WASTE TO ENERGY COGENERATION SYSTEM

Case Study: Olmsted Waste to Energy Plant

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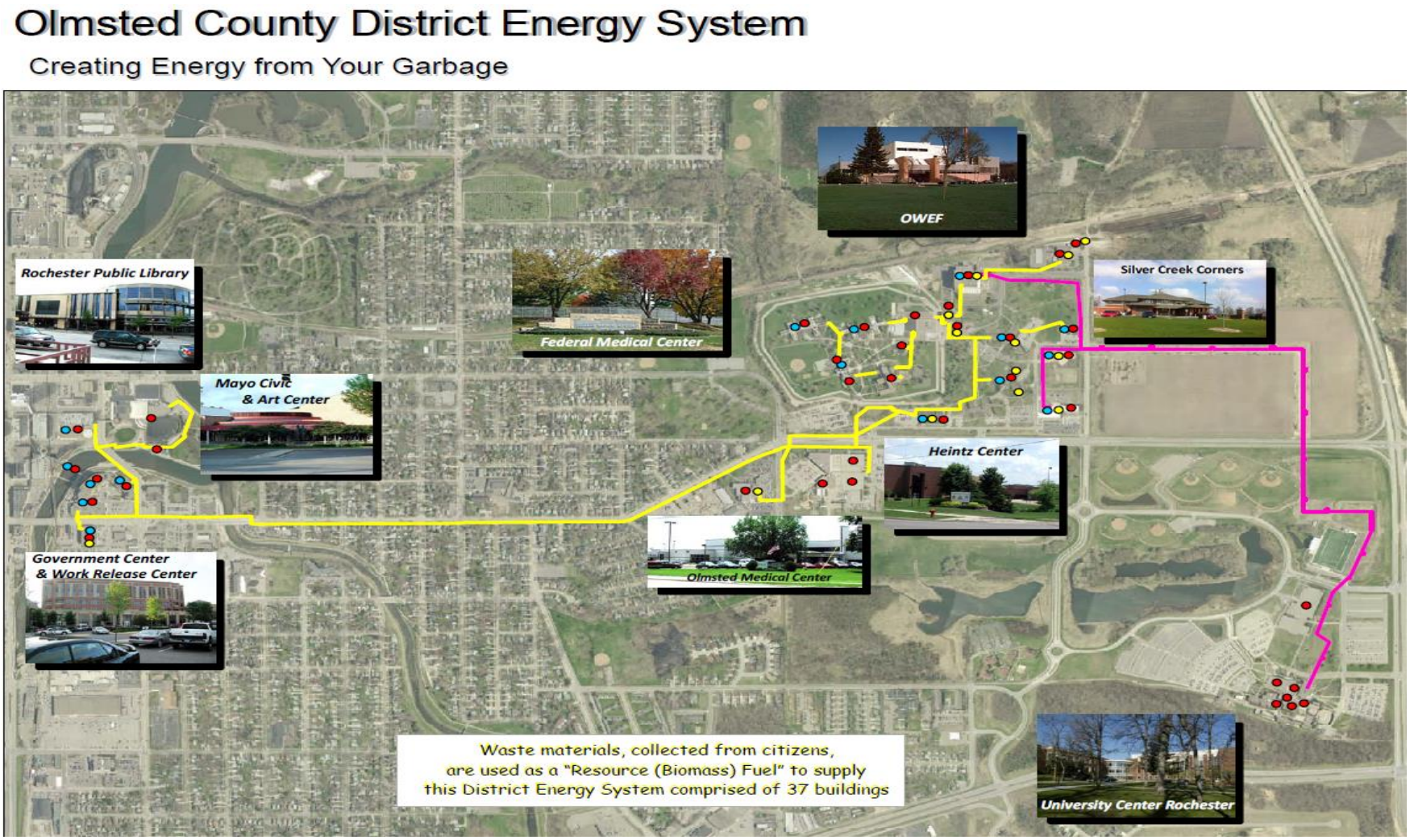
Olmsted Waste to Energy Facility(OWEF) Rochester, MN

Municipal Solid Waste

- 109,000 TPY
  - Olmsted County
  - City of Rochester
- Reclaimed Landfill- 17,400 TPY- 2016

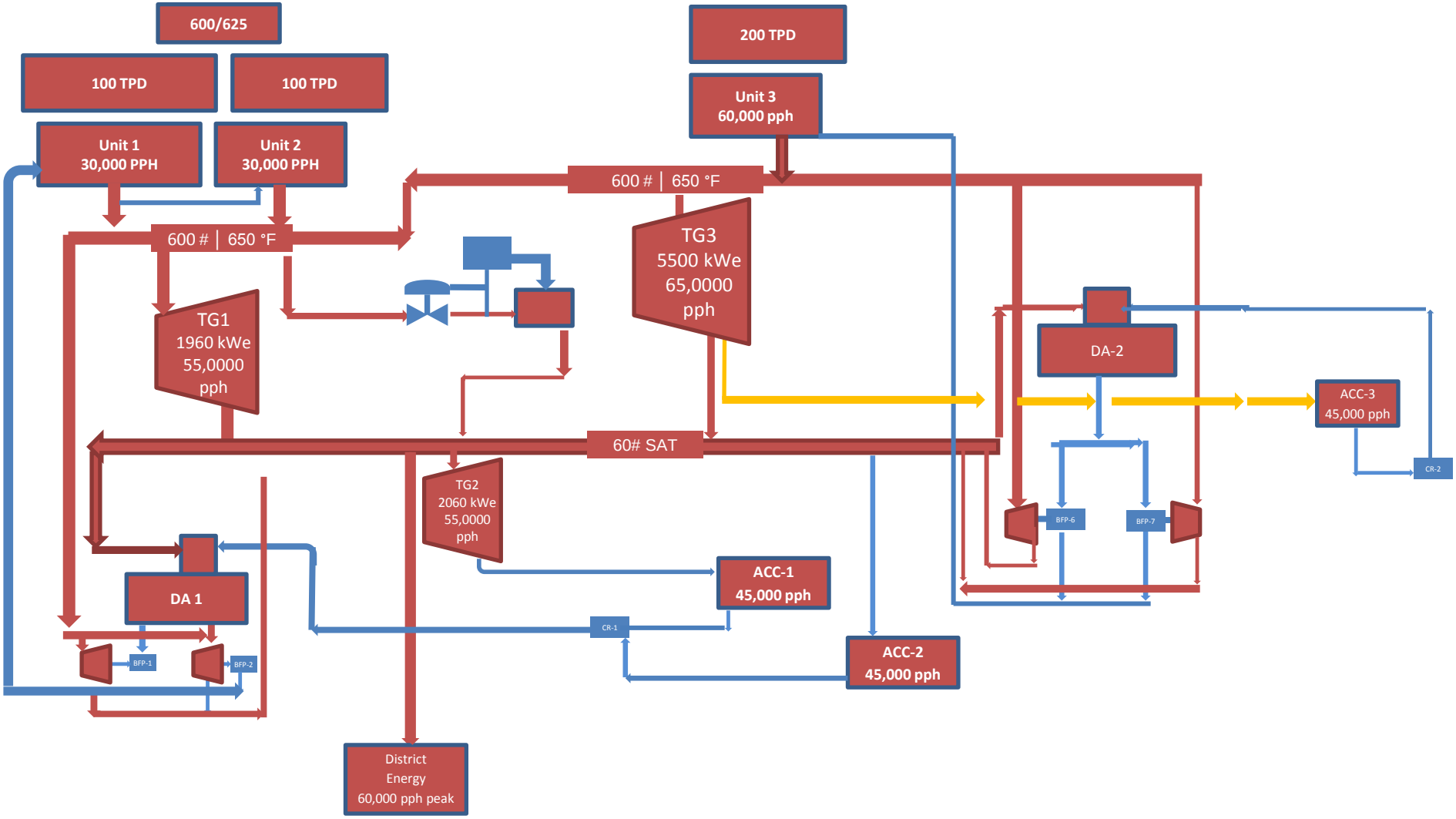
OWEF WtE Cogeneration Plant

- 120,000 pph of 600 psig/ 650 F steam
- Generates up to 9.5 MW Electricity
- Small county cooling loop- 500 tons absorber
- Serves 37 buildings over 3 miles of steam



Destination Medical Center

- $5.5 Billion over 20 years
- $580 Million in Public Funding
- Mayo Clinic Existing Central Cogeneration Plant
- OWEF District Energy


600/625
100 TPD
100 TPD
Unit 1
30,000 PPH
Unit 2
30,000 PPH
600 # | 650 °F
TG1
1960 kWe
55,0000
pph
200 TPD
Unit 3
60,000 pph
600 # | 650 °F
TG3
5500 kWe
65,0000
pph
DA-2
ACC-3
45,000 pph
CR-2
60# SAT
TG2
2060 kWe
55,0000
pph
BFP-6
BFP-7
ACC-1
45,000 pph
DA 1
CR-1
ACC-2
45,000 pph
BFP-1
BFP-2
District
Energy
60,000 pph peak

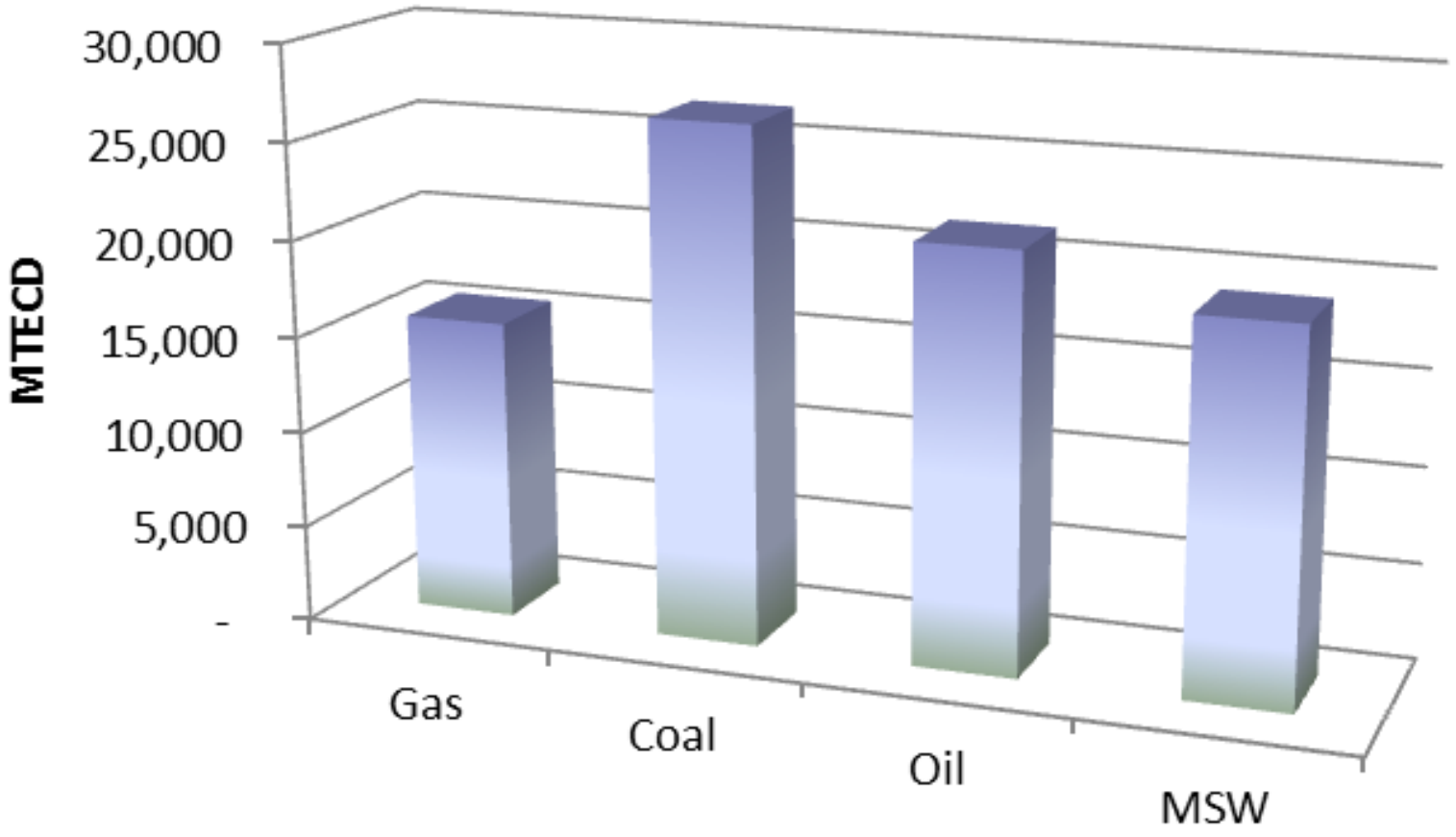
OWEF Plant Design

Boiler ID	**WCU 1**	**WCU 2**	**WCU 3**	**B4**
Primary Fuel	MSW	MSW	MSW	Natural Gas
Fuel Input, TPD	125	125	250	-
Nominal Boiler Output Capacity, HP	934	934	1,943	2,205
Operating Pressure, psig	600	600	620	250
Steam Temperature,°F	625	625	650	409

OWEF WCU Permit Limits

	WCU-1	WCU-2	WCU-3
MSW Throughput TPD	125	125	250
Steam Output , PPH	32,560	33,440	62,500

2012 OWEF Emissions Comparison



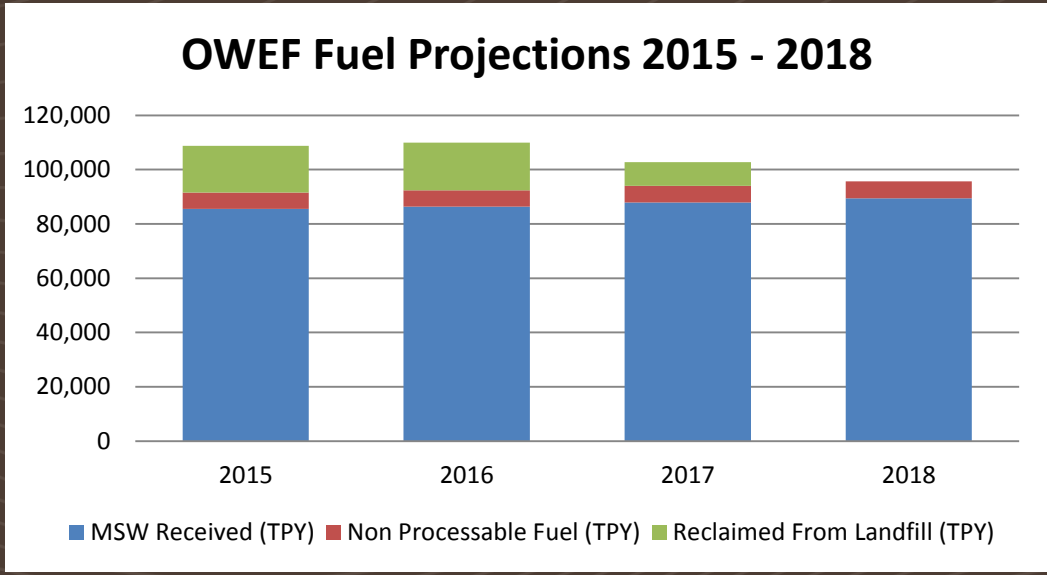
Electric Energy Portion of Emissions- Non-Biogenic Emissions

Fuel and Steam Production Assumptions 2016 Data

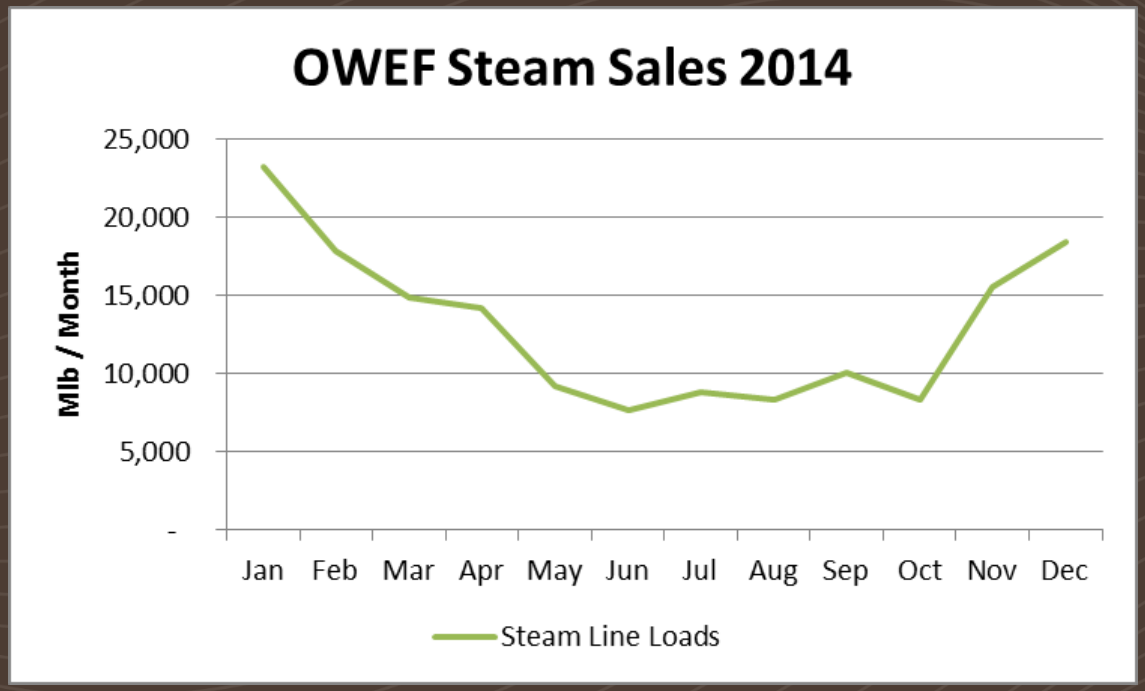
MSW Throughput TPD		301	TPD
Non Burnable	6%	16.6	6,077 TPY
Percent Reclaimed Fuel	16%	45	
Ave Fuel LHV, btu/lbm	5093	239 TPD	87,300 TPY
Ave hhv Reclaimed Fuel, btu/lbm	3700	45 TPD	16,562 TPY
Average Mixed LHV, btu/lbm	4870.9	BTU/LBM Mix	
Total Steam Produced	794,300	MLBM/YR	89,900 LBM/HR Ave

Fuel Available and Steam Production Projections

Fuel Category	2015	2016	2017	2018
MSW Received (TPY)	85,578	86,331	87,842	89,379
Non Processable Fuel (TPY)	5,972	6,077	6,183	6,292
Reclaimed From Landfill (TPY)	17,220	17,521	8,761	
Total (TPY)	108,770	109,929	102,786	95,671
Days per Year	365	366	365	365
Fuel Throughout Rate (TPD)	298	300	282	262
Percent Non-Burnable	5.5%	5.5%	6.0%	6.6%
Percent Reclaimed	15.8%	15.9%	8.5%	0.0%

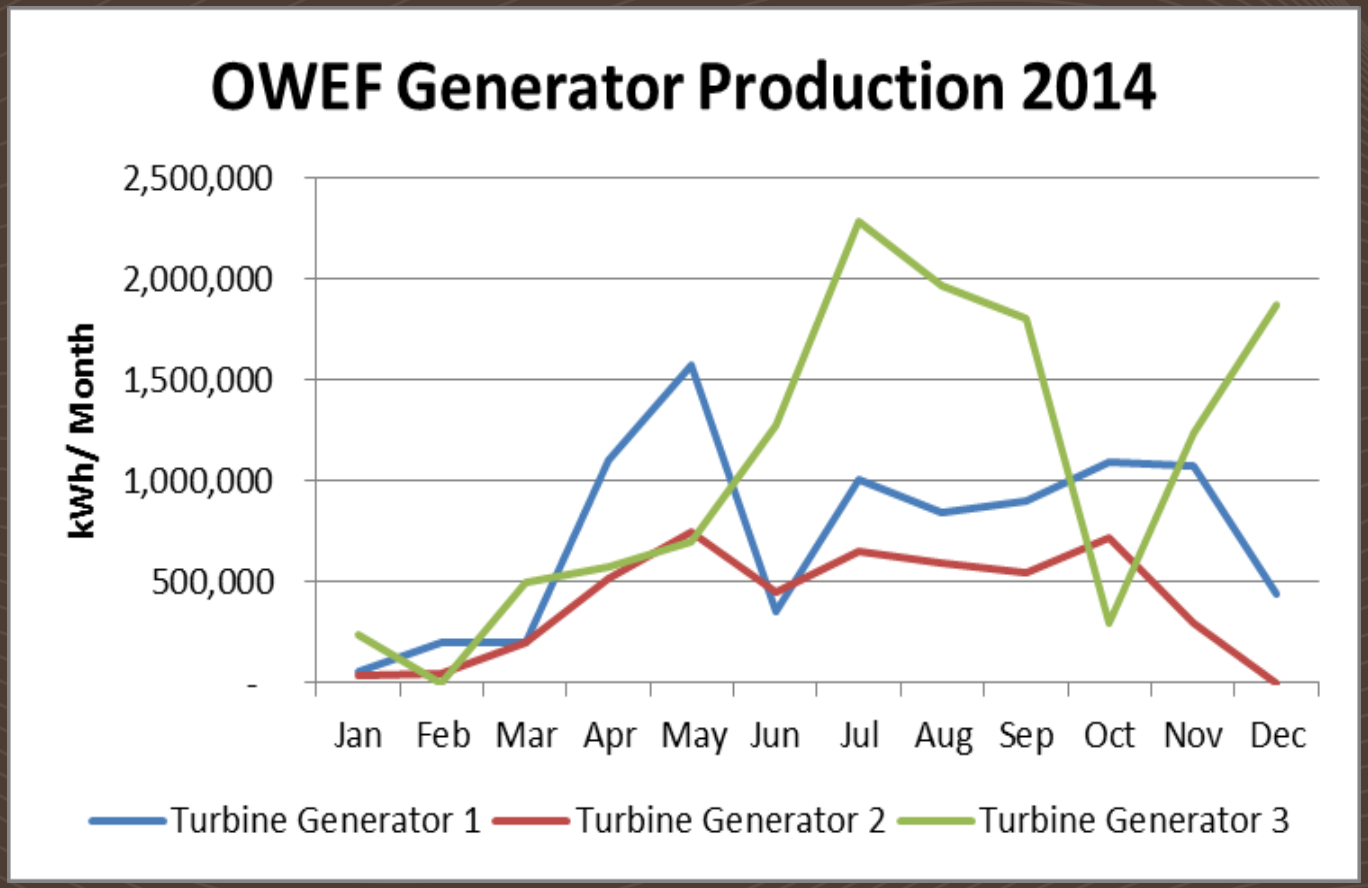


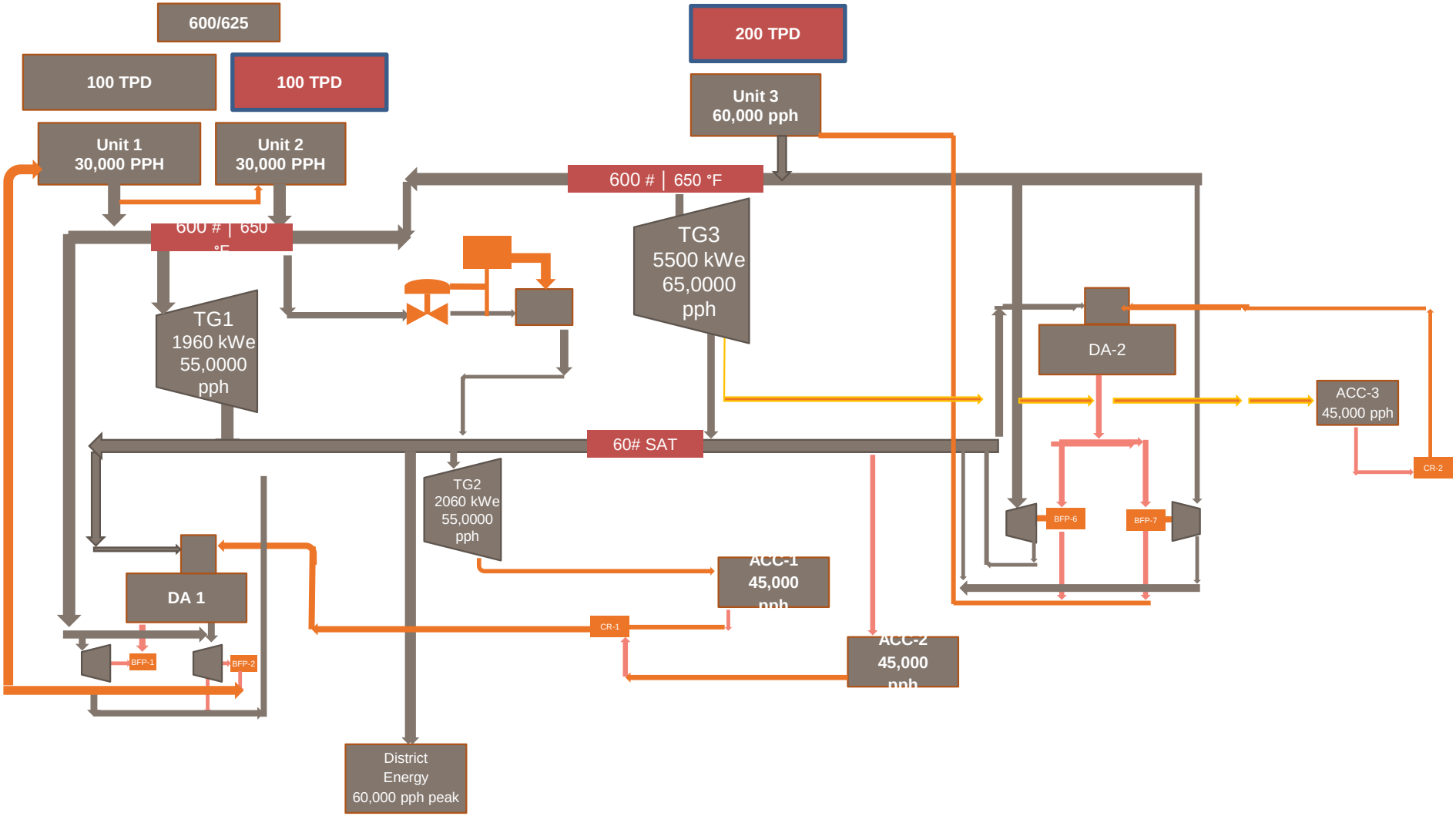
Steam Sales



Steam Distribution Sales 2014- ~ 140,000 MLB

Electric Generator Output Profile 2014




600/625
100 TPD
100 TPD
200 TPD
Unit 1
30,000 PPH
Unit 2
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600 # | 650 °F
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TG1
1960 kWe
55,0000
pph
TG3
5500 kWe
65,0000
pph
DA-2
ACC-3
45,000 pph
CR-2
60# SAT
TG2
2060 kWe
55,0000
pph
BFP-6
BFP-7
ACC-1
45,000
pph
DA 1
CR-1
BFP-1
BFP-2
ACC-2
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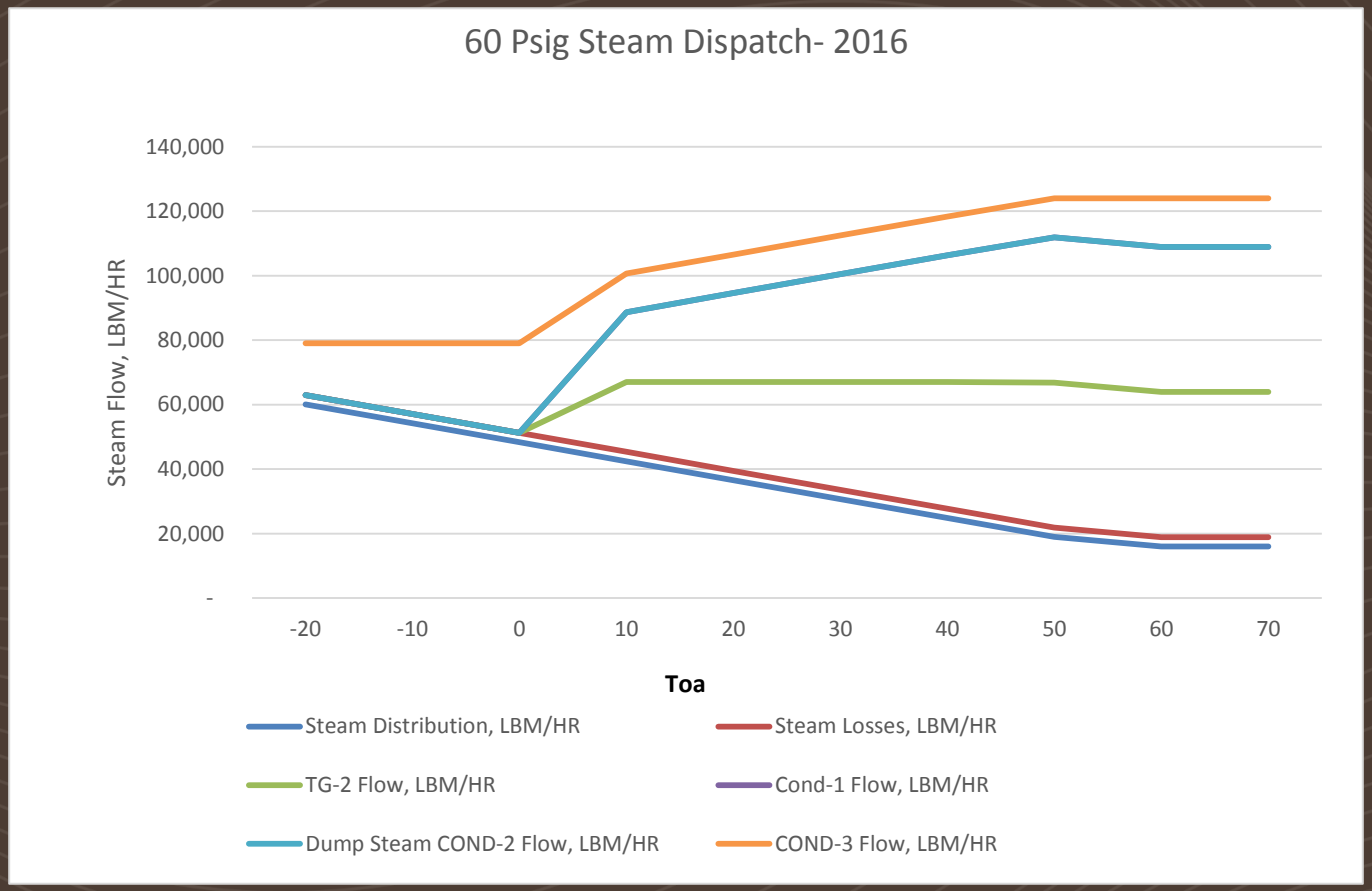
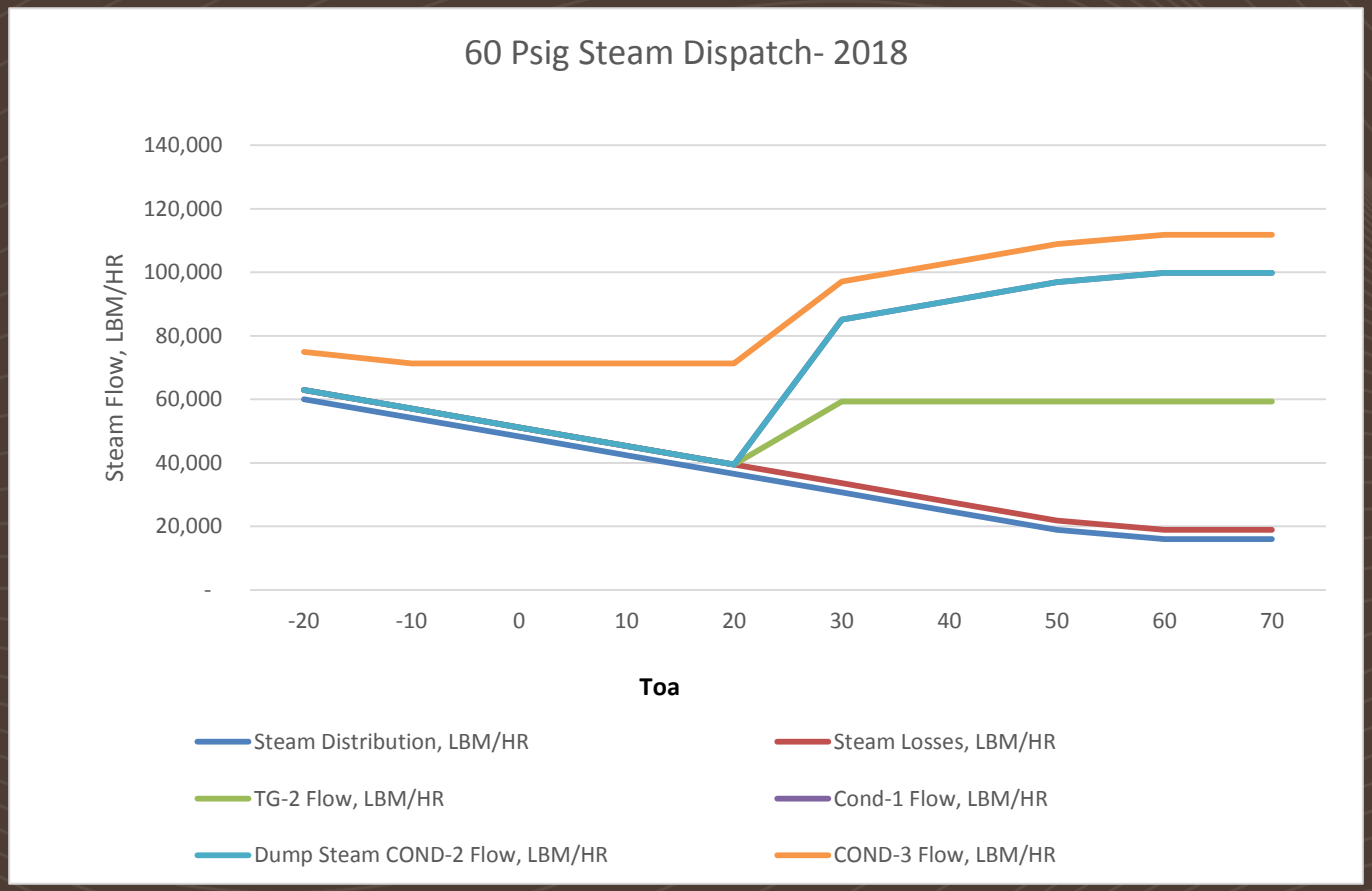
District
Energy
60,000 pph peak

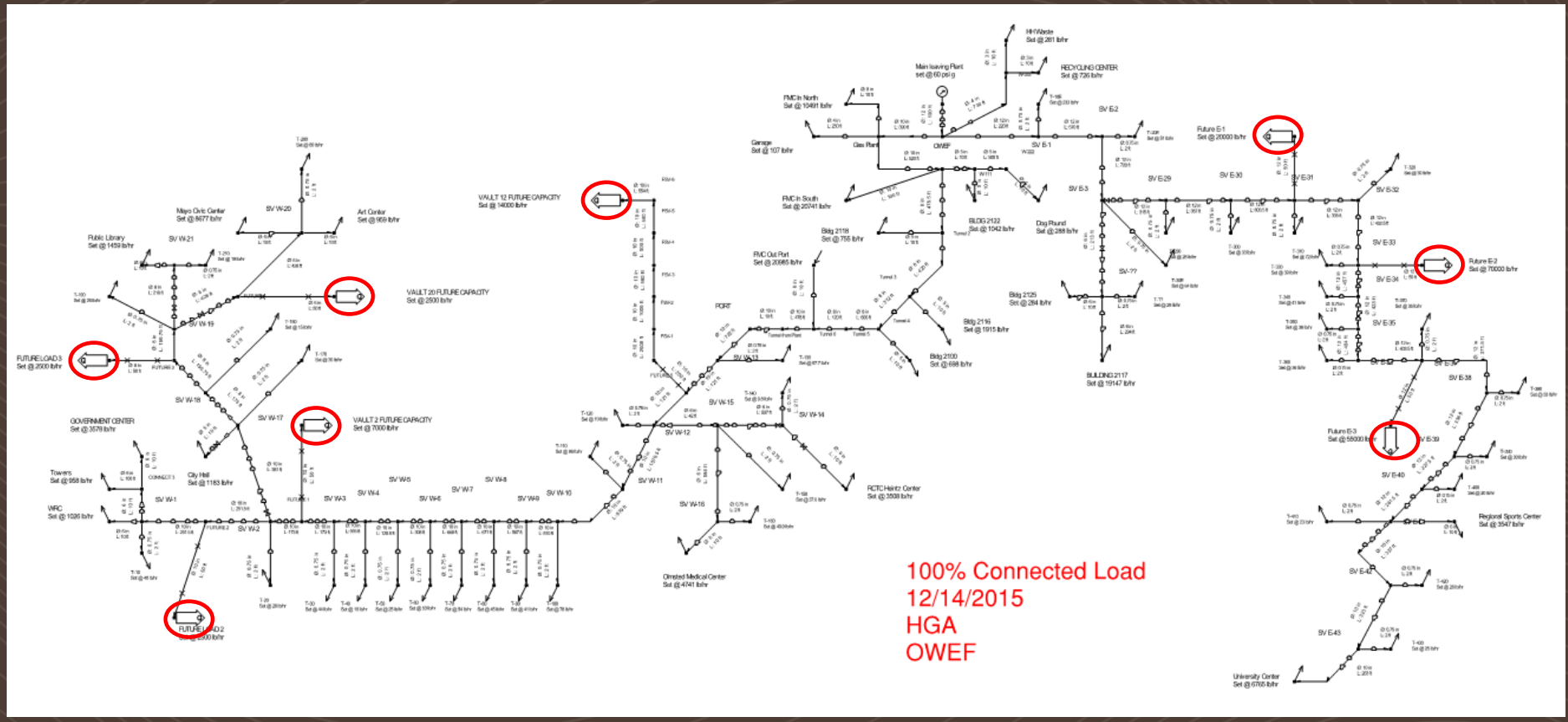
Projected Production Profile



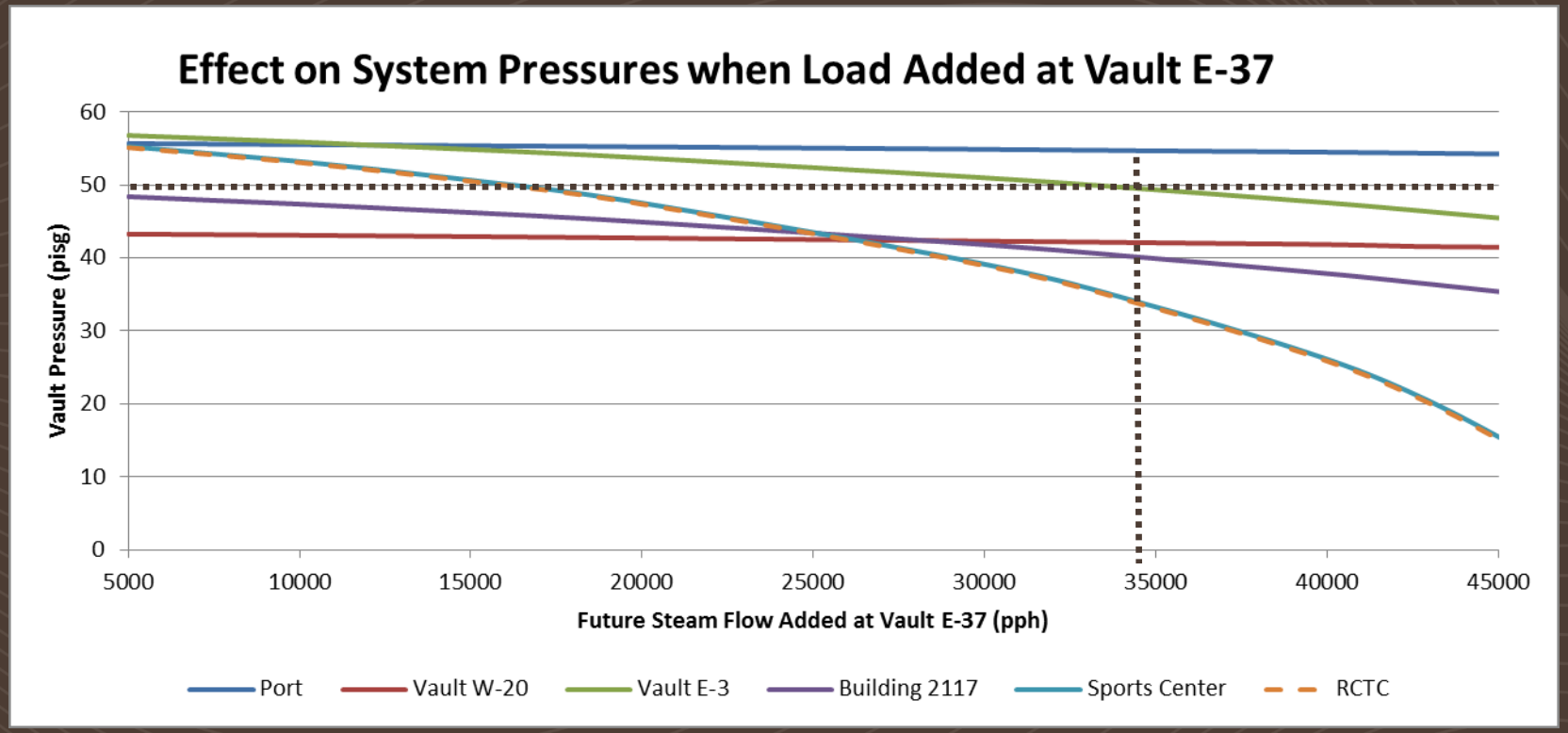
Projected Production Profile



OWEF MODELING



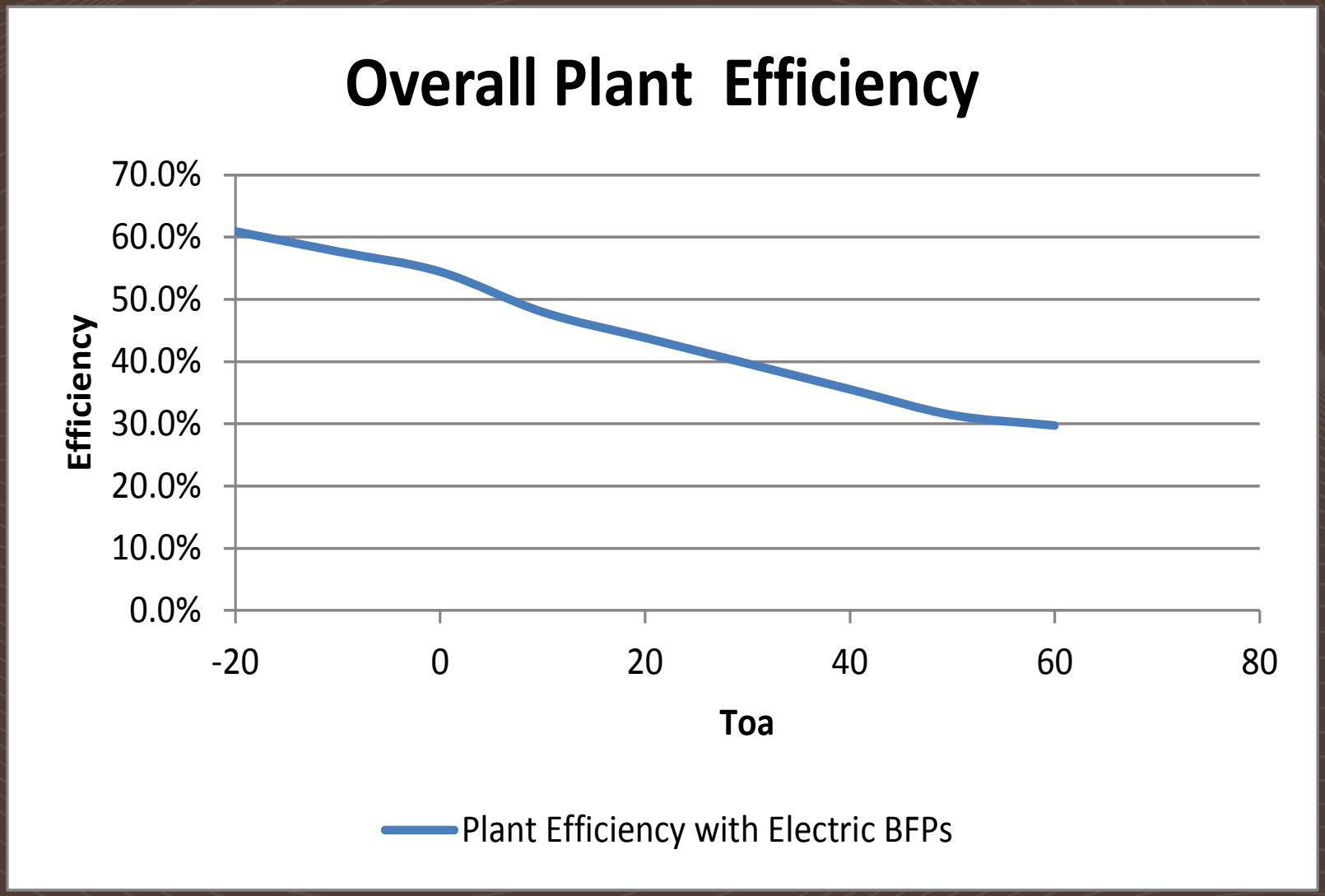
Impact of Adding Load at Vault E-37



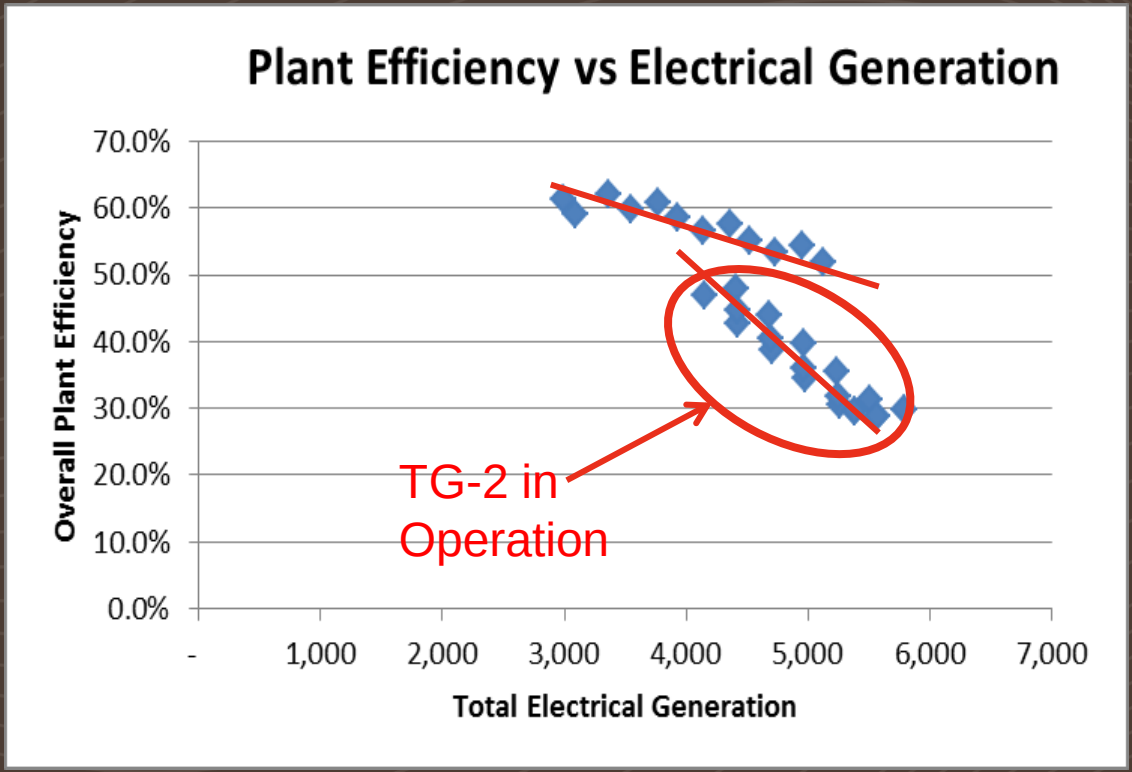
Piping Load Growth Potential

Existing Piping Load Growth Potential @ 90% Connected Load				
	Max Flow Added, LBM/HR			
Vault #	Minimum 40psig Supplied:	Minimum 50psig Supplied*:	Maximum Velocity 6000fpm	Maximum Velocity 8000fpm
W-2	2,100	See 70% Load	3,000	8,000
W-20	1,400	See 70% Load	800	2,500
E-31	34,000	22,500	15,000	28,000
E-33	34,000	20,000	15,000	28,000
E-37	28,000	15,000	15,000	28,000

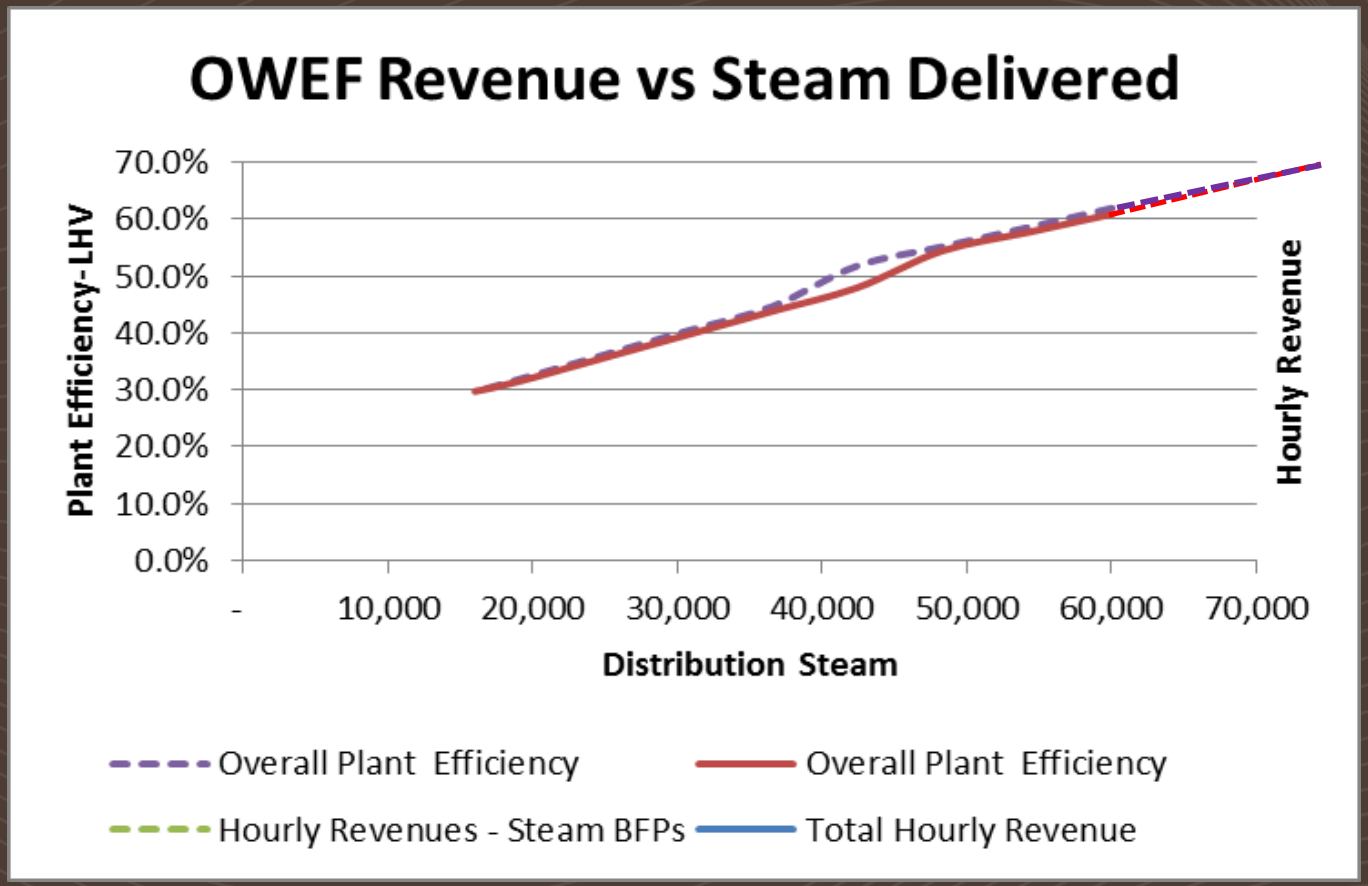
Existing Piping Load Growth Potential for 40 psig Supplied and 90% Load		
Vault	Max Flow Added LBM/HR	Effective Building Area
W-2	2,100	88,868
W-20	1,400	59,245
E-31	34,000	1,438,818
E-33	34,000	1,438,818
E-37	28,000	1,184,909


Overall Plant Efficiency
70.0%
60.0%
50.0%
40.0%
30.0%
20.0%
10.0%
0.0%
Efficiency
-20
0
20
40
60
80
Toa
Plant Efficiency with Electric BFPs

Performance



Customer Base and Distribution System



1.75 gpm x 6 min/shower= 10.5 gal

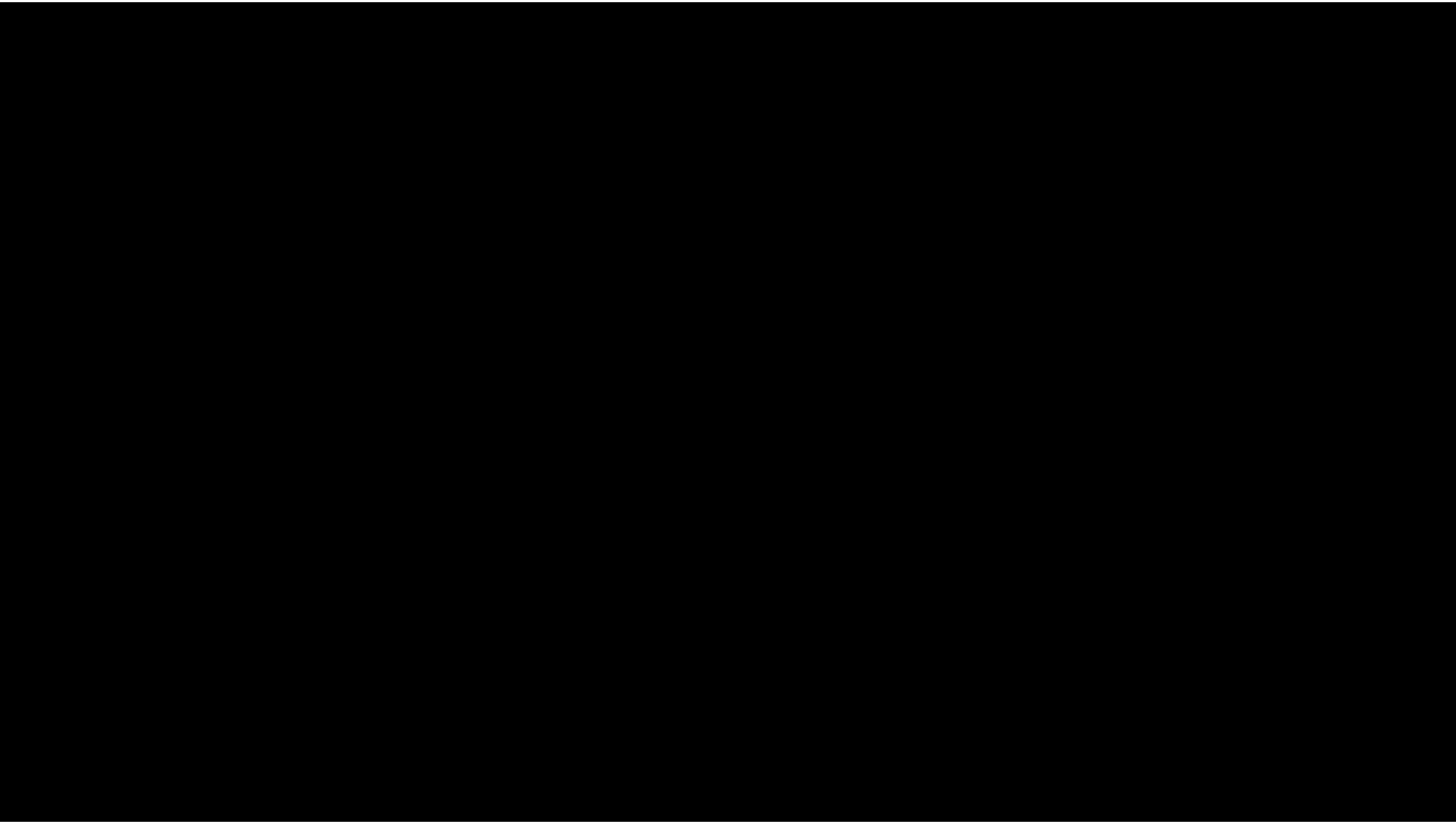
2.5 gpm x 6 min/shower= 15 gal

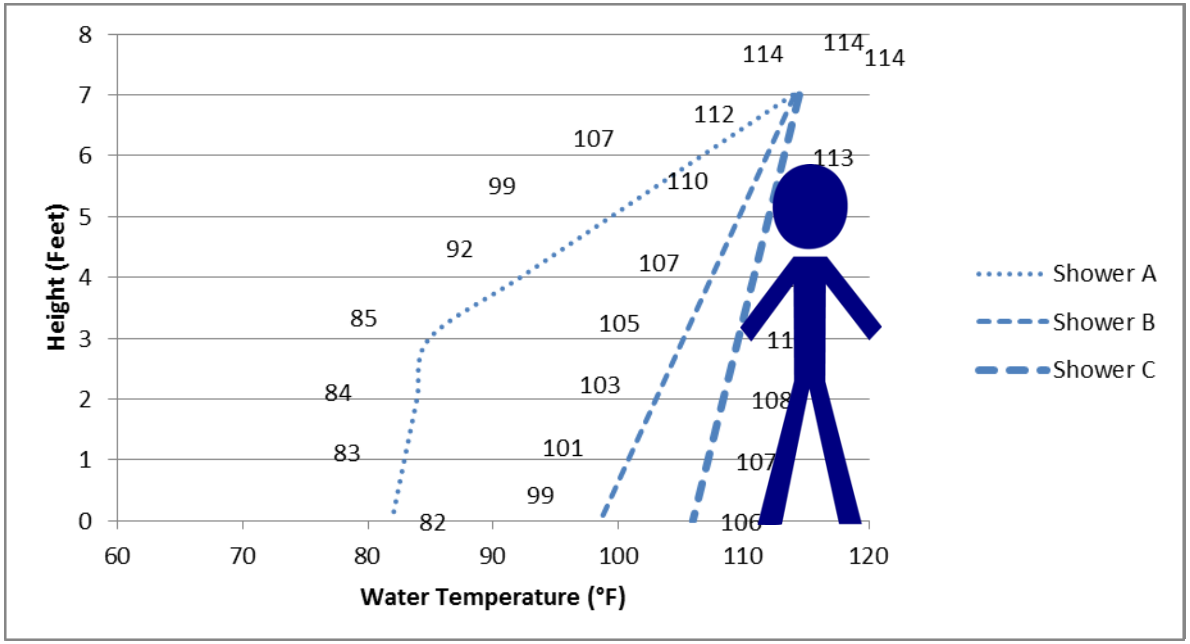
1.5 gpm x 6 min/shower= 9 gal

$Q = \dot{m} * Cp * dT = 500 * gpm * dT * t / 60\ min$

Assume
t = Length of shower = 6 min
Thw= 110°F, Tcw= 55°F, dT= 55°F

6,875 btu	4,813 btu	4,125 btu
Savings:	2,063 btu	2,750 btu





Gdh = LdT + GdH*(T-32)

G= Mass flow of Air
Dh= Change in air enthalpy
L= Mass flow of water
dT= Water Temperature change
dH= Change in air humidity ratio

5 min @ 2 gpm= 10 gallons

Assume
t = Length of shower = 45 sec + 10 gallons/V̇
Thw= 110°F, Tcw= 55°F, dT= 55°F

Corrected for Duration of Shower

1.75 gpm x 6.5 min/shower= 11.3 gal

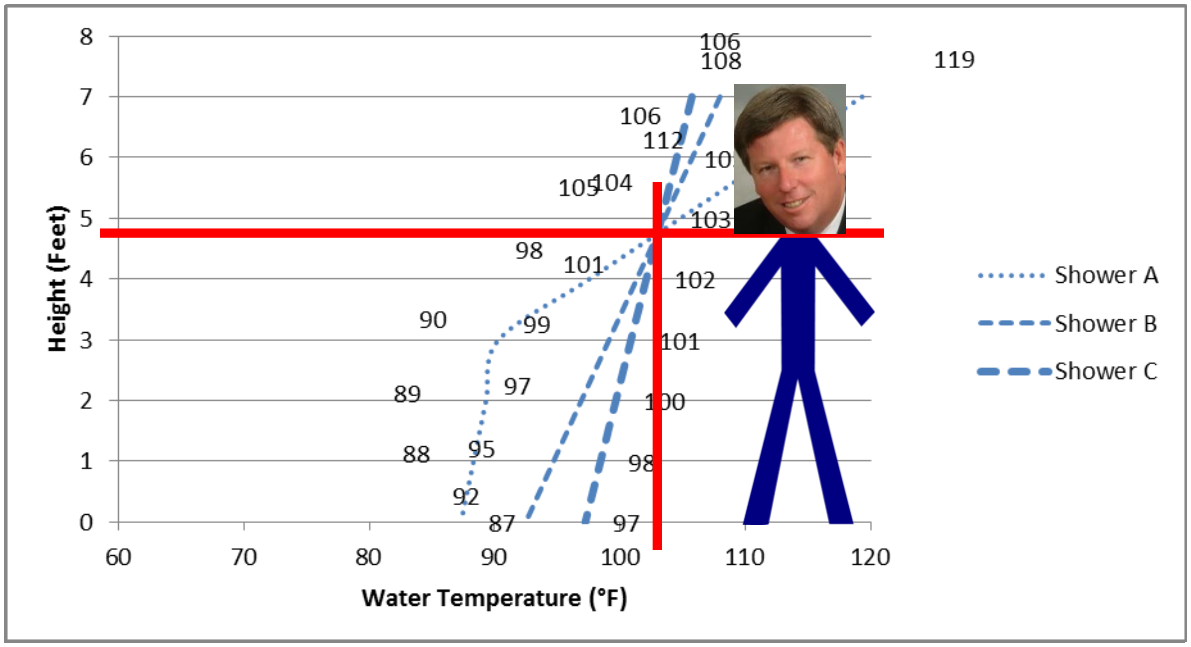
2.5 gpm x 4.8 min/shower= 11.9 gal

1.5 gpm x 7.6 min/shower= 11.1 gal

$Q = \dot{m} * Cp * dT = 500 * gpm * dT * t / 60\ min$

Assume
t = Length of shower = 45 sec + 10 gallons
Thw= 110°F, Tcw= 55°F, dT= 55°F

5,719 btu	5,685 btu	5,953 btu
Savings:	234 btu	268 btu



Adjust source Temperature to match temperatures at the shoulder 98°F + 5°F= 103°F

Piping Heat Loss- 120 ft of ¾" line, 5 ft of ½" line with 1" Armaflex- ~ 590 btu/hr
Temp loss from source to shower @ 70°F Ambient (will be greater if Space T is lower)

0.46°F 0.70°F 1.06°F

Corrected for Shower Duration + Delivery Temperature

1.75 gpm x 6.5 min/shower= 11.3 gal

2.5 gpm x 4.8 min/shower= 11.9 gal

1.5 gpm x 7.6 min/shower= 11.1 gal

$Q = \dot{m} * Cp * dT = 500 * gpm * dT * t / 60\ min$

Assume
t = Length of shower = 45 sec + 10 gallons

Thw= 106.3	108.9°F	120.4°F
5,089 btu	5,107 btu	6,159 btu
Savings:	19 btu	-1,070 btu

Total Annual Savings

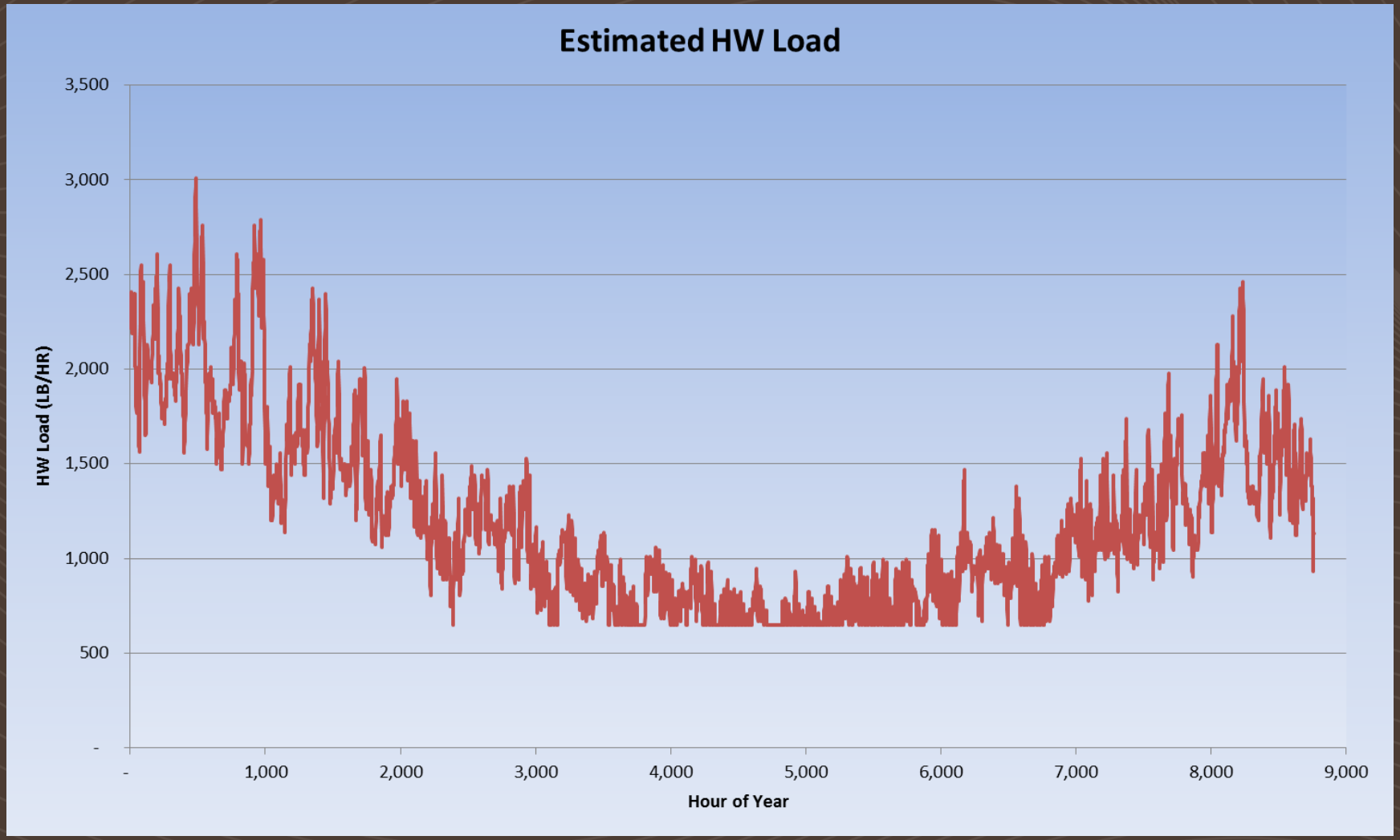
1.75 gpm x 6.5 min/shower= 11.3 gal

3 hrs of showers per day= 360 minutes/ 7.5 = 48 showers per day.
250 days/year

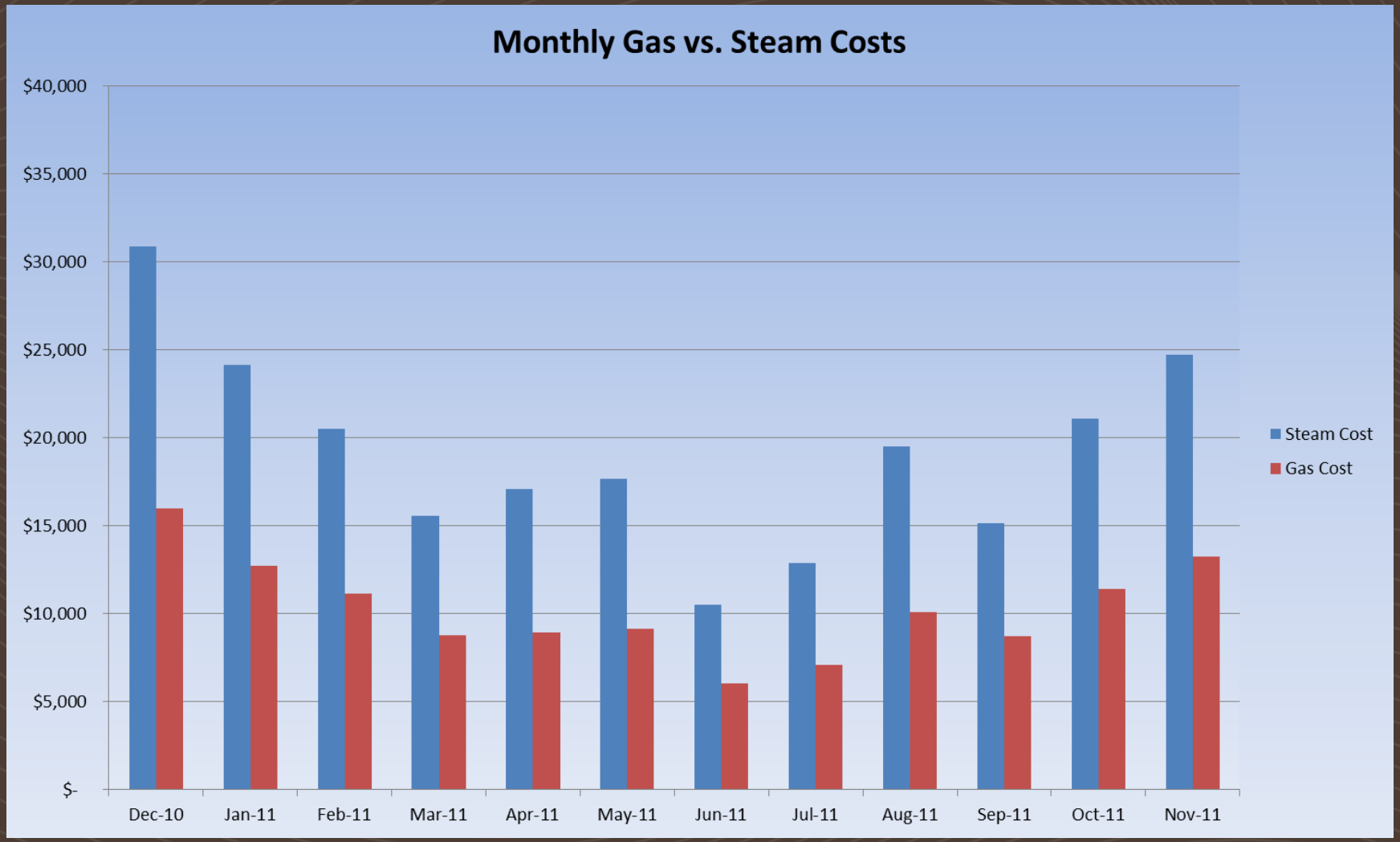
Reducing water volume required from 10 gal +45 sec to 3 gal + 45 sec, 61,000 mbh saved, or 17,900 kWh.

LEED Innovative Design

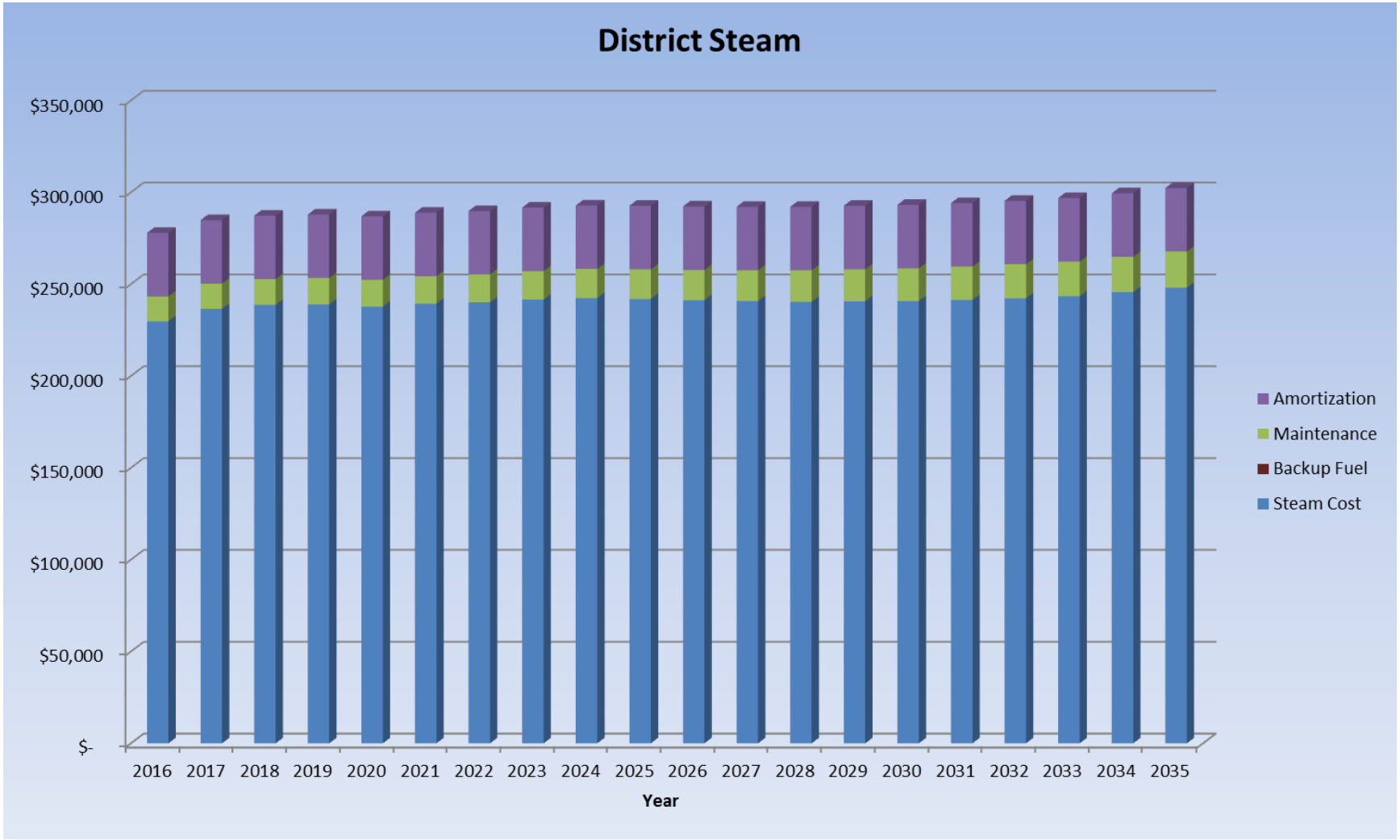
Customer Economics



Customer Economics



Customer Comparison



Life Cycle Cost Analysis - 20 Year Amortization Period					
Duration	20	years			
Discount Rate	3%				
Amortization Period	20	years			
Finance Rate	4.5%				
Average Utility Rate Inflation					
Natural Gas	1.7%		District Steam		0.4%
Fuel Oil	1.7%		Maintenance		2.0%

	New Boiler Plant	District Steam
System First Cost	$ 1,372,577	$ 449,837
Utility Incentive	$ -	$ -
Total First Cost	$ 1,372,577	$ 449,837
Amortization	$ 105,518	$ 34,582
Replacement Costs Through Year:		
5	$ -	$ -
10	$ -	$ -
15	$ -	$ -
20	$ -	$ -
First Year Gas Cost	$ 123,390	$ -
First Year District Steam Cost	$ -	$ 229,805
First Year Water Cost	$ -	$ -
First Year Electric Cost	$ -	$ -
Total First Year Energy Cost	$ 123,390	$ 229,805
Backup Fuel Cost	$ 2,987	$ -
Maintenance Cost	$ 41,177	$ 13,495
First Year O&M Cost	$ 167,554	$ 243,300
Life Cycle Cost	**$ 4,537,944**	**$ 4,325,927**

Assumptions:
-Electric usage is equivalent for the two options
-Utility rate inflation is based on data from the US Energy Information Administration Annual Energy Outlook

Environmental Impact of Adding Customer

	2015 w/ Customer	2015 w/o Customer
Total Annual Emissions, MTECD	45,915	45,915
Electrical Generation, MWH	28,367	28,358
Steam Sold, MLB	139,925	135,959
Total Energy Delivered, MMBTU	236,713	232,716
Thermal Emissions Factor, MTECD/MMBTU	0.1940	0.1973

Reduced Energy used from Plant, MMBTU	3,996
Apparent GHG Savings, MTECD	214

Actual Effect	
GHG from Alternate Elec Generation, MTECD	7
GHG Emissions fom Gas, MTECD	236
Total Incease in GHG Emissions, MTECD	243
Total Swing in Emissions, MTECD	**457**

- OWEF plant has the capacity to contribute up to an additional 60,000 PPH of firm capacity to heating loads to support City Growth.
- The magnitude of future waste streams are influenced by area growth and societal efforts to reduce waste.
- The existing distribution system is limited in its current capacity to support this growth.
- Hot water extension opens opportunities for growth and interaction with a possible Mayo Clinic district energy system.

CHP brings with it an interdependence such that the savings of one customer detracts from the efficiency of the system as a whole.

This interdependence impacts Energy Savings and Carbon reductions.

Total Savings does not always equal sum of parts.