Combined Heat and Power (CHP) Discussion

NSTAR Energy Efficiency Seminar

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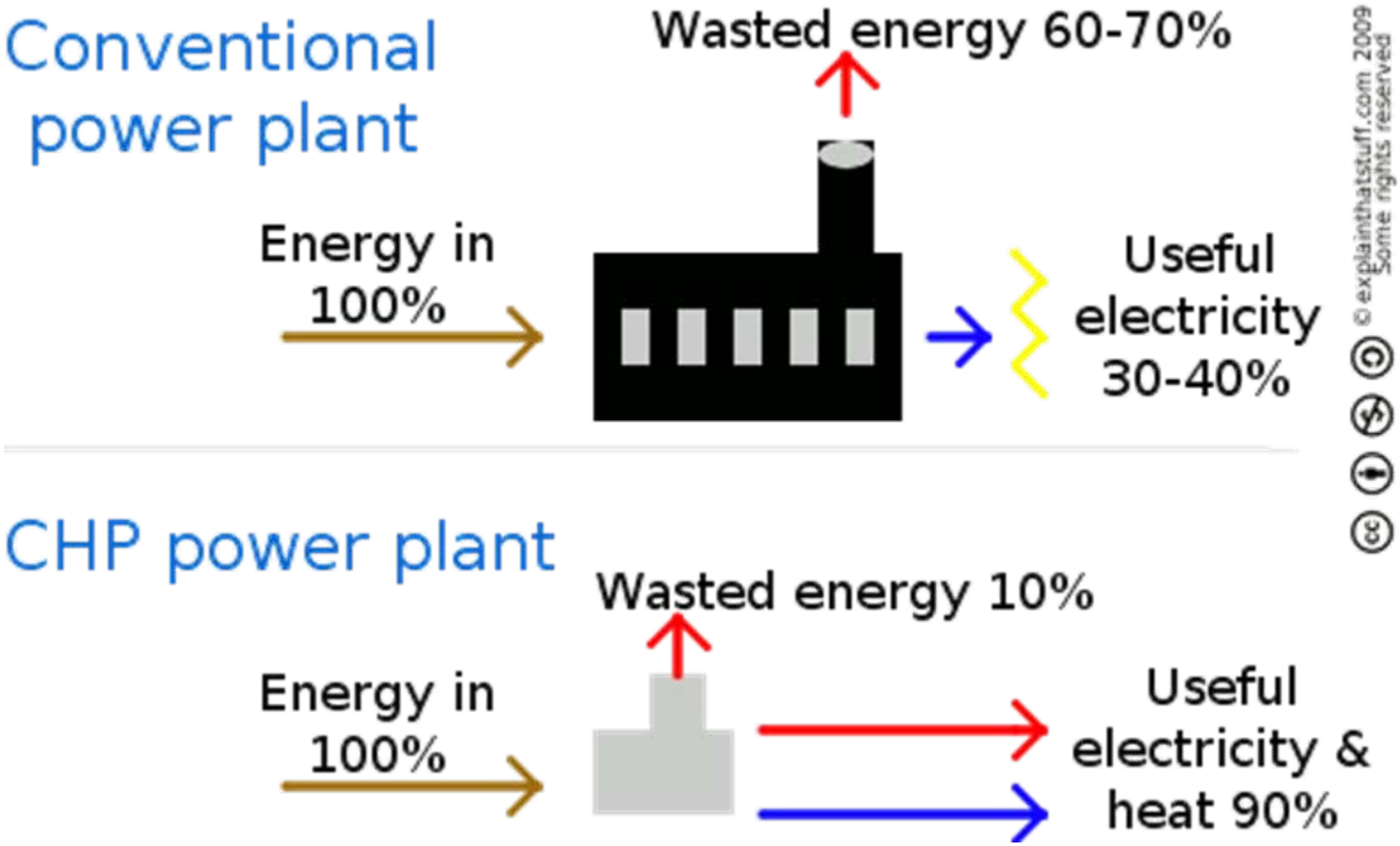
Combined Heat and Power (CHP)
(AKA-Cogeneration)

- “Cogeneration” :The Generation of two usable forms of energy from one single source of fuel.

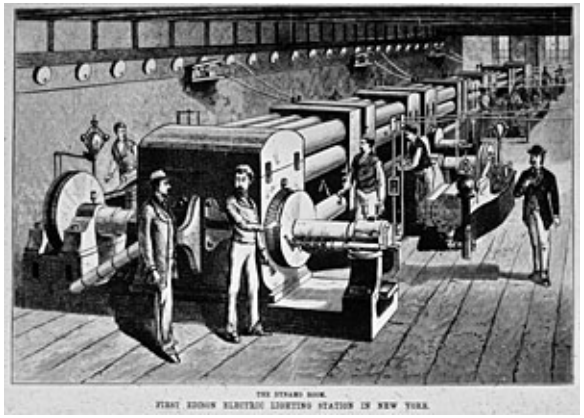
- “Trigeneration”: The Generation of three usable forms of energy from one single source of fuel.

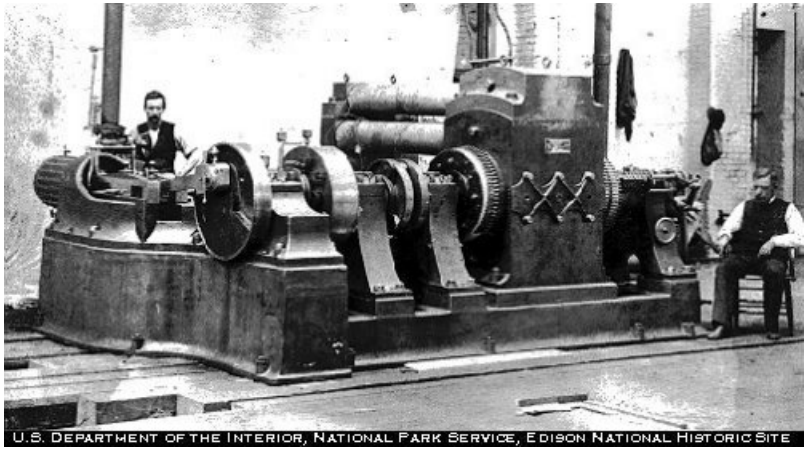
How does CHP Work?



The History of CHP

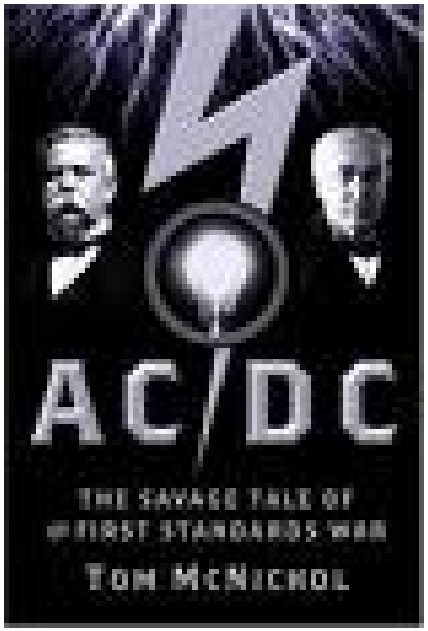
Edison Pearl Street Power Station 1882
10V DC Current/ Cogeneration
~50% total efficiency





Current Wars

Westinghouse/ Edison vs. Tesla
AC vs. DC



http://www.youtube.com/watch?v=RkBU3aYsf0Q

Environmental Impact of CHP as Compared to Centralized Electric Generation in the USA

U.S. ENVIRONMENTAL PROTECTION AGENCY

Clean Energy

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- Site Map

How Does the Electricity I Use Compare to the National Average?

The table below contains two charts:

- The first chart compares the fuel mix used to generate electricity in your region of the power grid to the national fuel mix.
- The second chart compares the average air emissions rates in your region of the power grid to the national average emissions rates.

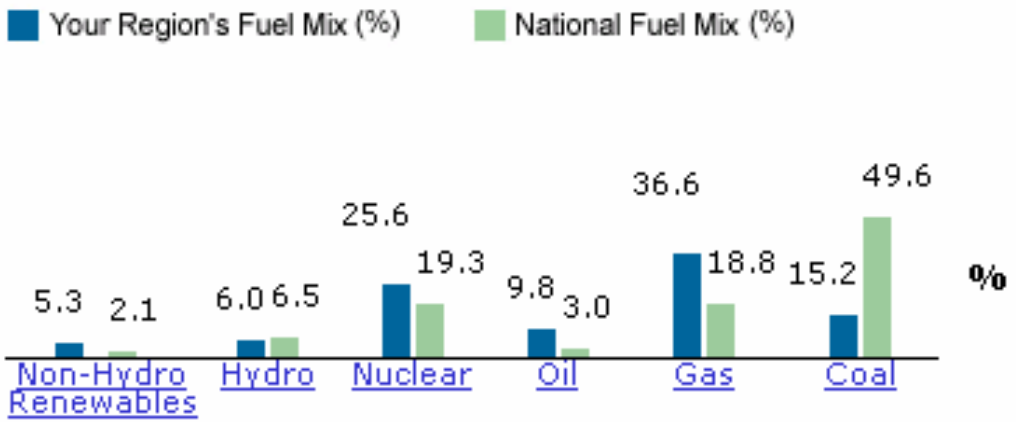
Current Electric Fuel Mix for MA Zip Code
Source: EPA- EGRID

FUEL MIX COMPARISON

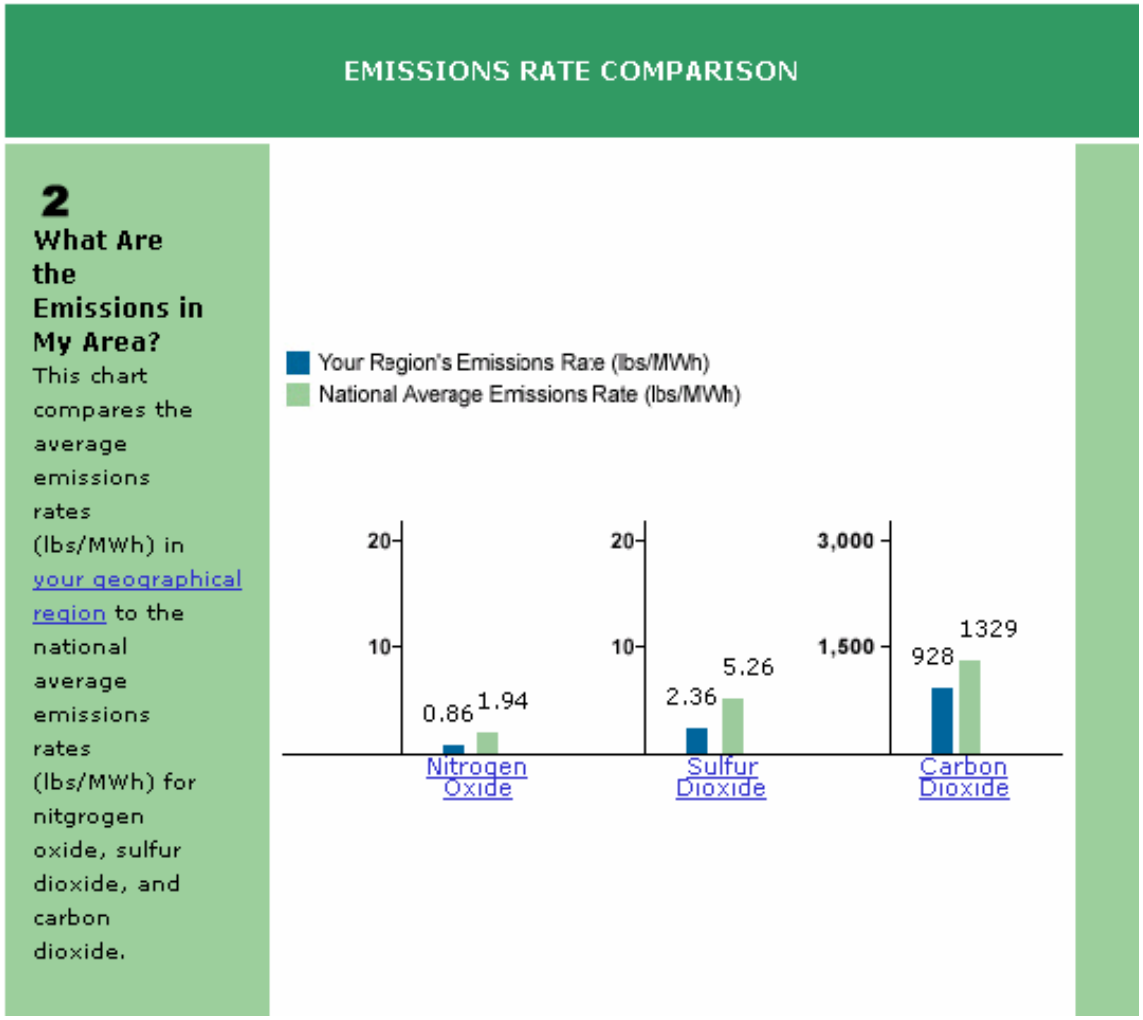
1

What Is My Fuel Mix?

This chart compares fuel mix (%) of sources used to generate electricity in your region to the fuel mix (%) for the entire United States.



Emissions Rate Comparison for MA compared to USA



Benefits of CHP?

In today's fast growing alternative energy market CHP is recognized as being a proven low risk technology that:

- Represents Dispatchable, Distributive Power Generation. (alternative to wind, solar and other "non-dispatchable" onsite power and distributed generation sources)
- Reduces an end users' Green House Gas emissions and carbon footprint with the fastest payback "per ton".
- Is always "green" as compared to grid power and conventional heating and cooling systems.
- Can also be 100% "renewable" with bio fuels (i.e. biogas from landfills, digesters, bio diesel, renewable fuels).
- Typically offers a more attractive ROI than other "green" energy technologies (i.e. Wind 20-25 yr ROI, Solar 15-25 yr ROI, CHP 2-8 yr ROI)
- Reduces dependence on imported fuels and reduces overall primary energy consumption
- Increasingly attracts government subsidies/incentives in recognition of its contribution to carbon reduction targets, economic competitiveness and homeland security goals.

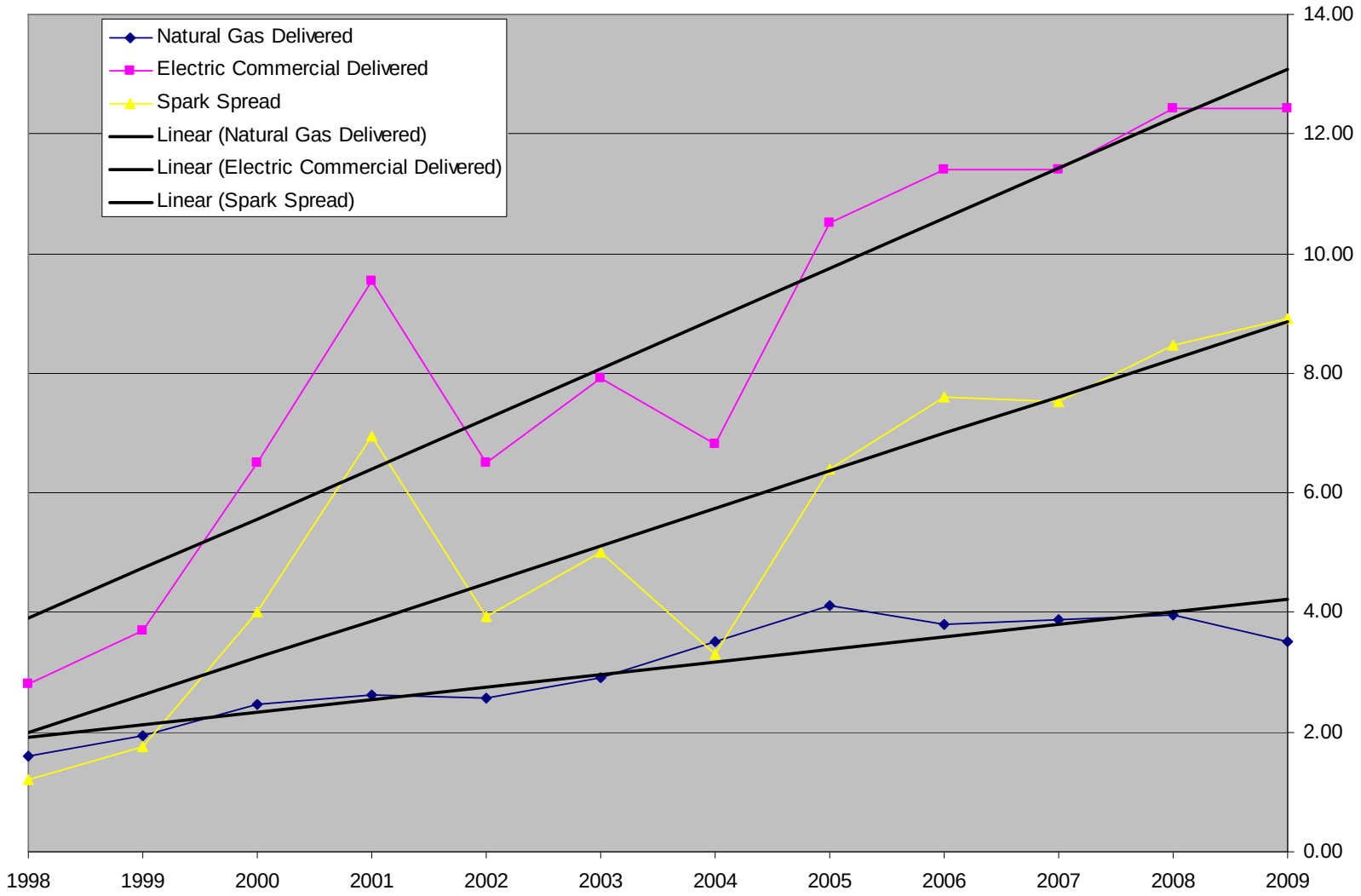
Types of CHP Applications

- Industrial
  - Drying Processes
  - Process heating
  - Process Cooling
  - Landfill Gas
  - Waste Water
  - Food Processing
  - Food Waste
  - Manufacturing
- Commercial
  - R&D
  - Hospitals
  - Educational Facilities
  - Large Retail Outlets
  - Data Centers
  - Hotels
  - Office Developments
  - Housing (District Heating)

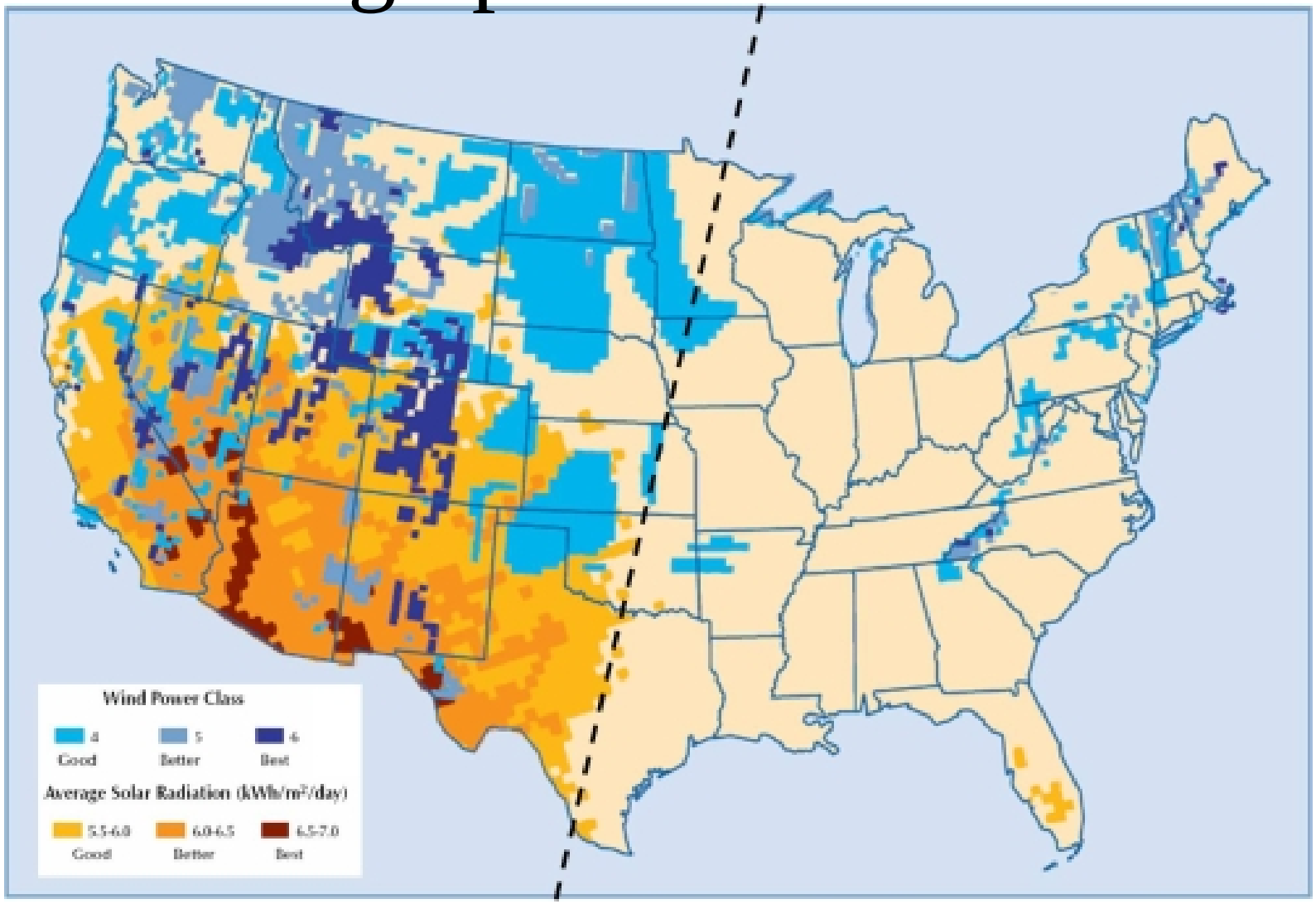
What Defines a Good CHP Market?

- Availability of Fuel – States with a well developed Nat Gas Network or clients with reliable gas production
- The Spark Spread – The difference between the cost of a unit of fuel and the value of a unit of electricity. Sub 5yr paybacks can typically be achieved where a ratio wider than 3 to 1 exists. (e.g. Electricity 15c/kWh, Gas 14$/Decatherm or 4.8c/kWh).
- Regulatory Support and incentives
- Practical emissions legislation
- Constrained Electric Grid and supply capacity (Inevitable upward price pressure)
- Evidence that CHP is being successfully applied.
- Strong corporate desire to be “green” with few technology options available outside of CHP.

Massachusetts Spark Spread 1998-2009



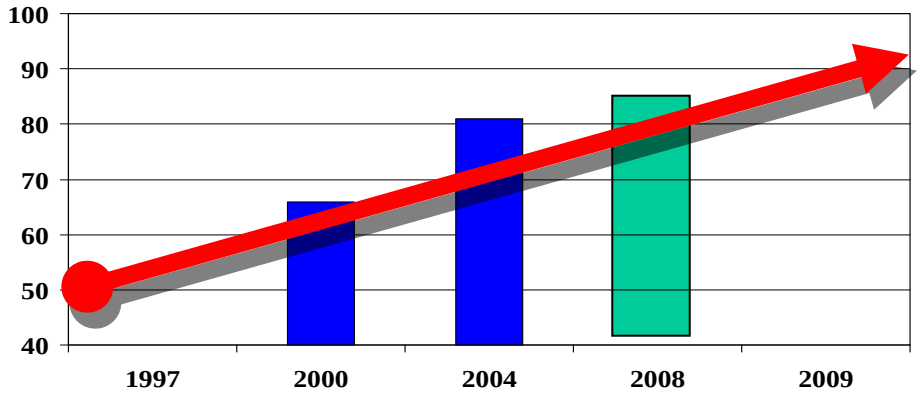
Geographical Assessment



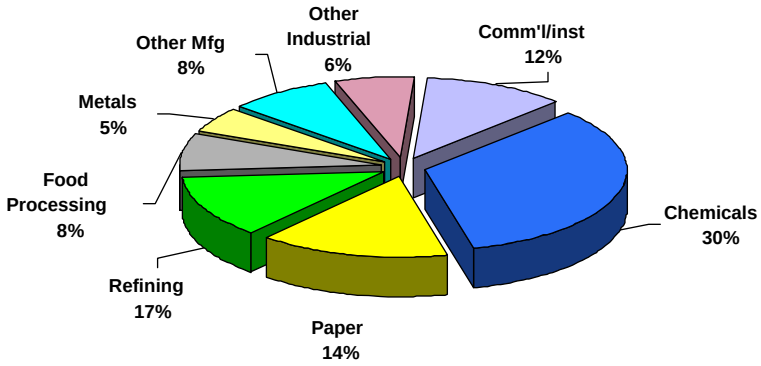
Source: Sean Casten – RED

US Total Market Potential

The USCHPA Challenge – 92 GW by 2010



2006 Market segmentation



Source: CHP/DHC Collaborative (IEA/DOE)

- Remaining US CHPA Target ~ 7GWe
- DOE Study Estimates the current market potential to be:
  - 70-90GWe Industrial
  - 40-60GWe Commercial Institutional
- One Half of Technical Potential is in Systems Below 5MWe (55 to 75GW potential)

Types of CHP Technologies
(most applicable)

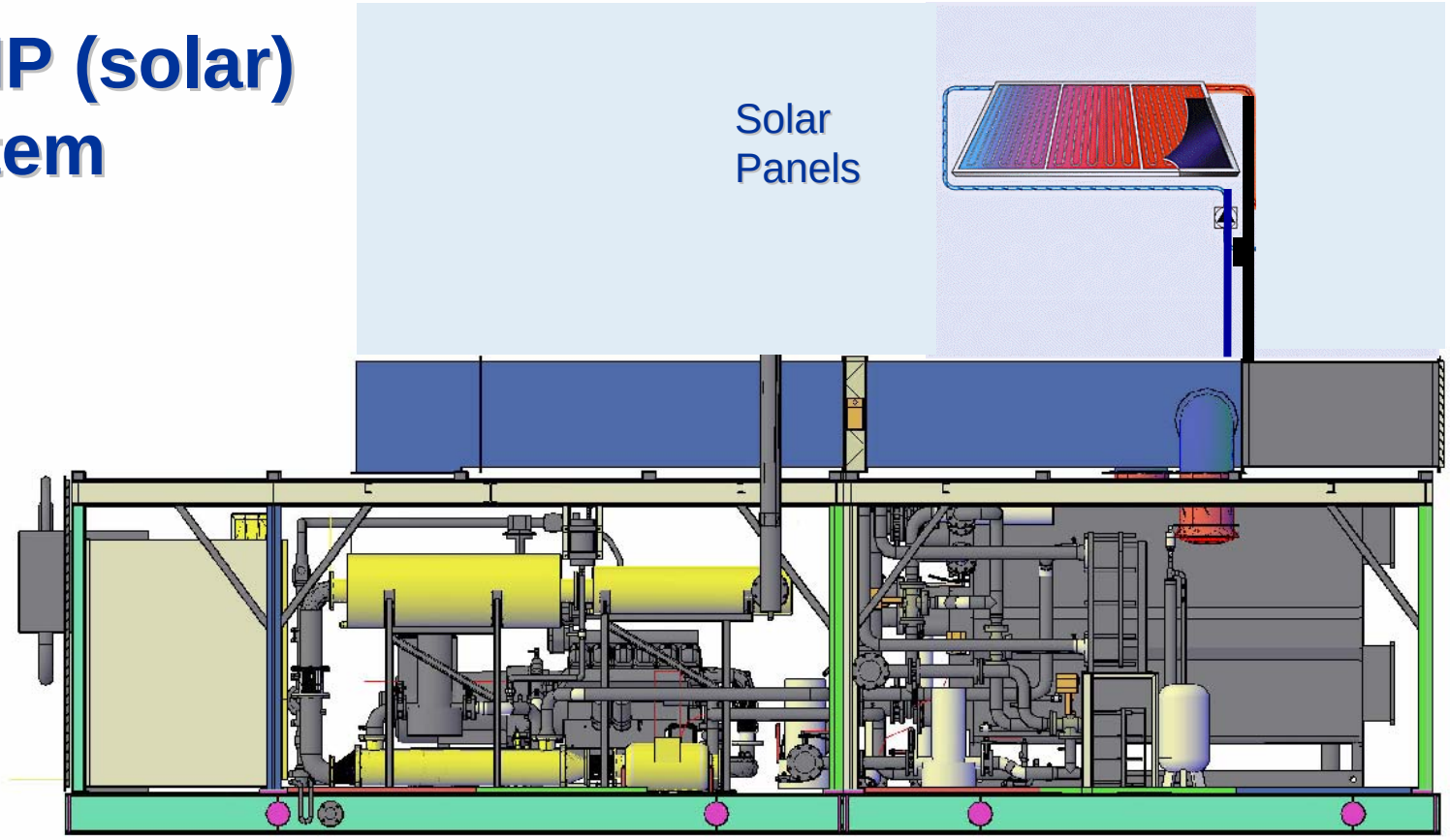
1. Reciprocating Engines
2. Turbines (Gas and Steam)
3. Microturbines
4. Fuel Cells
5. Micro-CHP (Residential)
6. Available Fuels Technologies

Reciprocating Natural Gas Engine CHP

- 570kWe Natural Gas CHP
- Hot-CAT Jacket Water 265F
- Producing LP Steam – 2400#hr
- SCR/Urea Emissions Treatment (BACT)

Wentworth Institute of Technology

CCHP (solar) System



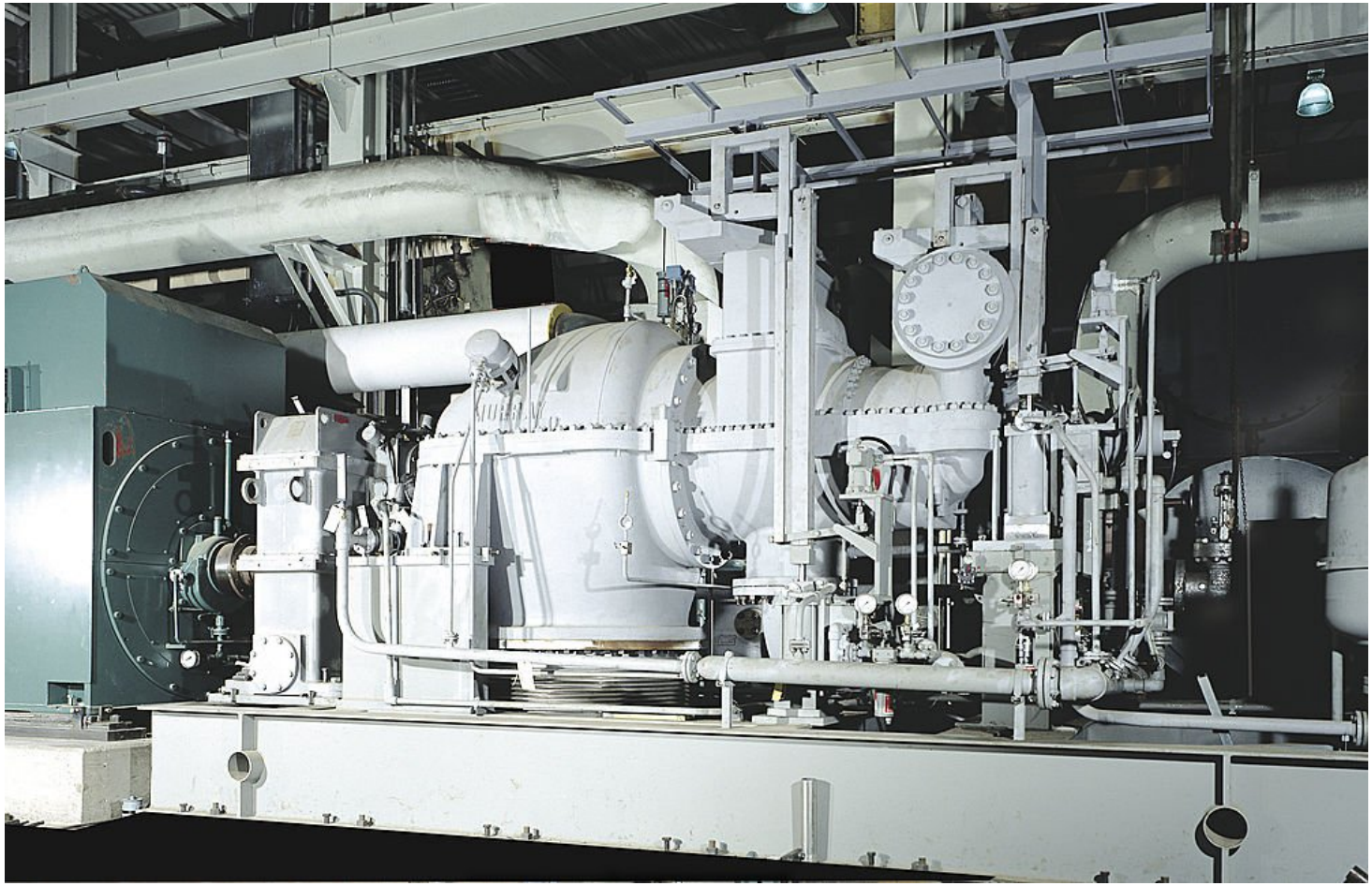
Control Room
Electronics

Natural Gas
Engine/Generator
250kW

Absorption Chiller
80 Tons

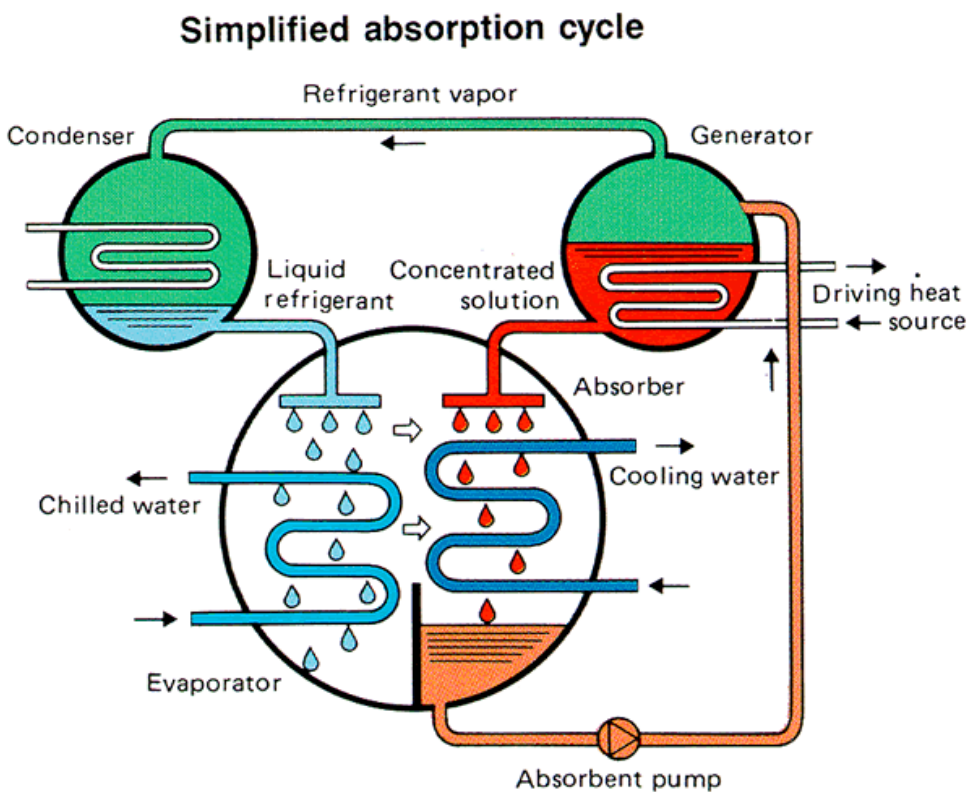
Natural Gas Turbine

Steam Turbine Generator Set



Microturbines

Absorption Chiller Principals



The ***refrigerant used is actually water***, as that is the working medium that experiences a phase change that causes the cooling affect.

The second fluid that drives the process is a salt, generally lithium bromide.

Heat is used to separate the two fluids; when they are brought back together in a near vacuum environment, the water experiences a phase change to remix with the salt at a very low temperature

At normal atmosphere pressure, water vaporizes at 212F; in an absorber, water vaporizes cold enough to produce ~43F chilled water.

Hot Water in

~ 185 °F

Cold Water Out

~ 43 °F

Fuel Cells

Performance Characteristics

Power

Electric power	400 kW/400 to 471 kVA initial 400 kW lifetime average 360 kW initial (ADG)
Voltage/frequency	480VAC/60 Hz/3 phase** 400VAC/50 or 60 Hz/3 phase

Efficiency

Electrical (LHV)	42% initial/40% nominal (5 yr)
Overall (LHV)	90%***

Fuel

Supply	Natural gas or ADG†
Consumption (HHV)	3.60 MMBtu/hr (1,054 kW) initial 3.79 MMBtu/hr (1,110 kW) average 3,493 scfh (98.9 Nm3/hr) initial 3,678 scfh (104.2 Nm3/hr) average
Pressure	4 to 14 in. water (1.0 to 3.5 kPa)‡

Heat Recovery

Low grade (140°F/60°C supply)§	1.537 MMBtu/hr (450 kW) initial 1.708 MMBtu/hr (500 kW) nominal
High grade (250°F/121°C supply)§	0.683 MMBtu/hr (200 kW) initial 0.785 MMBtu/hr (230 kW) nominal

Emissions*

NO_x	0.035 lb/MWh (0.016 kg/MWh)
CO	0.008 lb/MWh (0.004 kg/MWh)
CO_2	1120 lb/MWh (508 kg/MWh) average
SO_x	Negligible
Particulate matter/VOCs	Negligible

Water

Consumption	None (up to 86°F/30°C ambient)
Discharge	None (normal operating conditions)

Other

Noise	<65 dBA at 33 ft (10m) with no heat recovery <60 dBA at 33 ft (10m) with full heat recovery
Overhaul interval	10 yr

Q: How do you select a Prime Mover?

A: “Lowest Total Cost of Ownership”

- Required output vs. available size (Power and Thermal)
- Heat Balance and temperature profiles
- Generating Efficiency
- Price (First Cost and Parts)
- Reputation/Reliability
- Availability and Quality of Info
- Scheduled Downtime

CHP Prime Mover Database

Process for determining:

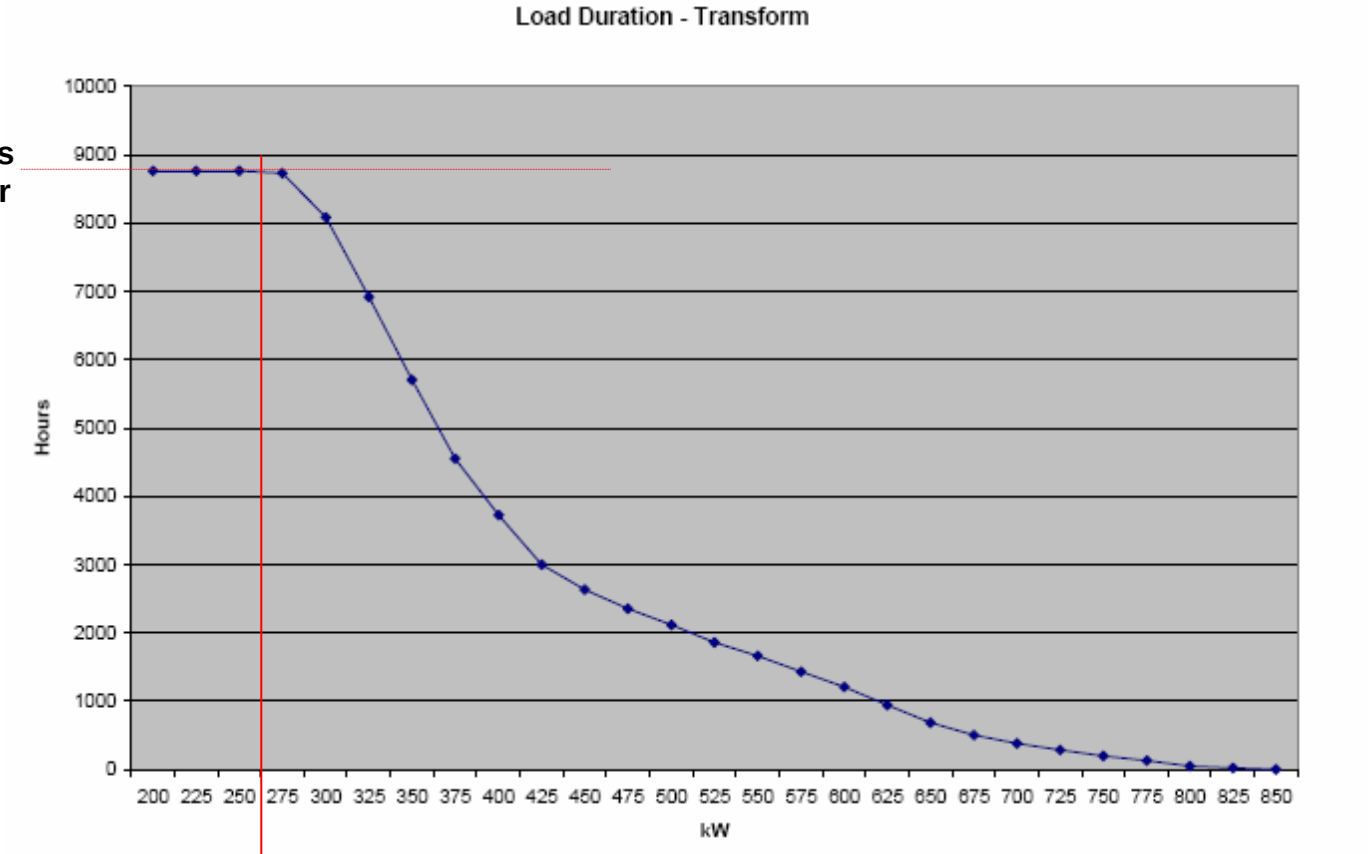
"Do I have an application for CHP?"

Project Development Elements for CHP Projects

1. Qualification (Spark Spread, Operation, Location)
2. Level 1 Feasibility (commercial analysis)
3. Level 2 Feasibility (PE analysis, review)
4. Procurement (Design, manufacture, factory compliance test)
5. Commission, Monitoring and O&M.

Site Electric Load Duration Studied

8760 hrs
Per year



Maximum size electrical generator for full load employment and 100% site utilization, no export.

250kWe = 1.35 MMBTU/hr heating = 76 USRT cooling

Level 1 Feasibility – Site Engineer Commercial Analysis:

Quick…Safe… Fair

1. Requires customer provided information
2. Model based on packaged systems
3. Typical accuracy is a *conservative* 80% historically.

Trigeneration Systems, Indicative Commercial Analysis

Simple CHP Analysis spreadsheet for base load schemes, flat profiles
Offsetting grid electricity, Mechanical Chillers, and gas fired boilers
Thermal usage split between hot water and chilled water

Yellow cells require a project specific value

SITE INPUTS		
Average Site Gas Price	9	$/MMBTU
Average Site Power Price	17	c/kWh
Power to Gas Price Ratio	5.54	
Existing Boiler Efficiency	85%	
Existing Chillers CoP	2.5	
Annual Hours in Cooling Mode	4318	hrs
Annual Hours in Heating Mode	4418	hrs
Project Life	15	yrs
CHP Gas Price	$11.00	$/MMBTU

CHP PERFORMANCE DATA		
CHP Availability	90%	
CHP Electrical Output (Gross)	250	kW
CHP Thermal Output	1,326,944	BTU/hr
CHP Gas Input (LHV)	2,708,049	BTU/hr
Abs Chiller Input	1,326,944	BTU/Hr
Abs Chiller CoP	0.68	
Abs Chiller Output	75	USRT
Electrical Efficiency	31.50%	
Thermal Efficiency	49.00%	
Total Efficiency	80.50%	

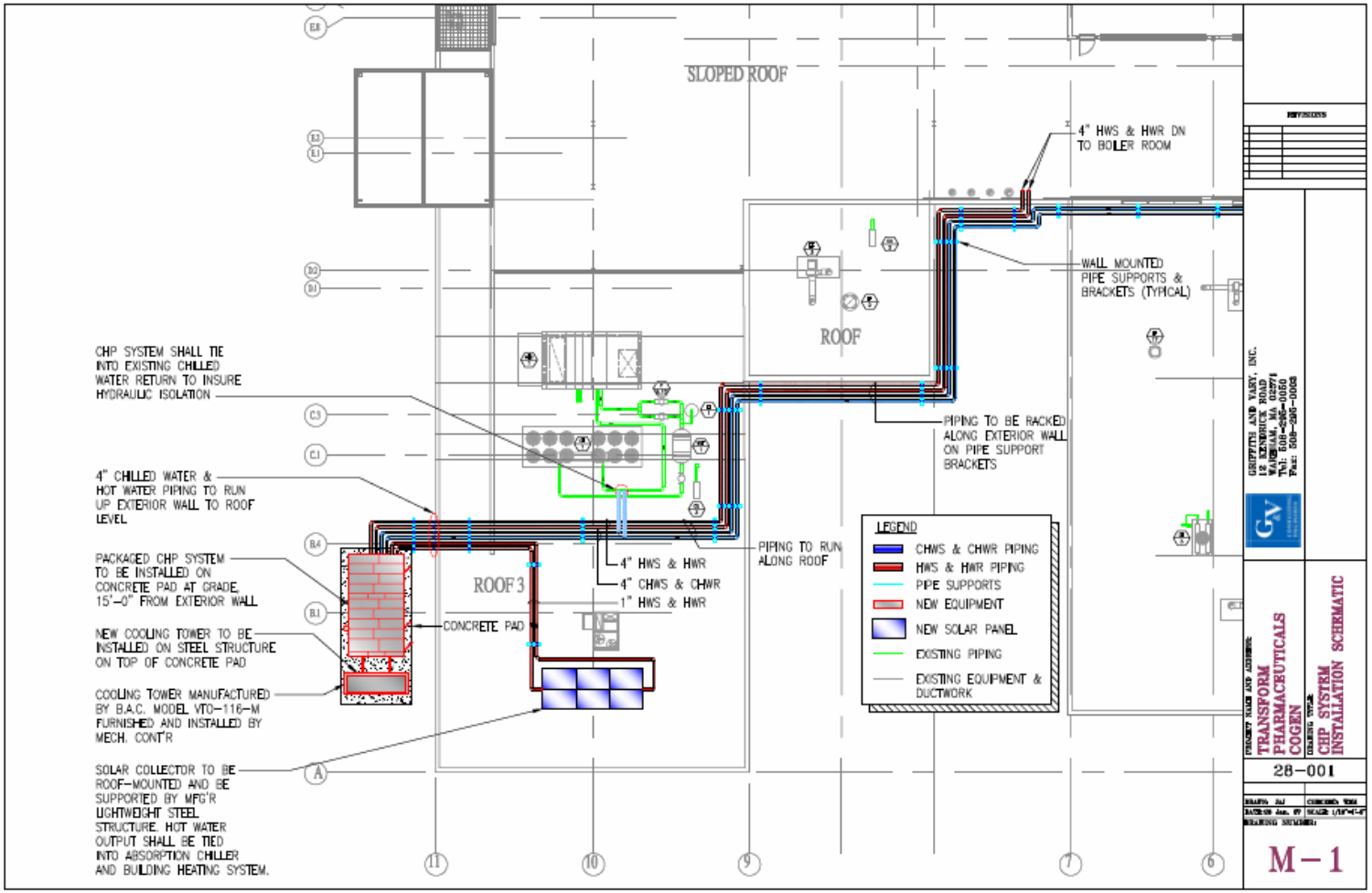
CHP COST DATA	
Package price per kW from price curve	$2,000
CCP package cost	$500,000
Turnkey Installation (% of Package Price)	25%
Turnkey Installation Cost	$500,000
Total Installed Price	$1,000,000
Less Capital Offset	$0
Less State Subsidy	$0
Real Capital Cost	$1,000,000

Metric Sense Check		
Gas Price	3.07	c/kWh
CHP Thermal Output	389	kW
CHP Gas Input	794	kW
Abs Chiller Output	264	kW
CHP Gas Price	3.75	c/kWh

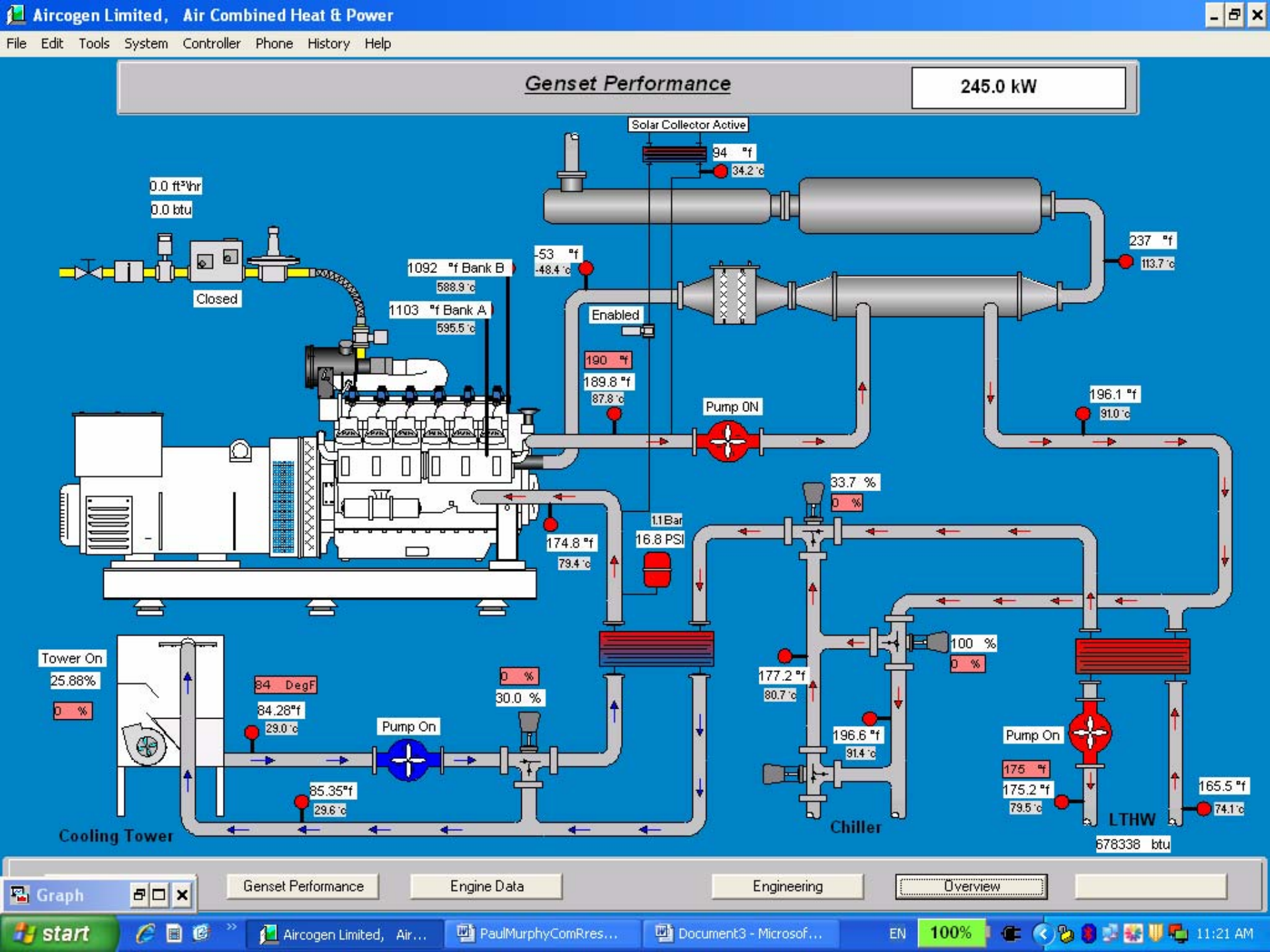
ANNUAL CHP REVENUES AND COSTS		
Generation Revenue	$334,152	
Power Offset by Abo	$69,883	
Thermal offset by CHP	$55,866	
Value of Additional Power Security	$1	
Value of Environmental Benefit	$1	
Gas Purchased	$234,210	
Maintenance Rate	0.020	$/kWh
Annual Maintenance	$39,312	

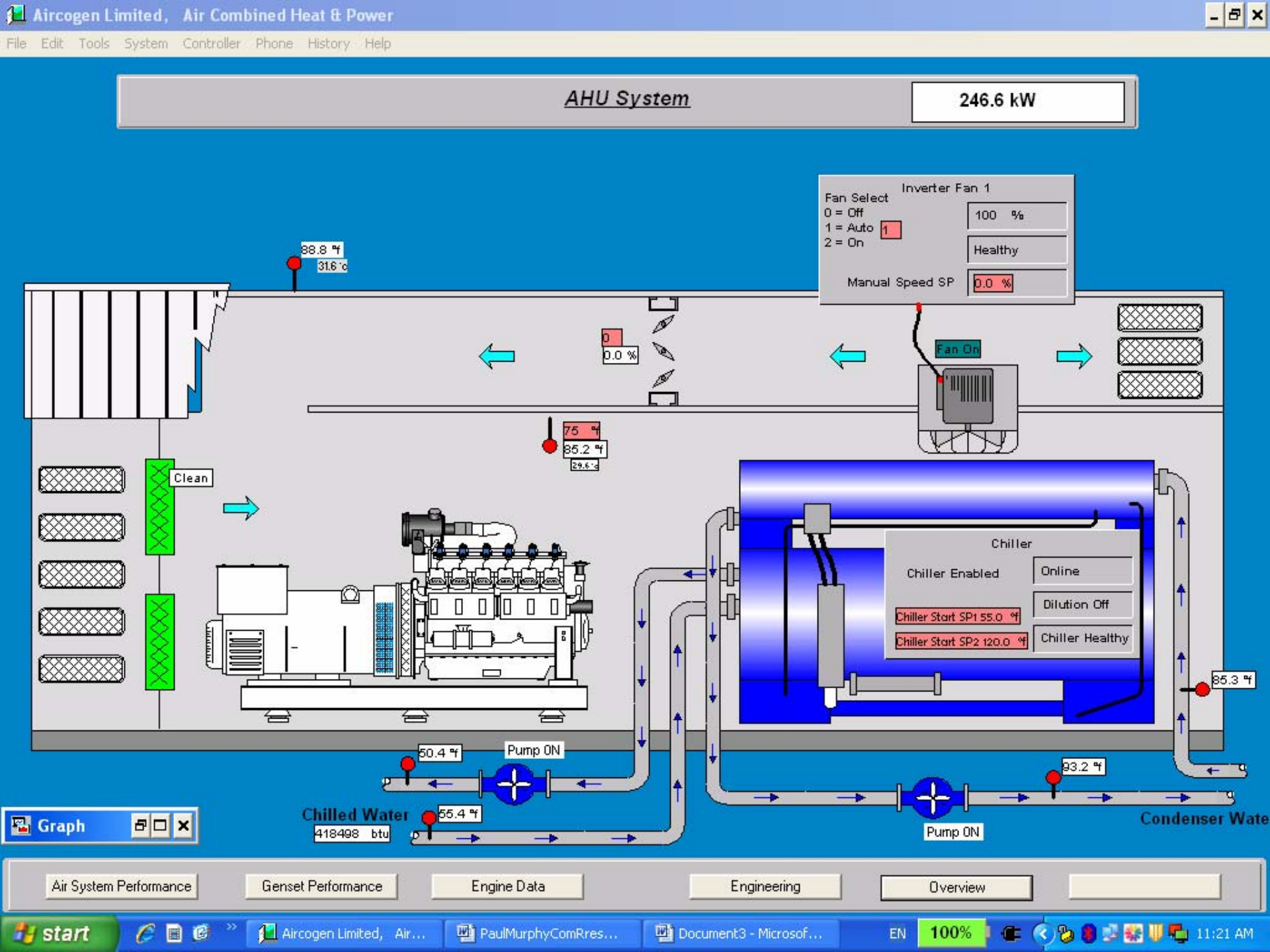
SIMPLE COMMERCIAL ANALYSIS	
Annual Indicative Saving	$186,380
Payback (Years)	5.37
IRR	
NPV	
Lifetime project saving	$2,795,701

Site Engineering Determined and Studied



2009 Northeast Energy Efficiency Partnerships (NEEP)
Northeast Business Leader Recognition Program Nominee
National Grid.
First Factory tested Solar Assisted Trigeneration System in the United States


Aircogen Limited, Air Combined Heat & Power
File Edit Tools System Controller Phone History Help
Genset Performance
245.0 kW
Solar Collector Active
94 °f
34.2 °c
0.0 ft³/hr
0.0 btu
Closed
1092 °f Bank B
588.9 °c
1103 °f Bank A
595.5 °c
-53 °f
-48.4 °c
Enabled
237 °f
113.7 °c
190 °f
189.8 °f
87.8 °c
Pump ON
196.1 °f
91.0 °c
33.7 %
0 %
1.1 Bar
16.8 PSI
174.8 °f
79.4 °c
Tower On
25.88%
0 %
84 DegF
84.28°f
29.0 °c
Pump On
0 %
30.0 %
85.35°f
29.6 °c
Cooling Tower
100 %
0 %
177.2 °f
80.7 °c
196.6 °f
91.4 °c
Chiller
Pump On
175 °f
175.2 °f
79.5 °c
165.5 °f
74.1 °c
LTHW
678338 btu
Graph
Genset Performance
Engine Data
Engineering
Overview
start
Aircogen Limited, Air...
PaulMurphyComRres...
Document3 - Microsof...
EN
100%
11:21 AM


Aircogen Limited, Air Combined Heat & Power
File Edit Tools System Controller Phone History Help
AHU System
246.6 kW
Inverter Fan 1
Fan Select
0 = Off
1 = Auto
2 = On
100 %
Healthy
Manual Speed SP
0.0 %
88.8 °f
31.6 °c
0
0.0 %
Fan On
75 °f
85.2 °f
29.6 °c
Clean
Chiller
Chiller Enabled
Online
Dilution Off
Chiller Start SP1 55.0 °f
Chiller Start SP2 120.0 °f
Chiller Healthy
85.3 °f
50.4 °f
Pump ON
Chilled Water
418498 btu
55.4 °f
93.2 °f
Pump ON
Condenser Wate
Graph
Air System Performance
Genset Performance
Engine Data
Engineering
Overview
start
Aircogen Limited, Air...
PaulMurphyComRres...
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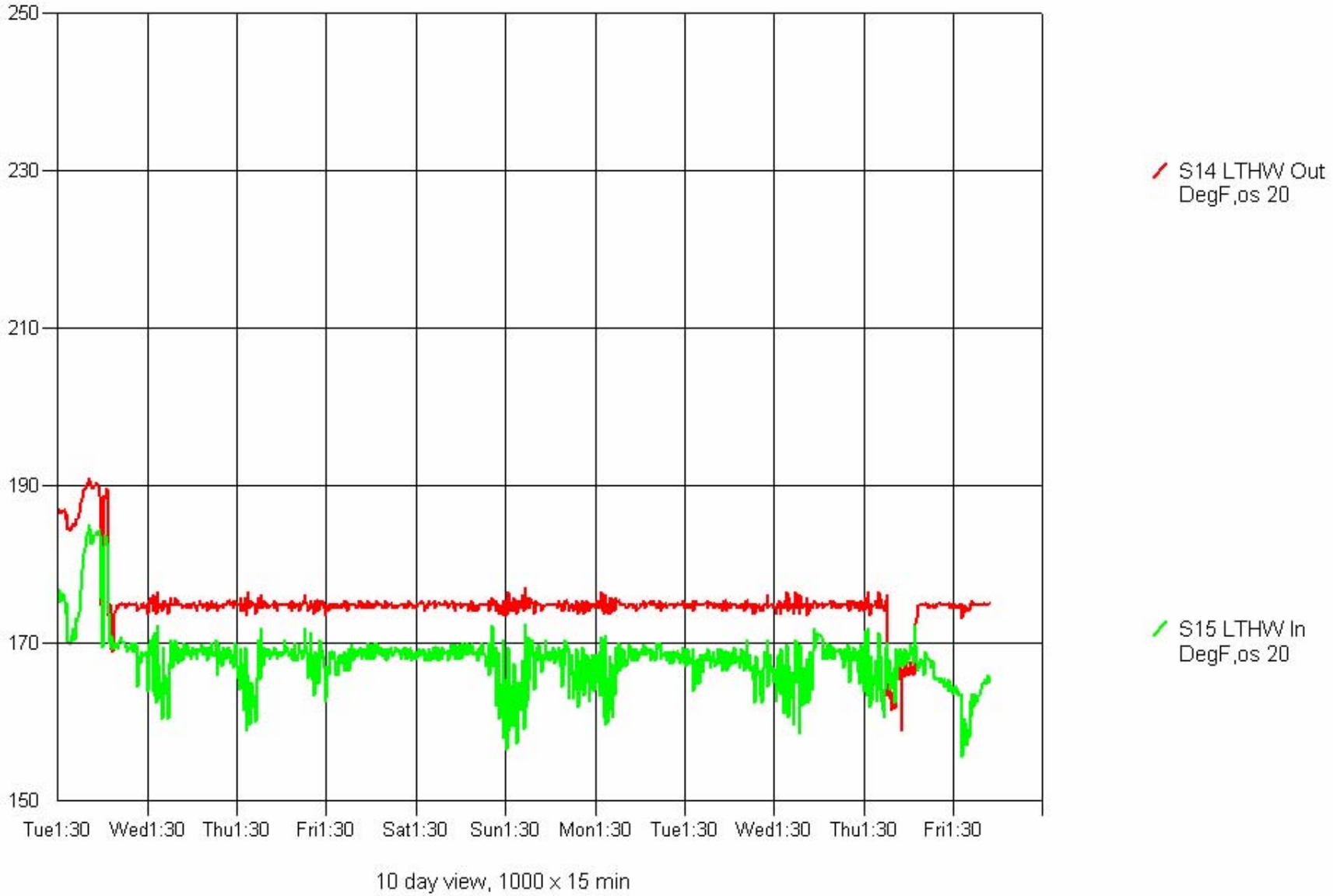
100%
11:21 AM

Doorway Graph

File Edit Options Statistics Group Wizards Help

Graph plotted at 11:26 Friday 8 May 2009

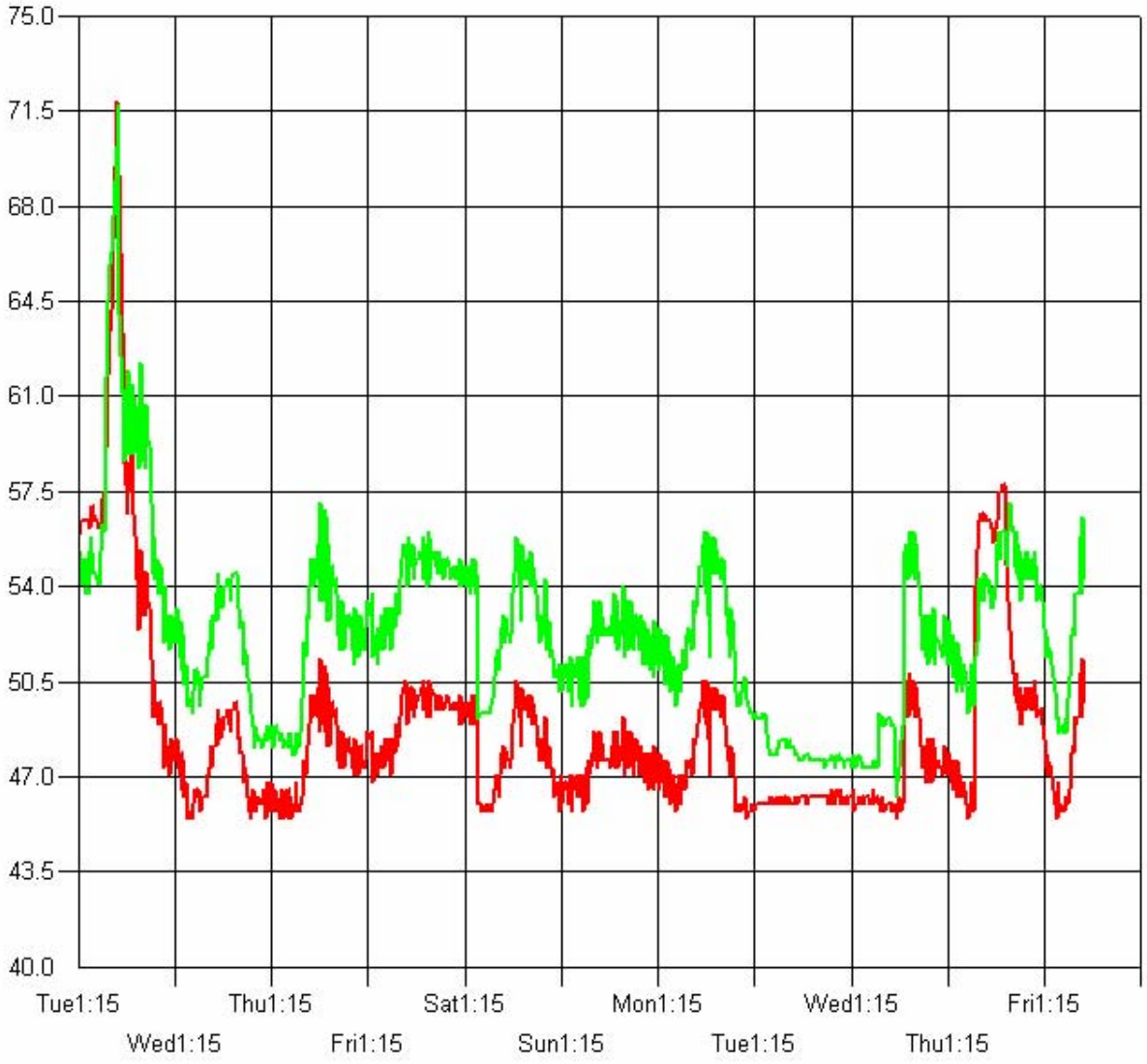


10 day view, 1000 x 15 min

Doorway Graph

File Edit Options Statistics Group Wizards Help

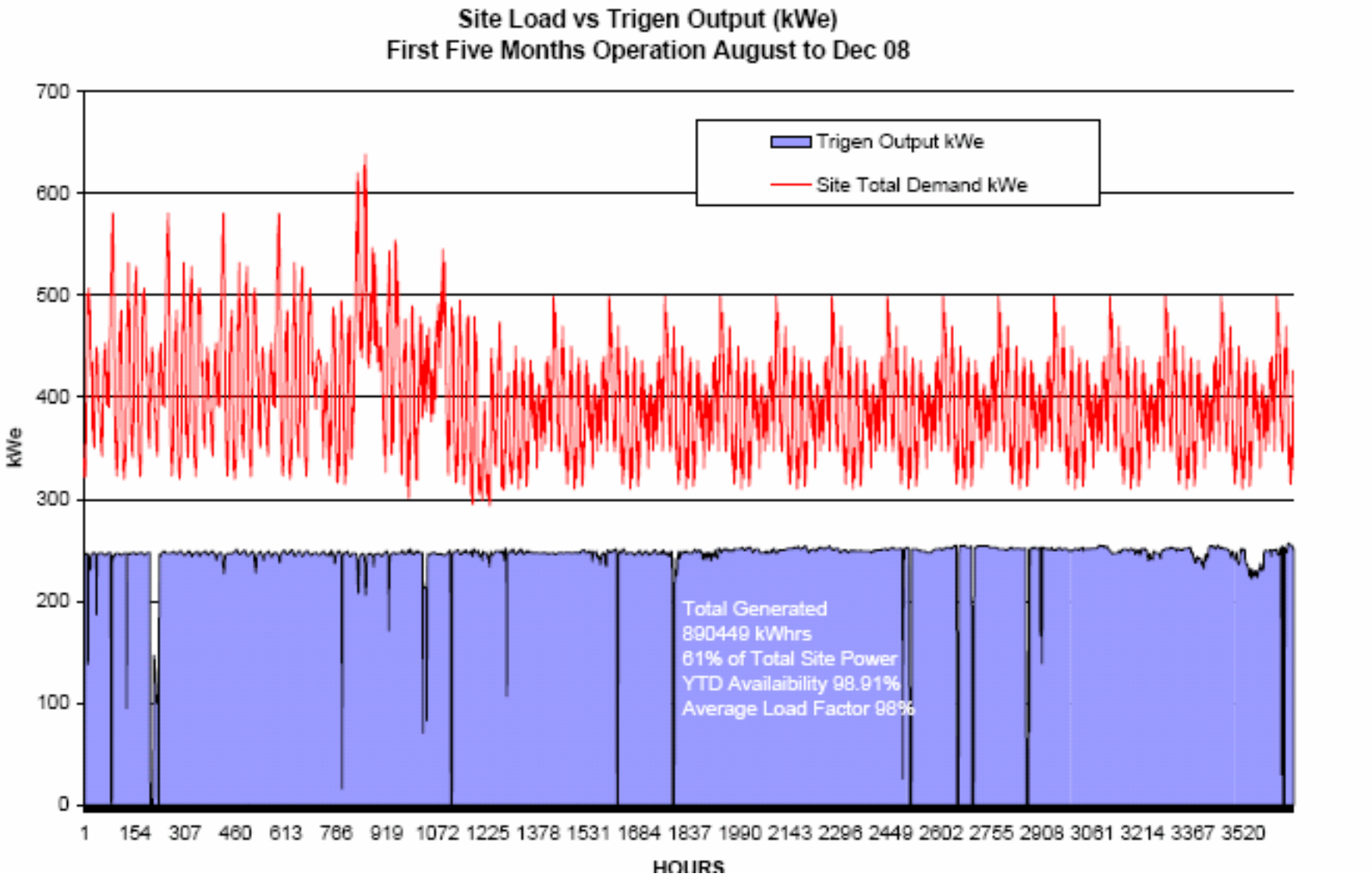
Graph plotted at 11:24 Friday 8 May 2009

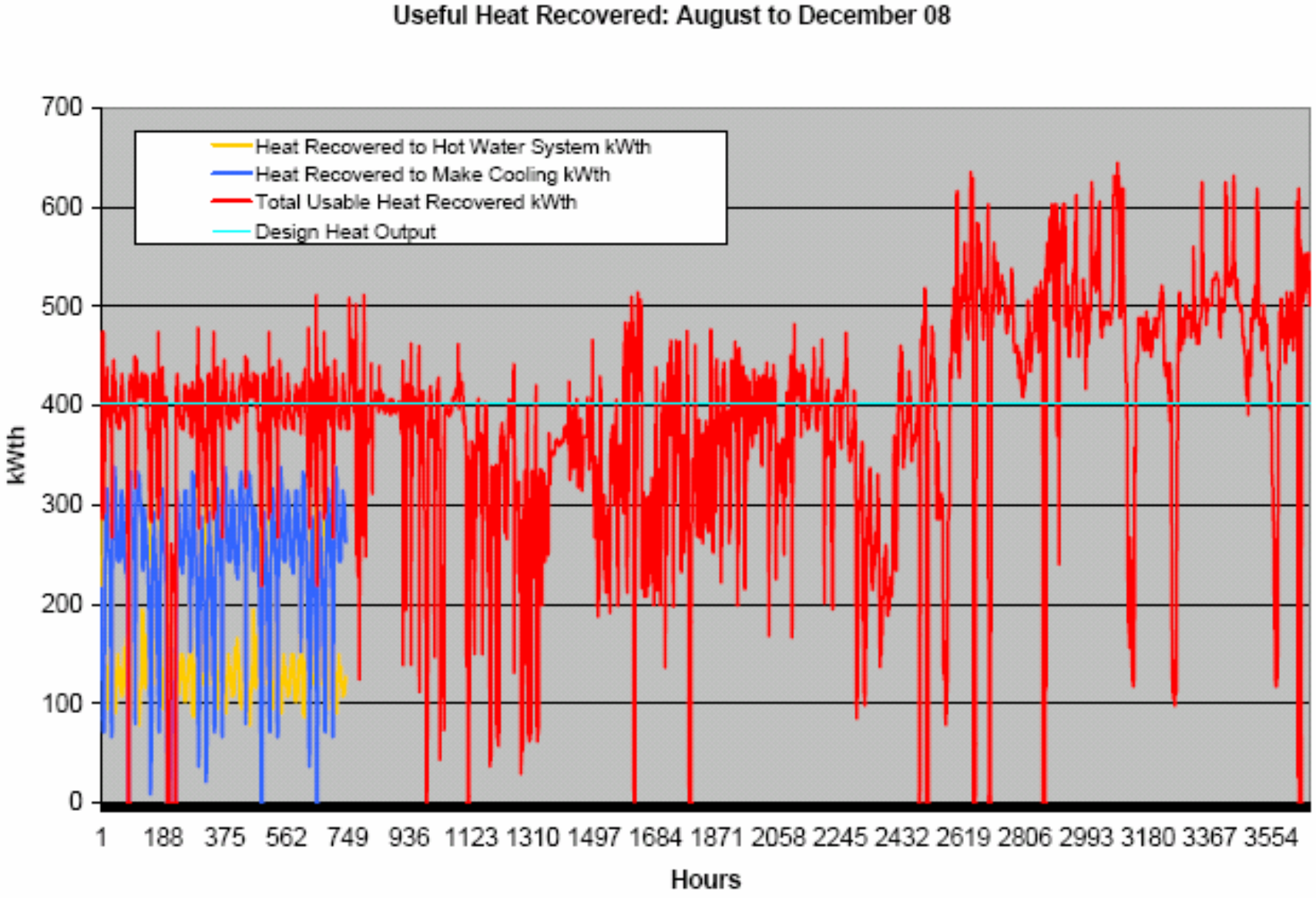


S22 Chilled Water Flow
DegF,os 20

S23 Chilled Water Return
DegF,os 20

10 day view, 1000 x 15 min


Site Load vs Trigen Output (kWe)
First Five Months Operation August to Dec 08
Trigen Output kWe
Site Total Demand kWe
kWe
700
600
500
400
300
200
100
0
Total Generated
890449 kWhrs
61% of Total Site Power
YTD Availaibility 98.91%
Average Load Factor 98%
1 154 307 460 613 766 919 1072 1225 1378 1531 1684 1837 1990 2143 2296 2449 2602 2755 2908 3061 3214 3367 3520
HOURS


Useful Heat Recovered: August to December 08
Heat Recovered to Hot Water System kWth
Heat Recovered to Make Cooling kWth
Total Usable Heat Recovered kWth
Design Heat Output
kWth
700
600
500
400
300
200
100
0
1
188
375
562
749
936
1123
1310
1497
1684
1871
2058
2245
2432
2619
2806
2993
3180
3367
3554
Hours

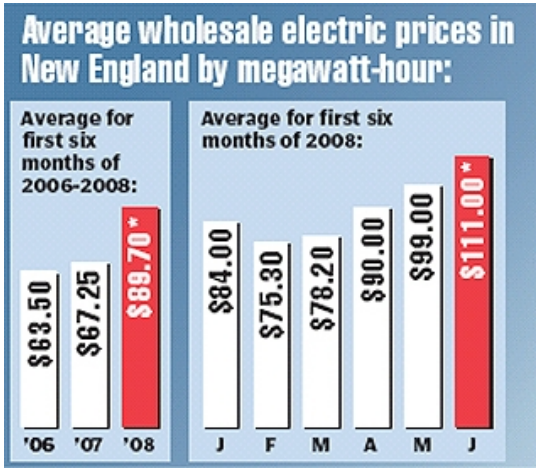
Recap- CHP Rules of the road

1. Size your system for 100% total energy utilization, no significant heat dumping, simultaneous thermal and power usage.
2. Size your system to 100% full employment, 96.5% availability of 8760 hours per year
3. Choose “lowest cost of ownership” 15 year design life or better, parts, fuel, maintenance, site conditions.
4. Proper Design and Application , Proper CHP System, long-term maintenance and fuel. The Three Legged Stool.
5. Size to baseload thermal first, confirm available baseload electric, hard to lose with an undersized, economic system, easy to lose with an oversized system.
6. Understand your purpose of ownership..economics, environmental, plant reliability boost or science project?

Regional Review (New England)

Strong Regional Factors exist to potentially influence market surge in CHP and GREEN Technologies 2010 Onwards:

- Regional Green House Gas Initiative (RGGI) signed into law 2007. First USA Cap and Trade program for 10 NE and Mid Atlantic States.
- Optimal "Spark Spread" continues to develop in New England, electric power rates forecasted to increase.
- EPA-DEP to announce new emissions credit program for CHP
- Massachusetts Electric Utilities ordered to "De-Couple" Rates. Obstacles for CHP such as volume driven electric rates will be eliminated.



Source: *Boston Herald*

Thank you

Questions ??

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