

Quantitative Analysis of District Energy in University Campuses

: District Energy Trends in USA Campuses

**S. M. Rakiul Islam, Md. Kamal Hossain,
Sung-Yeul Park**

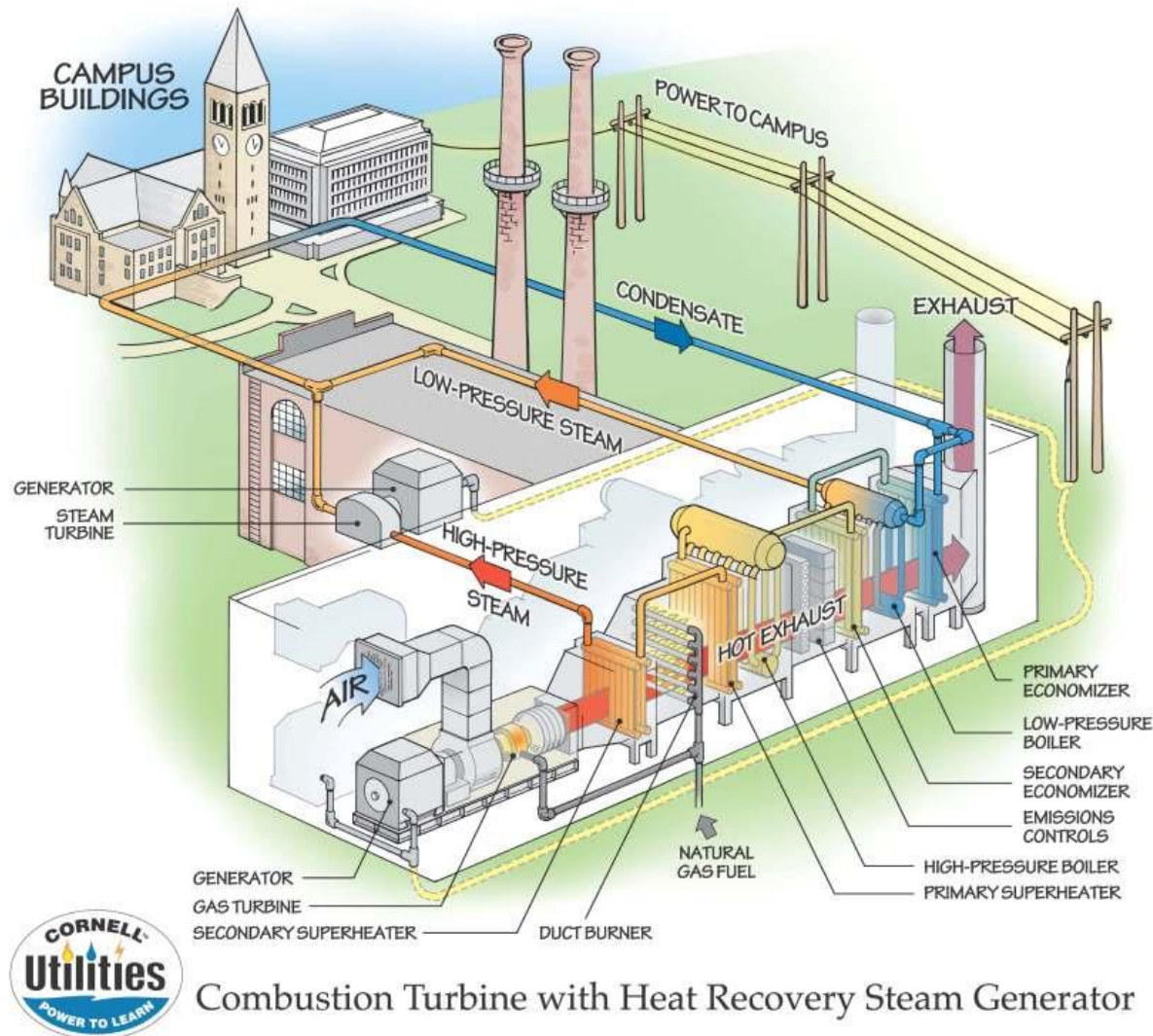
February 9th , 2016

Department of Electrical and Computer Engineering
Center for Clean Energy Engineering
University of Connecticut

Outlines

- Introduction and Motivation
- General Configuration of CHP on US Campuses
- UConn Combined Heat and Power Plant
- Timeline of Survey and Analysis
- U.S. DOE CHP Installation Database
- Descriptive Analysis of Survey Data
- Statistics of District Energy in USA Campuses
- Conclusions
- Appendix: Energy Policies for CA, IL, and MA

Introduction: CHP Facilities on US Campuses



Combustion Turbine with Heat Recovery Steam Generator

Source: <https://energyandsustainability.fs.cornell.edu/util/heating/production/cep.cfm/>

Motivation

- IDEA presentation, Nov 2003
- Update of CHP on Campuses, since 2003
- Advances in Technologies

Current CHP Opportunities at U.S. Colleges and Universities

**Report for Oak Ridge National Laboratory and
the U.S. Department of Energy**

November 2003



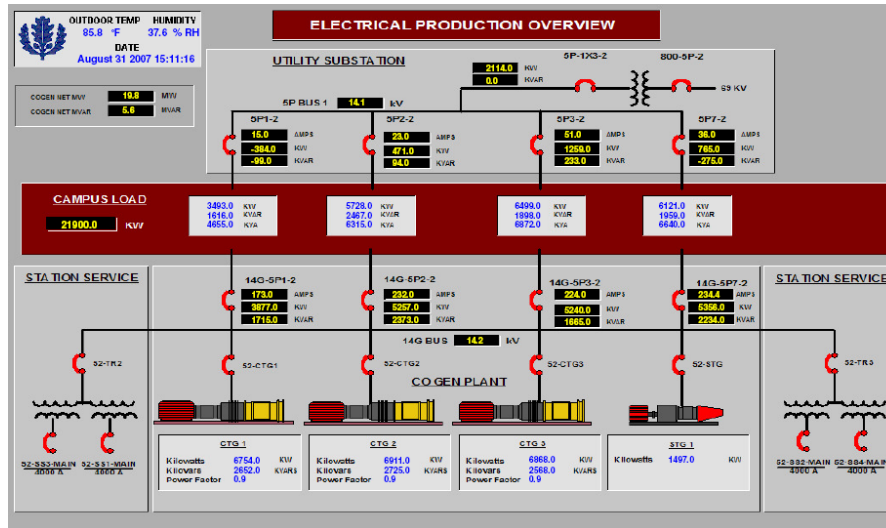
Source: <http://energy.gov/eere/amo/downloads/chp-opportunities-us-colleges-and-universities-november-2003>

UConn Combined Heat and Power Plant

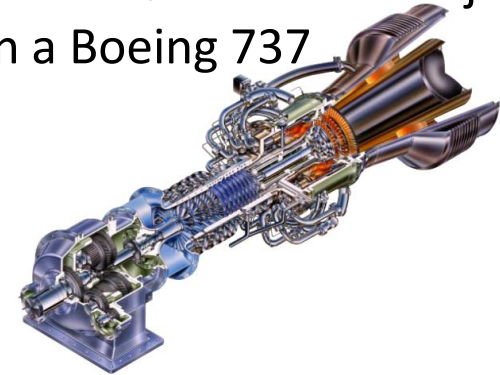


Source: www.energy.uconn.edu

UConn Combined Heat and Power Plant



7 MW - About 1/3 the size of a jet engine on a Boeing 737



Solar Turbines
A Caterpillar Company

Taurus 70 Gas Turbine
for Generator Applications



Source: www.energy.uconn.edu

Timeline of Survey and Analysis

Period	Activities
June – August, 2015	Surveyed 92 University campuses among IDEA members
Sep – Oct, 2015	Updated 87 surveyed universities with additional parameters and verified first screening data
Nov – Dec, 2015	Surveyed additional 175 University campuses based on DOE database. Combined data from two screening and verified the combined data
Jan, 2016	Analyzed data using SPSS (statistical software) 252: IDEA members(79), Non-IDEA members(173) Total number of University Facilities: 255 Total number of University Campuses: 252 Multiple facilities at the same University: 3

- Minimum capacity of these campus from DOE database: 5kW

1st Screened Universities: IDEA members

Arizona State University
Auburn University
Ball State University
Bowdoin College
Bucknell University
California Institute of Technology
Carnegie Mellon University
Colgate University
Colorado School of Mines
Colorado State University
Columbia University
Cornell University
Dartmouth College
Duke University FMD
Duquesne University
Emory University
English Biomass Partners - Ferrum College
Georgia Institute of Technology
Harvard University
Illinois State University
Iowa State University
Johns Hopkins University
Kent State University
Massachusetts Institute of Technology
Miami University
Michigan State University
North Carolina State University
Northern Arizona University
Oberlin College and Conservatory

Ohio University
Oklahoma State University
Pennsylvania State University
Princeton University
Purdue University
Rice University
Rowan University
Rutgers University
Stanford University
Syracuse University
Texas A&M University
Texas State University
Texas Tech University
The George Washington University
Tufts University
University of Akron
University of Alabama at Birmingham
University of Alaska Fairbanks
University of Alberta
University of Arizona
University of Arkansas
University of California - Los Angeles
University of California - San Francisco
University of Cincinnati
University of Colorado - Boulder
University of Connecticut
University of Florida
University of Georgia
University of Idaho

University of Illinois
University of Iowa
University of Maine
University of Maryland
University of Massachusetts Medical School
University of Michigan
University of Minnesota
University of Missouri at Columbia
University of Nebraska, Lincoln
University of Nevada Reno
University of New Hampshire
University of New Mexico
University of North Carolina - Chapel Hill
University of Oregon
University of Rochester
University of Texas - Austin
University of Texas Medical Branch
University of Utah
University of Vermont
University of Virginia
University of Washington
University of Wisconsin - Madison
University of Wyoming
Utah State University
Vanderbilt University
Wake Forest University
Yale University
University of California San Diego
University of Massachusetts Amherst

U.S. DOE CHP Installation Database

U.S. DOE Combined Heat and Power
Installation Database

Add a CHP Site

Home

About

Download Data

Sign Up

Search



Choose a State

Click a state below to view CHP data

LOG IN

Choose a state

Example Search
Window
for California

Combined Heat and Power Installations in California

LOG IN

Choose a state

City	Organization Name	Facility Name	Application	SIC4	NAICS	Op Year	Prime Mover	Capacity (KW)	Fuel Type
			uni						
Pasadena	California Institute Of Technology	Cal Tech -Central Utility Plant	Colleges / Univ.	8221	61131	2003	CC	12,560	NG
Los Angeles	University Of California	University Of California - Los Angeles	Colleges / Univ.	8221	61131	1993	CC	43,000	NG

Source: <https://doe.icfwebservices.com/chpdb/>

2nd Screened Universities: Non IDEA

University Of Montevallo
Harding University, Inc.

Mt. San Antonio Community College
Santa Rosa Junior College
Cerritos Community College District

Saddleback Community College
Miramar Community College
San Bruno College
Chaffey College

Chabot Las Positas Community College
University Of California-Santa Barbara
California State University,Northridge
Pasadena City College
California State Univ. San Bernardino
California State University East Bay
Pierce College
Long Beach College
Southern California Baptist University
Community College
De Anza Campus
Mesa Community College
Irvine Valley Community College
East Los Angeles College
Berkeley Cogeneration Project - University
Of California / PE Berkeley
San Diego State University (SDSU)

University of California Irvine
University Of California
International Power Technology
University Of California

Biola University
University Of California

Pacific Union College
California State University, Fullerton
University Of San Francisco

Allan Hancock Joint Community College
EUA Cogenics
University Of California
Clarke & Rush Mechanical

California State University
California Baptist College
Occidental College
Occidental College
Fresno Pacific College
California Polytechnic State University
California State University
California Polytechnic State University
Claremont Colleges
Humboldt State University
College of the Canyons
University of Redlands
CMC Engineering
Tecogen

University Of Northern Colorado
Fairfield University
Central Connecticut State University (New
Britain)
Wesleyan University
Western Connecticut State University
Eastern Connecticut State University

Pensacola College
University of Central Florida

University of Iowa, Oakdale Renewable Energy Plant
University Of Northern Iowa
Southern Illinois University

Eastern Illinois University CHP Plant
Illinois Institute Of Technology
University of Illinois at Chicago - East Campus
University of Illinois, Chicago - West Campus

Loyola University Medical Center
Chicago State College
Northeastern Illinois University
College of DuPage
Mooseheart College, Power House
Joliet Junior College
Lewis University
Sauk Valley Community College
Triton College
Illinois Central College
University Of Notre Dame Power Plant
Indiana State University
Energy Center in Stinson-Remick Hall
Kansas State University Utilities Power Plant

Louisiana Tech University Power Plant
Tulane Educational Fund

Louisiana State University
Harvard uni, Blodgett Pool
Harvard University Gym - Shad Hall
Harvard Blackstone Steam Plant

2nd Screened Universities: Non IDEA

Williams College

Springfield Technical Community College

Mount Holyoke College
Amherst College

Bridgewater State College Tinsley Center
Smith College

University of Massachusetts - Dartmouth
Bunker Hill Community College
Wellesley College
Clark University
Simmons College
Massachusetts College Of Liberal Arts
Hampshire College
Atlantic Union College
Wentworth Institute of Technology
Great Barrington College
Worcester State University
Mass College of Pharmacy
Cape Cod Tech CHP
Assumption College

Gateway Life Sciences Building and Campus Center

Mount Wachusett Community College
Cape Cod Community College
Mass Maritime Academy

Johns Hopkins University, Homewood Campus

Johns Hopkins University, Mt. Washington Campus

Johns Hopkins University - Wolman Hall
Bates Energy Associates
Colby College

University of Maine

Northern Michigan University

Central Michigan University
Eastern Michigan Univ

Ferris State College
Western Michigan University

Northwood Institute
Albion College
University of Detroit Mercy
College of Engineering
Grand Valley State Univ
Henry Ford Community College
M-TEC Facility
Washtenaw Community College
Henry Ford Community College
Cloquet Community College
Southeast Missouri State University
Mississippi State University
University of Montana
University of Montana

Montana State University

NC State University Solar Center
University of Nebraska
Montclair University

Rutgers, The State University Of New Jersey

Princeton University

Jersey Shore University Medical Center
Drew University
University Of Medicine & Denistry Of NJ

St Lawrence University

University Of Medicine & Denistry Of NJ

GEM Energy, State University of New York (SUNY)
Rockefeller University

State University of New York
Hofstra University

Staten Island University Hospital
St. John's University (Cogen Financial)
State University of New York
Clarkson University
New York University
Oklahoma State University
University Of Oklahoma
Oregon State University
Oregon Health and Science University
Clarion University
Indiana University Of Pennsylvania
Brown University
Clemson University
Bob Jones University

University of South Carolina

University of Tennessee
University Of Texas System
University Of Texas System

University Of Richmond

Norwich University

University of Wisconsin
University of Wisconsin Oshkosh

Descriptive Analysis of Survey Data

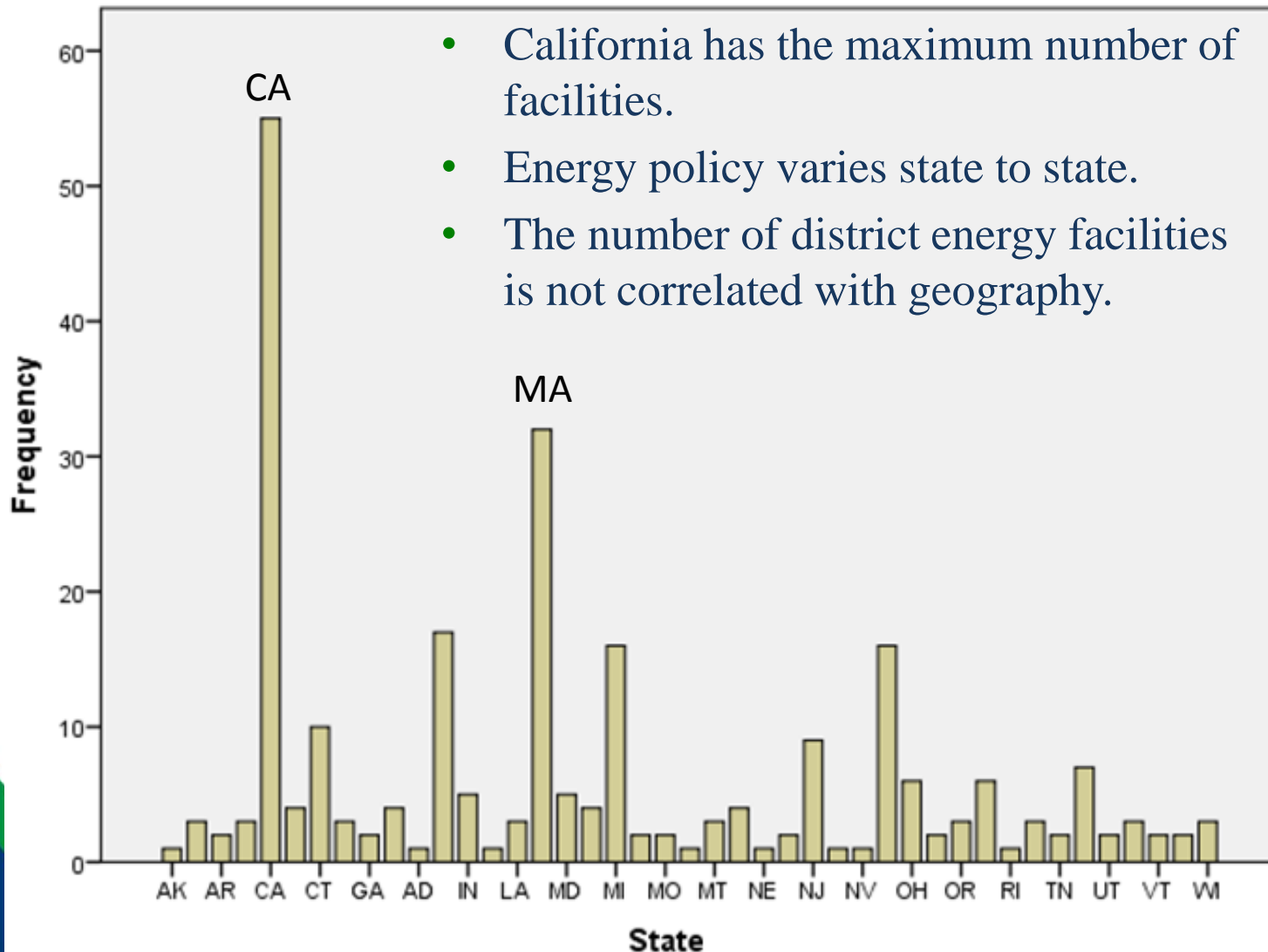
Variables		Samples, N	Minimum	Maximum	Mean	Std. Deviation
IDEA (Y=1/N=2)		255			1.702	
Total generation from every source (MW)		35	1.2	150.0	30.8	34.8
Installation Year of the Facility		52	1891.0	2014.0	1975.8	38.1
Total Consumption(MW)		23	6.6	57.5	26.1	17.0
C H P	Electrical power(MW)	231	0.005	175.0	10.5	20.1
	Thermal Power(lb/hr)	28	22000.0	1300000.0	337325.0	302576.6
	Efficiency(0.0 to 1.0)	22	0.43	0.8	0.7	0.1
Operation Year of CHP		219	1898.0	2014.0	1995.9	17.5
Chilled water (ton/hour)		36	400.0	40000.0	17057.2	12624.9
Year of publication		210	1994.0	2015.0	2014.6	2.3
source of information		255		Internet		

District Energy Facilities Sorted by State

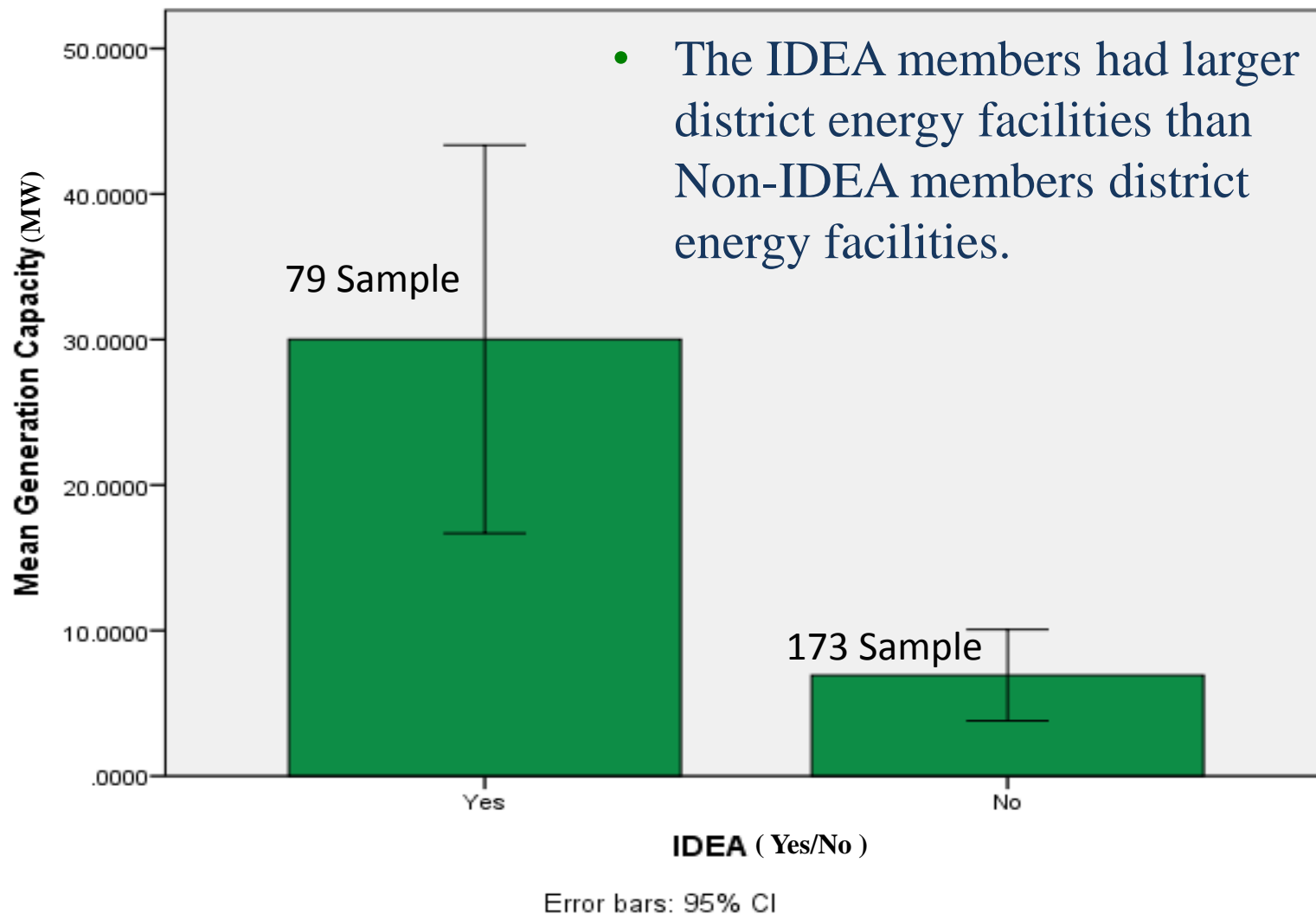
State	Number of Facilities	Percentage
AK	1	0.4
AL	3	1.2
AR	2	0.8
AZ	3	1.2
CA	55	21.3
CO	4	1.6
CT	10	3.9
FL	3	1.2
GA	2	0.8
IA	4	1.6
AD	1	0.4
IL	17	6.6
IN	5	1.9
KS	1	0.4
LA	3	1.2
MA	32	12.4
MD	5	1.9
ME	4	1.6
MI	16	6.2
MN	2	0.8
MO	2	0.8

State	Number of Facilities	Percentage
MT	3	1.2
NC	4	1.6
NE	1	0.4
NH	2	0.8
NJ	9	3.5
NM	1	0.4
NV	1	0.4
NY	16	6.2
OH	6	2.3
OK	2	0.8
OR	3	1.2
PA	6	2.3
RI	1	0.4
SC	3	1.2
TN	2	0.8
TX	7	2.7
UT	2	0.8
VA	3	1.2
VT	2	0.8
WA	2	0.8
WI	3	1.2

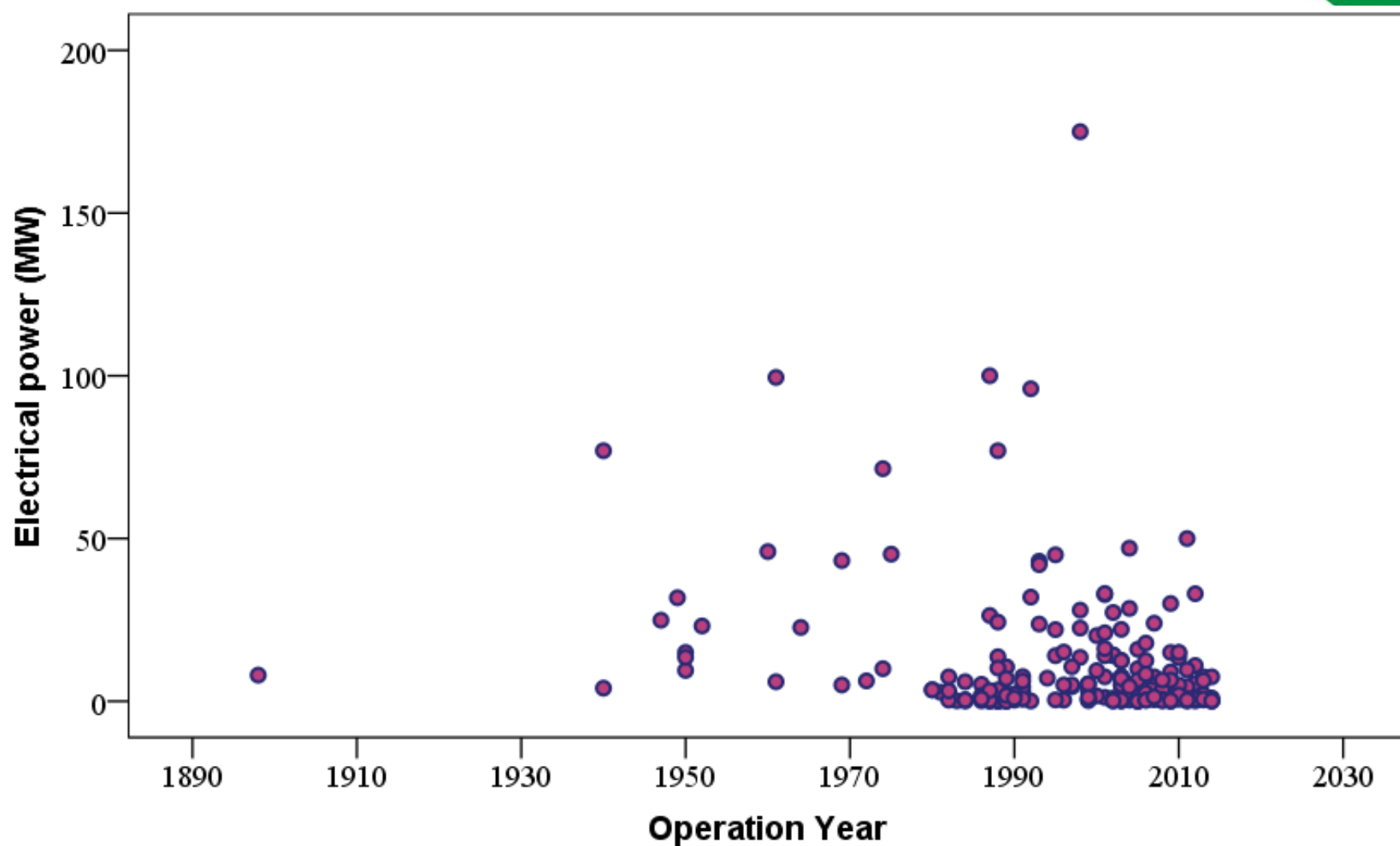
District Energy Facilities



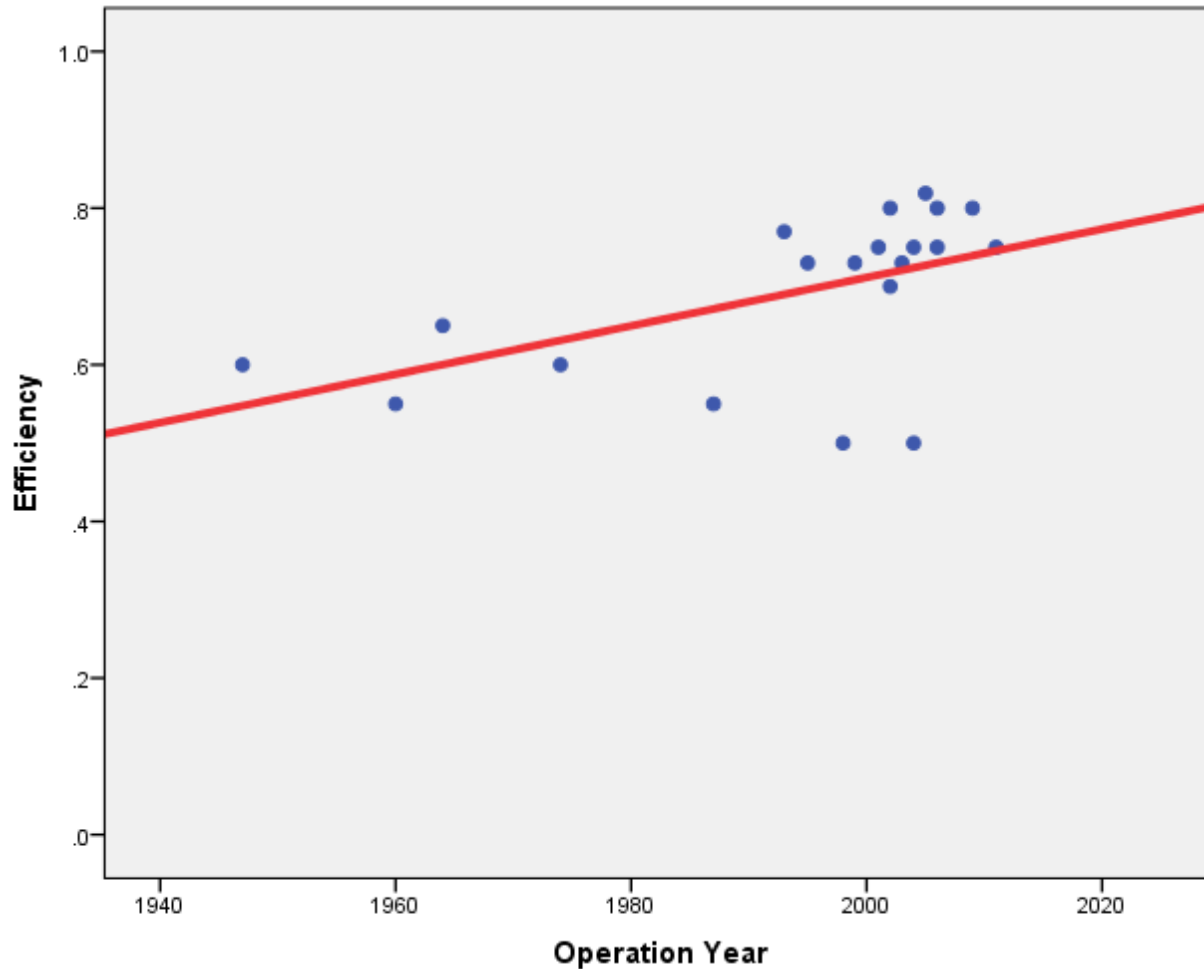
Comparison of Generation Capacity of IDEA and Non-IDEA University facilities



Historical Data of CHP capacity

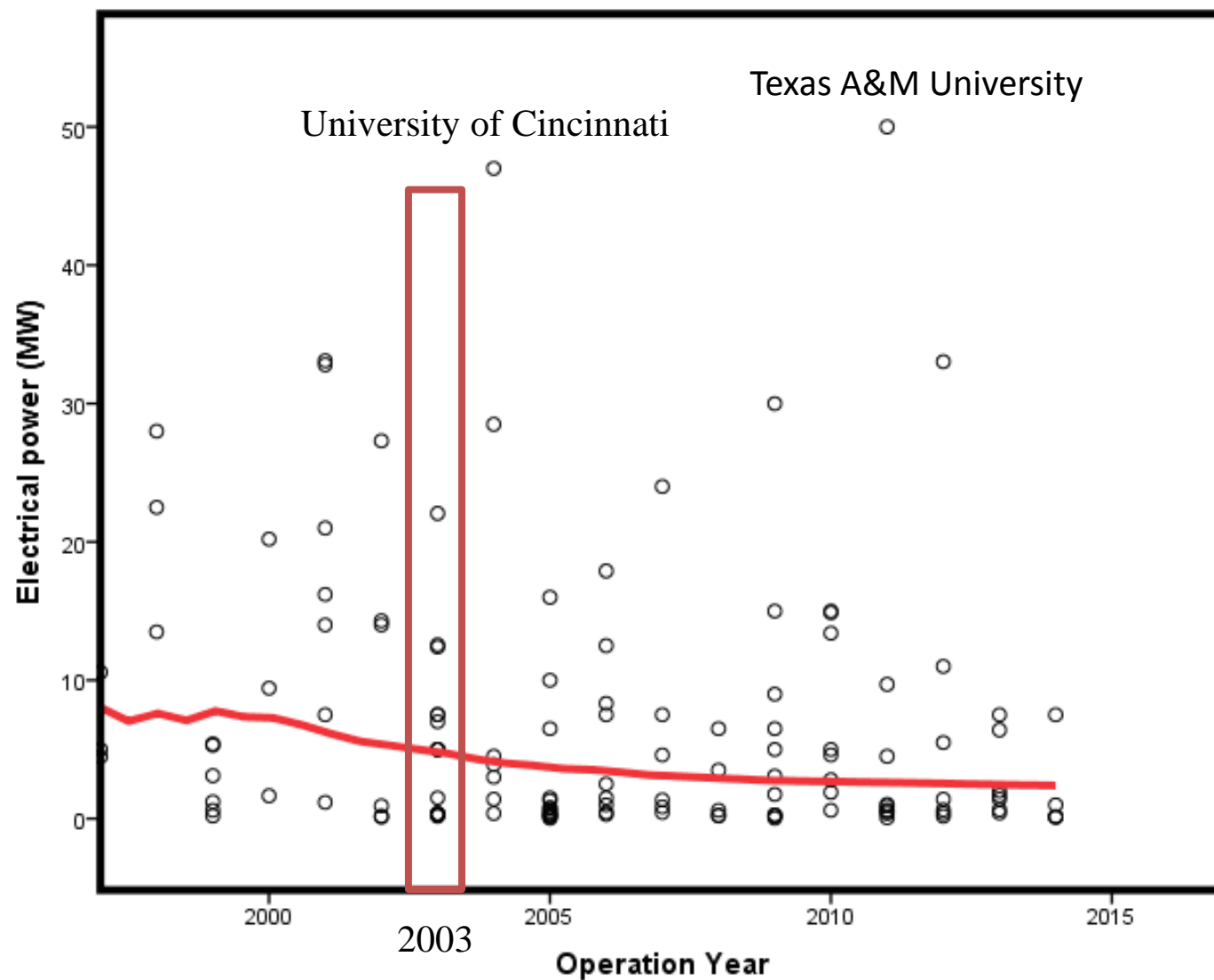


Efficiency of the CHP over the years

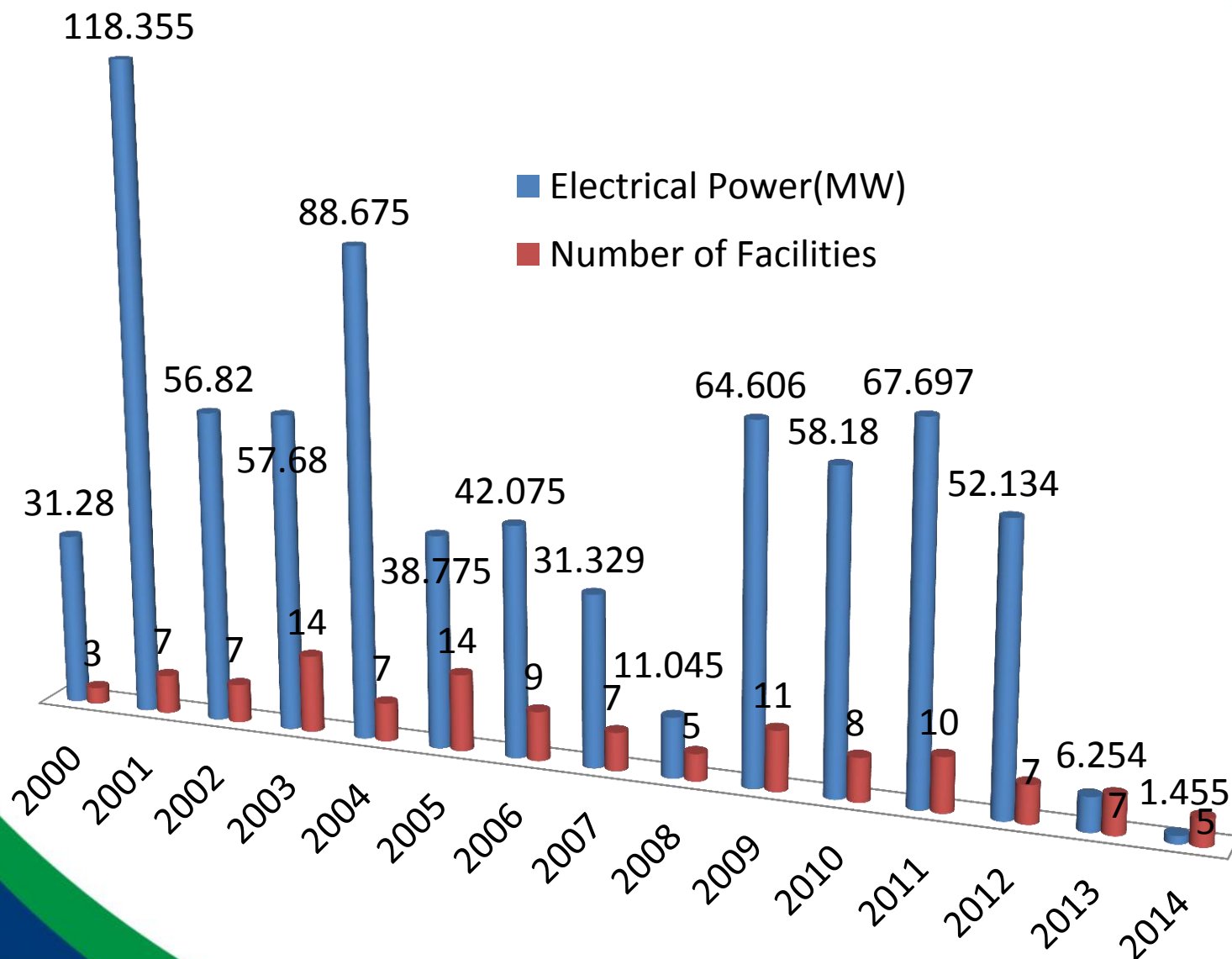


- Efficiency increases with time.
- After 2000s, efficiency reached around 80%.
- Older facilities can be replaced with more efficient ones.

CHP Capacities after 2000s

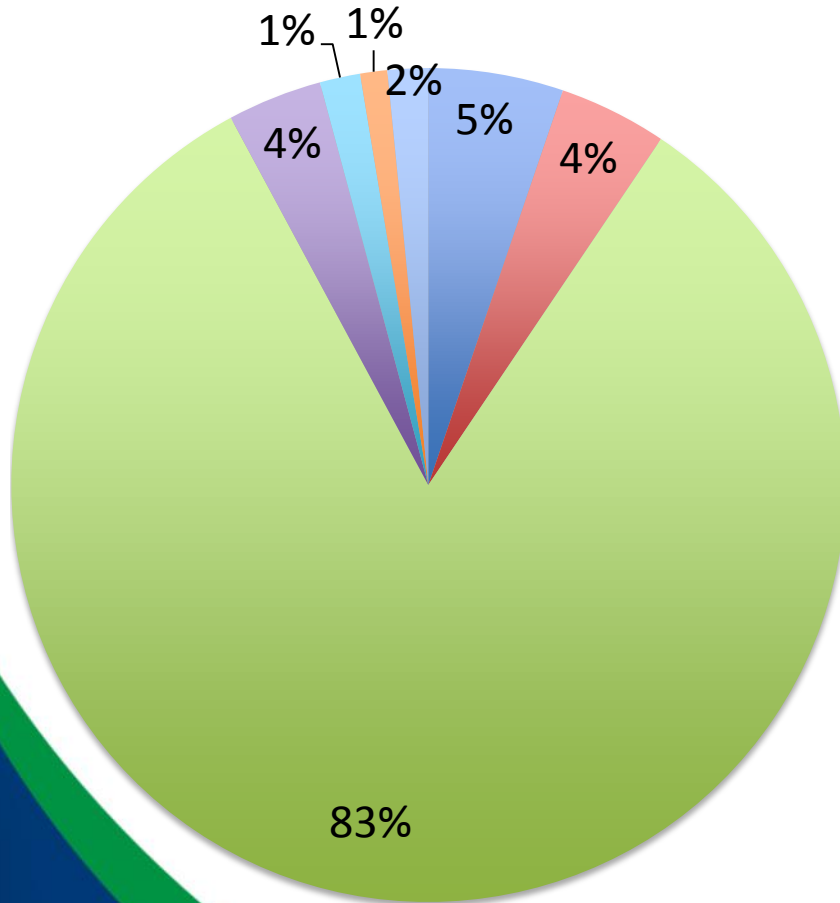


CHP Capacities after 2000s



Fuel Used in CHP Facilities

Fuel Type Distribution(191 Facilities)



BIOMAS

COAL

NG

OIL

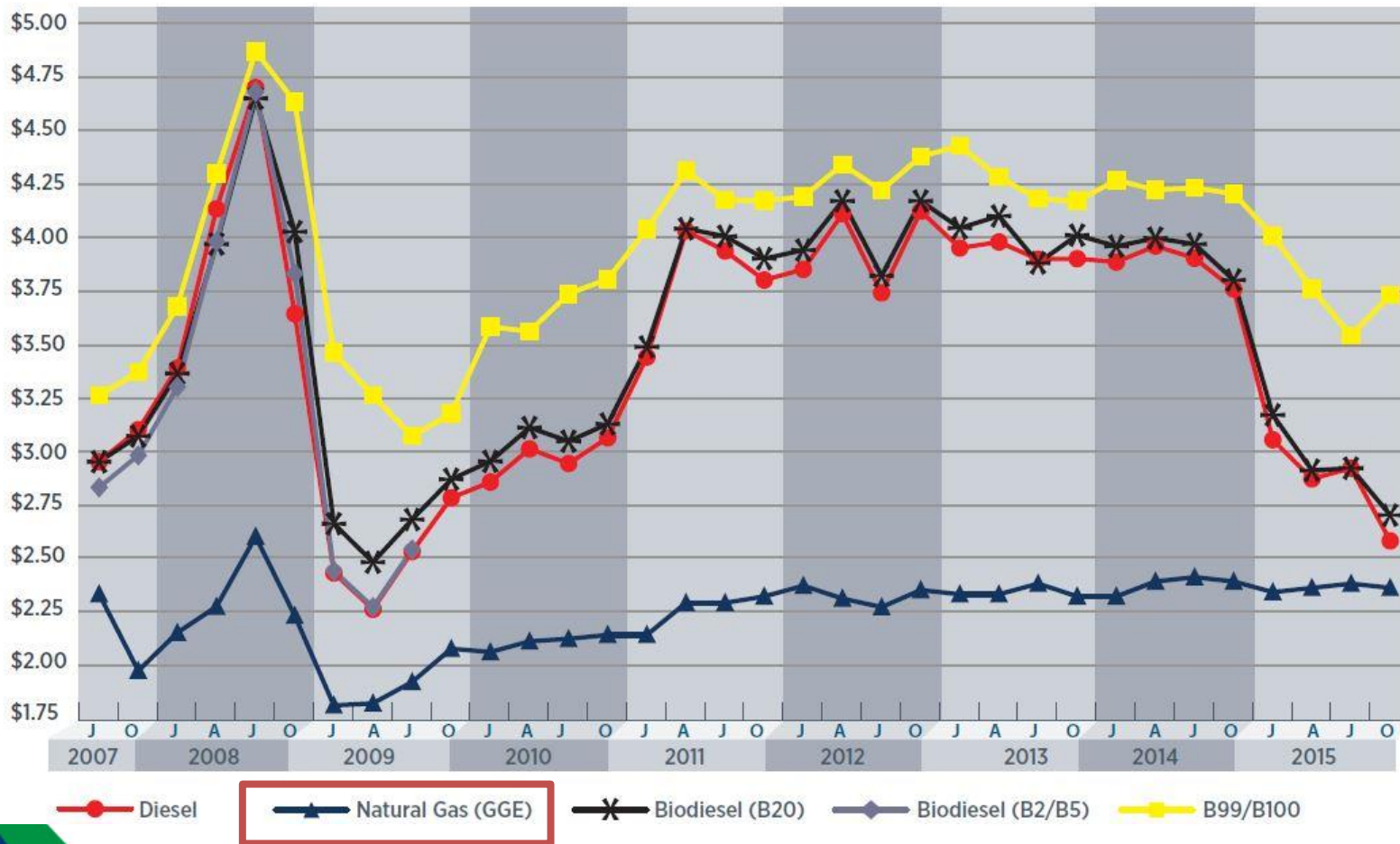
WAST

WOOD

OTH

BIO-MASS	Biomass, LFG, Digester Gas, Bagasse	10	5%
COAL	Coal	8	4%
NG	Natural Gas, Propane	158	83%
OIL	Oil, Distillate Fuel Oil, Jet Fuel, Kerosene, RFO	7	4%
WAST	Waste, Waste Heat, MSW, Black Liquor, Blast Furnace, Gas, Petroleum Coke, Process Gas	3	1%
WOOD	Wood, Wood Waste	2	1%
OTH	Other	3	2%

Trends of CHP Fuels

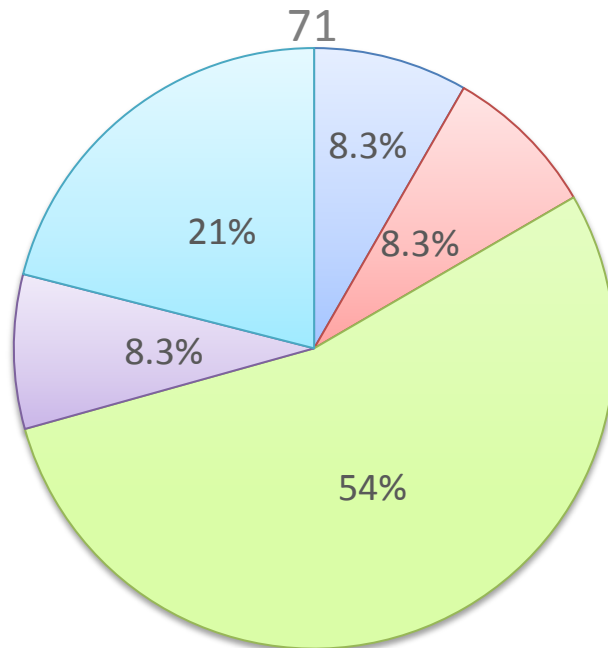


Fuel price (USD/Gallon)

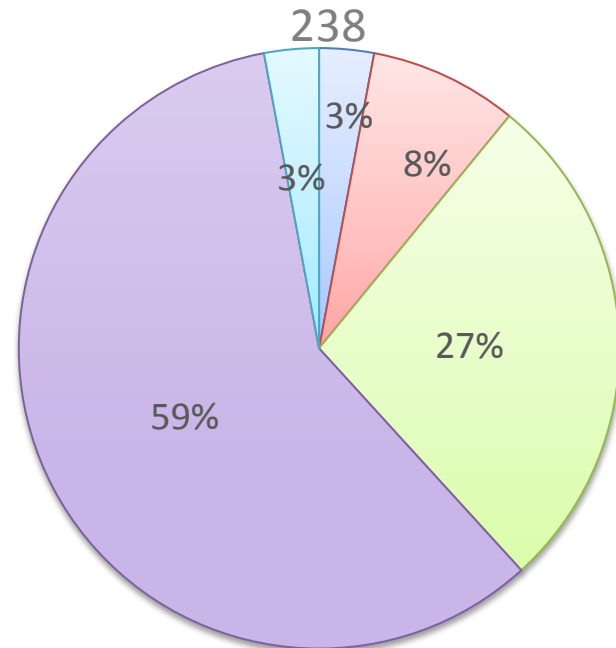
Source: ALTERNATIVE FUEL PRICE
REPORT, OCTOBER 2015
U.S. Department of Energy

Comparison of 2003 and 2015 Surveys

2003



2015



Conclusion

- Recent trend of district energy was analyzed among 253 US universities.
- Compared to the 2003, the number of campuses to use CHP consistently increased.
- Most of the recently built facilities are around 5MW.
- Energy efficiency is improving due to the advanced technologies.
- Fuel price of the natural gas is steady.

Appendix.1: Energy Policy of California

- » The California Air Resources Board's (ARB) Climate Change Scoping Plan, pursuant to Assembly Bill 32 (Núñez, Chapter 488, Statutes of 2006), sets a target of 4,000 megawatts (MW) of additional CHP capacity, and 6.7 million metric tons of carbon dioxide of associated annual GHG emissions reductions, by 2020.
- » Assembly Bill 1613 (Blakeslee, Chapter 713, Statutes of 2007), the Waste Heat and Carbon Emissions Reduction Act, creates a feed-in tariff to incentivize the development of small CHP (no larger than 20 MW).
- » Governor Jerry Brown's Clean Energy Jobs Plan calls for an additional 6,500 MW of new CHP capacity by 2030.
- » California Public Utilities Commission's Qualifying Facilities and CHP Program Settlement Agreement mandates that California's three largest investor-owned utilities achieve 4.8 million metric tons of carbon dioxide of the GHG reductions recommended in the Climate Change Scoping Plan.
- » California also directly supports CHP development through the Self Generation Incentive Program (SGIP), which provides financial incentives for a variety of small-scale distributed energy resources – including both conventional- and renewable-fueled CHP.

<http://www.energy.ca.gov/chp/>

Appendix.2: Energy Policy of Illinois

Public Sector Combined Heat and Power (CHP) Pilot Program

The CHP Pilot Program provides cash incentives for combined heat and power (CHP) projects that increase energy efficiency of local governments, municipal corporations, public school districts, community college districts, public universities, and state/federal facilities located in the service territories of Commonwealth Edison ("ComEd"), Ameren Illinois ("Ameren"), Nico Gas ("Nicor"), Peoples Gas ("Peoples"), and/or North Shore Gas ("North Shore").

CHP is an efficient and clean approach to generating power and thermal energy from a single fuel source. CHP is used either to replace or supplement conventional separate heat and power. Instead of purchasing electricity from the local utility and burning fuel in an on-site furnace or boiler to produce needed steam or hot water, a facility can use CHP to provide both energy services in one energy- efficient step. Every CHP application involves the recovery of thermal energy that would otherwise be wasted to produce additional power or useful thermal energy; as such, CHP can provide significant energy efficiency and environmental advantages over separate heat and power. It is reasonable to expect CHP applications to operate at 75% or greater, a large improvement over the national average of 45% for these services when separately provided.

The CHP Pilot Program is structured with performance based incentives to provide financial assistance during various stages of a project, including after the design phase, commissioning, and after 12 months of measured operational performance:

- **Design Incentive:** \$75/kW capacity (following completion of the design phase)
- **Constructive Incentive:** \$175/kW capacity (following successful commissioning of the system)
- **Production Incentive:** \$0.08/kWh ($\eta \geq 70\%$ HHV) OR \$0.06/kWh ($60\% \leq \eta < 70\%$ HHV) of "useful electric energy" produced (after 12 months of operation based on meeting the measured operating requirements of the system)

For Conventional CHP systems to qualify, the minimum measured performance level must be an annual energy efficiency of 60% with at least 20% of the system's waste heat energy output in the form of useful thermal energy utilized in the facility. For additional requirements, please refer to the "Downloadable Application" below. Final applications requiring an engineering feasibility analysis are due November 21, 2014.

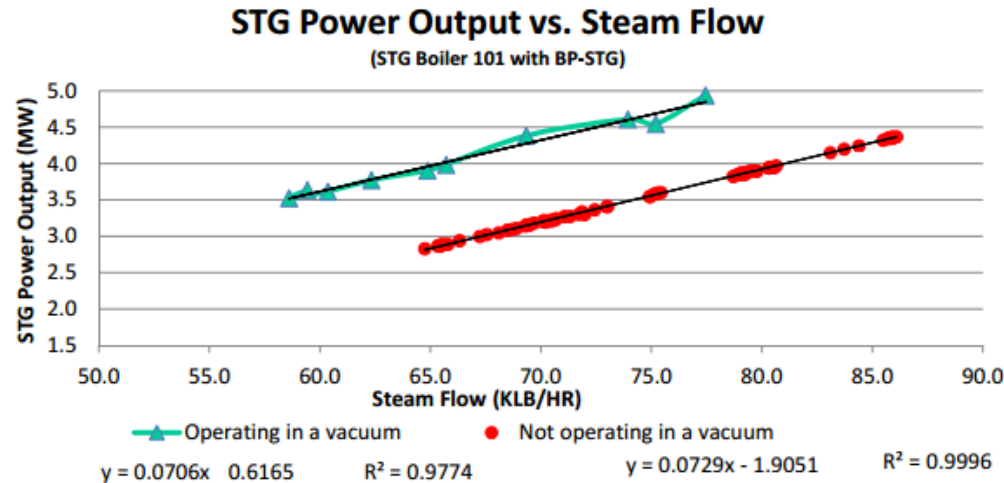
- [Download Application \(PDF\)](#)
- [Download Application \(Word\)](#)
- [Downloadable Workbook organizing output of Feasibility Analysis and TRC Calculator Data](#)

<http://www.illinois.gov/dceo/whyillinois/KeyIndustries/Energy/Pages/CHPprogram.aspx>

Appendix.3: Public records of Massachusetts



Combined Heat & Power Process – Improved Performance



- **New BPSTG / Steam Bypass Valve improve steam to electricity conversion process**
 - 18% improvement (10.6% efficiency overall)
 - +1.3 MW increase in generation from steam generators
 - Sustainable May - November
 - Should see an increase of +4.5 M kWh / year
 - ~30 M kWh total/year from steam (25.1 M kWh currently)

6

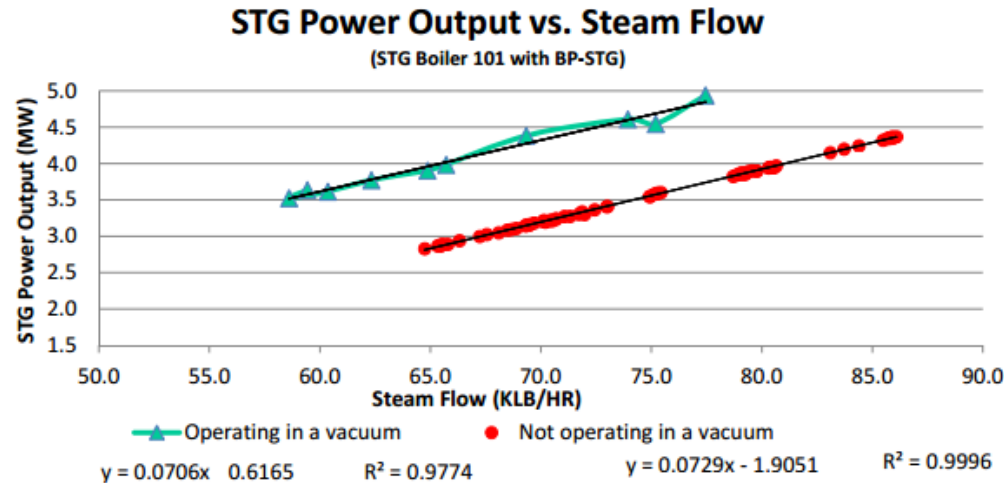
<http://www.mwra.state.ma.us/monthly/wac/presentations/2014/110714-chp.pdf>

<http://www.mass.gov/eea/docs/doer/energy-efficiency/eeac-2010-report-ee-advisory-council.pdf>

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<http://www.mass.gov/eea/docs/doer/energy-efficiency/eeac-2010-report-ee-advisory-council.pdf>

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Thanks for your time!

Questions?

Sung Yeul Park, Ph.D.

Associate Professor

Electrical & Computer Engineering Dept
Center for Clean Energy Engineering

Ph: 860-428-5647

E-mail: supark@engr.uconn.edu

Mailing Address

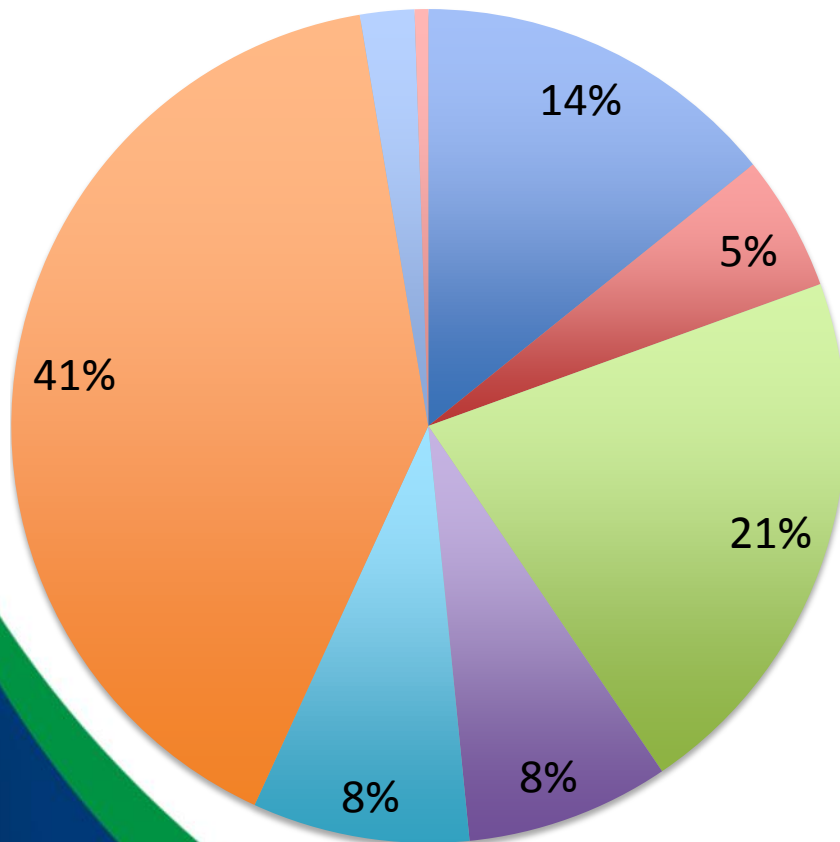
University of Connecticut

371 Fairfield Way, Unit 2157

Storrs, CT 06269-2157

Types of Prime Movers Used in CHP Plants

Prime Mover Type Distribution(190 Facilities)



B/ST

CC

CT

FCEL

MT

ERENG

BPST

OTH

B/ST	Boiler/Steam Turbine	27	14%
CC	Combined Cycle	10	5%
CT	Combustion Turbine	40	21%
FCEL	Fuel Cell	15	8%
MT	Microturbine	16	8%
ERENG	Reciprocating Engine	77	41%
BPST	Backpressure Steam Turbine	4	2%
OTH	Other	1	1%