BUILDING A WORLD OF DIFFERENCE

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BALANCING STEAM AND ELECTRIC DEMANDS WITH COMBINED HEAT AND POWER

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AGENDA

- POWER GENERATION
  - Thermal Efficiency
  - Fuel Costs
- COMBINED HEAT AND POWER, CHP
  - Year Round Steam Use, Chilled Water
  - Costs

POWER GENERATION

Two Recent Projects

Coal Plant, 200 MW

Combined Cycle Plant, 800 MW

POWER GENERATION

Coal Plant, 200 MW

- 2,600 psig boiler, 1055F Superheated Steam
- 9884 Btu/kW hr heat rate
- 34.5% Thermal Efficiency

POWER GENERATION

Combined Cycle Plant, 800 MW

- Triple Pressure HRSG, 1056F Superheated Steam
- 6208 Btu/kW hr heat rate
- 55.0% Thermal Efficiency

POWER GENERATION

Fuel Cost of Generation

Coal Plant: $0.022 per kW hr

Combined Cycle Plant: $0.028 per kW hr

$50/ton coal and $4.5/MMBtu gas

COMBINED HEAT AND POWER, CHP

Trend to Move Away from Coal

Solar Titan 250 Combustion Turbine Gen

- **25 MW nominal capacity, 19.1 MW net output**
- **10,550 Btu/kW hr heat rate**
- **32.3% Thermal Efficiency**

COMBINED HEAT AND POWER, CHP

Solar Titan 250 Combustion Turbine Gen

Fuel Cost of Production: $0.048/kW hr

Based on $4.50/MMBtu gas

COMBINED HEAT AND POWER, CHP

Add Heat Recovery Steam Generator

Solar Titan 250 Combined Cycle CHP

- 157,200 lbs/hr Fully Fired Steam Capacity
- 915 psig, 835 F Superheated Steam
- 8 MW Backpressure Steam Turbine Generator
- 90 psig backpressure

COMBINED HEAT AND POWER, CHP

Solar Titan 250 Combined Cycle CHP

Unfired Steam Production

- 75,120 lbs/hr Unfired Steam Capacity
- 23.2 MW net output
- 9,755 Btu/kW hr heat rate
- 35.0% Thermal Efficiency

COMBINED HEAT AND POWER, CHP

Solar Titan 250 Combined Cycle CHP

Fuel Cost of Production: $0.044/kW hr

Negligible fuel cost on the unfired steam

What is the value of the exhaust steam?

COMBINED HEAT AND POWER, CHP

Unfired Steam Value

Needed for heating, used for cooling

Alternately use a gas fired boiler

Use 80% boiler efficiency

COMBINED HEAT AND POWER, CHP

Unfired Steam Value

Fuel cost of steam production in an 80% eff gas fired boiler: $5.70 per klb steam

Based on $4.50/MMBtu gas

COMBINED HEAT AND POWER, CHP

Unfired Steam Value

If there is a need for the full amount of unfired steam, at 95% availability:

625,000 klbs steam/year

$3,560,000 fuel cost saved/year

COMBINED HEAT AND POWER, CHP

Unfired Steam, Using it all

Winter heating

Summer Cooling

Consider Condensed Power Gen, or Steam Driven Chillers

COMBINED HEAT AND POWER, CHP

Steam Driven Chillers

One Stage Steam Absorption

Two Stage Steam Absorption

Steam Turbine Driven Centrifugal

COMBINED HEAT AND POWER, CHP

Steam Driven Chillers with 80 psig steam

One Stage Absorption: 18 lbs stm/ton hr

Two Stage Absorption: 9.7 lbs stm/ton hr

Steam Turbine Driven: 9.7 lbs stm/ton hr

COMBINED HEAT AND POWER, CHP

Two Stage Absorber with 80 psig steam

If half of the annual unfired steam is used by steam absorption chillers

32,200,000 ton hours of cooling

COMBINED HEAT AND POWER, CHP

Two Stage Absorber with 80 psig steam

32,200,000 ton hours annually of cooling, if produced by electricity at 0.51 kW/ton

16,400,000 kW hours saved

$721,000 saved at $0.044 per kWhr

COMBINED HEAT AND POWER, CHP

How about fired steam?

Solar Titan 250 Combined Cycle CHP

- 157,200 lbs/hr Fully Fired Steam Capacity
- 27.6 MW net output
- 11,842 Btu/kW hr heat rate
- 28.8% Thermal Efficiency

COMBINED HEAT AND POWER, CHP

Solar Titan 250 Combined Cycle CHP

Fuel Cost of Production: $0.053/kW hr

Is there a fuel cost on the unfired steam?

COMBINED HEAT AND POWER, CHP

Solar Titan 250 Combined Cycle CHP

The answer depends:

- **At $0.053 per kW hr, the cost of fuel is covered in the electric generation charge. No cost to steam.**
- **At $0.044 per kW hr, the difference needs to be made up as a cost of steam.**

COMBINED HEAT AND POWER, CHP

Solar Titan 250 Combined Cycle CHP

At $0.044 per kW hr fuel cost:

- **The 27.6 MW will recover $1,213 per hour fuel cost of a total cost of $1,473 per hour to fuel the system**
- **That leaves $260 per hour as the cost of steam.**

At 157,200 pph 80 psig steam, fuel cost is $1.65 per klb steam.

COMBINED HEAT AND POWER, CHP

Two Stage Absorber with 80 psig steam

If half of the annual fired steam is used by steam absorption chillers:

67,400,000 ton hours of cooling

COMBINED HEAT AND POWER, CHP

Two Stage Absorber with 80 psig steam

67,400,000 ton hours annually of cooling with steam uses 654,000 klbs.

Fuel cost for that steam $1,080,000

COMBINED HEAT AND POWER, CHP

Two Stage Absorber with 80 psig steam

67,400,000 ton hours annually of cooling, produced by electricity at 0.51 kW/ton hr

34,400,000 kW hours saved

$1,510,000 saved at $0.044 per kWhr

COMBINED HEAT AND POWER, CHP

Two Stage Absorber with 80 psig steam

Annual Cost difference of steam and electric chilling :

$1,510,000 cost of fuel for electricity

- $1,080,000 cost of fuel for steam

$430,000 annual fuel savings

COMBINED HEAT AND POWER, CHP

Table of Fuel Cost of Steam, $/klb

Electricity Cost, $/kWh	4.5	5.5	6.5	7.5	8.5
0.034	3.39	5.47	7.55	9.64	11.72
0.044	1.63	3.71	5.80	7.88	9.96
0.054	(0.13)	1.96	4.04	6.12	8.20
0.064	(1.88)	0.20	2.28	4.36	6.44
0.074	(3.64)	(1.56)	0.52	2.60	4.69
0.084	(5.40)	(3.32)	(1.24)	0.85	2.93
0.094	(7.16)	(5.08)	(2.99)	(0.91)	1.17
0.104	(8.92)	(6.83)	(4.75)	(2.67)	(0.59)

Cost of natural gas, $/MMbtu

DISCUSSION

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