Efficient Energy for Smarter Cities

“Options for Combined Cooling and Power ”

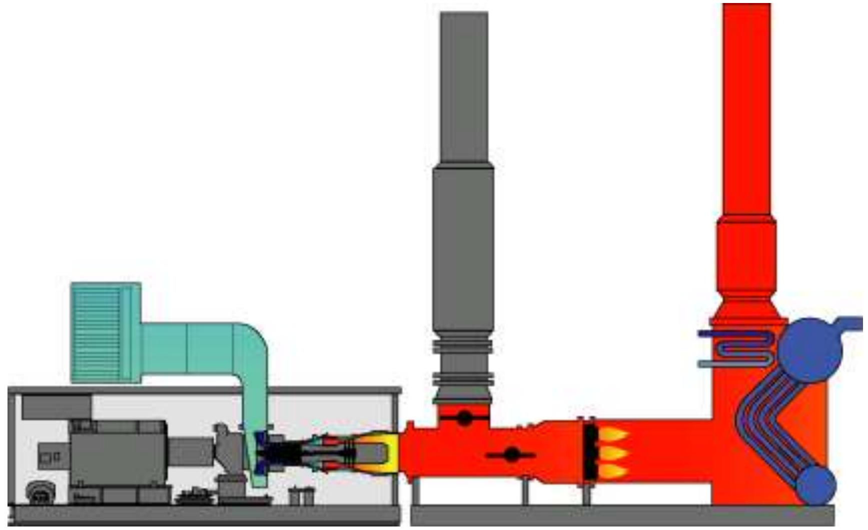
By
Chris Lyons

An Overview of Solar Turbines Incorporated

Multitude of Combined Cooling and Power (CHP) Options

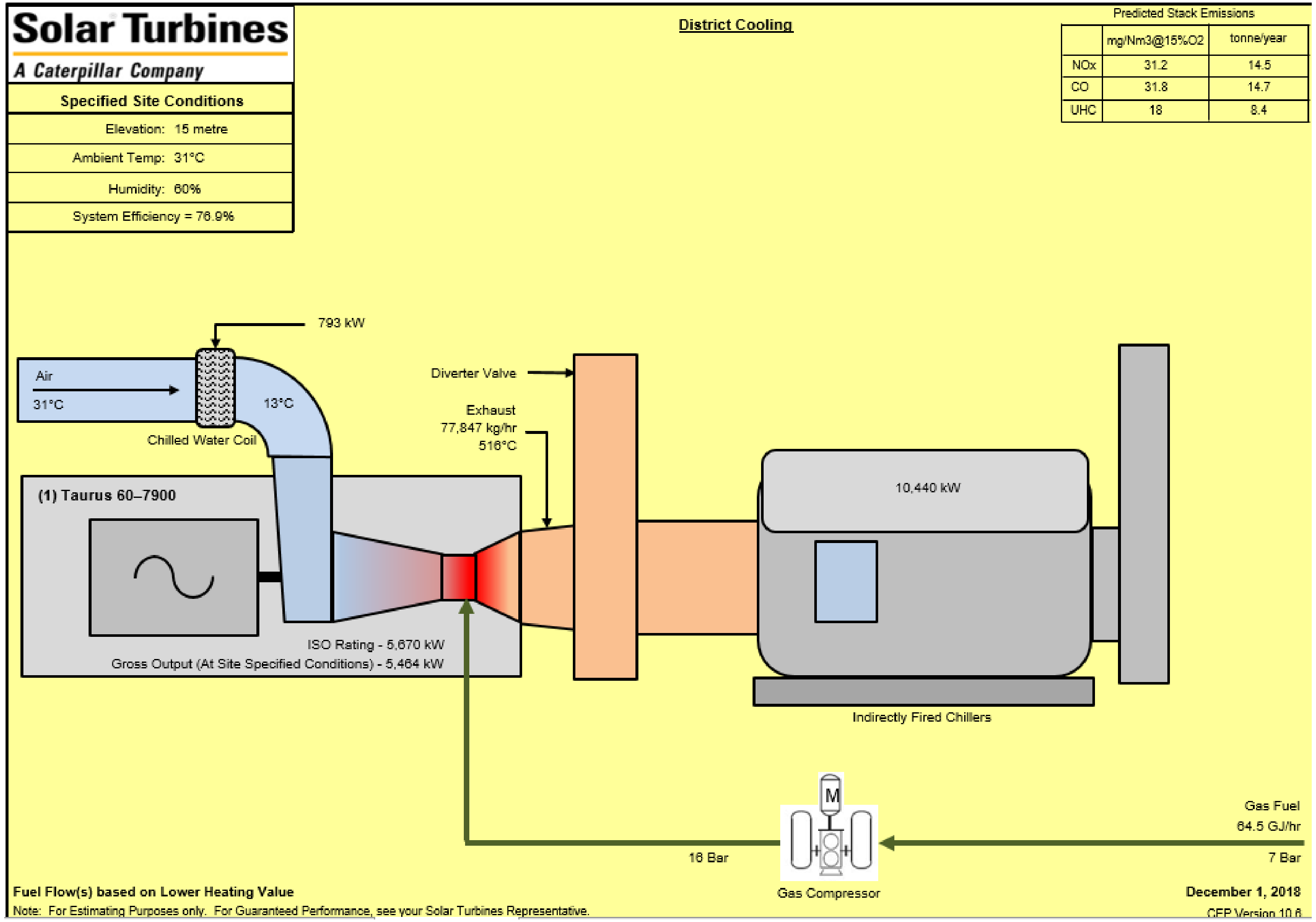
- Steam Turbine Drive Chillers
- Steam Double Effect Absorption Chillers
- How Water Double Effect Absorption Chillers
- Steam Single Effect Absorption Chillers
- Hot Water Single Effect Absorption Chillers
- Turbine Exhaust Fired Absorption Chillers

How Does Combined Cooling and Power (CHP) Help?

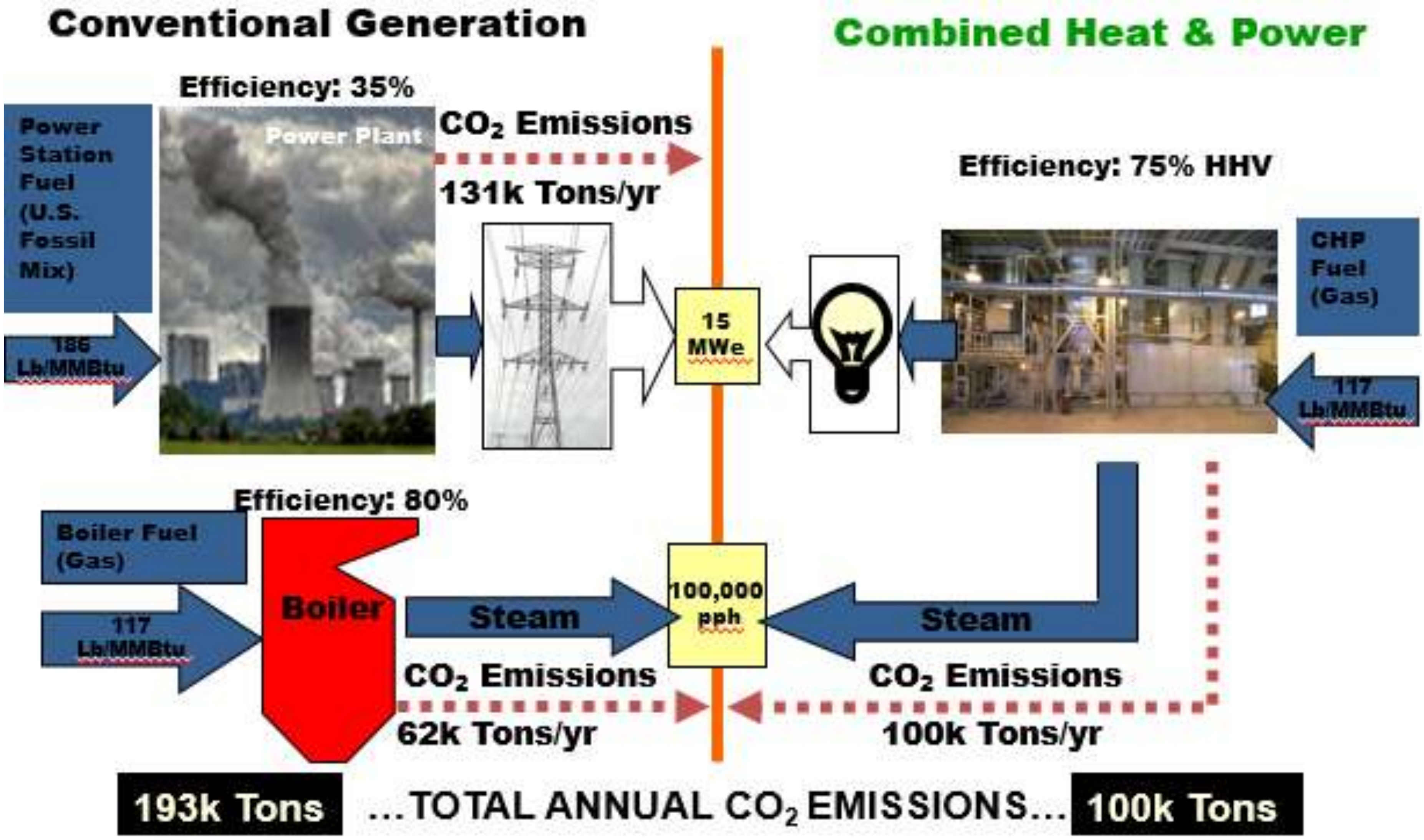


- Excellent efficiency
- Reduces GHG pollutants and low criteria pollutants
- Multiple fuel capabilities including renewables
- Provides grid VAR support
- Reduces grid congestion
- Anchor resource for microgrids
- Supports energy storage
- Improves consumer reliability and grid resiliency
- Can have great economics

Efficiencies over 70%



Significant Reduction in GHG Emissions



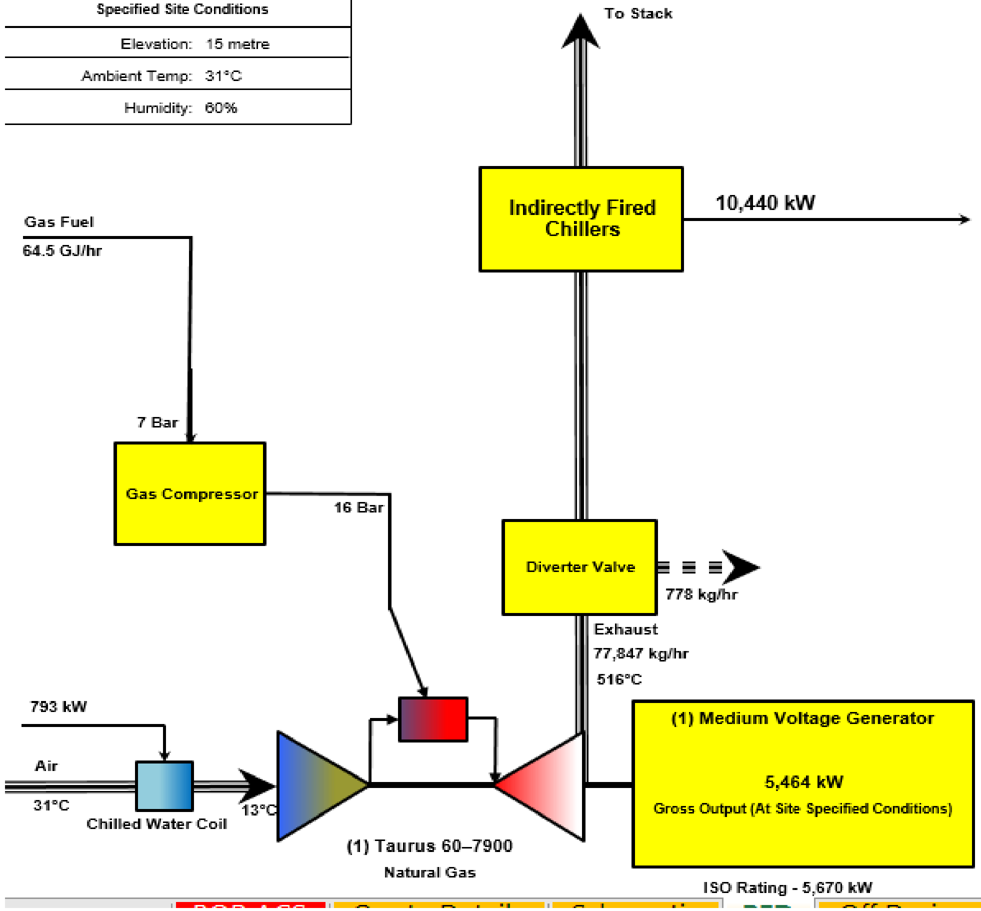
Low Criteria Air Pollutants, NOx, CO, etc.

Solar Turbines
A Caterpillar Company

Proposed Process Flow Diagram

Specified Site Conditions	
Elevation:	15 metre
Ambient Temp:	31°C
Humidity:	60%

Predicted Stack Emissions	mg/Nm3@15 %O2	tonne/year
NOx	31.2	14.5
CO	31.8	14.7
UHC	18	8.4



CHP has Low Emissions and is Base Load

Category	10 MW CHP	10 MW PV	10 MW Wind	Combined Cycle (10 MV Portion)
Annual Capacity Factor	85%	22%	34%	70%
Annual Electricity	74,446 MWh	19,272 MWh	29,784 MWh	61,320 MWh
Annual Useful Heat	103,417 MWh_t	None	None	None
Footprint Required	6,000 sq ft	1,740,000 sq ft	76,000 sq ft	N/A
Capital Cost	$20 million	$60.5 million	$24.4 million	$10 million
Annual Energy Savings	308,100 MMBtu	196,462 MMBtu	303,623 MMBtu	154,649 MMBtu
Annual CO_2 Savings	42,751 Tons	17,887 Tons	27,644 Tons	28,172 Tons
Annual NOx Savings	59.4 Tons	16.2 Tons	24.9 Tons	39.3 Tons

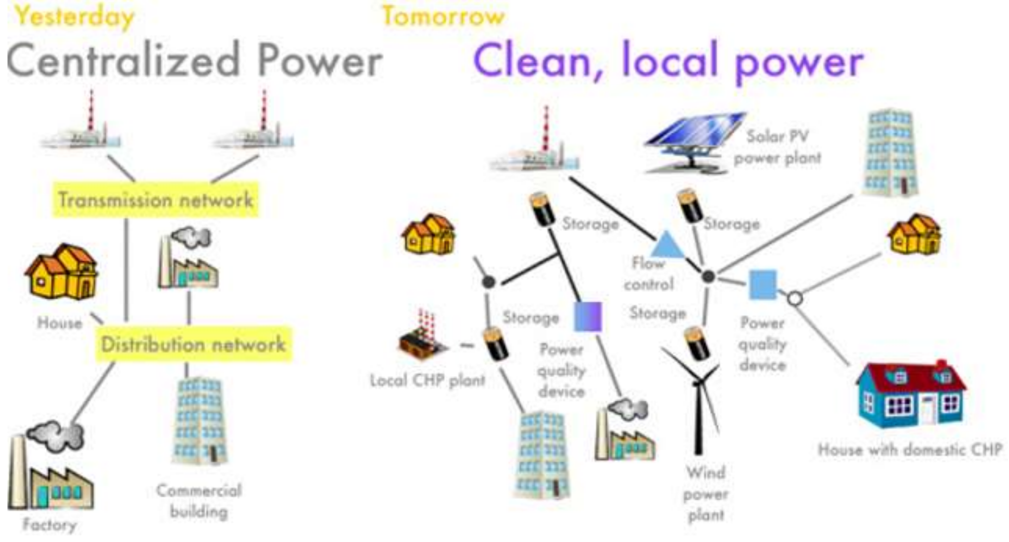
Source: DOE EERE CHP Report

Can Use Renewable and High Hydrogen Fuels

10 MWe Plant Using Landfill Gas

28 MWe Plant Using Hydrogen Refinery Off Gas

CHP can Reduce Congestion, Provide VAR's, Energy Storage &



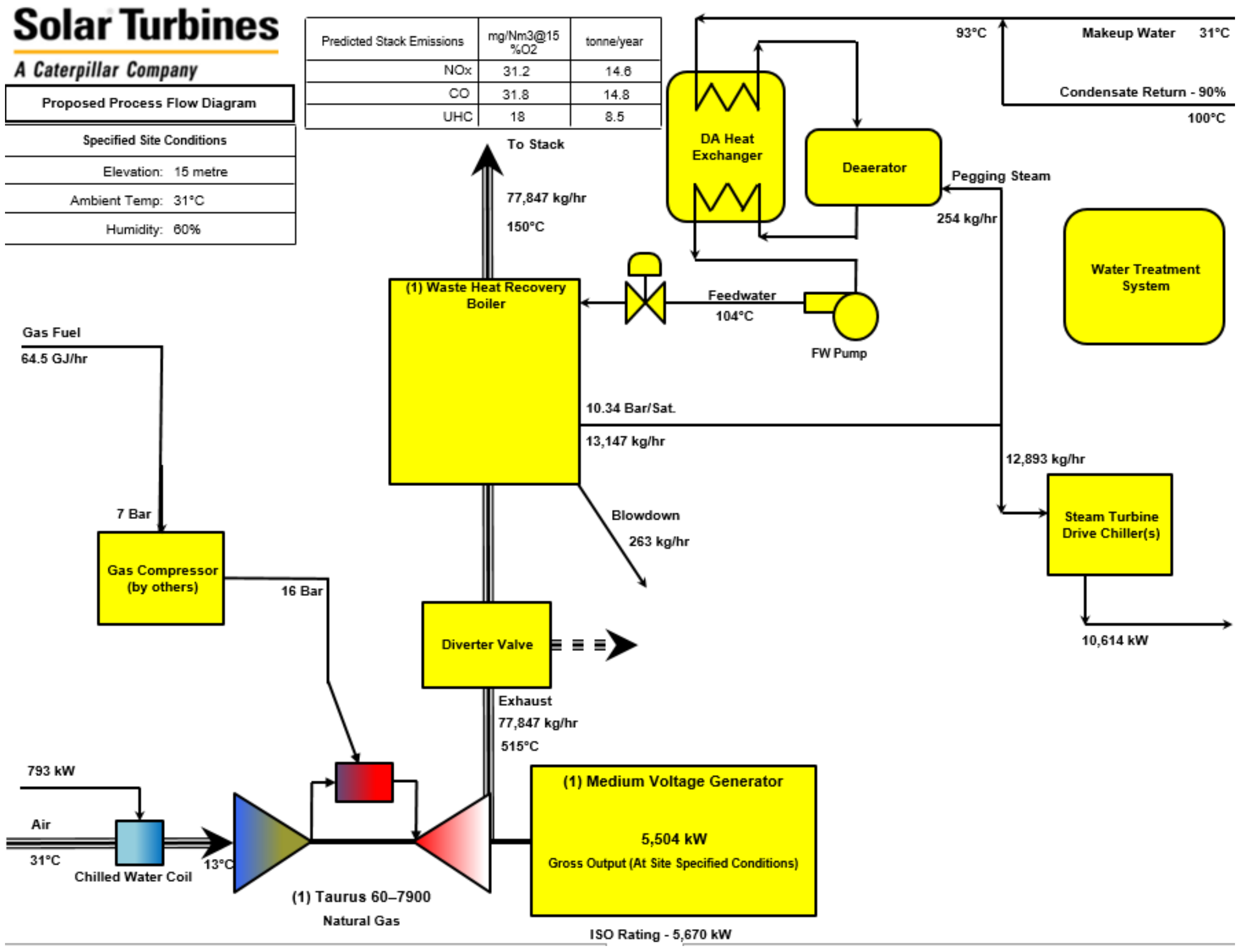
Source: Distributed Generation and Energy Storage Summit

CHP Does not Require T&D to Operate

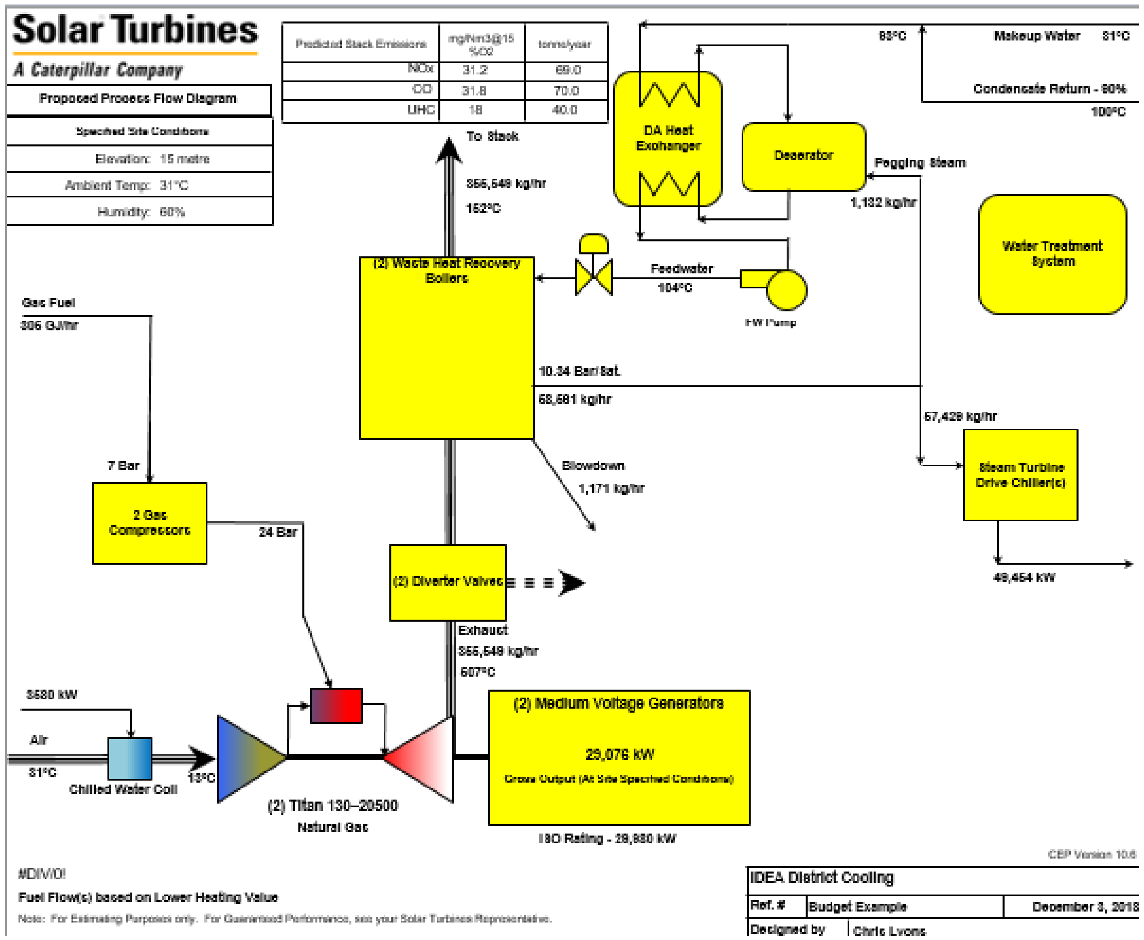
Think about Grid Supply Concerns, Cyber and Other Threats

Small Scale to Large Scale

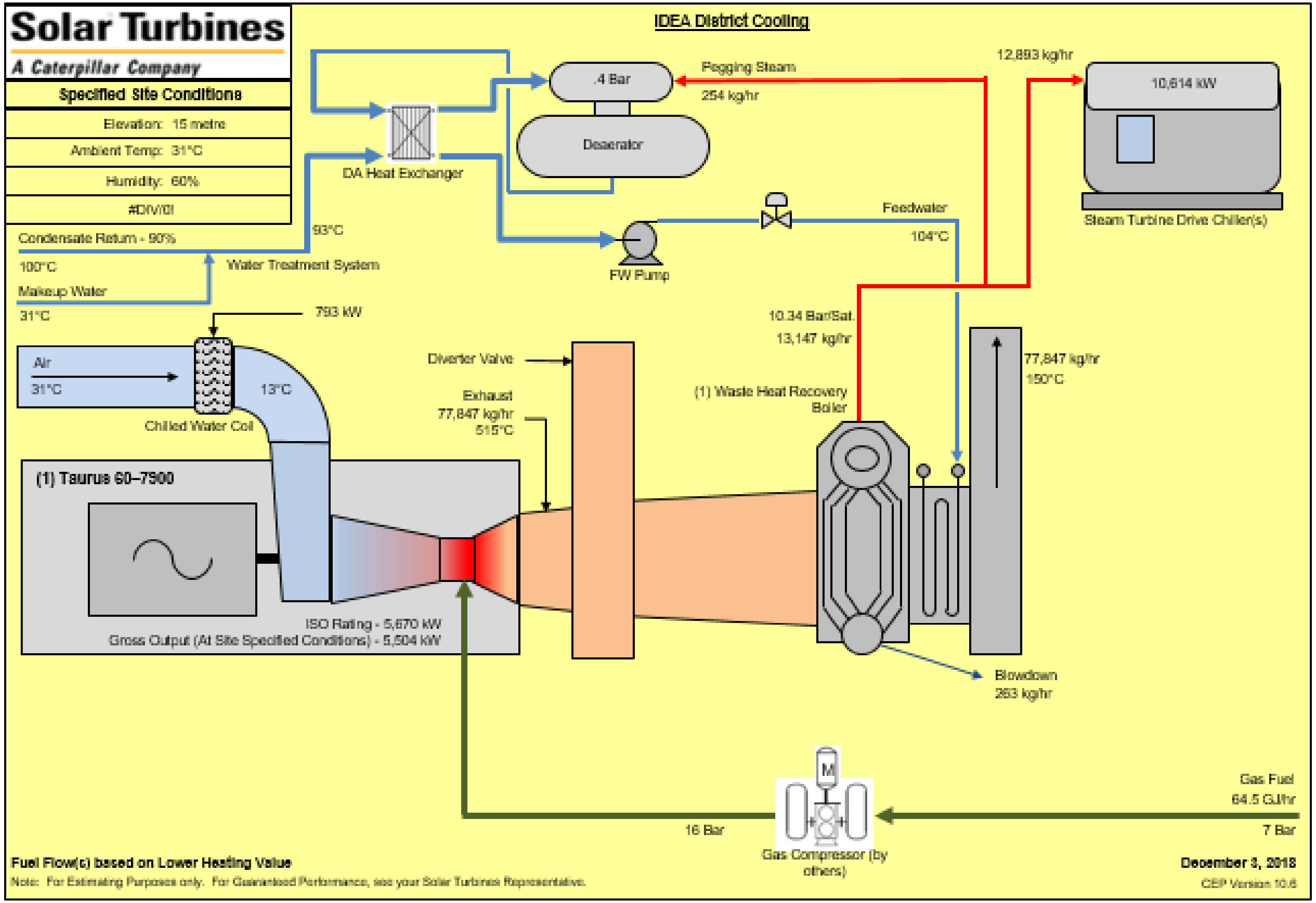
5.5 MWe with 3000 Tons of Chilling



30 MWe with 14000 Tons of Chilling



Small Scale Steam Turbine Drive Case Example



Economics are Fuel and Local Electric Cost

Current System Costs (power/steam limited by demand values entered above):		
Annual Electricity Cost (offset by proposed system):		
	5,425 kW x 0.1 $/kW x 8500 hrs/year =	$4,611,300
Steam Production Costs (fuel and O&M):		
	No process steam requirement	$0
Current Annual Maintenance Costs to be Offset..		$0
Total Annual Current Costs		**$4,611,300**
Proposed Cogeneration System Costs (operating at less than design output):		
Annual Cogeneration System Fuel Cost:		
	64.54 GJ/hr x $4.00/GJ x 1.109 HHV/LHV x 8500 hrs/year =	$2,432,900
Turbine Maintenance Cost (based on gross power output):		
	Turbine Equipment Service Agreement Selected =	$500,000
Balance of Plant Maintenance Cost (based on gross power output):		
	$0.006/kW-hr x 5,504 kW x 8500 hrs/year =	$280,800
Standby Power Cost (based on gross power output):		
	$3.00/kW-month x 12 months x 5,425 kW =	$195,300
Increase/Decrease in Annual Operations Cost..		$0
Avoided Costs, $/year..		-$1,972,000
Lease Costs..		$0
Export KW Revenue, $/year..		$0
Total Annual Proposed Costs		**$1,437,000**
Net Annual Savings		**$3,174,300**
Payback, years		**3.4**
After Tax Net Present Value		**$22,528,700**
After Tax Internal Rate of Return		**31.6%**

Examples of Steam Turbine Chillers

York YST Steam Drive Chillers, 600 Tons (2100 kW) to 2800 Tons (9800 kW)

Steam Absorption Chillers

8 x 2000 Ton (7030 kW) York Chillers - 8 Bar steam

5 x 2600 Ton (9130 kW) York Chillers – 8 Bar Steam

Combustion Turbines and Exhaust Fired Absorbers in Indi

BROAD DISTRIBUTED ENERGY CASE STUDIES

DISTRICT A/C

DLF, INDIA

- The generator supplies electricity to buildings. BROAD chillers uses exhaust & jacket water for cooling. The backup burner provides cooling during generators' idle time or partial load
- Cooling capacity 270,000kW
  32 × Exhaust, hot water & direct-fired chillers
  Cooling efficiency 120%
- Power generator capacity 186,000kW
  39 × Engines & gas turbines
  Power generation efficiency 35%
- Payback period 1.5 years
- Yearly energy saving 137,000 ton oil
- Yearly CO_2 cutting 410,000 ton
- Equivalent of planting 22,000,000 trees

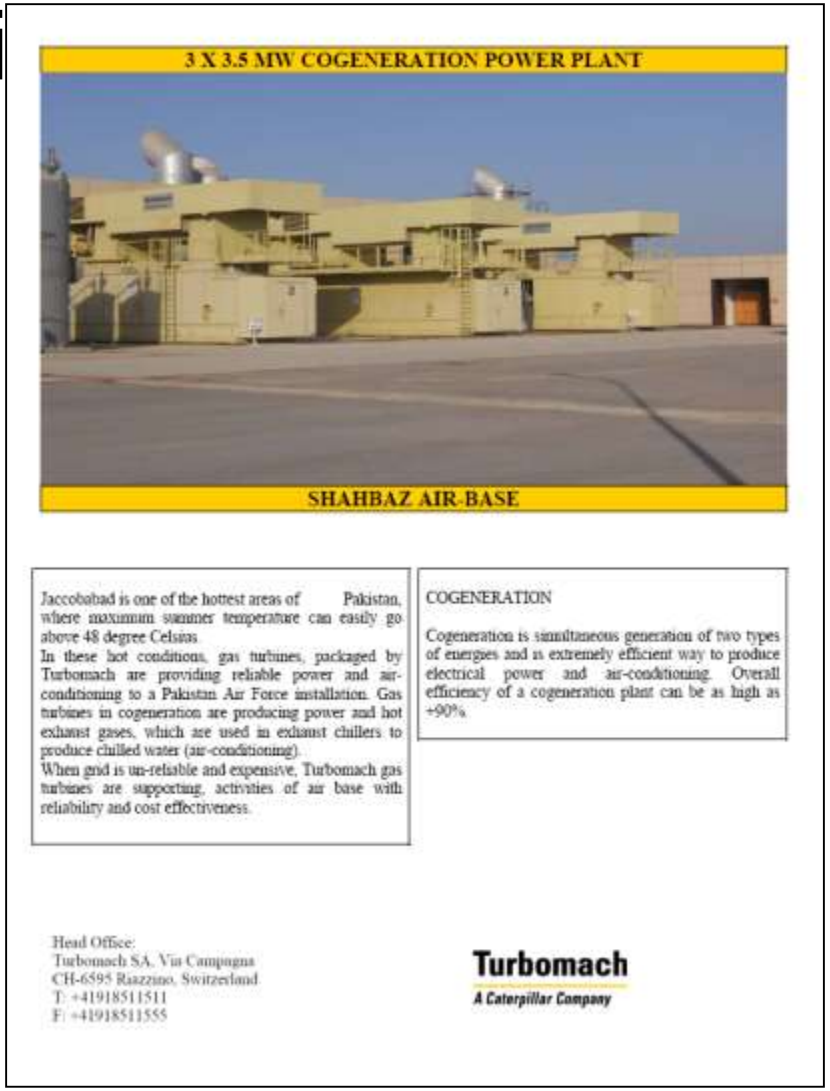
The world largest typical distributed energy system which was totally unaffected in India black-out in July, 2012

BROAD exhaust non-electric chiller

Gas engine

BROAD CCHP Exhaust, hot water & direct-fired type

Energy efficiency: Power + Cooling 92%



3 X 3.5 MW COGENERATION POWER PLANT

SHAHBAZ AIR-BASE

Jaccobabad is one of the hottest areas of Pakistan, where maximum summer temperature can easily go above 48 degree Celsius.
In these hot conditions, gas turbines, packaged by Turbomach are providing reliable power and air-conditioning to a Pakistan Air Force installation. Gas turbines in cogeneration are producing power and hot exhaust gases, which are used in exhaust chillers to produce chilled water (air-conditioning).
When grid is un-reliable and expensive, Turbomach gas turbines are supporting activities of air base with reliability and cost effectiveness.

COGENERATION

Cogeneration is simultaneous generation of two types of energies and is extremely efficient way to produce electrical power and air-conditioning. Overall efficiency of a cogeneration plant can be as high as +90%.

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Turbomach
A Caterpillar Company

Combustion Turbine Exhaust Chillers

3 x 4.5 MWe GT with 1300 Ton Thermax Chillers

4.5 MWe GT with 2500 Ton Broad Chiller

Conclusions

→ The use of **Gas Turbines with Steam Turbine Drive and Absorption chillers is a proven technology in CCHP applications.**

→ CCHP based on Gas Turbine can be a viable Electric Utility and or End User Option When taking into account all benefits

→ **Well defined feasibility criteria**.

→ **Various Thermally Driven Chiller Options** can be the **heat sink** that "close the energy balance" for industrial and commercial applications **reducing the daily costs of your customers**

Thank You !

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