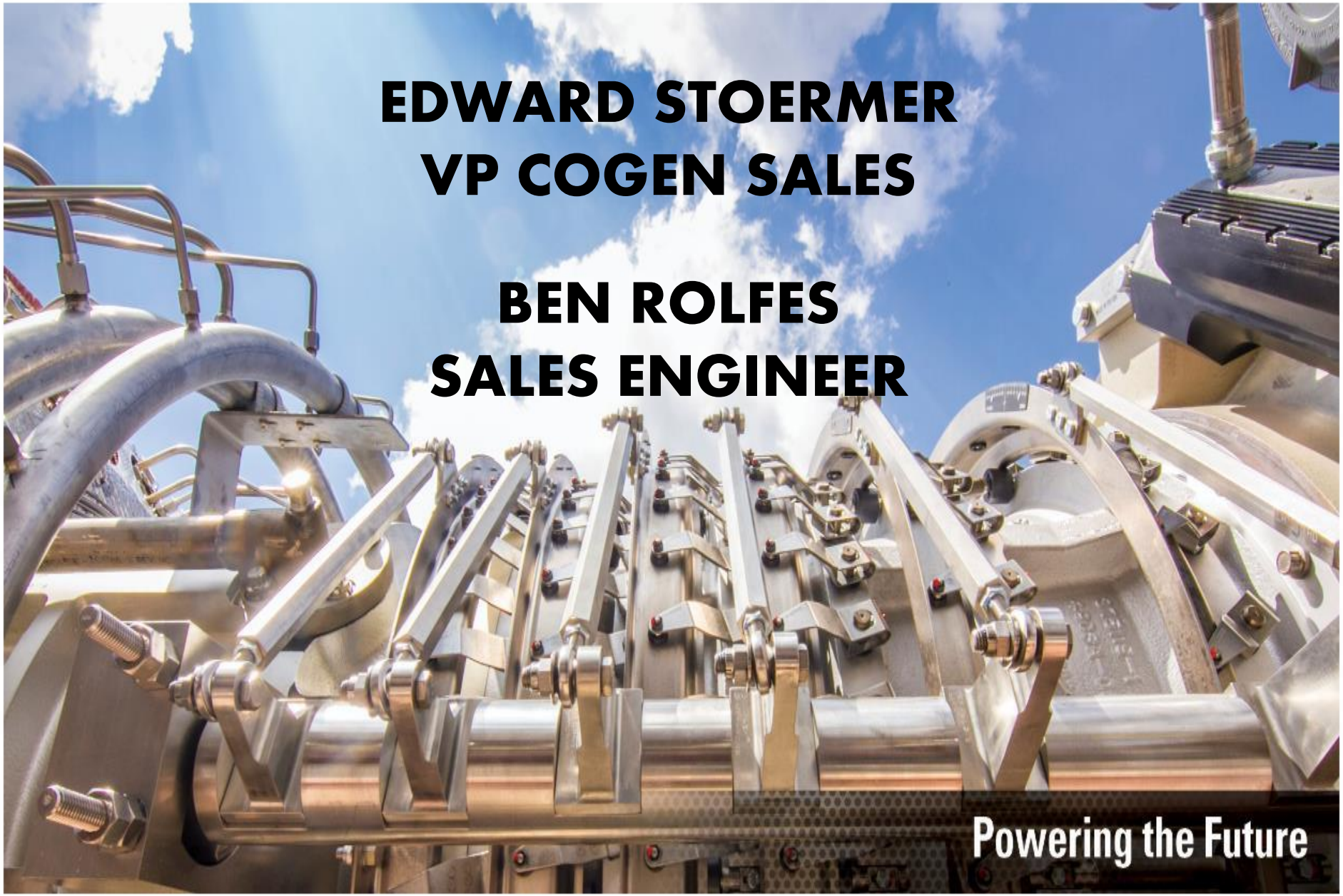
SUSTAINABILITY WITH AN ROI:

COMBINED HEAT AND POWER

Solar Turbines
A Caterpillar Company

LATHROP TROTTER
Since 1922



Solar Turbines
A Caterpillar Company

LATHROP TROTTER
Since 1922

AGENDA SEPTEMBER 2022 OMEC

1. **OBJECTIVE**: EXPLAIN HOW CHP HELPS ACHIEVE SUSTAINABILITY, OPERATIONAL, AND FINANCIAL GOALS
2. WHAT IT IS & HOW IT WORKS
3. IRA Tax Incentives
4. THE HEAT PART OF CHP
5. WHERE IT APPLIES
6. SIZE AND SELECTION OF GAS TURBINE (GT) & HEAT RECOVERY STEAM GENERATOR (HRSG)
7. TYPICAL PRELIMINARY CHP REPORT
8. DRIVERS: ECONOMICS & EMISSIONS REDUCTION
9. SUSTAINABILITY AND WHY CHP REALLY "MOVES THAT NEEDLE"
10. GREEN HYDROGEN.
11. Q&A SESSION

COMBINED HEAT & POWER : CHP / CO-GENERATION

COMBINED HEAT AND POWER: USES ONE FUEL SOURCE TO PRODUCE TWO TYPES OF USEFUL ENERGY.

FUELS:

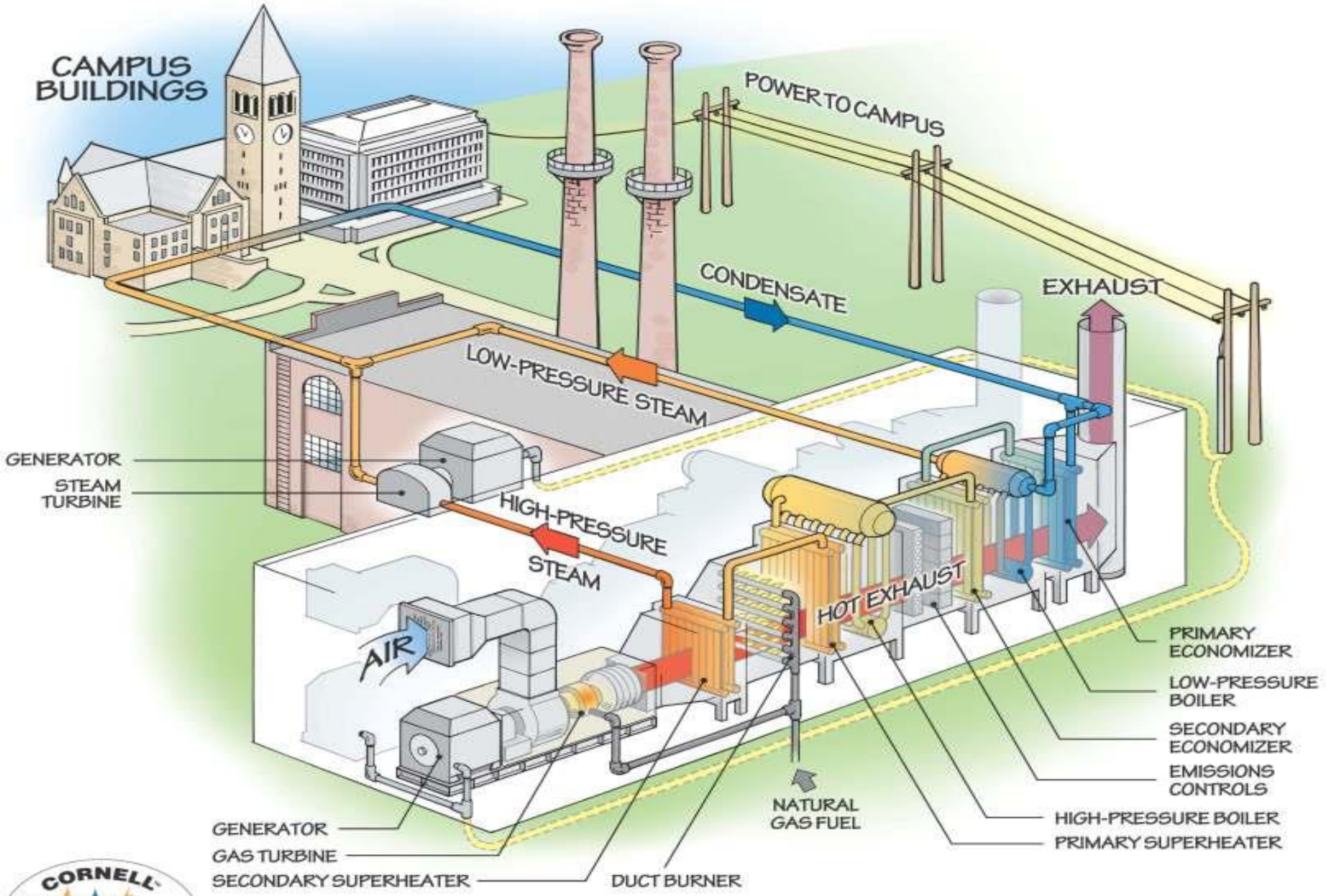
NATURAL GAS, **DIGESTER GAS, LANDFILL GAS, RENEWABLE NAT GAS, HYDROGEN,** LIQUID FUELS, “OPPORTUNITY” FUELS.

USEFUL ENERGY PRODUCED:

1. ELECTRICAL ENERGY FOR PLANTS OR CAMPUSES.

2. STEAM FOR PROCESS OR HEATING OR POWER GEN

3. CHILLED & HOT WATER, HOT AIR FOR PROCESS DRYING



CORNELL Utilities POWER TO LEARN

Combustion Turbine with Heat Recovery Steam Generator

NATURAL GAS & REFINERY GAS

AGENDA 02-23-22 OHIO MANUFACTURERS' EDUCATION COUNCIL

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WHAT CHP IS NOT:

SMALL POWER PRODUCERS ARE MORE EFFICIENT THAN LARGE POWER PRODUCERS

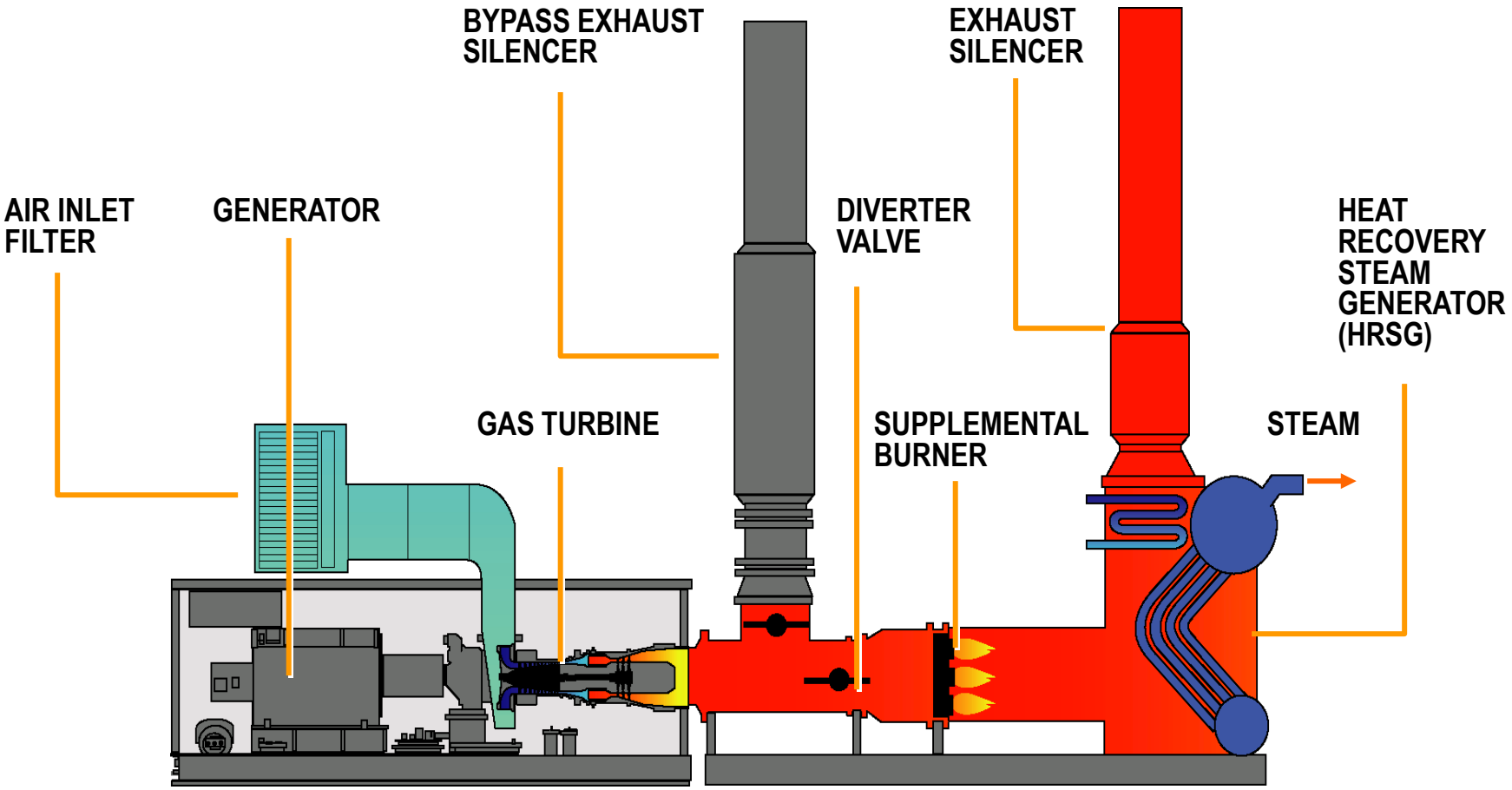
Small Scale Power (CHP) Project

Utility Scale Power Producer

CHP DIFFERENCE

	ENERGY	ENERGY USAGE	ENERGY USAGE, MW	ENERGY INPUT, MW	SYSTEM EFFICIENCY
Without CHP	Thermal	36 000 lbs/hr	10.7	13.1	82%
	Electrical	5 460 kW	5.5	15.6	35%
	Total	--	16.2	28.7	56%
With CHP	Thermal	36 000 lbs/hr	10.7	20.1	-
	Electrical	5 460 kW	5.5		-
	Total	--	16.2	20.1	80.5%

43% Improvement in Efficiency


BYPASS EXHAUST SILENCER
EXHAUST SILENCER
AIR INLET FILTER
GENERATOR
DIVERTER VALVE
HEAT RECOVERY STEAM GENERATOR (HRSG)
GAS TURBINE
SUPPLEMENTAL BURNER
STEAM

High Hydrogen
Titan – 130 Units
burn 50% H2

- **AS RENEWABLE NATURAL GAS & GREEN HYDROGEN BECOME READILY AVAILIABLE, SOLAR GT'S CAN ACCEPT THAT AS A FUEL AND BE ZERO EMISSIONS !!**

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INFLATION REDUCTION ACT (IRA)

INFLATION REDUCTION ACT (IRA)

The recently passed IRA increased the ITC to 30% (was 10%) if certain provisions could be met.

1. **Must meet the Prevailing Wage and Apprenticeship levels. This includes construction and repairs for the first 5 years of op.**
2. **Must be started by the end of 2024.**
3. **Must meet 60% efficiency – wouldn't be a problem for CHP.**

INFLATION REDUCTION ACT (IRA)

- **NEW: the tax credits are fully fungible. Meaning that you can sell the tax credit to another party. So if the end user's annual tax liability is less than the total of the tax credit, then:**
  - **End user can either roll the remaining tax credit to the following year(s) or**
  - **End user can sell the tax credit to another company who may want them.**

INFLATION REDUCTION ACT (IRA)

2. Must be started by the end of 2024 with a 5% spend by 12-31-24.

If your facility is considering Infrastructure up grades: Boilers, Chillers, Electrical, then the project economics improve even further due to a possible “cost avoidance” by not having to upgrade infrastructure.

FROM 10% ITC TO 30% - 40% - 50%

- **30% ITC**

Should be attainable provided you met prevailing wages and in some cases that may not be an issue given how hard it is to find people – need to pay more.

FROM 10% ITC TO 30% - 40% - 50%

- **40% for 100% Made in America**

- **Lathrop Trotter CHP Preferred Component Suppliers:**

  ALL MADE IN USA

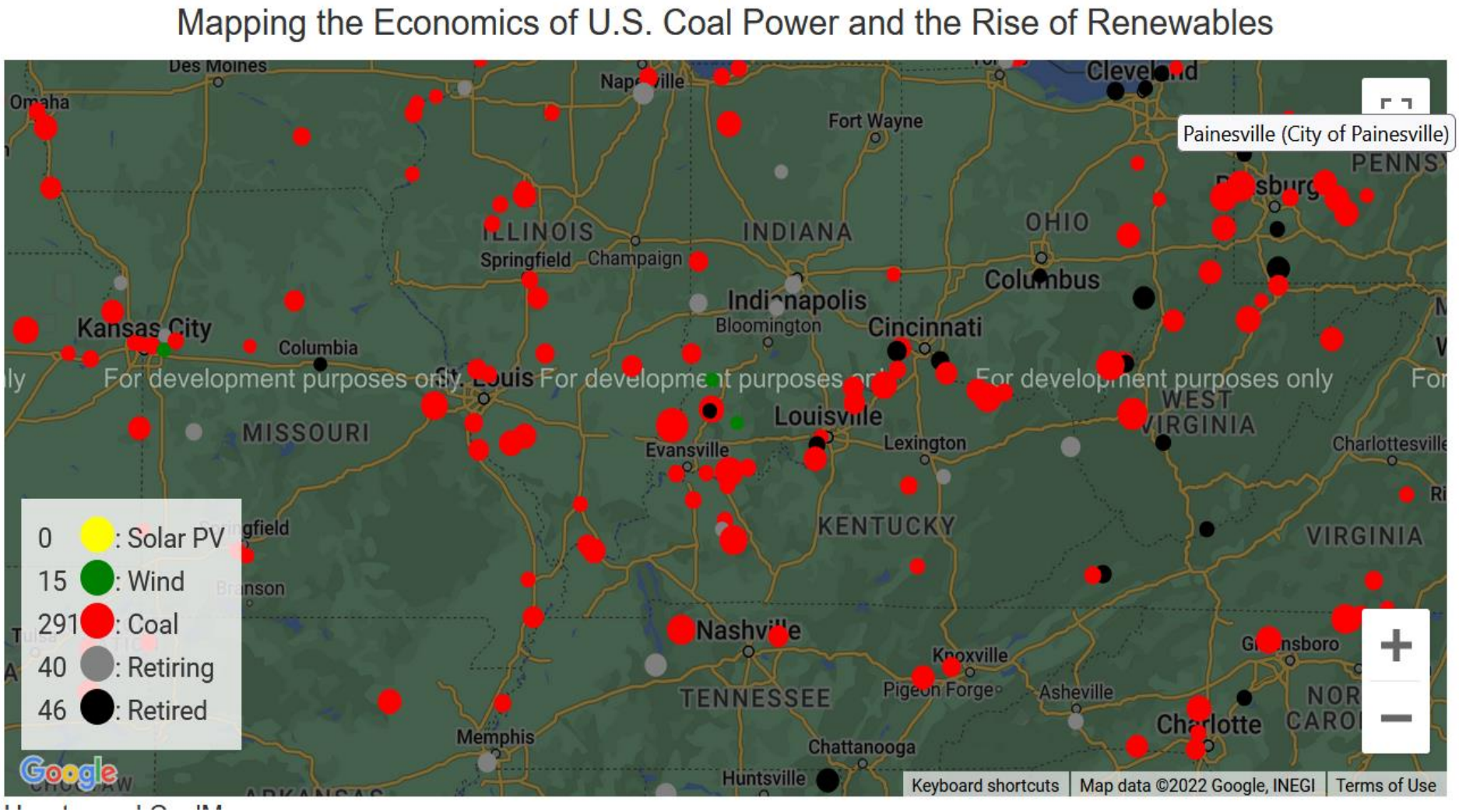
- **Solar Gas Turbines**: Manufactured in San Diego California
- **Rentech Boilers**: Manufactured in Abilene TX
- **Industrial Steam Deaerators**: Chicago IL & Iowa

FROM 10% ITC TO 30% - 40% - 50%

- **50% ITC**

- **For projects going into areas where coal fired plants have or will be taken off line and coal mines closed or will be closing.**

COALMAP


Mapping the Economics of U.S. Coal Power and the Rise of Renewables
Painesville (City of Painesville)
0 : Solar PV
15 : Wind
291 : Coal
40 : Retiring
46 : Retired
For development purposes only
Keyboard shortcuts
Map data ©2022 Google, INEGI
Terms of Use

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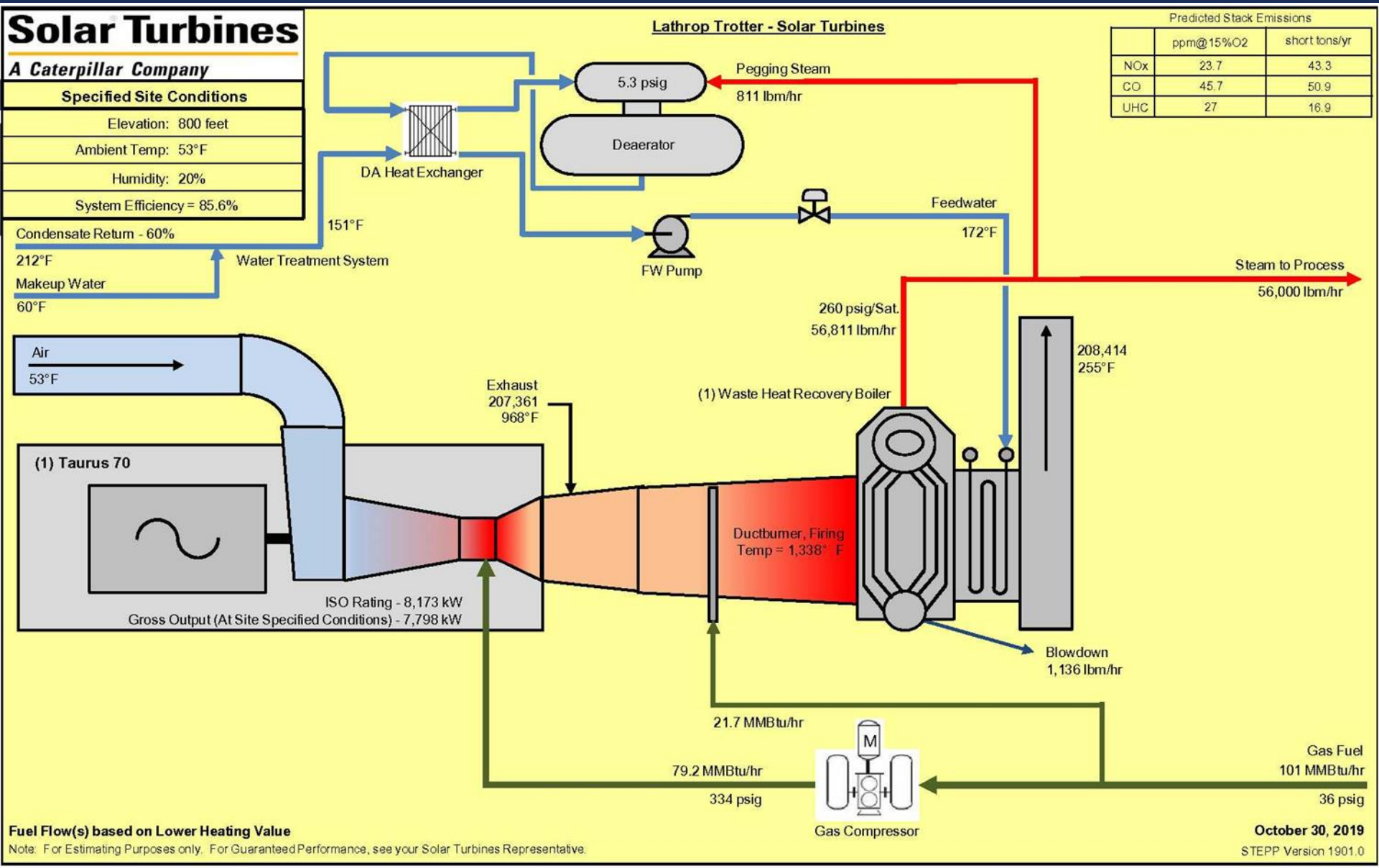
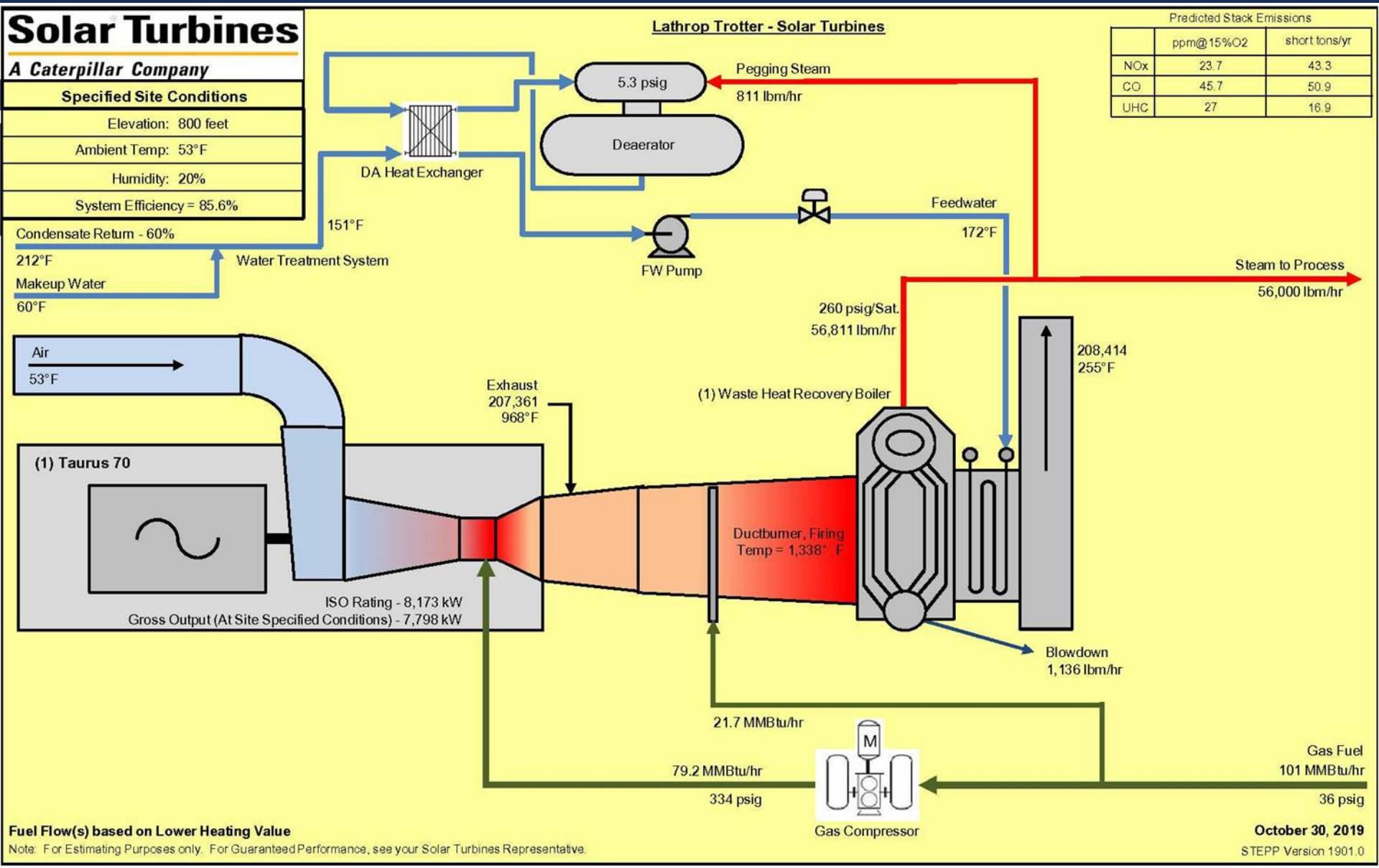

Solar Turbines
A Caterpillar Company
Specified Site Conditions
Elevation: 800 feet
Ambient Temp: 53°F
Humidity: 20%
System Efficiency = 85.6%
Lathrop Trotter - Solar Turbines
Predicted Stack Emissions
ppm@15%O2
short tons/yr
NOx 23.7 43.3
CO 45.7 50.9
UHC 27 16.9
5.3 psig
Pegging Steam
811 lbm/hr
Deaerator
DA Heat Exchanger
Feedwater
172°F
FW Pump
151°F
Condensate Return - 60%
212°F
Water Treatment System
Makeup Water
60°F
Steam to Process
56,000 lbm/hr
260 psig/Sat.
56,811 lbm/hr
208,414
255°F
Air
53°F
Exhaust
207,361
968°F
(1) Waste Heat Recovery Boiler
(1) Taurus 70
Ductburner, Firing
Temp = 1,338° F
ISO Rating - 8,173 kW
Gross Output (At Site Specified Conditions) - 7,798 kW
Blowdown
1,136 lbm/hr
21.7 MMBtu/hr
M
79.2 MMBtu/hr
334 psig
Gas Compressor
Gas Fuel
101 MMBtu/hr
36 psig
Fuel Flow(s) based on Lower Heating Value
Note: For Estimating Purposes only. For Guaranteed Performance, see your Solar Turbines Representative.
October 30, 2019
STEPP Version 1901.0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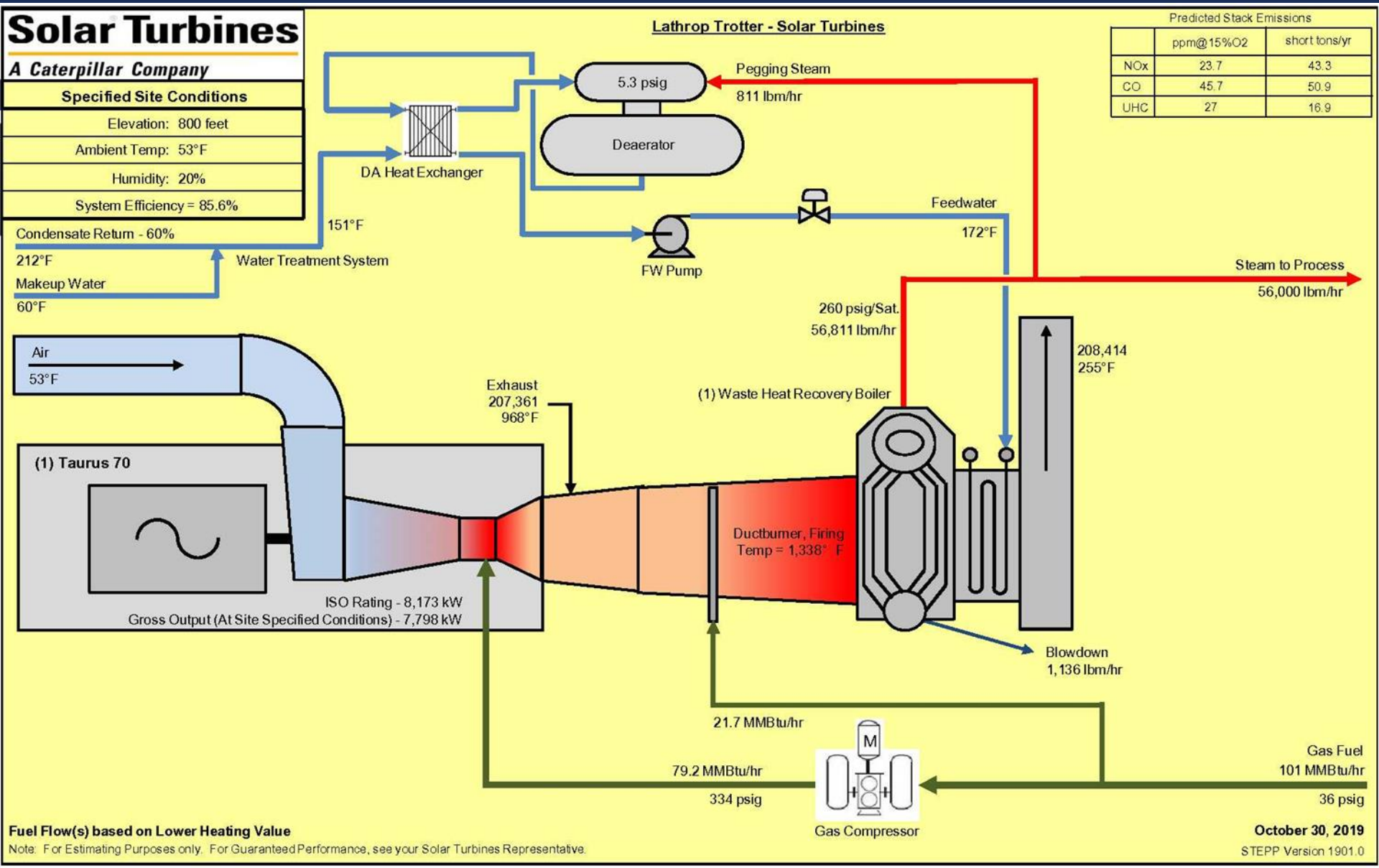
WATER TUBE STYLE HEAT RECOVERY STEAM GENERATOR

TO RECOVER THE EXHAUSTED ENERGY FROM THE GAS TURBINE THESE HRSG'S CONVERT THE HOT GASES TO USEABLE STEAM FOR THE PLANT / PROCESS OR CAMPUS FOR HEATING.

FIRE TUBE STYLE HRSG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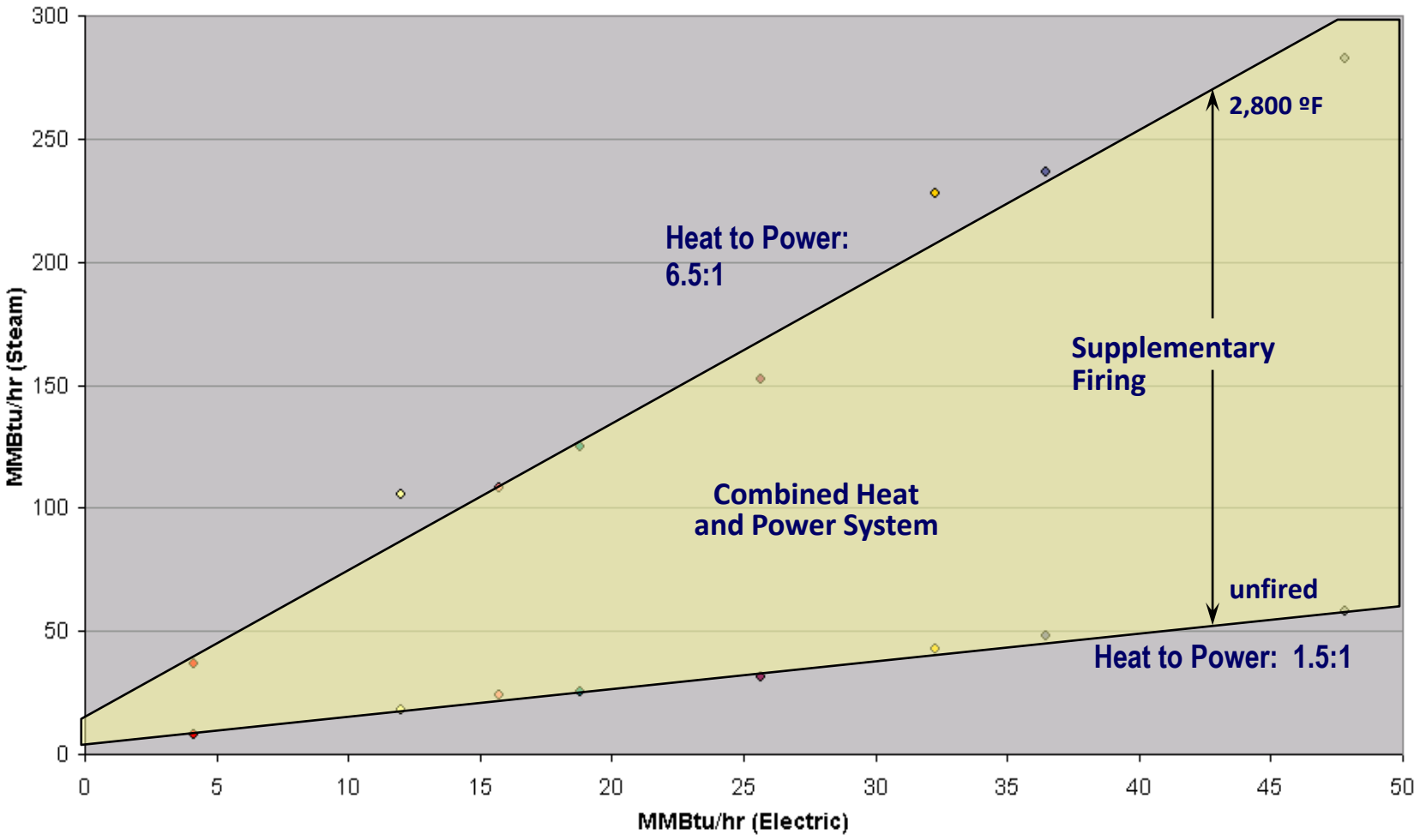
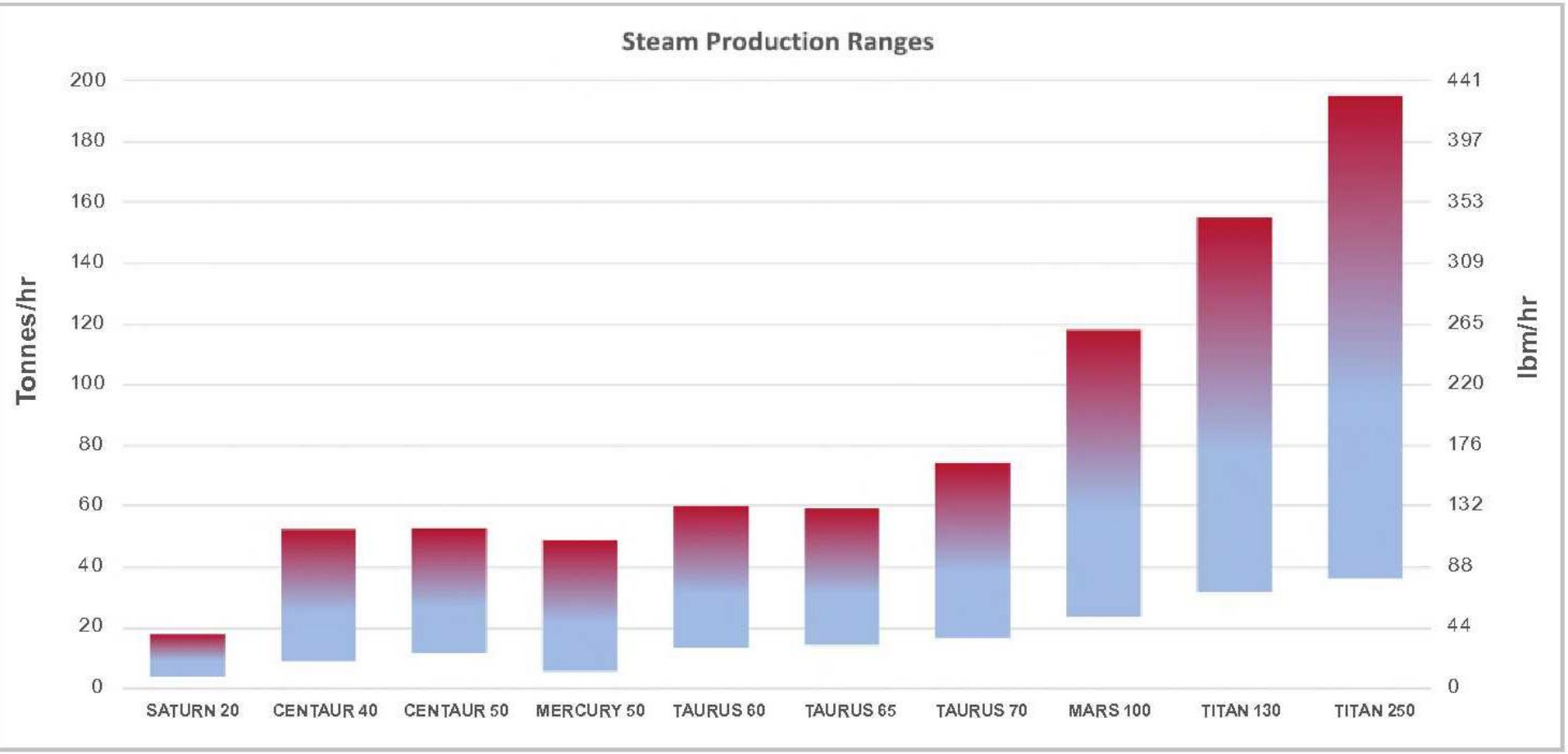
Duct Burner

HEAT / POWER RATIOS FOR CHP

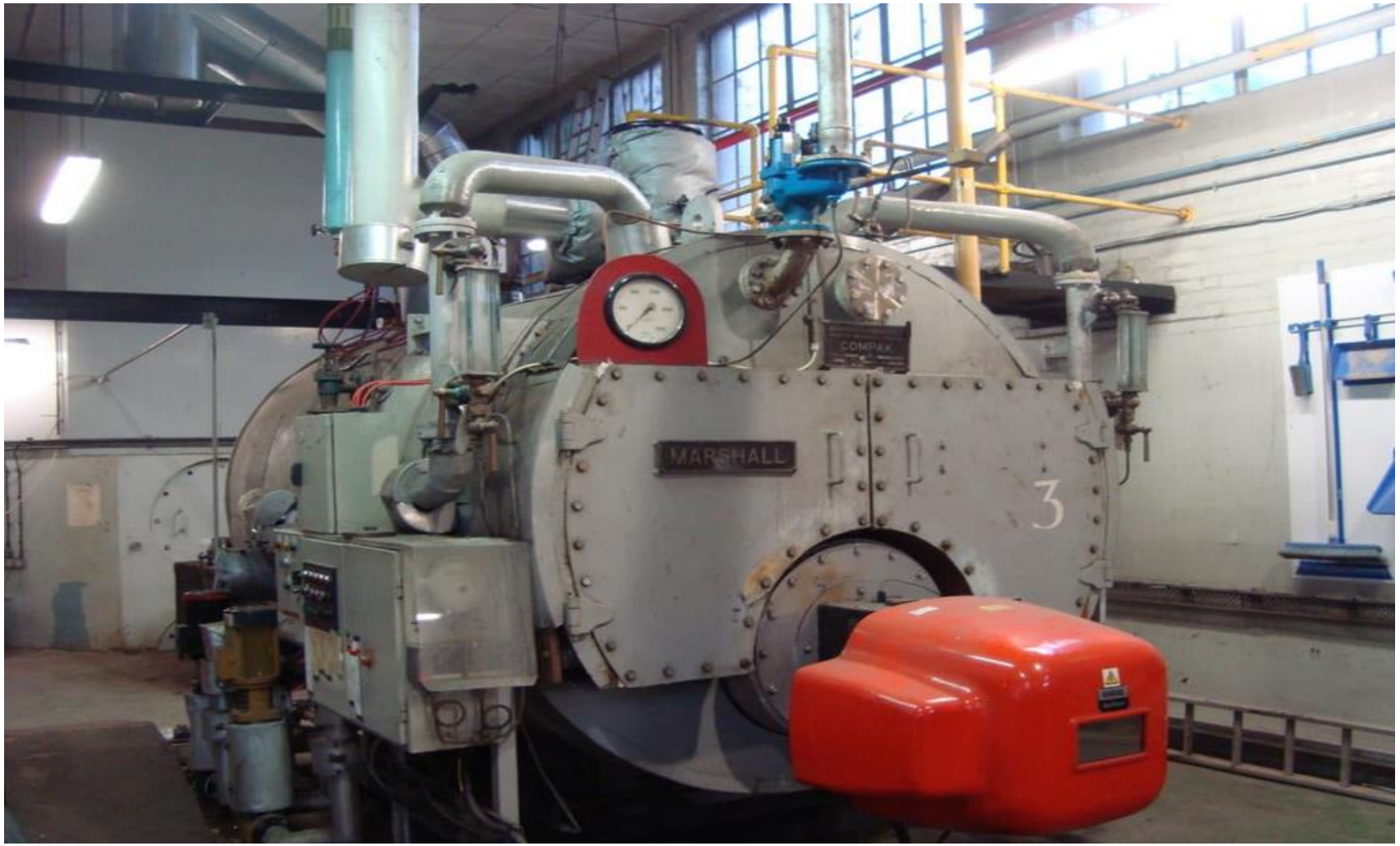


COMBINED HEAT AND POWER PERFORMANCE




WHERE DOES CHP APPLY?

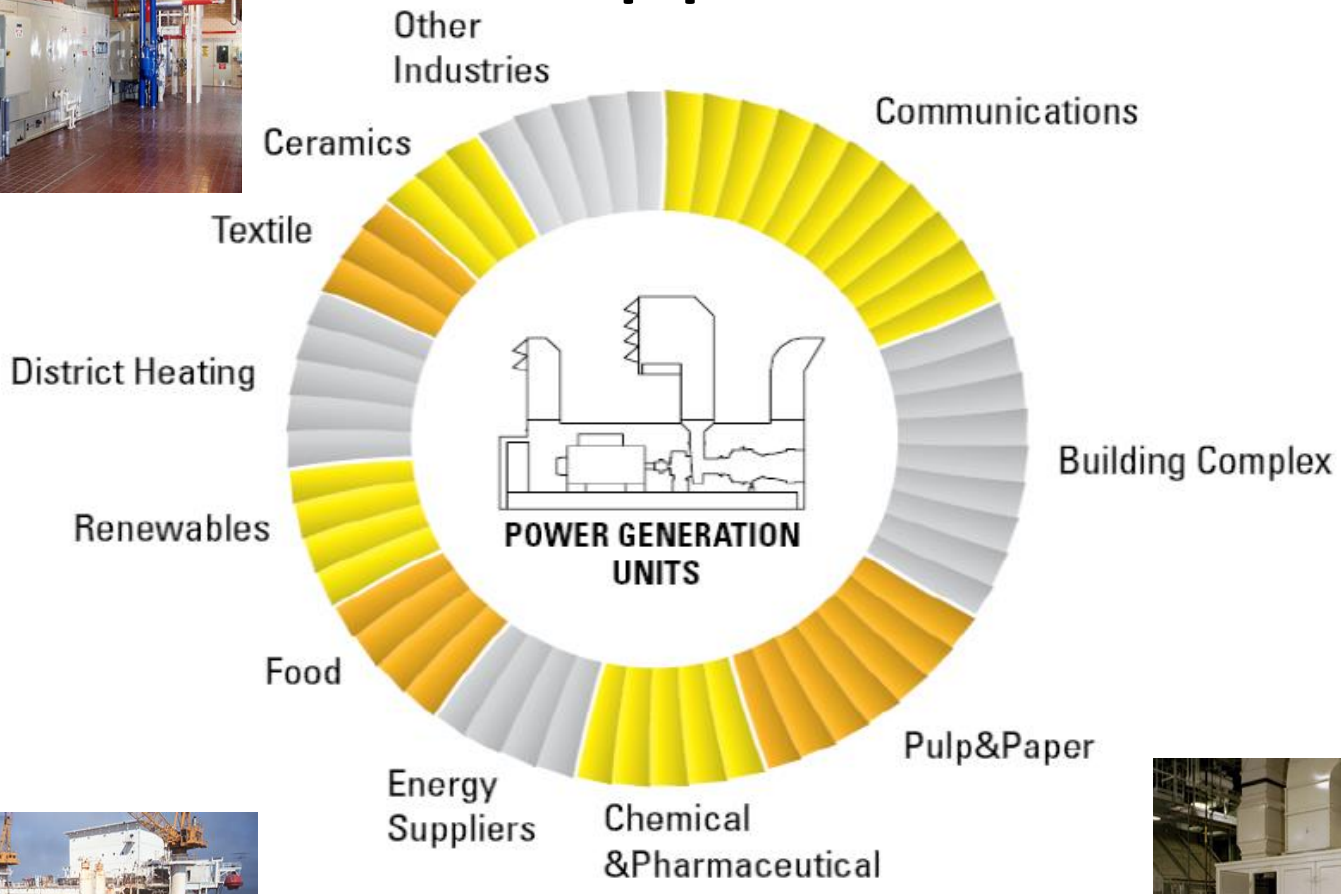
WHERE WE HAVE SUFFICIENT THERMAL (STEAM) LOADS



INDUSTRIES USING CHP

HIGHER EDUCATION: ENERGY STAR

CHP Application

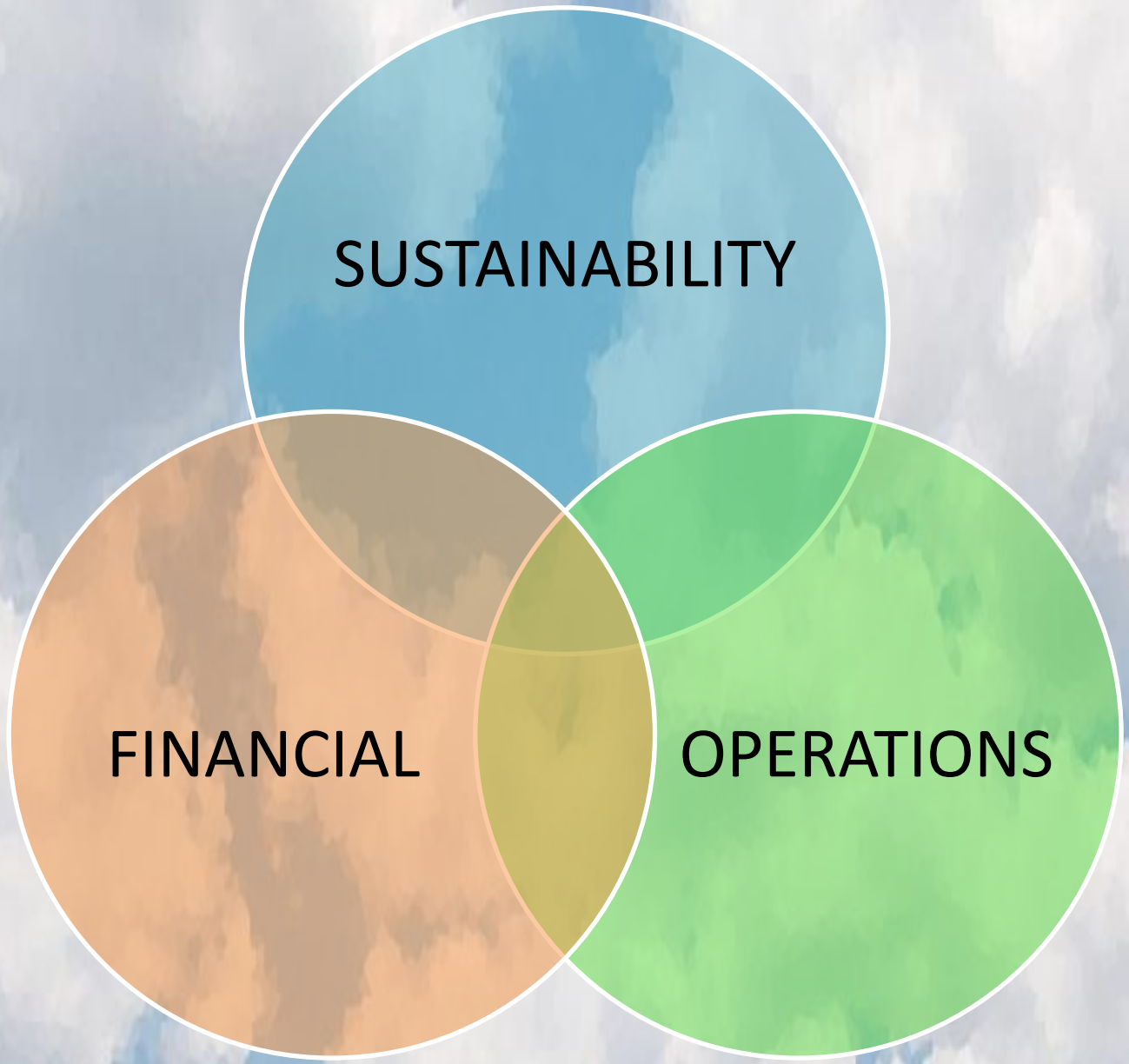


Solar Fleet fits most industrial thermal needs

SUSTAINABILITY

OPERATIONS

FINANCIAL


SUSTAINABILITY
FINANCIAL
OPERATIONS

CHP MEETING MULTIPLE CORPORATE GOALS

DEPARTMENT	GOALS	HOW CHP MEETS GOALS
SUSTAINABILITY	REDUCE EMISSIONS & ACHIEVE GOALS 30-50% is Typical	EFFICIENCY & CLEAN FUELS
OPERATIONS	IMPROVE RELIABILITY & OPERATING EXPENSE REDUCE PRODUCTON COSTS	REDUNDANCY & RELIABILITY IMPROVEMENTS. REDUCE ENERGY COSTS
FINANCIAL	REDUCE PER UNIT COST OF PRODUCTION	REDUCE ENERGY EXPENDITURES
FINANCIAL	IMPROVE FORCASTING ACCURACY	FUEL COST STABILITY & PREDICTABILITY
OVERALL COMPANY	GOOD NEIGHBOR	PATH WAY ZERO CARBON EMISSIONS WITH ROI

AGENDA SEPTEMBER 2022 OMEC

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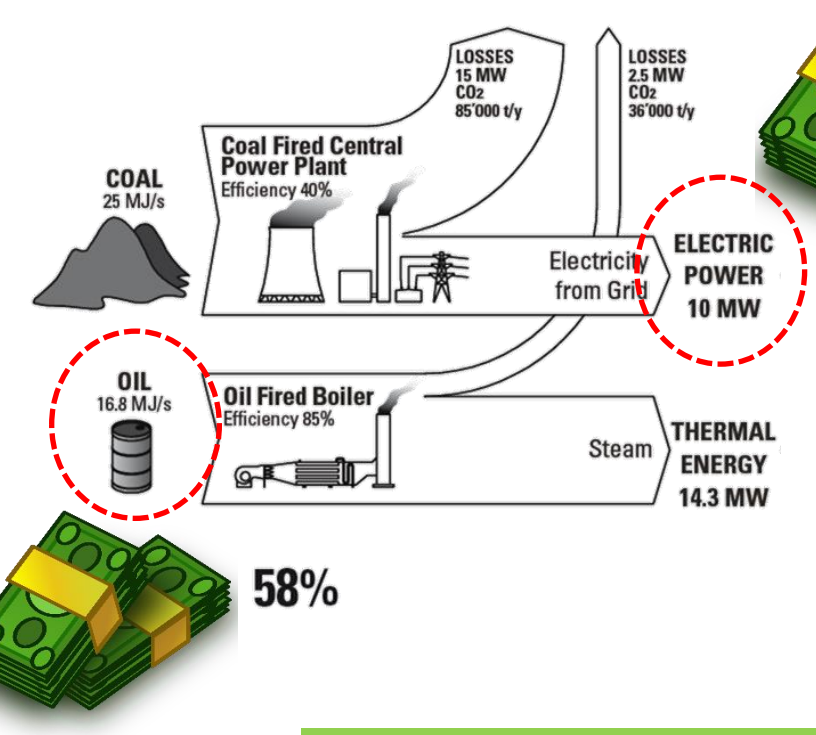
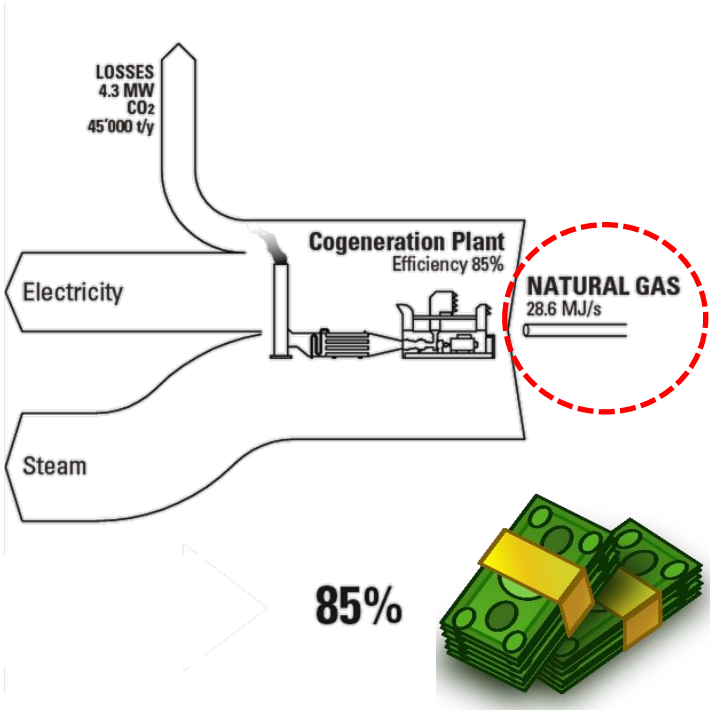
EFFICIENCY = CARBON REDUCTION AND $ SAVINGS



FACILITY



Key question I CHP Analysis:
Is the cost of extra natural gas (or other fuel) for CHP system going to be less than the current electricity and fuel bill to supply my plant needs?

The results generated by the CHP Emissions Calculator are intended for educational and outreach purposes only; it is not designed for use in developing emission inventories or preparing air permit applications.

Annual Emissions Analysis					
	CHP System	Displaced Electricity Production	Displaced Thermal Production	Emissions/Fuel Reduction	Percent Reduction
NOx (tons/year)	43.51	78.92	44.50	79.90	65%
SO2 (tons/year)	1.66	150.70	0.22	149.27	99%
CO2 (metric tons/year)	83,973	112,520	48,035	76,583	48%
Carbon (metric tons/year)	22,902	30,687	13,100	20,886	48%
Fuel Consumption (MMBtu/year)	1,555,699	1,341,814	889,908	676,023	30%
Acres of Forest Equivalent				20,886	
Number of Cars Removed				13,054	

Displaced Electricity Generation Profile: eGRID State Average Fossil 2016

Region Selected: Ohio

This reduction is equal to removing the carbon that would be absorbed by 20,886 acres of forest

This reduction is equal to removing the carbon emissions from 13,054 cars

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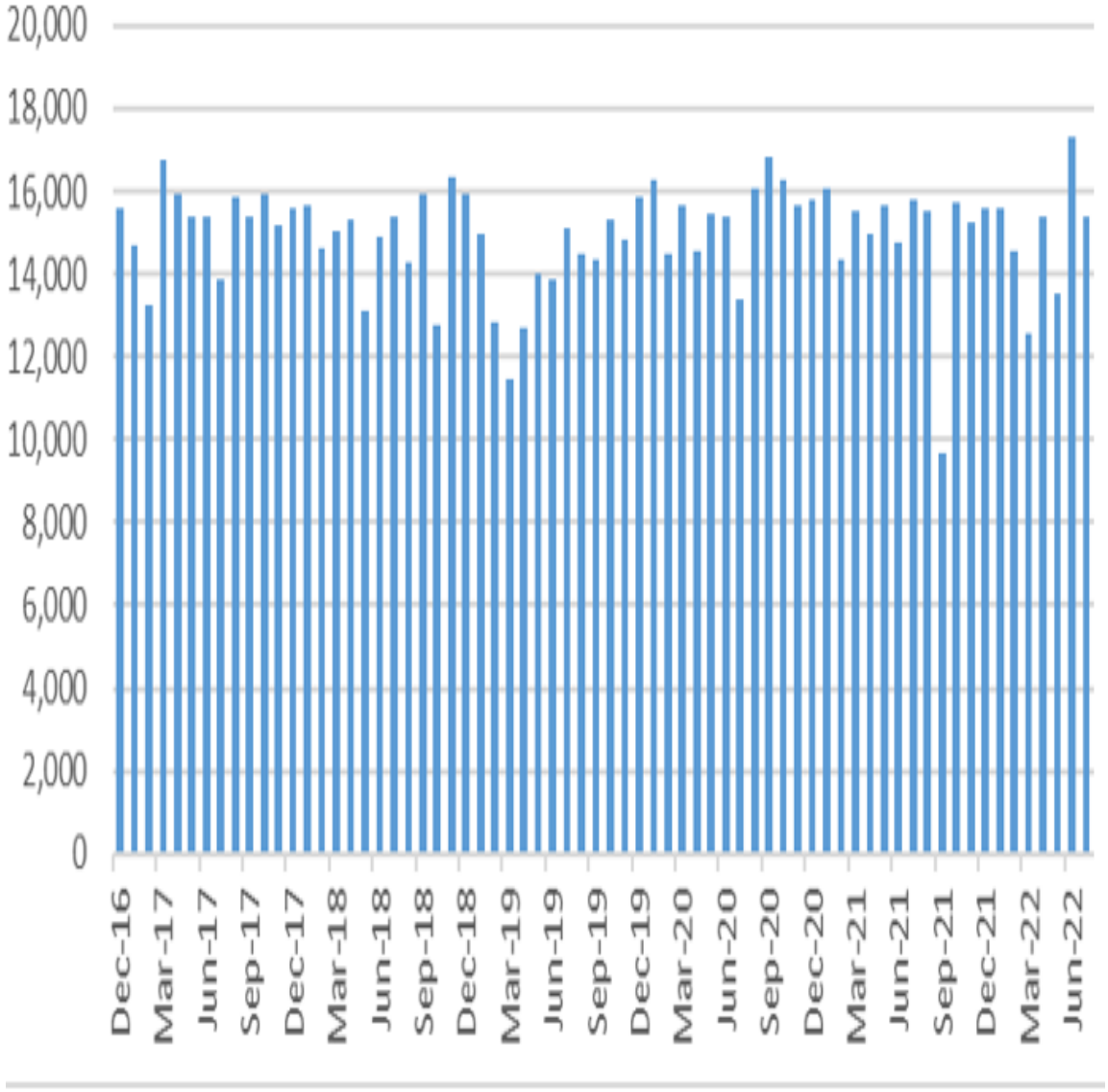
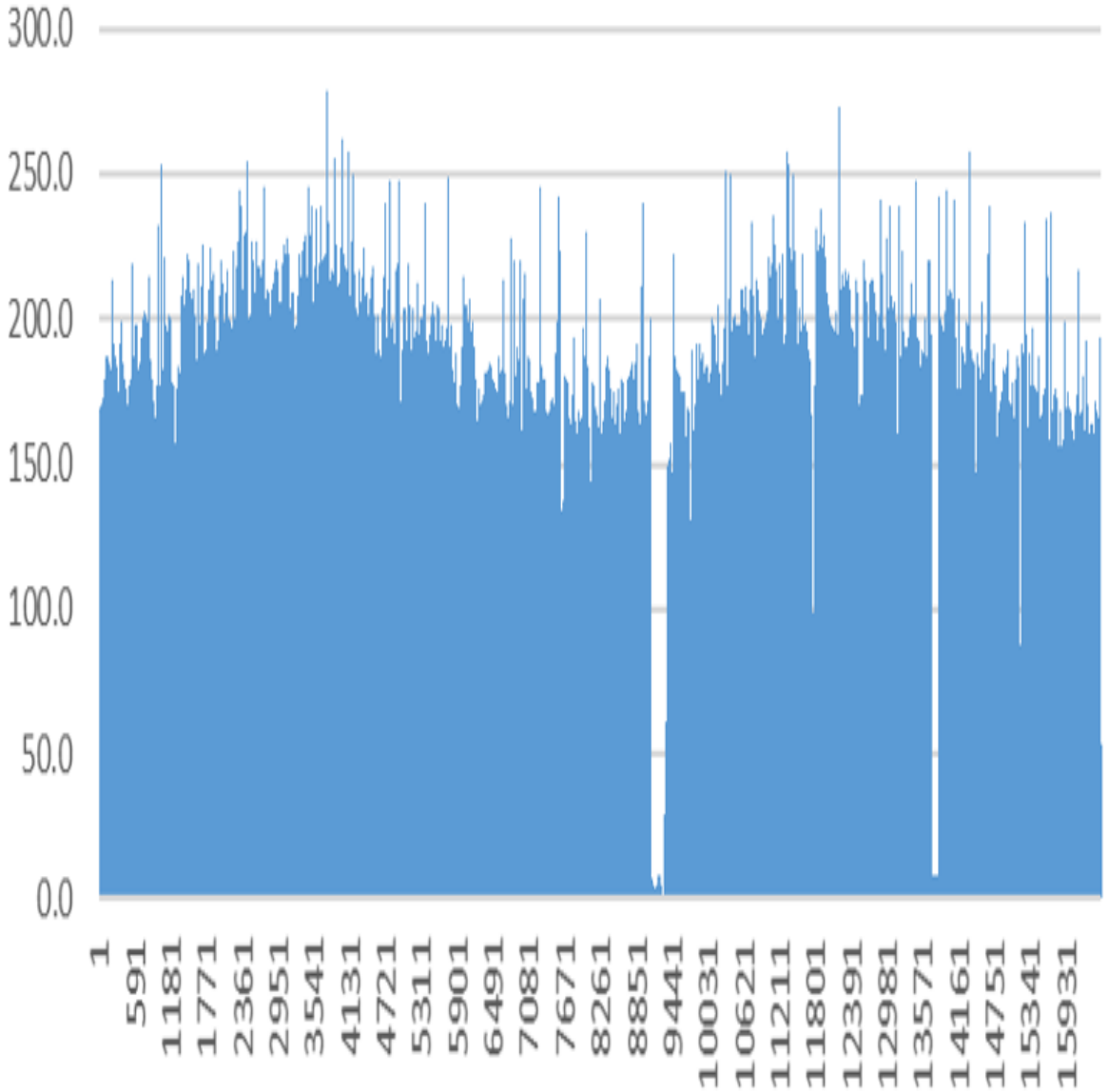
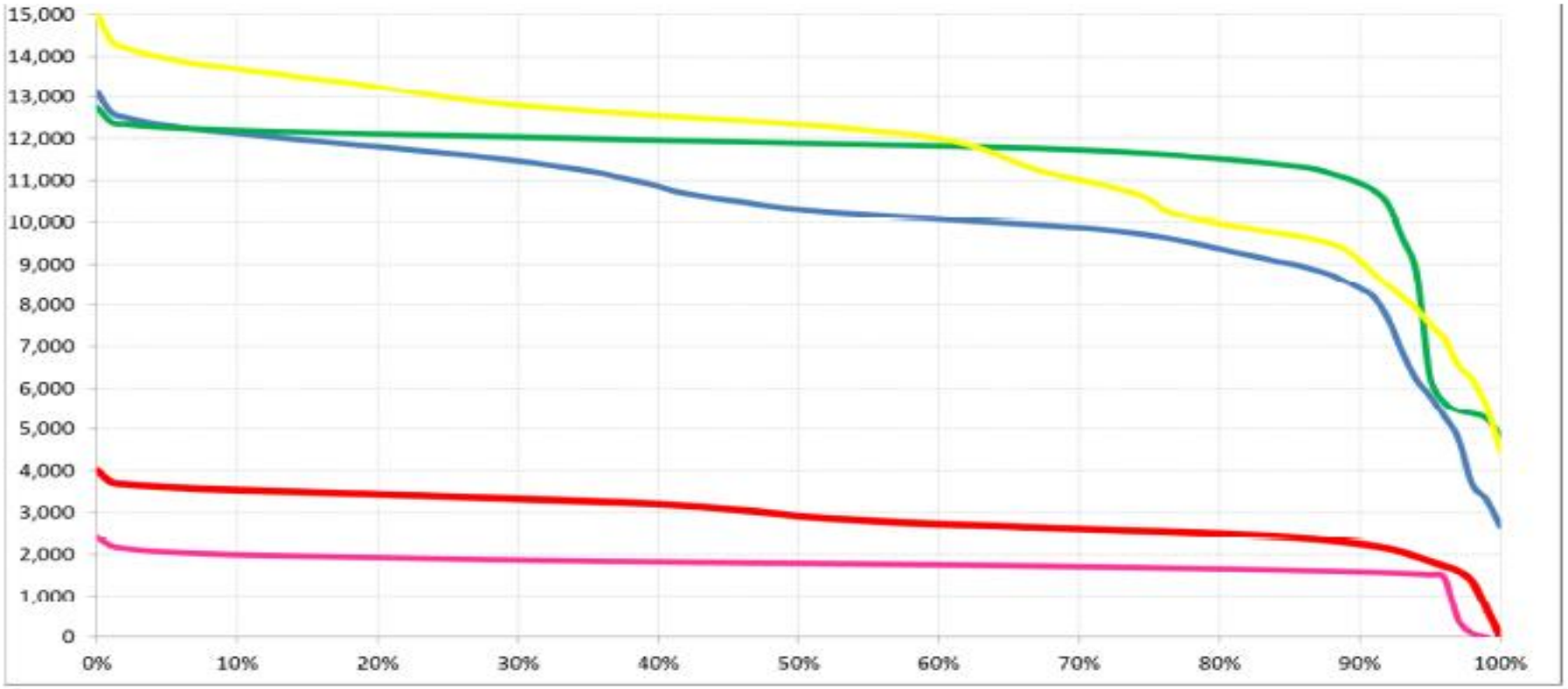
Monthly Electrical Load



Hourly Steam Flow



Load Duration Curves



The load durations curves above show one year of hourly electric loads sorted high to low for each of the five sites. The graphs are not 'stacked' so the relative size can be viewed

Solar Turbines
A Caterpillar Company

Lathrop Trotter - Solar Turbines

Solar Turbines Engine Performance Program v.1901.0

Customer Name	Lathrop Trotter - Solar Turbines
Project Name	Sample - Industrial Manufacturing
Project Location	Ohio, Indiana, Kentucky, Pennsylvania

Turbine Selected/Modeled	Taurus 70-11101S Axial
Fuel Type	Natural Gas
Dual Fuel or Single Fuel?	Gas Only

See STEPP TOOLS tab to select engine, reset selections, and access other program features

Display selected column's results in other sheets		○	○	◉	○	○	○
SITE CONDITIONS	Site Elevation	feet	800	800	800	800	800	800
	Ambient Temperature (T1)	°F	-10	32	53	53	68	93
	Relative Humidity	%	0	5	20	20	40	70
	Barometric Pressure	"Hg	29.1	29.1	29.1	29.1	29.1	29.1
	Inlet Duct Loss	"H2O	4.0	4.0	4.0	4.0	4.0	4.0
	Exhaust Duct Loss	"H2O	10.0	10.0	10.0	10.0	10.0	10.0
	Site Fuel Gas Pressure	psig	36	36	36	36	36	36
	Process Steam Pressure	psig	260	260	260	260	260	260
	Steam Saturation Temperature	°F	410	410	410	410	410	410
	Process Steam Temperature	°F	410	410	410	410	411	411
	Steam Flow to Process	lbm/hr	80,000	70,000	56,000	80,000	60,000	50,000
	Condensate Temperature	°F	212	212	212	212	212	212
	Condensate Return	%	60	60	60	60	60	60
	Makeup Water Temperature	°F	60	60	60	60	60	60

Solar Turbines

A Caterpillar Company

Solar Turbines - Lathrop Trotter

Midwest USA

Project Description:

(1) Taurus 70-11101S Axial with fired HRSG and SCR Emission Control System

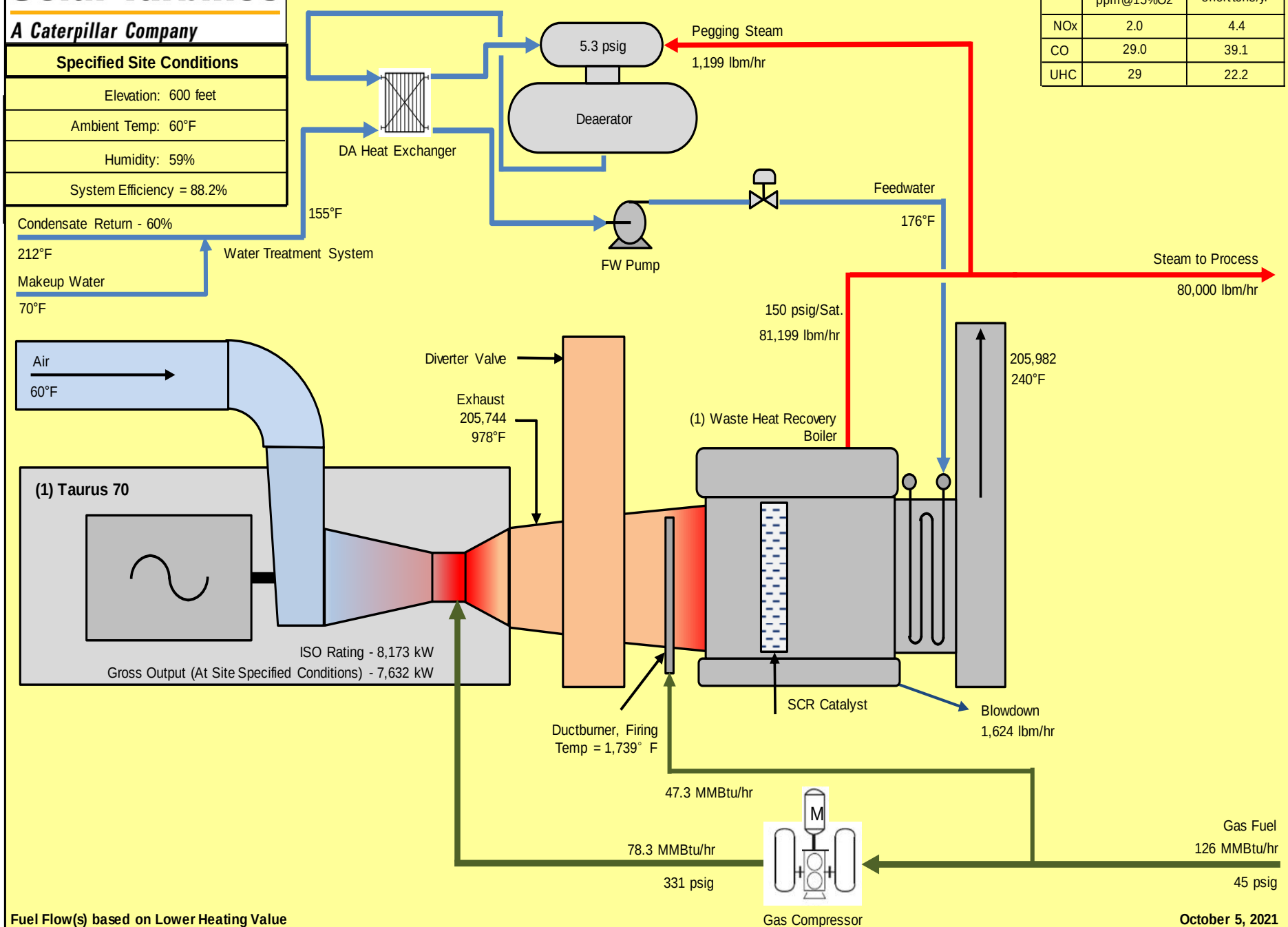
Solar Turbines
A Caterpillar Company

Solar Turbines - Lathrop Trotter

Specified Site Conditions
Elevation: 600 feet
Ambient Temp: 60°F
Humidity: 59%
System Efficiency = 88.2%

Predicted Stack Emissions

	ppm@15%O2	short tons/yr
NOx	2.0	4.4
CO	29.0	39.1
UHC	29	22.2



Fuel Flow(s) based on Lower Heating Value

Note: For Estimating Purposes only. For Guaranteed Performance, see your Solar Turbines Representative.

October 5, 2021

STEPP Version 2101

Cogeneration Plant Estimated Performance Summary

KW Gross Output @ ISO Conditions:	8,170	KW
KW Gross Output @ specified site conditions:	7,632	KW
Net Gas Turbine Power Production:	7,330	KW
Boiler Steam Flow (HRSG design uses 27.0°F pinch, 18.0°F approach):	81,202	lbm/hr
Steam Flow to Process:	80,000	lbm/hr

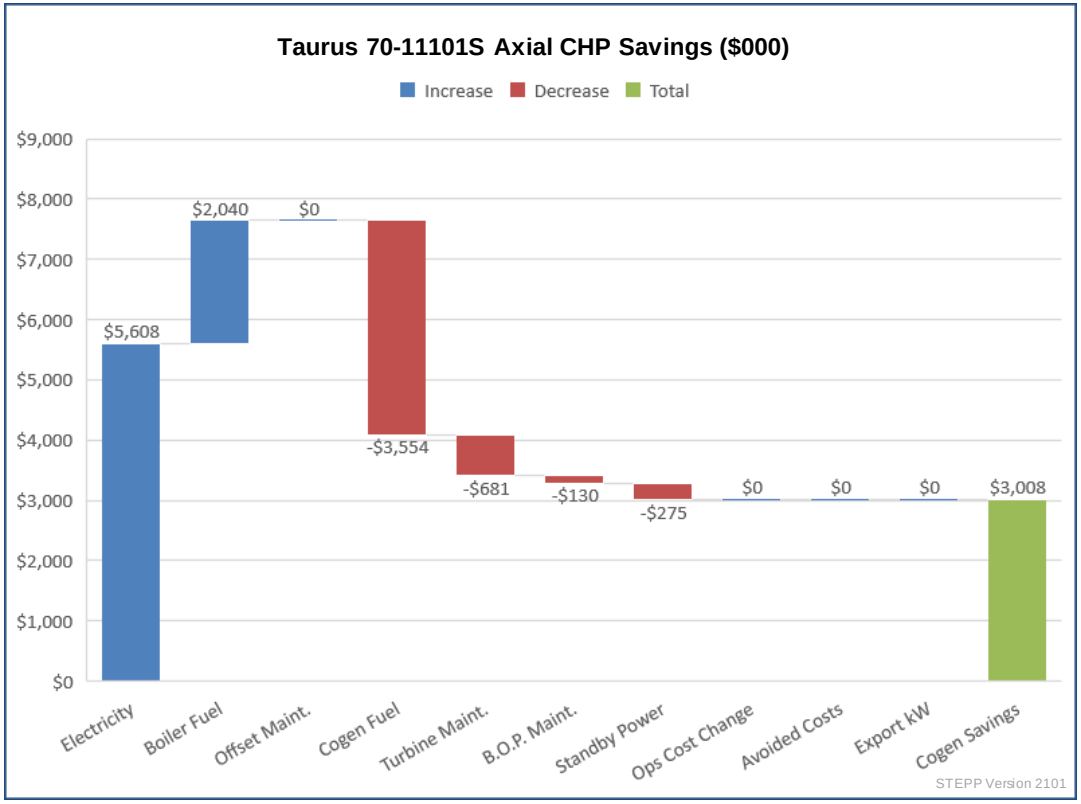
Cycle Performance (lower heating value basis):

Net Turbine Electrical Heat Rate:	10,680	Btu/kWHR
Gross Plant Heat Rate (Process steam or Tons converted to equivalent KW):	3,870	Btu/kWHR
Overall Cycle Efficiency (LHV):	88.2	%

STEPP Version 2101

Annual Savings

Current System Costs:		
Annual Electricity Cost (offset by proposed system):		
	7,330 kW x 0.09$/kW x 8500 hrs/year =	$5,607,500
Steam Production Costs (fuel and O&M):		
	81,199 lbm/hr x 8500 hrs/year x $3.00/klbm =	$2,040,000
Current Annual Maintenance Costs to be Offset……		$0
Total Annual Current Costs		**$7,647,500**
Proposed Cogeneration System Costs:		
Annual Cogeneration System Fuel Cost:		
	125.6 MMBtu/hr x $3.00/MMBtu x 1.109 HHV/LHV x 8500 hrs/year =	$3,554,000
Turbine Maintenance Cost (based on gross power output):		
	$0.0105/kW-hr x 7,632 kW x 8500 hrs/year =	$681,200
Balance of Plant Maintenance Cost (based on gross power output):		
	$0.002/kW-hr x 7,632 kW x 8500 hrs/year =	$129,800
Standby Power Cost (based on gross power output):		
	$3.00/kW-month x 12 months x 7,632 kW =	$274,800
Increase/Decrease in Annual Operations Cost……		$0
Avoided Costs, $/year……		$0
Export KW Revenue, $/year……		$0
Total Annual Proposed Costs		**$4,639,800**


Taurus 70-11101S Axial CHP Savings ($000)
Increase
Decrease
Total
$9,000
$8,000
$7,000
$6,000
$5,000
$4,000
$3,000
$2,000
$1,000
$0
$5,608
$2,040
$0
-$3,554
-$681
-$130
-$275
$0
$0
$0
$3,008
Electricity
Boiler Fuel
Offset Maint.
Cogen Fuel
Turbine Maint.
B.O.P. Maint.
Standby Power
Ops Cost Change
Avoided Costs
Export kW
Cogen Savings
STEPP Version 2101

The results generated by the CHP Emissions Calculator are intended for educational and outreach purposes only; it is not designed for use in developing emission inventories or preparing air permit applications.

Annual Emissions Analysis					
	CHP System	Displaced Electricity Production	Displaced Thermal Production	Emissions/Fuel Reduction	Percent Reduction
NOx (tons/year)	43.51	78.92	44.50	79.90	65%
SO2 (tons/year)	1.66	150.70	0.22	149.27	99%
CO2 (metric tons/year)	83,973	112,520	48,035	76,583	48%
Carbon (metric tons/year)	22,902	30,687	13,100	20,886	48%
Fuel Consumption (MMBtu/year)	1,555,699	1,341,814	889,908	676,023	30%
Acres of Forest Equivalent				20,886	
Number of Cars Removed				13,054	

Displaced Electricity Generation Profile: eGRID State Average Fossil 2016

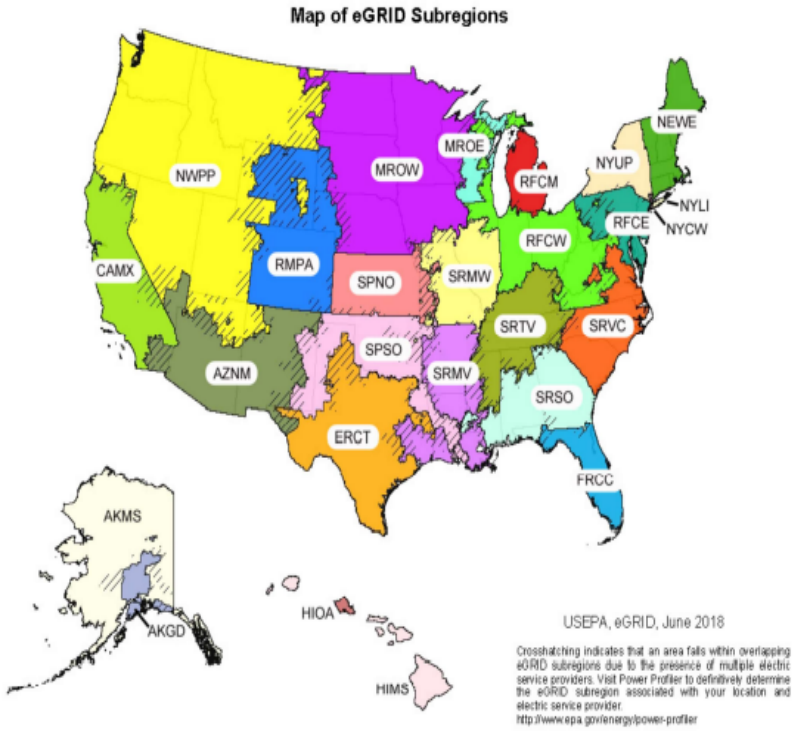
Region Selected: Ohio

This reduction is equal to removing the carbon that would be absorbed by 20,886 acres of forest

This reduction is equal to removing the carbon emissions from 13,054 cars

Estimating Future Emissions by eGRID Subregion

The subregion emission rates most accurately represent the actual electricity used by consumers by limiting the import and export of electricity within an aggregated area.



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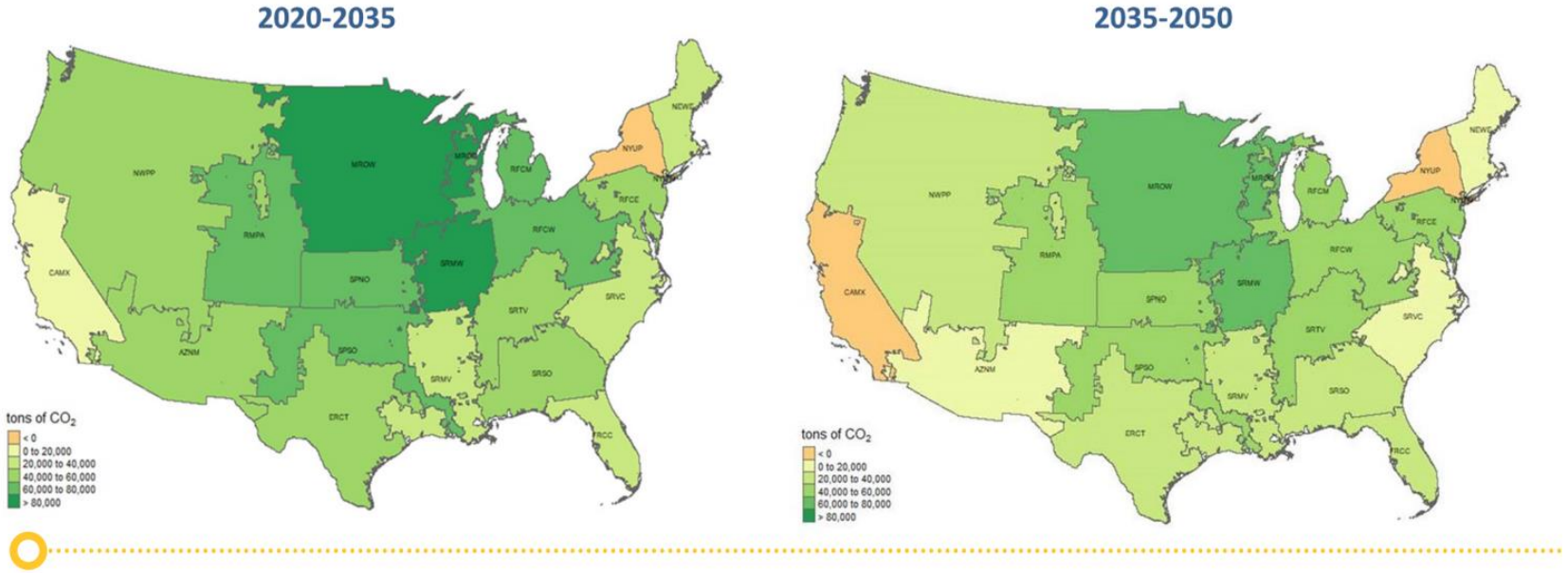
CHP REDUCES CARBON EMISSIONS ***DRASTICALY*** USING NATURAL GAS & REACHES ZERO EMISSIONS ON RNG & GREEN H2



Lifetime Carbon Emission Reductions for CHP Systems

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Evaluating CHP Emission Impacts

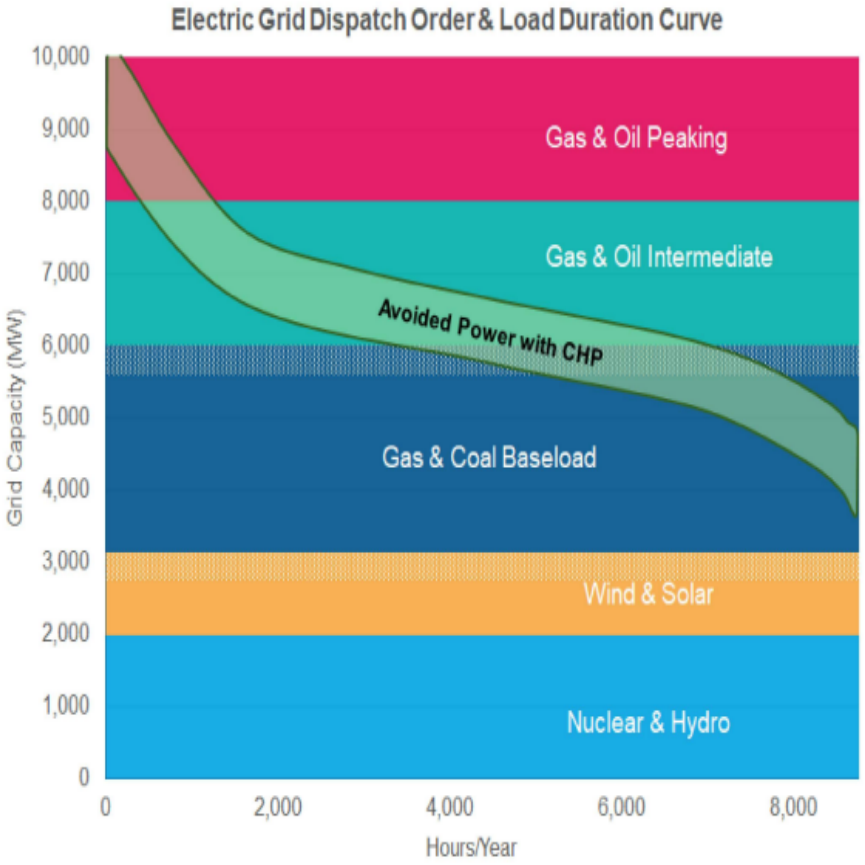
Displaced grid emissions for CHP are based on *marginal utility generation*

Marginal units are those at the "top of the stack" that set the electricity price in real-time or day-ahead pricing

Currently, marginal generation tends to be provided by units fueled by gas, oil, and in some cases coal

- For CHP systems that operate 24/7, average *fossil fuel* emission factors from eGRID can be used
- For CHP systems that operate during day/evening hours, average *non-baseload* emission factors from eGRID provide a better estimate

Limitations in accurately estimating marginal emissions with eGRID



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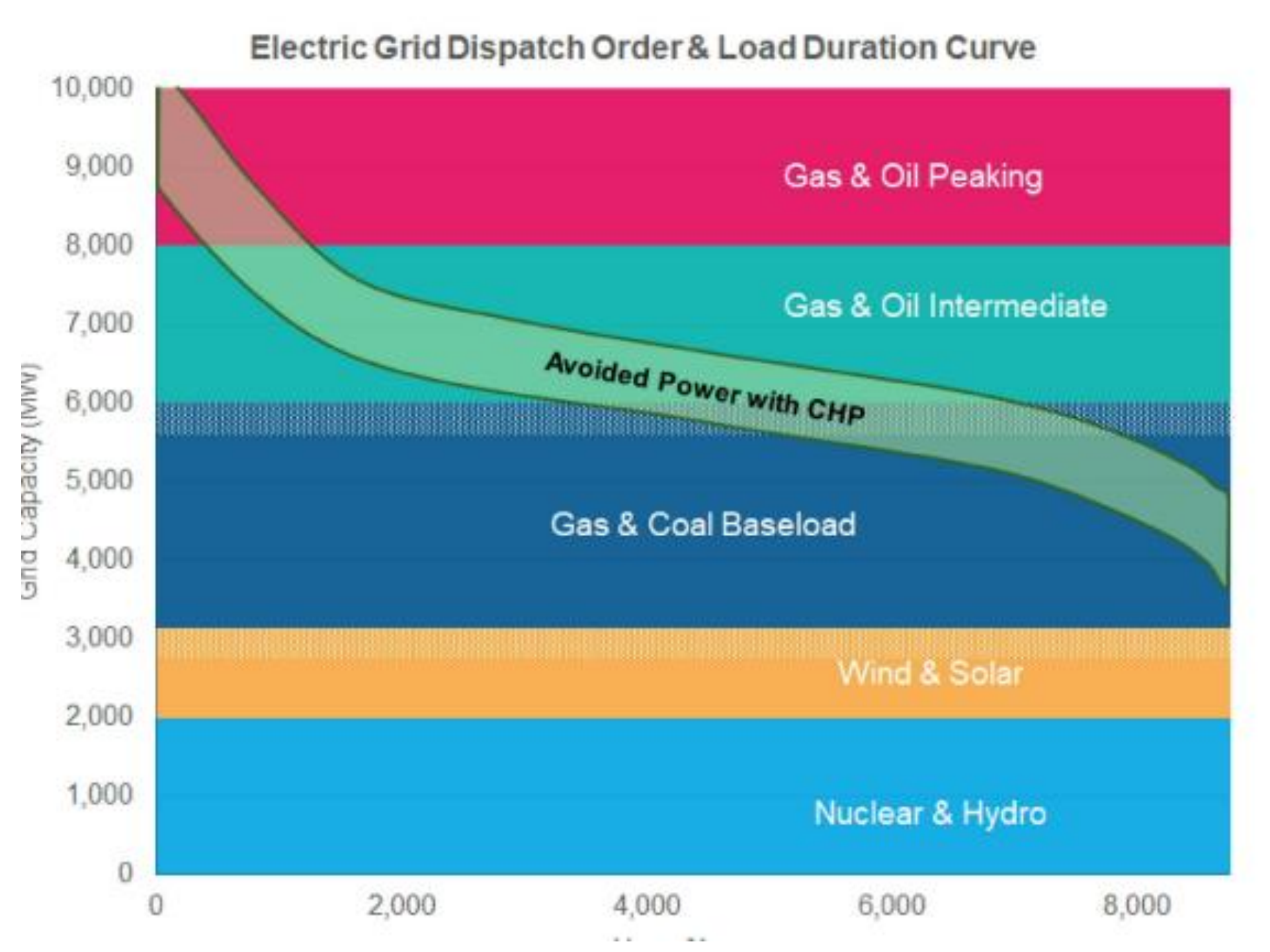
Electric Grid Dispatch Order & Load Duration Curve
10,000
9,000
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
Grid Capacity (MW)
Gas & Oil Peaking
Gas & Oil Intermediate
Avoided Power with CHP
Gas & Coal Baseload
Wind & Solar
Nuclear & Hydro
0
2,000
4,000
6,000
8,000

Category	10 MW CHP	10 MW WHP	10 MW PV	10 MW Wind	10 MW NGCC
Annual Capacity Factor	85%	85%	24.9%	35.5%	57.6%
Annual Electricity, MWh	74,460	74,460	21,812	31,098	50,458
Annual Useful Heat Provided, MWh_{th}	97,505	None	None	None	None
Capital Cost, $ million	$20.2 m	$15.0 m	$17.8 m	$16.2 m	$10.0 m
Annual Energy Savings, MMBtu	360,420	787,597	230,720	328,938	200,693
Annual CO_2 Savings, Tons	**53,297**	**78,265**	**22,927**	**32,687**	**33,571**
Annual NOx Savings, Tons	45.4	39.6	14.5	20.7	32.0

CHP's Higher Efficiency Results in Energy and Emissions Savings Compared to Today's Grid

(Average Fossil Generation)

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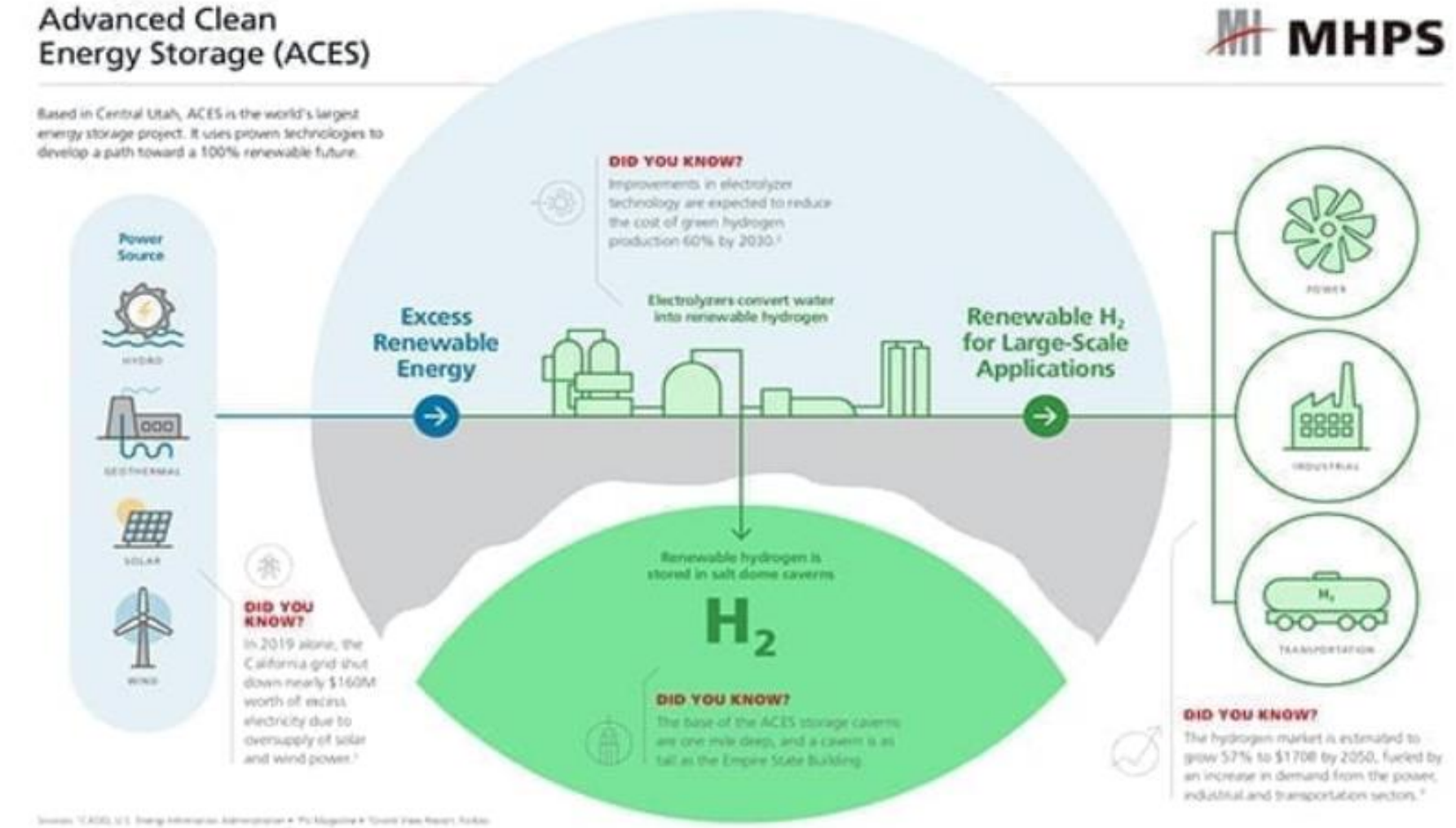
GREEN HYDROGEN

A KEY FACTOR IN REACHING ZERO EMISSIONS WITH CHP



INFLATION REDUCTION ACT (IRA)

WHAT MAKES CHP WORK ?

1. **Economics of Heat Recovery that replaces purchased fuel**.
2. Economically Viable Pathway to Zero for **Sustainability Goals**
3. More **Predictable** Energy Costs.
4. Improved **Reliability** Power and Heat.
5. **Avoided Costs** should be considered.
6. **Teamwork** and **Experience.**
7. **TAX INCENTIVES VIA IRA**

LATHROP TROTTER
Manufacturers Representatives

- **Gas Turbines (2-25MW):** Solar Turbines
- **Heat Recovery Boilers:** RENTECH & Superior Boiler Works
- **Gas Compressors:** Vilter / Emerson
- **Deaerators and FW Equipment:** Industrial Steam
- **Steam Turbine Gen Sets:** Dresser-Rand / Siemens (<60MW)

Solar® Turbines

A Caterpillar Company

Thank you. Are there any questions?

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