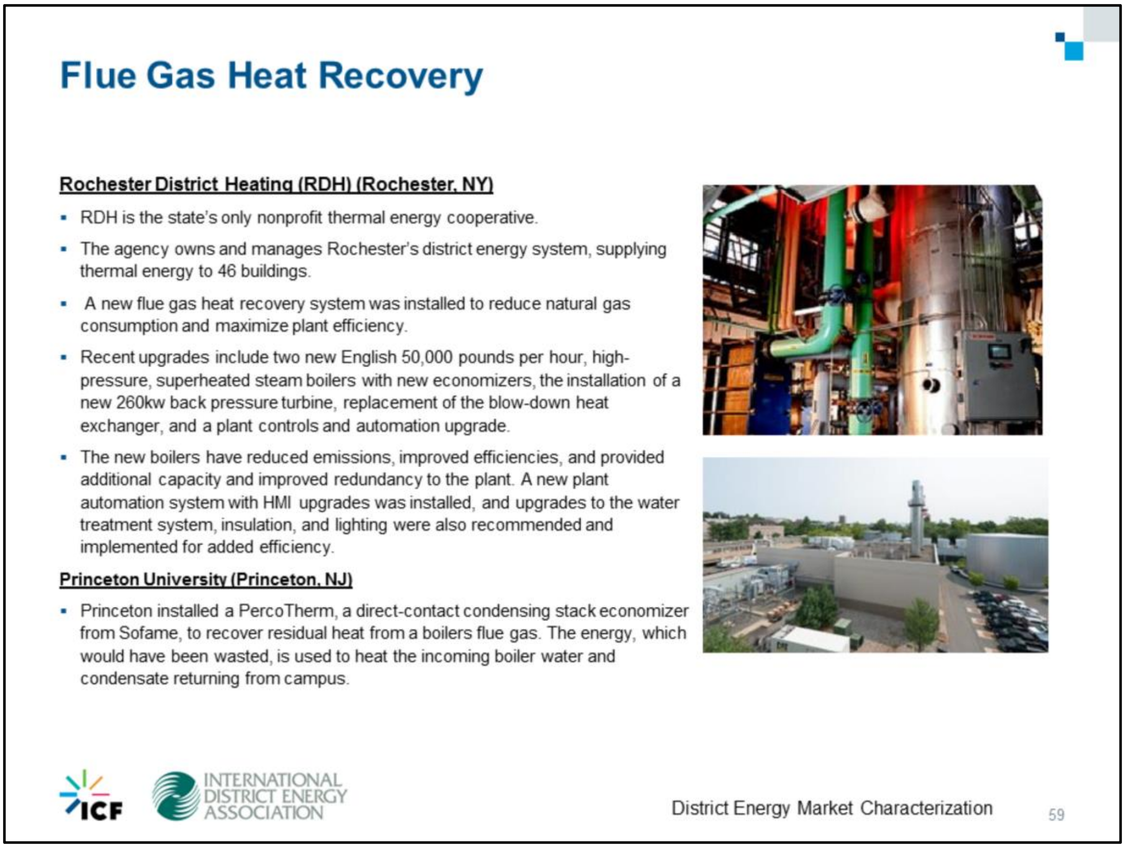
- TwentyNine Palms: http://greenfleet.dodlive.mil/files/2010/04/29-Palms.pdf
- TwentyNine Palms: http://www.decengineers.com/dec-projects/military/project-4/
- Hudson Yards: https://www.smartcitiesdive.com/ex/sustainablecitiescollective/planning-smarter-cities-developing-district-energy/158906/
- Hudson Yards: https://thermaxprofetherm.wordpress.com/2016/05/16/thermaxs-chiller-heaters-for-new-yorks-hudson-yards-redevelopment-project/

System Sketches: Improved Operations and Maintenance



Flue Gas Heat Recovery

Rochester District Heating (RDH) (Rochester, NY)

- RDH is the state's only nonprofit thermal energy cooperative.
- The agency owns and manages Rochester's district energy system, supplying thermal energy to 46 buildings.
- A new flue gas heat recovery system was installed to reduce natural gas consumption and maximize plant efficiency.
- Recent upgrades include two new English 50,000 pounds per hour, high-pressure, superheated steam boilers with new economizers, the installation of a new 260kw back pressure turbine, replacement of the blow-down heat exchanger, and a plant controls and automation upgrade.
- The new boilers have reduced emissions, improved efficiencies, and provided additional capacity and improved redundancy to the plant. A new plant automation system with HMI upgrades was installed, and upgrades to the water treatment system, insulation, and lighting were also recommended and implemented for added efficiency.

Princeton University (Princeton, NJ)

- Princeton installed a PercoTherm, a direct-contact condensing stack economizer from Sofame, to recover residual heat from a boilers flue gas. The energy, which would have been wasted, is used to heat the incoming boiler water and condensate returning from campus.

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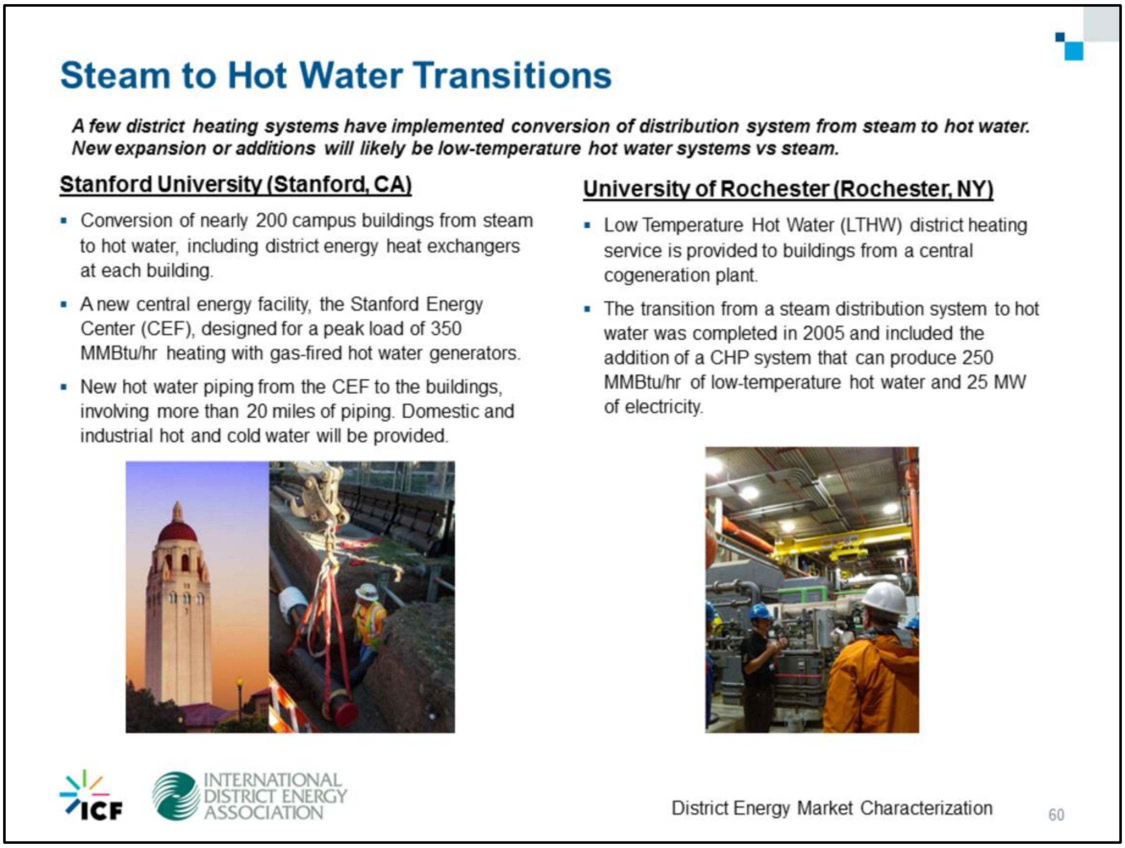
- Rochester: https://www.emcorbetlem.com/case-studies/rochester-district-heating
- Princeton: http://www.sofame.com/home.htm



Steam to Hot Water Transitions

A few district heating systems have implemented conversion of distribution system from steam to hot water. New expansion or additions will likely be low-temperature hot water systems vs steam.

Stanford University (Stanford, CA)

- Conversion of nearly 200 campus buildings from steam to hot water, including district energy heat exchangers at each building.
- A new central energy facility, the Stanford Energy Center (CEF), designed for a peak load of 350 MMBtu/hr heating with gas-fired hot water generators.
- New hot water piping from the CEF to the buildings, involving more than 20 miles of piping. Domestic and industrial hot and cold water will be provided.

University of Rochester (Rochester, NY)

- Low Temperature Hot Water (LTHW) district heating service is provided to buildings from a central cogeneration plant.
- The transition from a steam distribution system to hot water was completed in 2005 and included the addition of a CHP system that can produce 250 MMBtu/hr of low-temperature hot water and 25 MW of electricity.

- Stanford: https://www.districtenergy.org/HigherLogic/System/DownloadDocumentFile.ashx?DocumentFileKey=f4d12883-8cd0-62fd-5860-24f29c94819d&forceDialog=0
- U Rochester:
    - https://www.facilities.rochester.edu/central_utilities/
    - http://www.urecon.com/documents/pdfs/projects/IDEA_UofR.pdf
    - http://www.fvbenergy.com/projects/university-of-rochester-system-expansion-and-conversion/

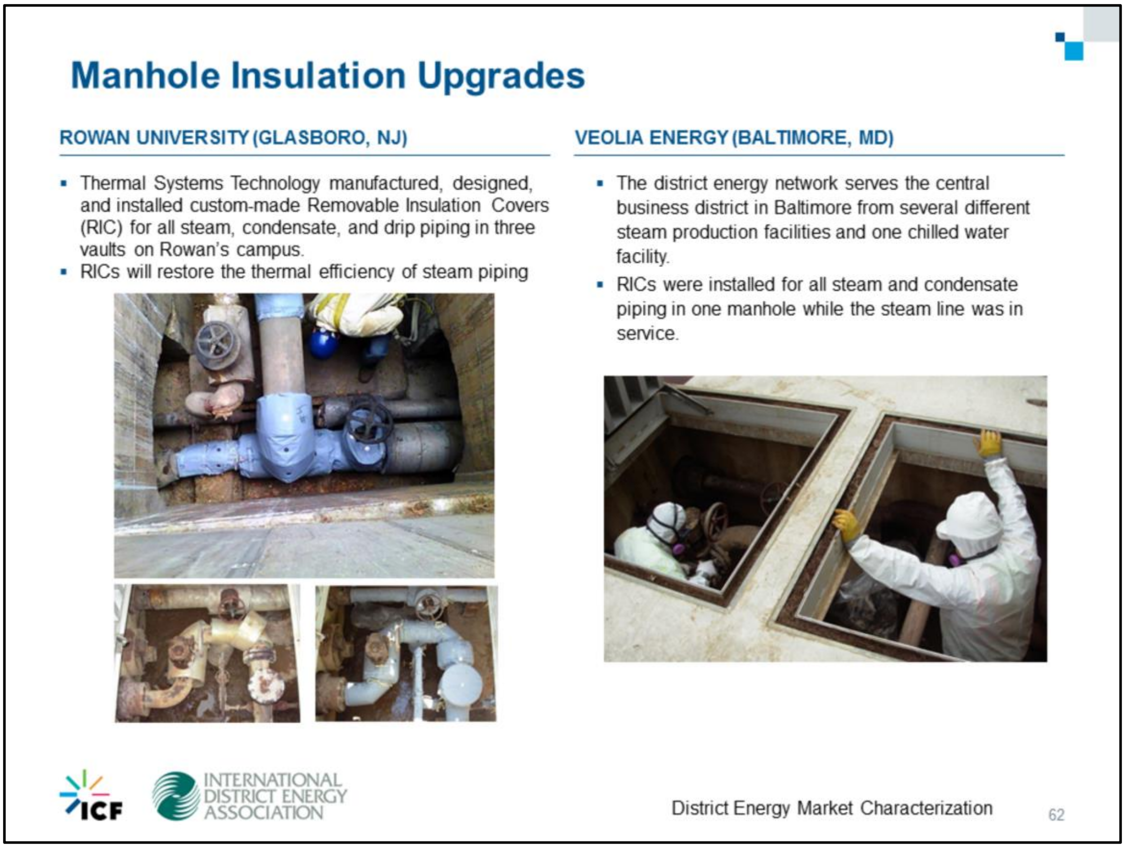
Steam Trap Audits and Replacement

Northwestern University (Evanston, IL)

- The annual steam trap survey begun in 2013 has helped monitor and replace failing traps, resulting in savings of almost $2 million each year.

Bronx VA Hospital (New York City, NY)

- The Bronx campus of the James J. Peters Healthcare System (formerly known as the Bronx VA Medical Center) replaced steam traps and installed a new steam trap monitoring system.
- The new steam trap monitoring system will ensure energy savings are realized and sustained by alerting maintenance when a trap fails.



Manhole Insulation Upgrades

ROWAN UNIVERSITY (GLASBORO, NJ)

- Thermal Systems Technology manufactured, designed, and installed custom-made Removable Insulation Covers (RIC) for all steam, condensate, and drip piping in three vaults on Rowan's campus.
- RICs will restore the thermal efficiency of steam piping

VEOLIA ENERGY (BALTIMORE, MD)

- The district energy network serves the central business district in Baltimore from several different steam production facilities and one chilled water facility.
- RICs were installed for all steam and condensate piping in one manhole while the steam line was in service.

- Veolia: Veolia Energy Baltimore owns and operates over 15 miles of steam distribution piping that serves over 250 commercial, government, institutional, and hospitality customers.
- Rowan: Crews removed and disposed of all existing insulation from the steam, condensate, and drip piping prior to measurement, manufacture, and installation of RICs.

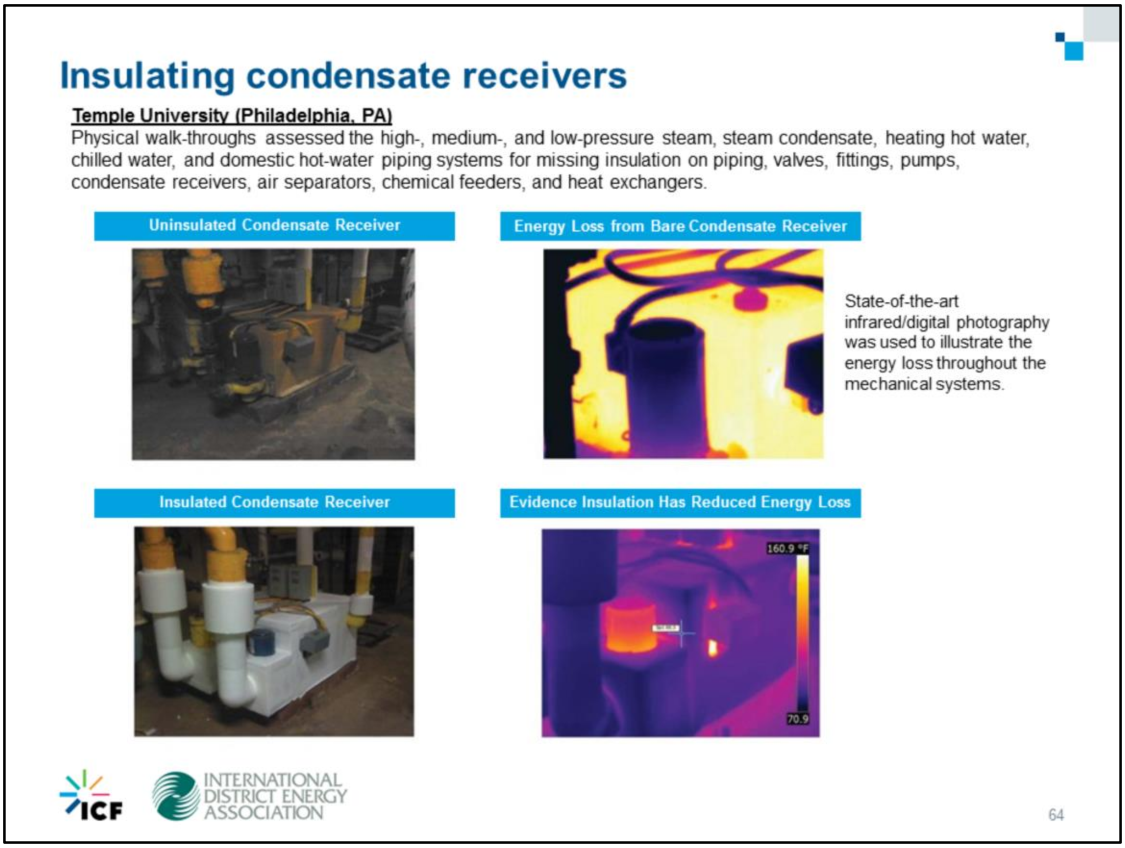
Steam Pipe Restoration

NRG (Harrisburg, PA)

- October 2014 - A section of buried low-pressure steam piping was thermally restored with ConduFill® injected into the void space within a 14-inch diameter outer steel casing to restore thermal efficiency, prolonging the life of the piping system.

GSA (Washington, DC)

- July 2016 - Steam line restoration project for GSA, upgraded and restored the thermal efficiency of a section of 12-inch high-pressure steam piping on Pennsylvania Ave.



Insulating condensate receivers

Temple University (Philadelphia, PA)

Physical walk-throughs assessed the high-, medium-, and low-pressure steam, steam condensate, heating hot water, chilled water, and domestic hot-water piping systems for missing insulation on piping, valves, fittings, pumps, condensate receivers, air separators, chemical feeders, and heat exchangers.

Uninsulated Condensate Receiver

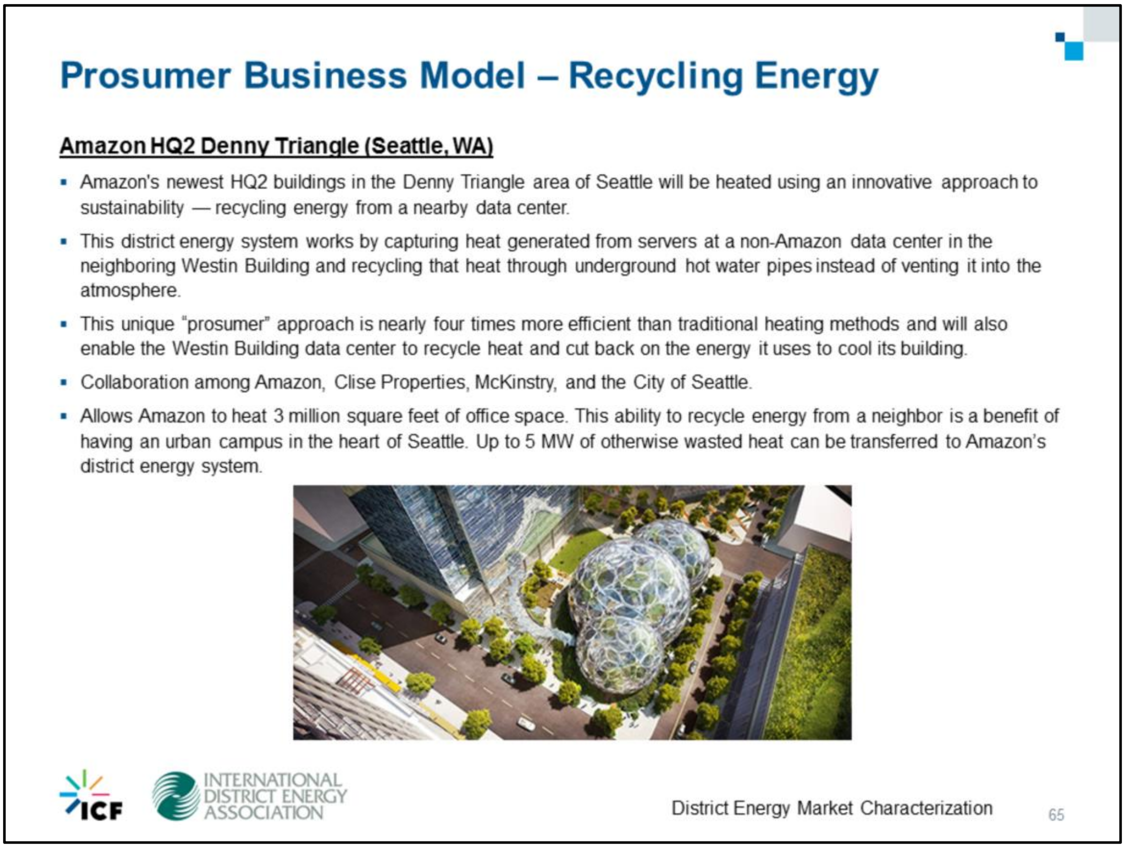
Energy Loss from Bare Condensate Receiver

State-of-the-art infrared/digital photography was used to illustrate the energy loss throughout the mechanical systems.

Insulated Condensate Receiver

Evidence Insulation Has Reduced Energy Loss

Temple: https://insulation.org/io/articles/insulation-passes-the-test-at-temple-university/



Prosumer Business Model – Recycling Energy

Amazon HQ2 Denny Triangle (Seattle, WA)

- Amazon's newest HQ2 buildings in the Denny Triangle area of Seattle will be heated using an innovative approach to sustainability — recycling energy from a nearby data center.
- This district energy system works by capturing heat generated from servers at a non-Amazon data center in the neighboring Westin Building and recycling that heat through underground hot water pipes instead of venting it into the atmosphere.
- This unique "prosumer" approach is nearly four times more efficient than traditional heating methods and will also enable the Westin Building data center to recycle heat and cut back on the energy it uses to cool its building.
- Collaboration among Amazon, Clise Properties, McKinstry, and the City of Seattle.
- Allows Amazon to heat 3 million square feet of office space. This ability to recycle energy from a neighbor is a benefit of having an urban campus in the heart of Seattle. Up to 5 MW of otherwise wasted heat can be transferred to Amazon's district energy system.

Amazon: https://dbdh.dk/district-energy-and-amazons-hq2-decision/

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