COMBINED HEAT AND POWER
SUSTAINABILITY + ROI:

Solar Turbines
A Caterpillar Company

LATHROP TROTTER
Since 1922

EDWARD STOERMER
COGEN SALES LEAD

CRAIG PLEIMAN
SALES ENGINEER

Solar Turbines
A Caterpillar Company

LATHROP TROTTER
Since 1922

INTRODUCTIONS:
LATHROP TROTTER / KOCH APPLIED

EDWARD STOERMER:

CRAIG PLEIMAN:

SOLAR GAS TURBINES (CATERPILLAR CO)

.

WHAT WE WILL COVER TODAY

1 **GAS TURBINE BASICS (5 MIN)**

2. **COMBINED HEAT AND POWER (CHP) BASICS (5 MIN)**

3. **HEAT SINKS THE 1 THING TO REMEMBER**

4. **DRIVERS: ECONOMICS+RELIABILITY+SUSTAINABILITY**

5. **WHERE IT APPLIES**

6. **SIZE AND SELECTION OF GAS TURBINE (GT) & HEAT RECOVERY STEAM GENERATOR (HRSG)**

7. **TYPICAL PRELIMINARY CHP REPORT**

8. **SEIZE THE OPPORTUNITY**

9. **SUSTAINABILITY AND WHY CHP REALLY "MOVES THAT NEEDLE"**

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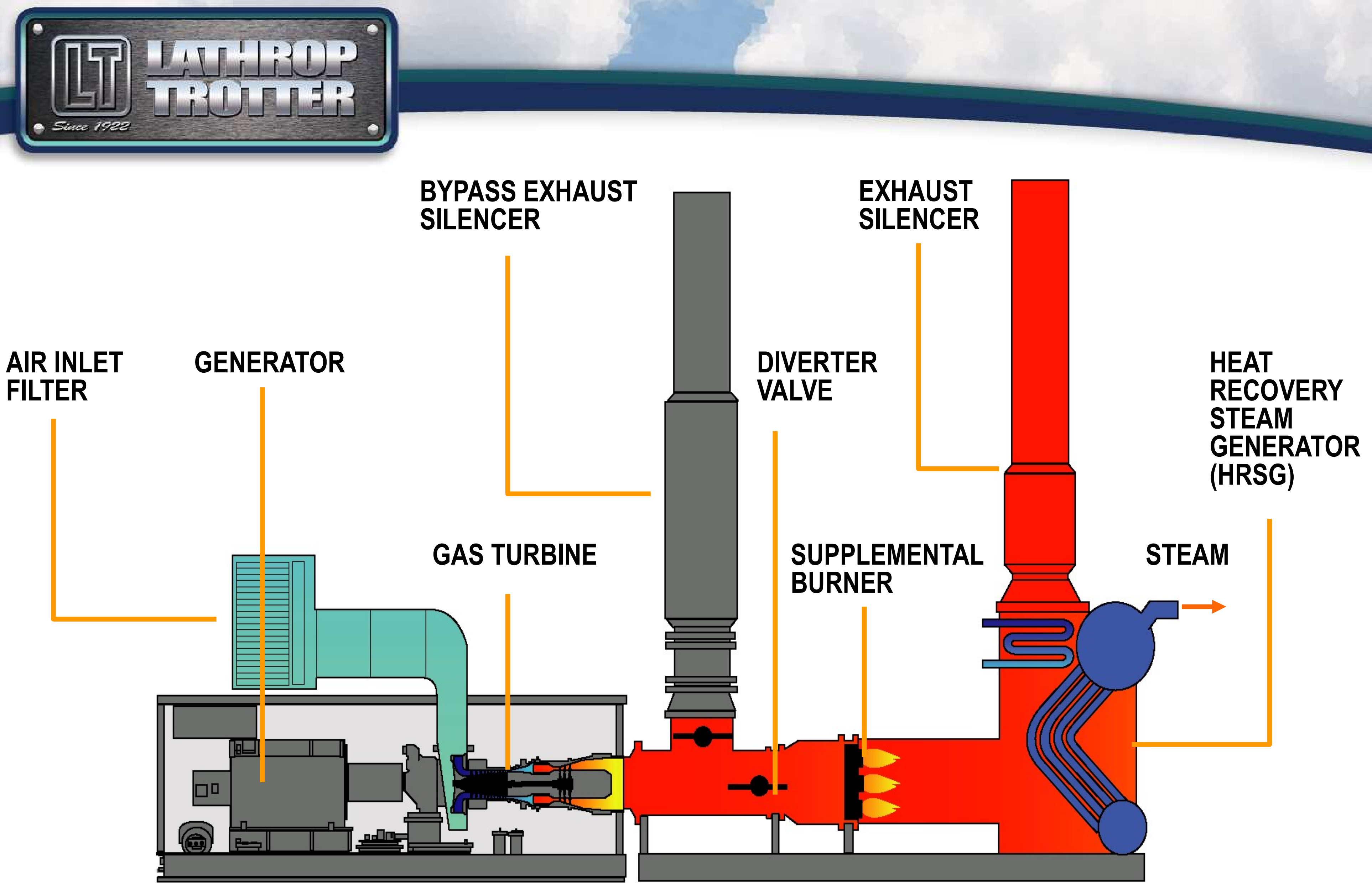
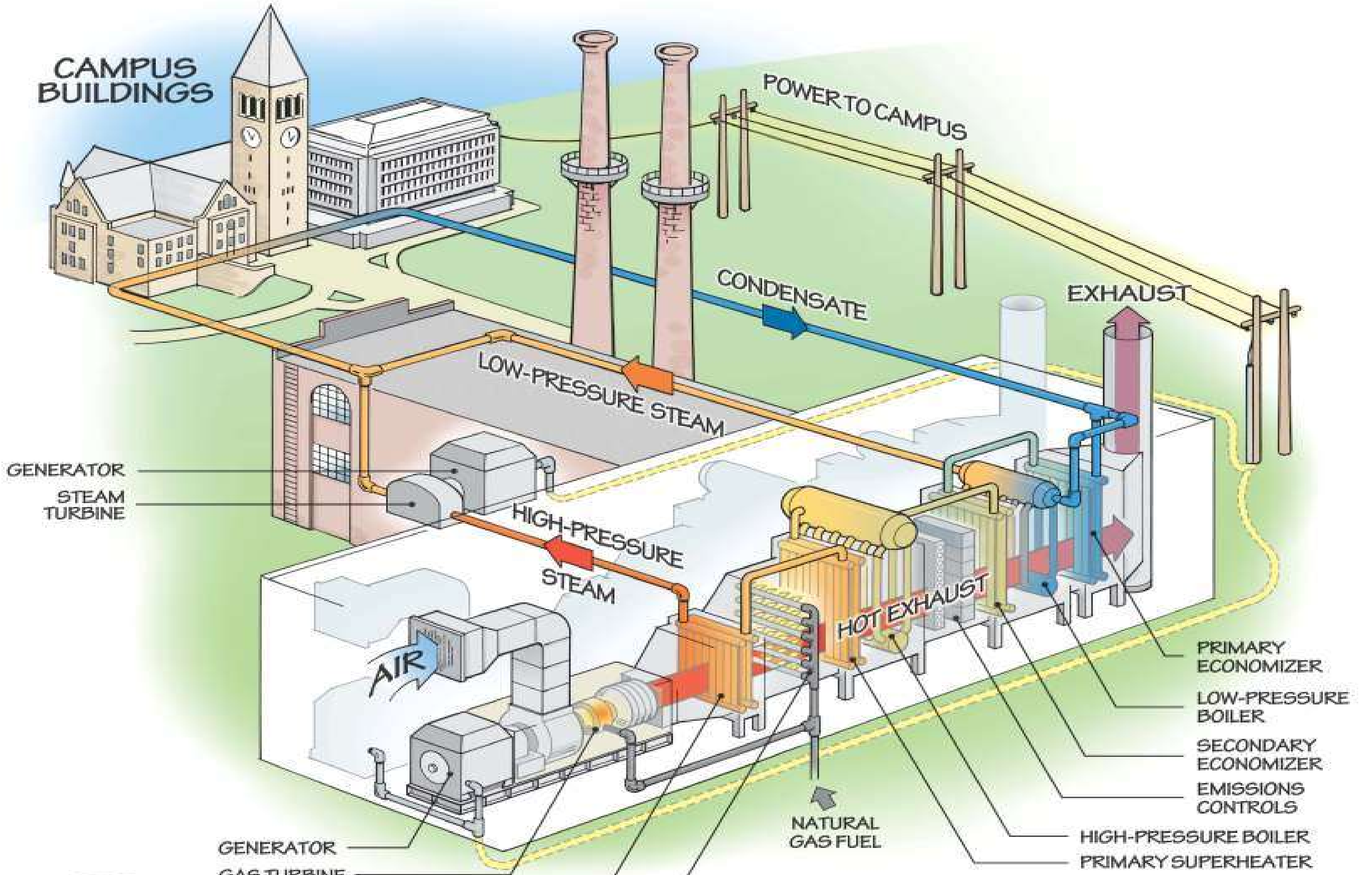
3 DIFFERENT CHP TECHNOLOGIES

- **GAS TURBINES**
  - **Steam generation 20,000 PPH AND >**
  - **Larger capacities 4MW >**
- RECIPROCATING ENGINES
  - Quicker starts
  - Higher fuel to power efficiency, but less heat output.
  - Hot water heat sinks are best
- **STEAM TURBINES**
  - **Larger steam systems that use multiple pressures**
  - **Backpressure STG's can be lowest cost in $/kw.**



LATHROP TROTTER
Since 1922
BYPASS EXHAUST SILENCER
EXHAUST SILENCER
AIR INLET FILTER
GENERATOR
DIVERTER VALVE
HEAT RECOVERY STEAM GENERATOR (HRSG)
GAS TURBINE
SUPPLEMENTAL BURNER
STEAM



CORNELL Utilities POWER TO LEARN

Combustion Turbine with Heat Recovery Steam Generator

CHP: Use one fuel source to produce two types of useful energy.

1. ELECTRICAL POWER

CHP: Use one fuel source to produce two types of useful energy.

1. USEFUL HEAT (STEAM)

FUELS:

NATURAL GAS

DIGESTER GAS

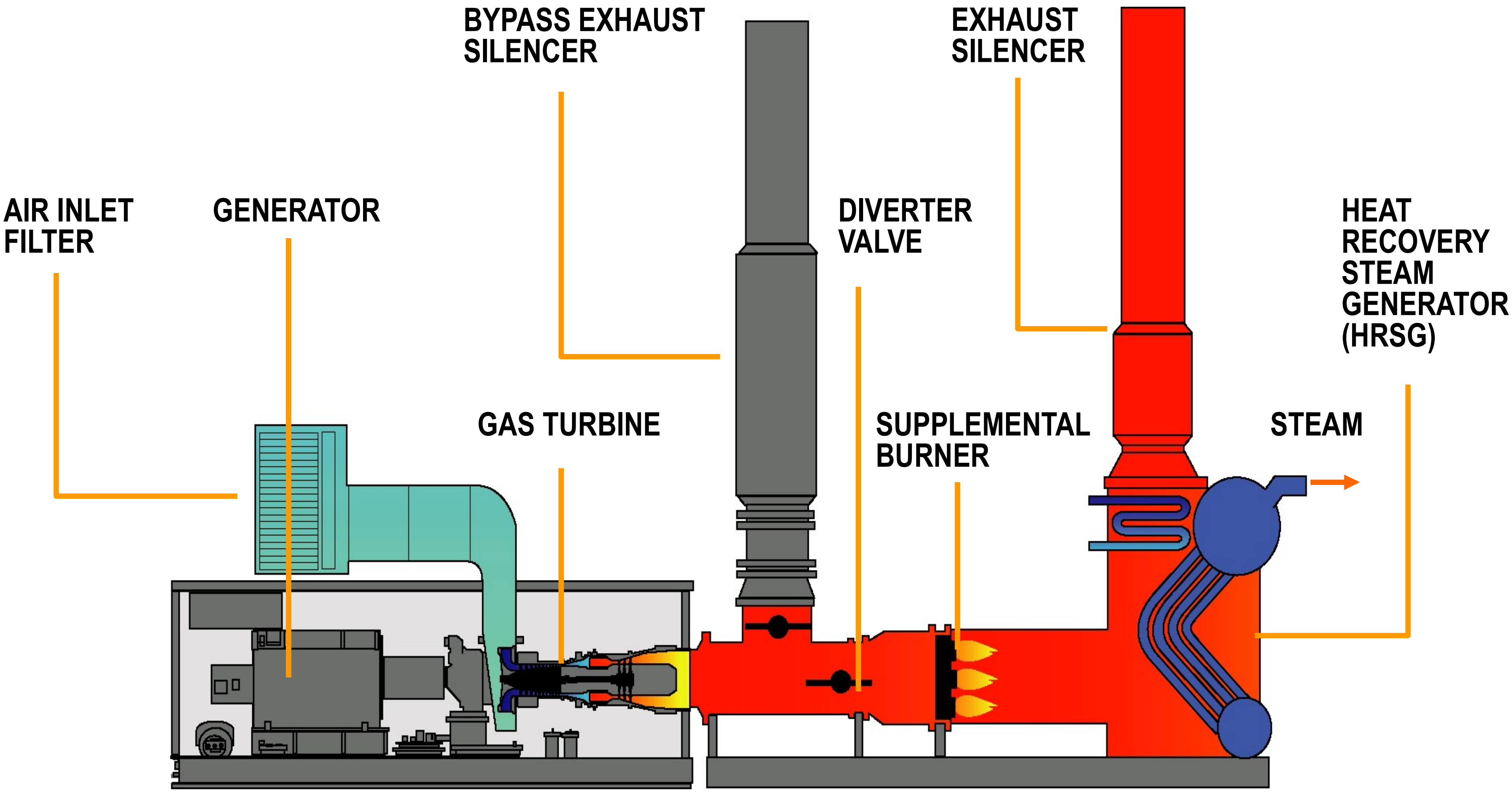
LANDFILL GAS

RENEWABLE NAT GAS

HYDROGEN (%)

LIQUID FUELS: #2 Oil

"OPPORTUNITY" FUELS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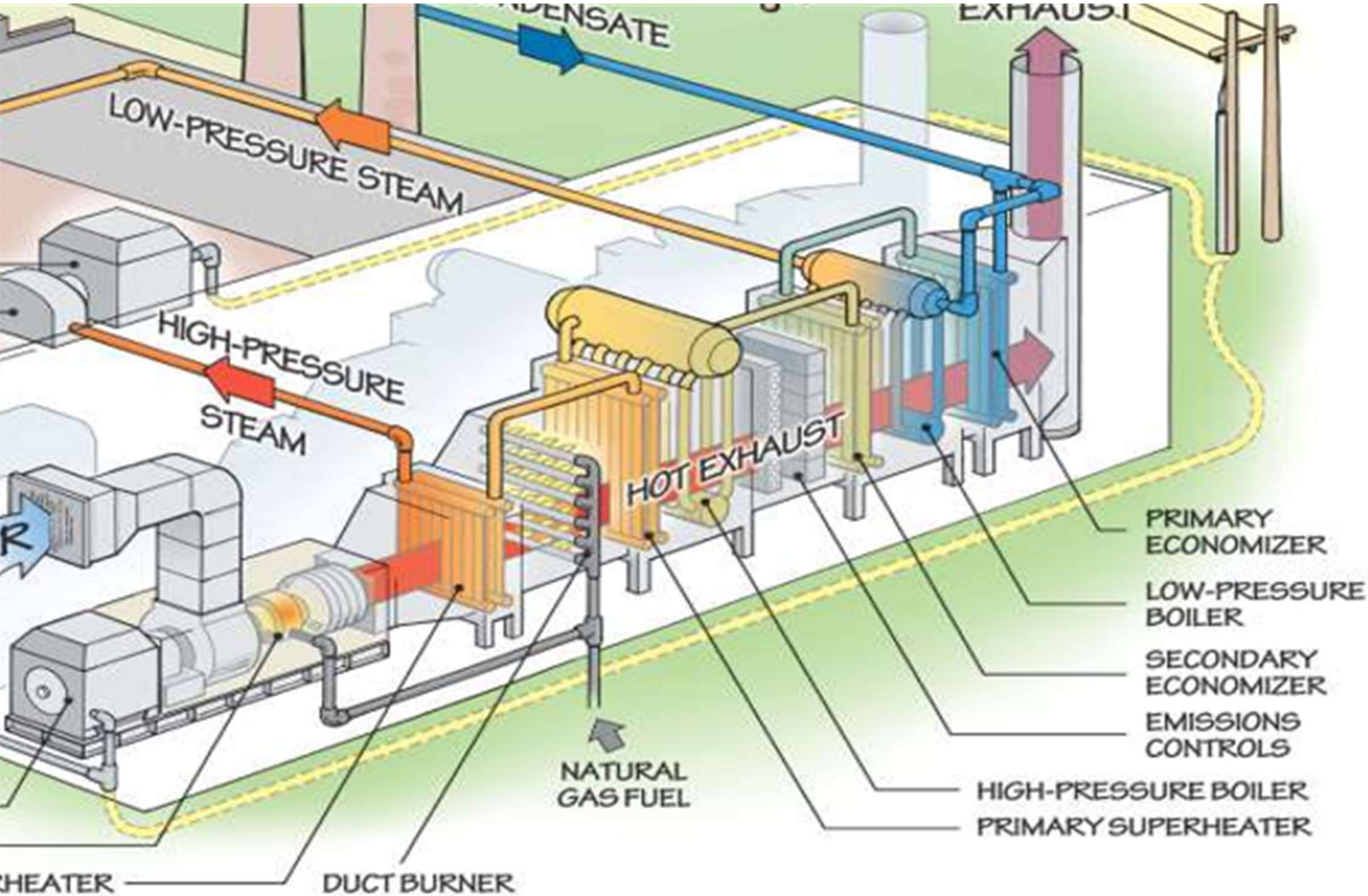
GAS TURBINE
SUPPLEMENTAL BURNER
STEAM

HIGHER EDUCATION: ENERGY STAR



ion Turbine with Heat Recovery Steam Generator

NATURAL GAS & REFINERY GAS

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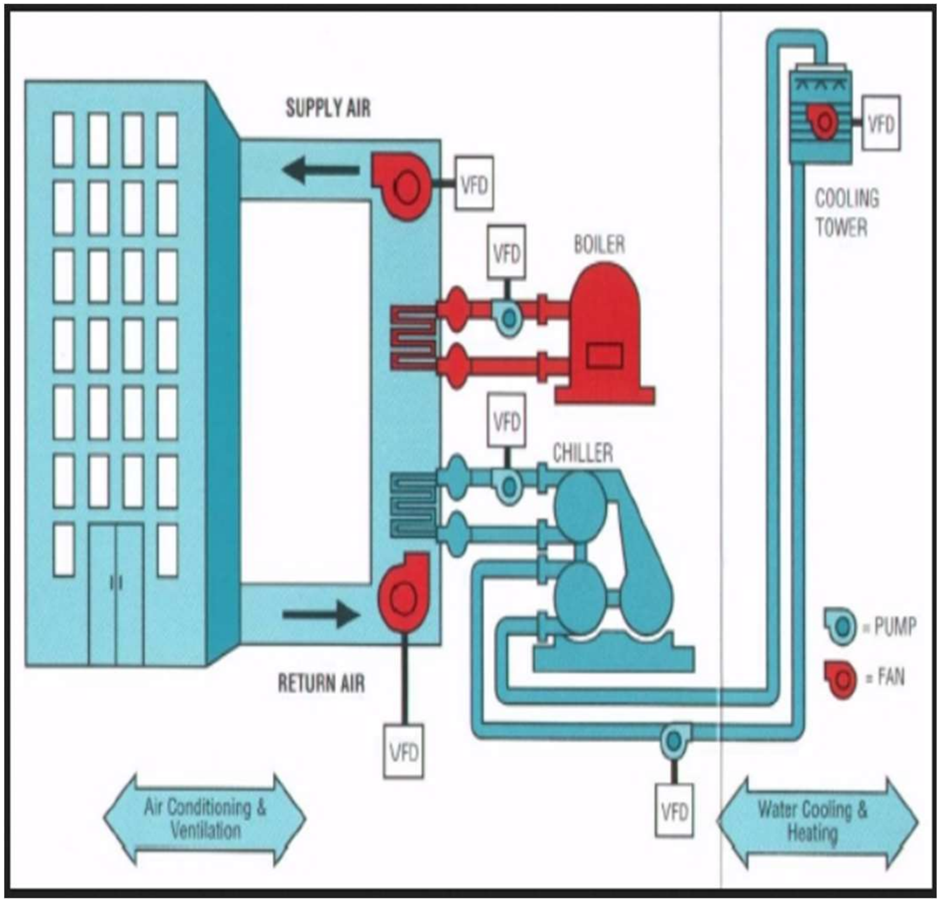
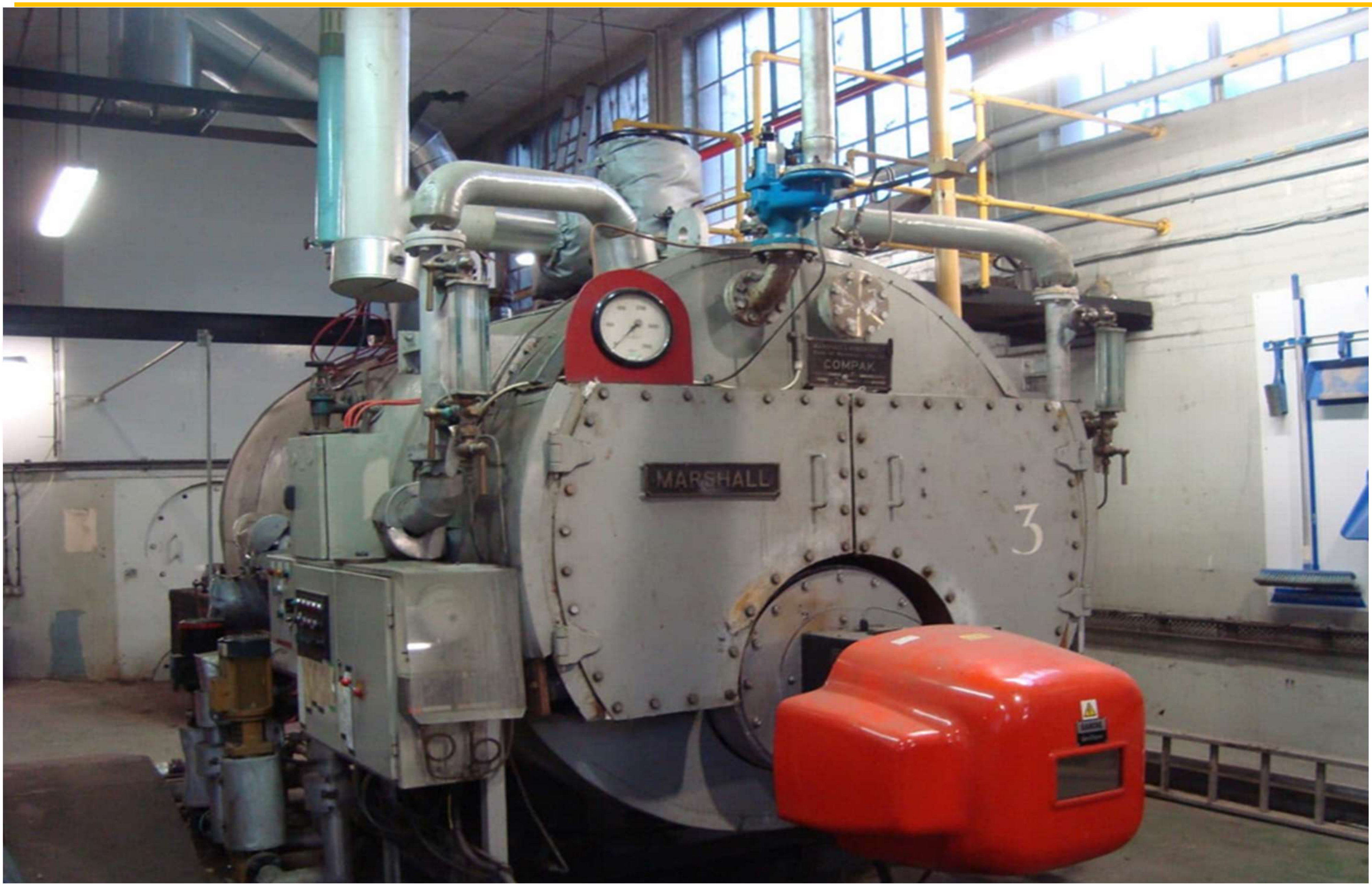
INDUSTRIAL AND COMMERCIAL HEATING SYSTEMS



WHERE WE HAVE SUFFICIENT THERMAL (STEAM) LOADS



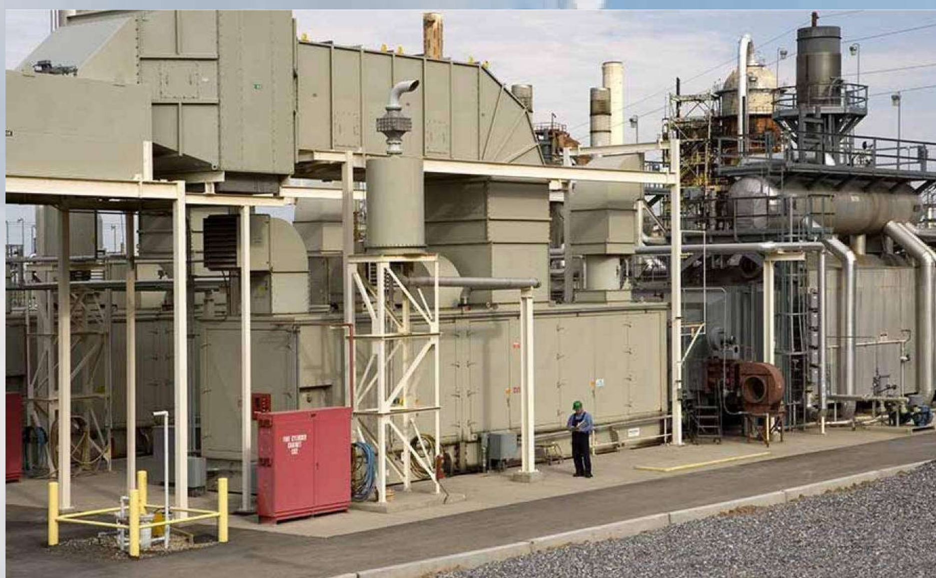
TYPICAL "HEAT SINKS" OR STEAM USERS

- Dairies
- Chemical Plants
- Food and Beverage
- Hospitals
- Refining
- Pharmaceuticals
- Campus
- Microgrids

- Cooking / Sterilization
- Process Heat
- Sterilization / Process
- HVAC / Sterilization
- Process
- Process and HVAC
- District Steam Heating
- Heating for the Grid

SMALL POWER PRODUCERS CAN BE MORE EFFICIENT THAN LARGE POWER PRODUCERS !!

Small Scale Power (CHP) Project

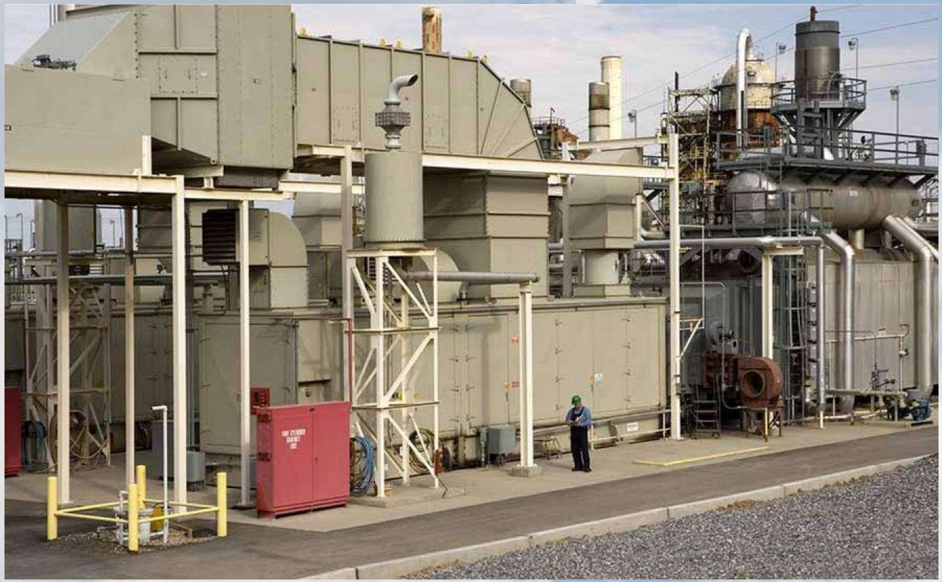


Utility Scale Power Producer

WHAT CHP IS NOT:

SMALL POWER PRODUCERS CAN BE MORE EFFICIENT THAN LARGE POWER PRODUCERS IF THEY RECOVER AND USE THE THERMAL ENERGY

Small Scale Power (CHP) Project



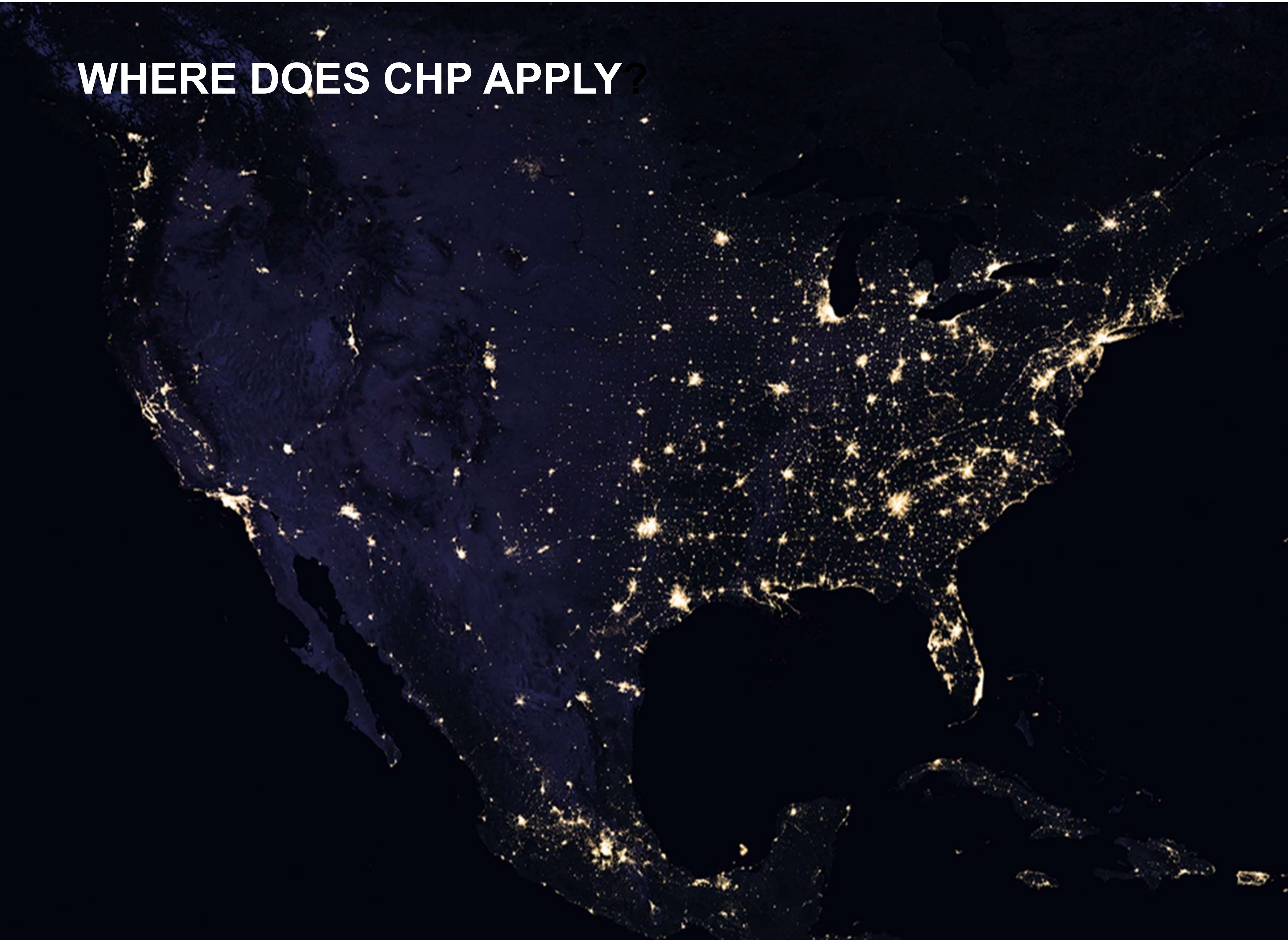
Utility Scale Power Producer

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

WHERE DOES CHP APPLY?



INDUSTRIES USING CHP

DRIVERS: THEN AND NOW

- **A decade ago, the drivers were:**
- Almost Exclusively Economics

- **Now the drivers are:**
- Economics +
- Sustainability Corporate Goals +
- Reliability & Resiliency + Future Flexibility (Fuels)

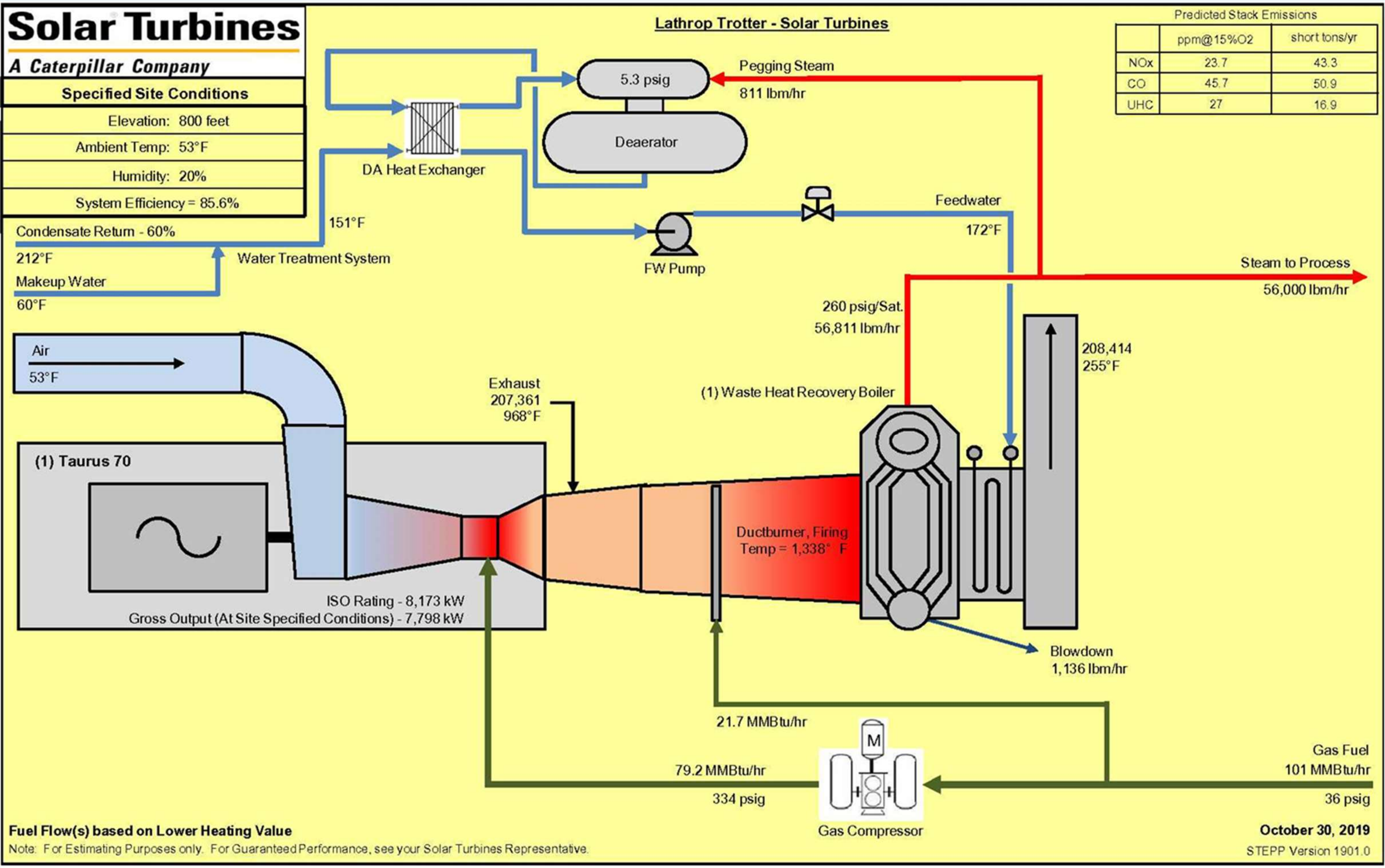
SUSTAINABILITY

OPERATIONS

FINANCIAL

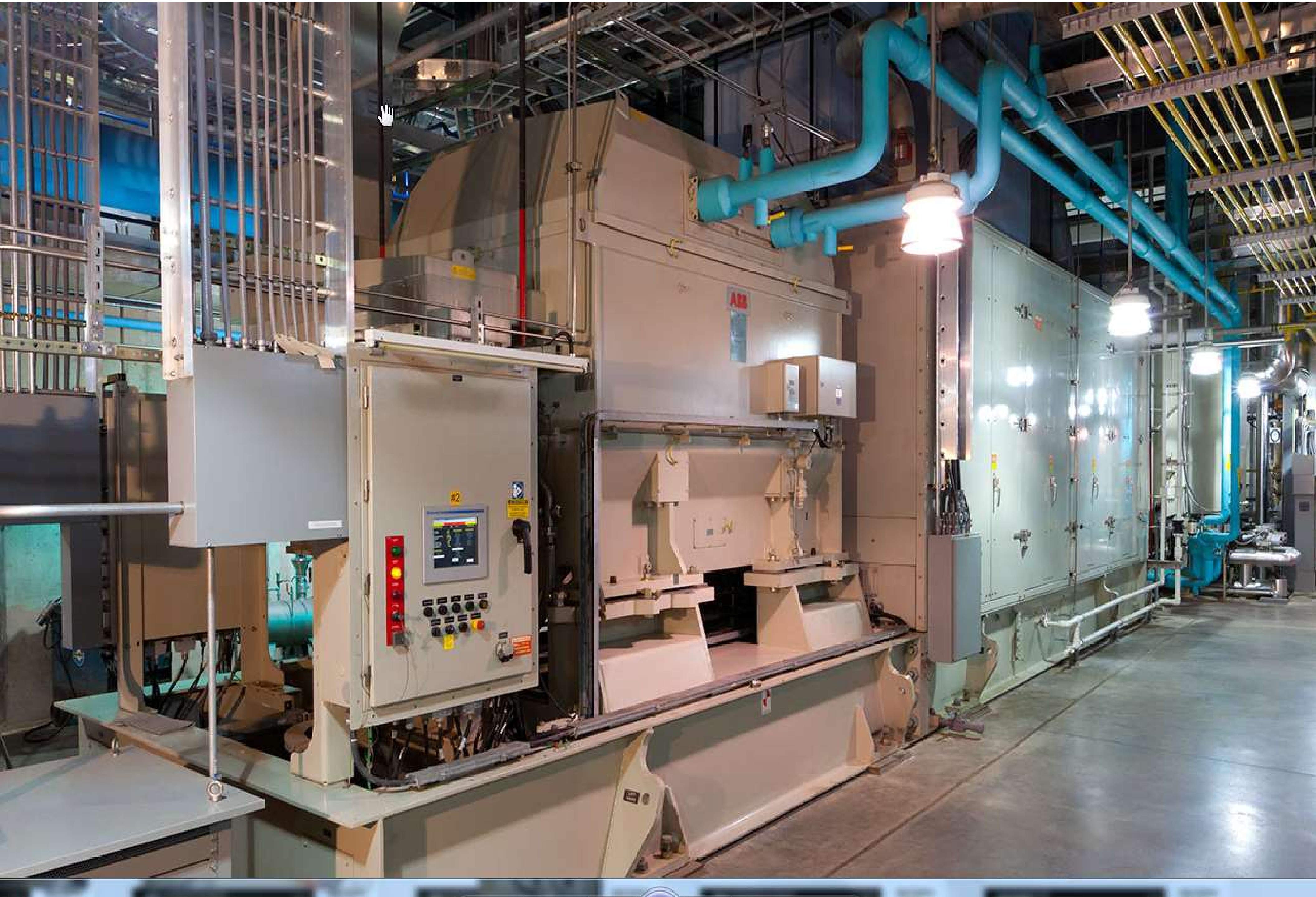
DEPARTMENT	GOALS	HOW CHP MEETS GOALS
SUSTAINABILITY	REDUCE **EMISSIONS** & ACHIEVE GOALS 30-50% (Typical)	EFFICIENCY & CLEAN FUELS
OPERATIONS	IMPROVE **RELIABILITY** & REDUCE OPERATING EXPENSE	REDUNDANCY & RELIABILITY IMPROVEMENTS. REDUCE ENERGY COSTS
FINANCIAL	**REDUCE PER UNIT COST** OF PRODUCTION	REDUCE ENERGY RQUIRED PER UNIT PRODUCED
FINANCIAL	**IMPROVE FORCASTING ACCURACY EFFICIENT USE OF CAPITOL**	FUEL COST STABILITY & PREDICTABILITY OF NATURAL GAS vs ELECTRICAL POWER
OVER ALL COMPANY	GOOD NEIGHBOR	**PATH WAY to ZERO CARBON EMISSIONS**


SUSTAINABILITY
FINANCIAL
OPERATIONS



Predicted Stack Emissions

	ppm@15%O2	short tons/yr
NOx	23.7	43.3
CO	45.7	50.9
UHC	27	16.9

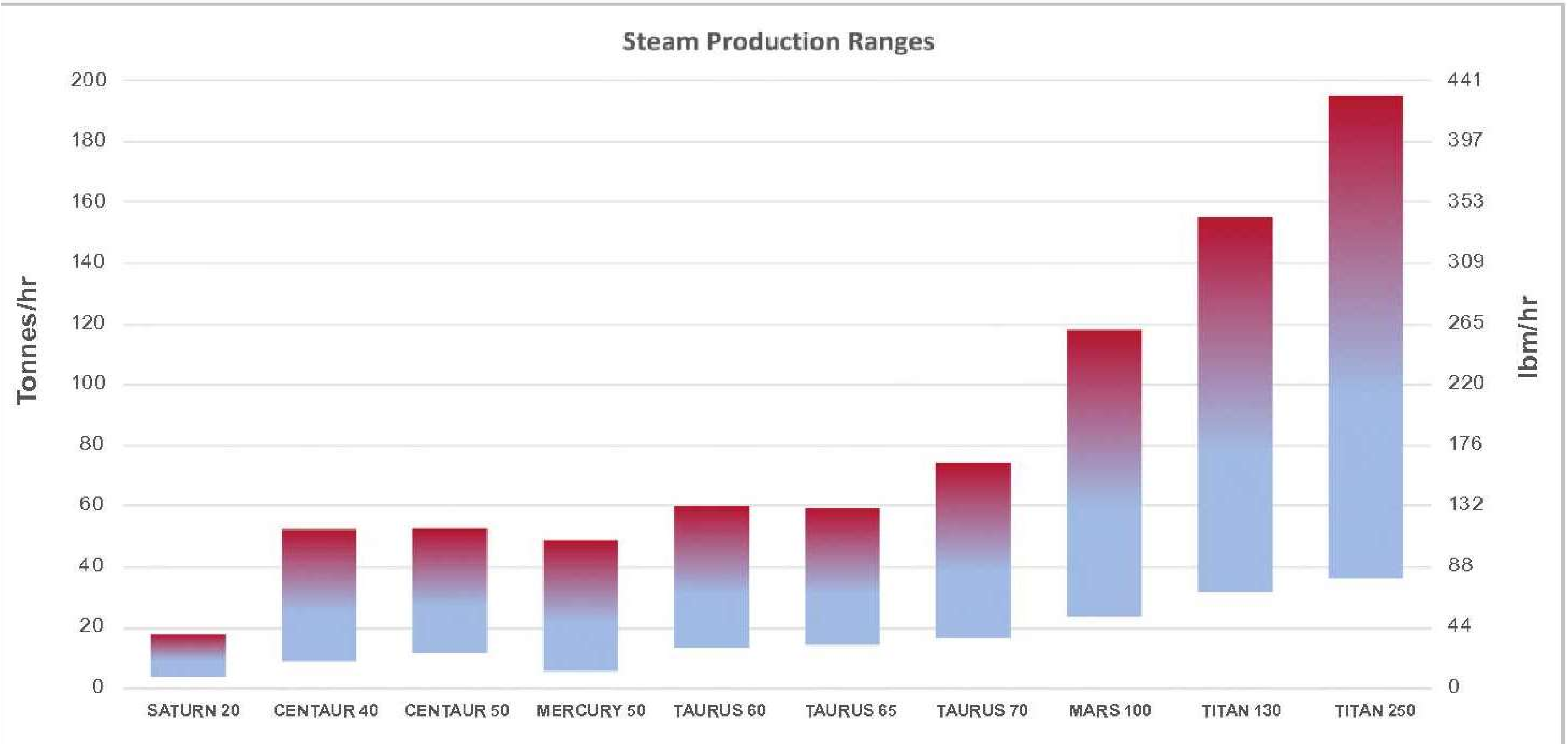


WATER TUBE STYLE HEAT RECOVERY STEAM GENERATOR

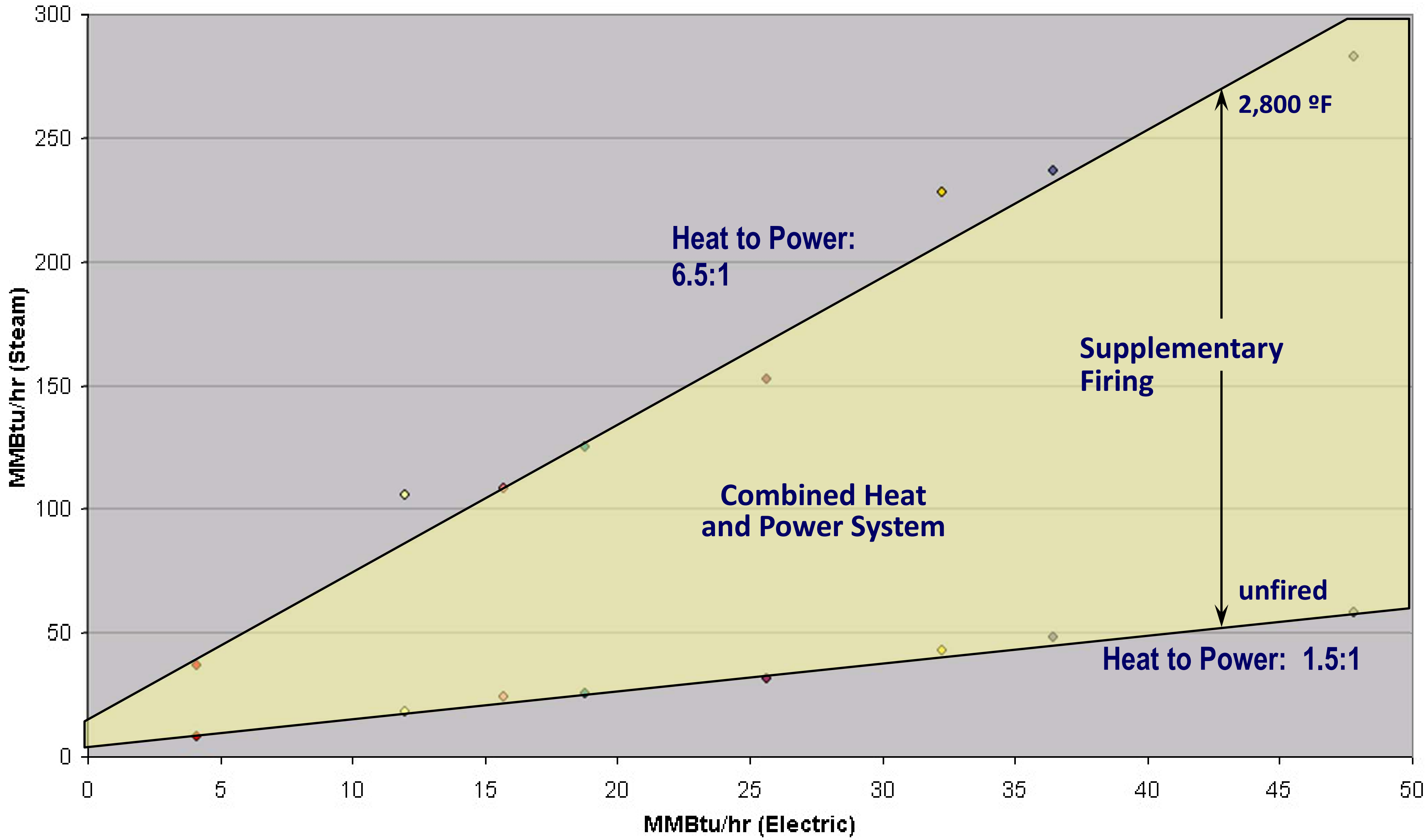
TO RECOVER THE EXHAUSTED ENERGY FROM THE GAS TURBINE THESE HRSG'S CONVERT THE HOT GASES TO USEABLE STEAM FOR THE PLANT / PROCESS OR CAMPUS FOR HEATING.

Duct Burner

COMBINED HEAT AND POWER PERFORMANCE



HEAT / POWER RATIOS FOR CHP



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

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

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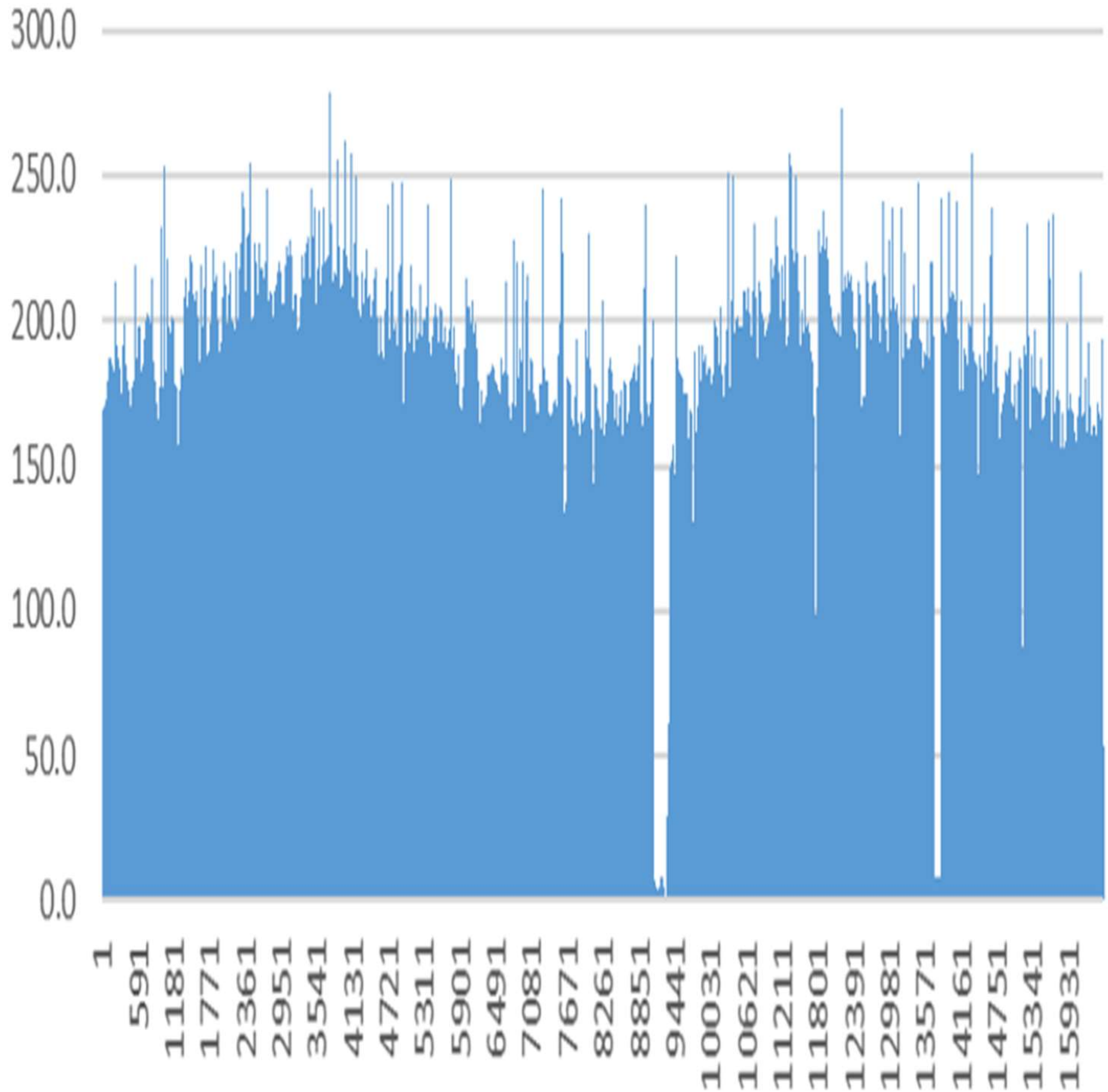
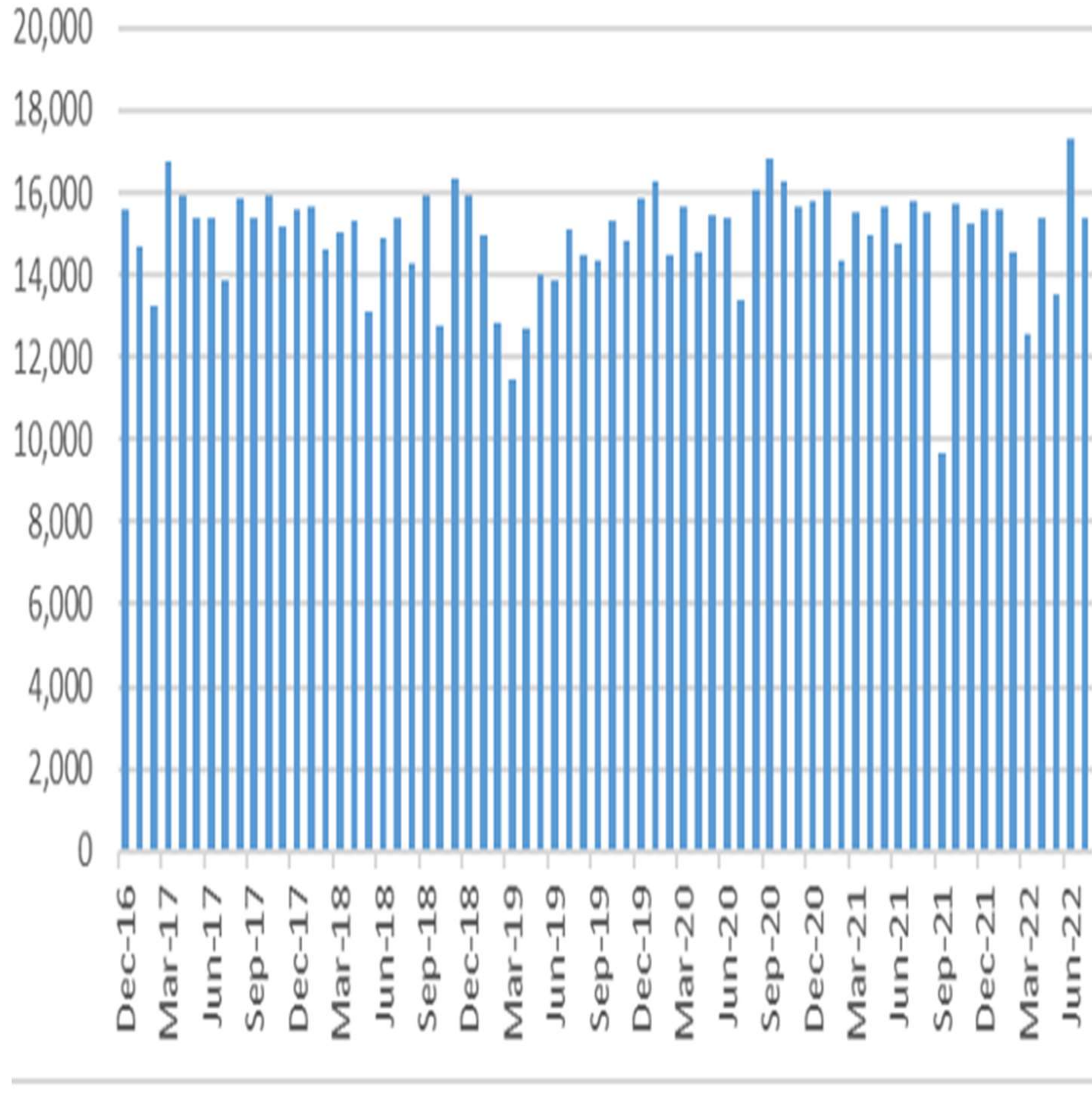
Hourly Steam Flow





20,000
18,000
16,000
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
Dec-16
Mar-17
Jun-17
Sep-17
Dec-17
Mar-18
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Dec-18
Mar-19
Jun-19
Sep-19
Dec-19
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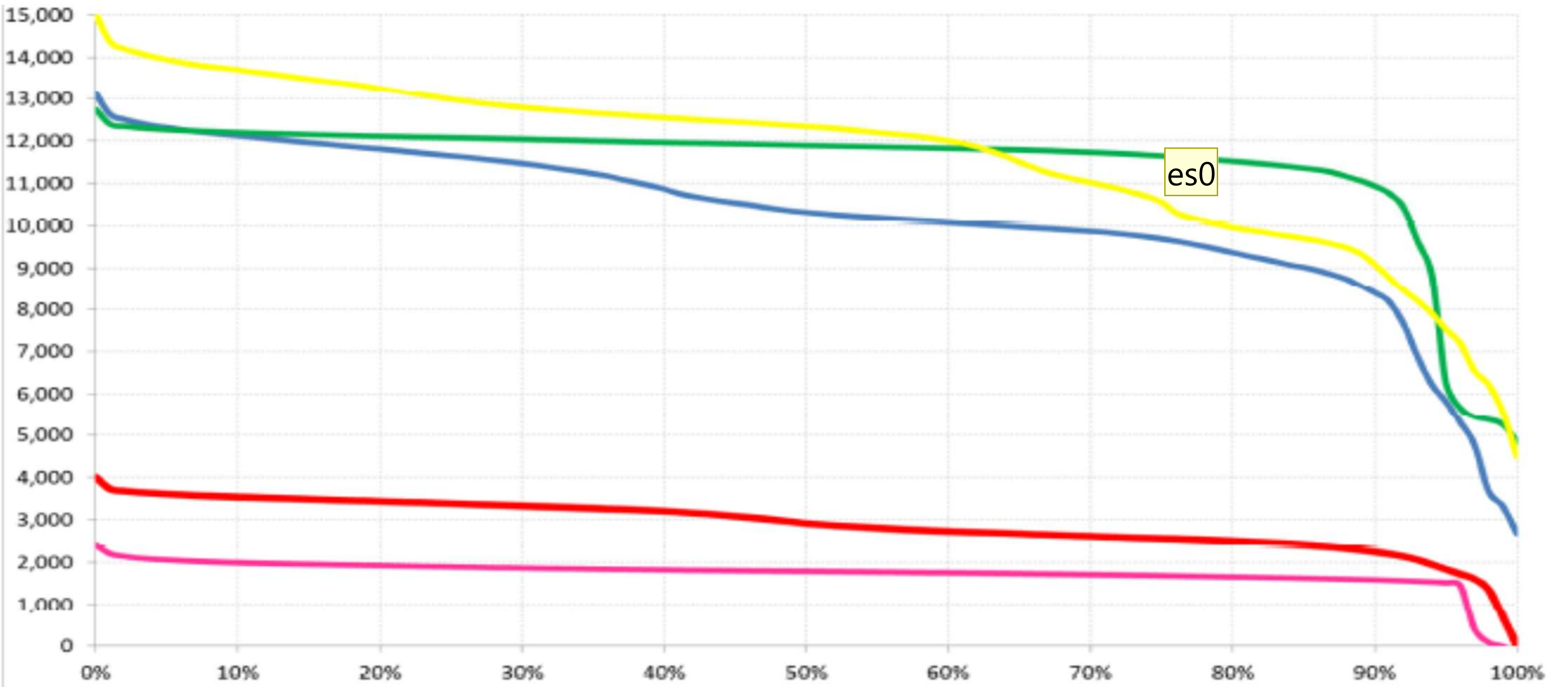
Mar-22
Jun-22

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

Slide 50

es0 Preliminary sizing starts at 75%

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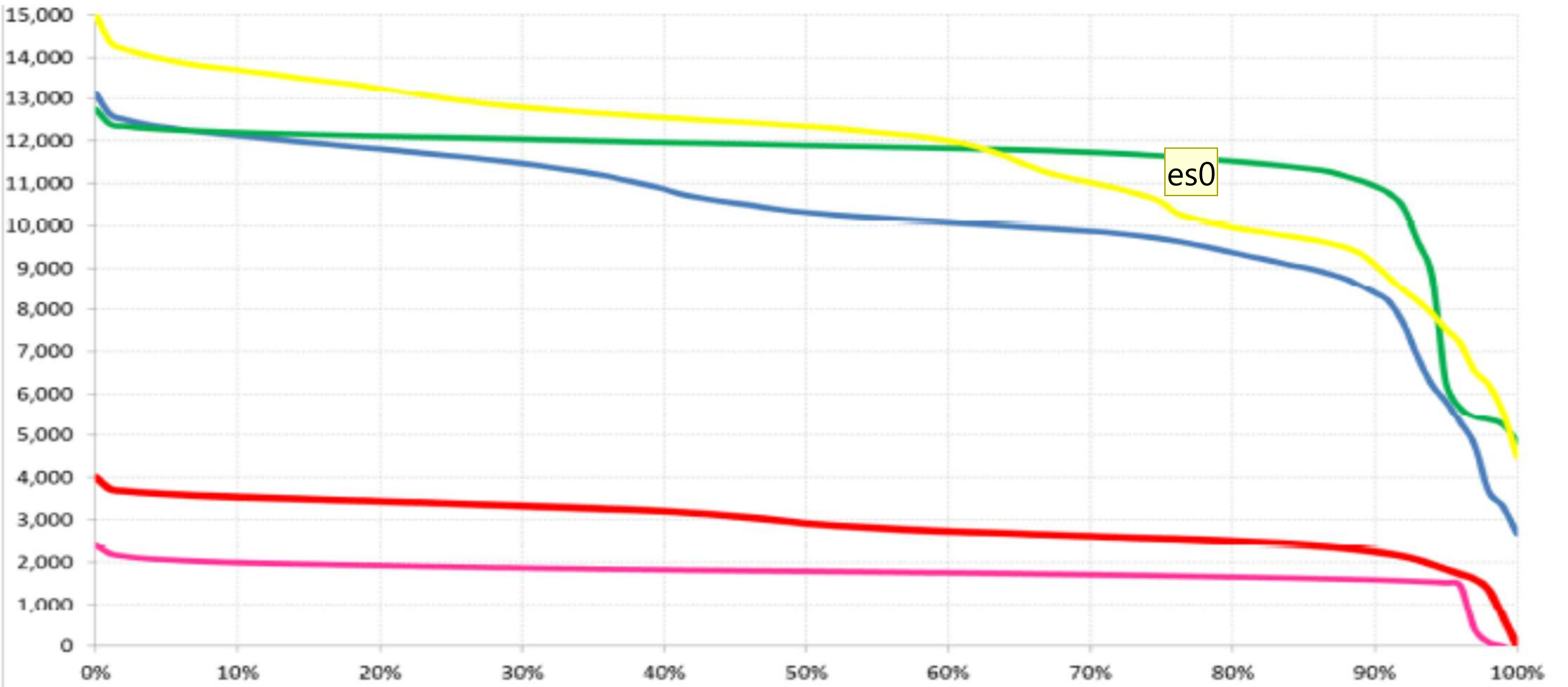
Load Duration Curves



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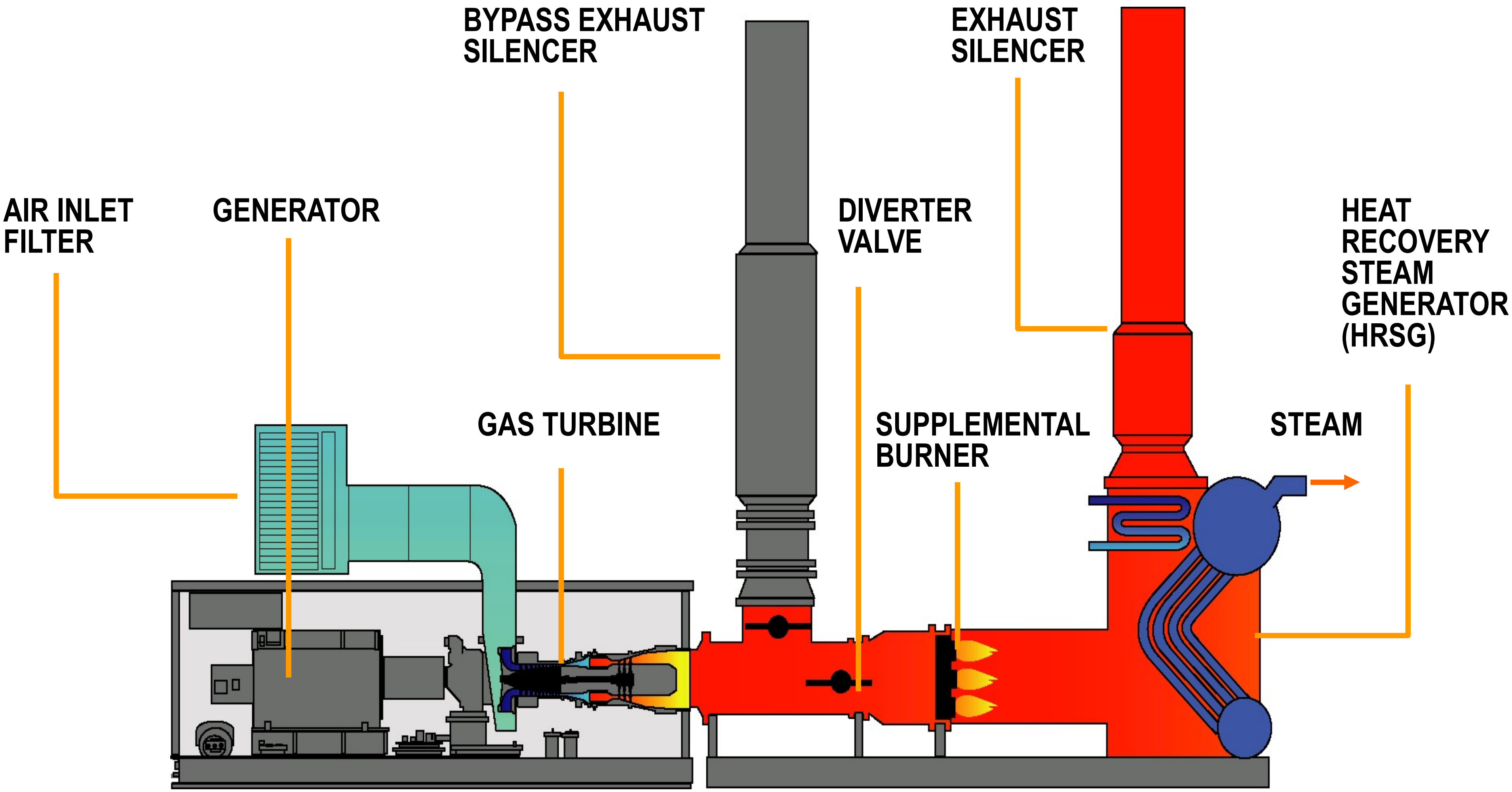
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GAS TURBINE
SUPPLEMENTAL BURNER
STEAM

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

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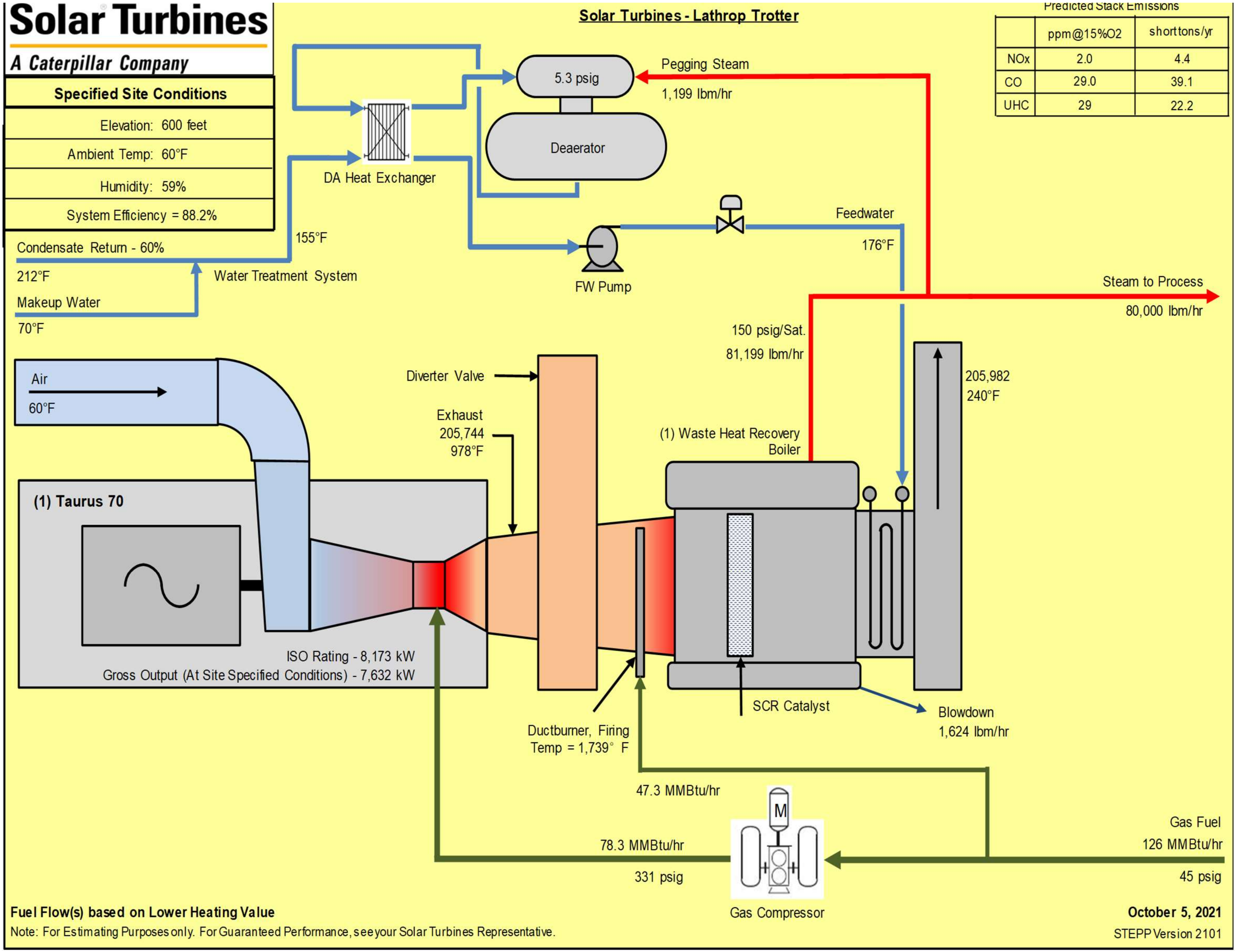


Specified Site Conditions

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

Predicted Stack Emissions

	ppm@15%O2	shorttons/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

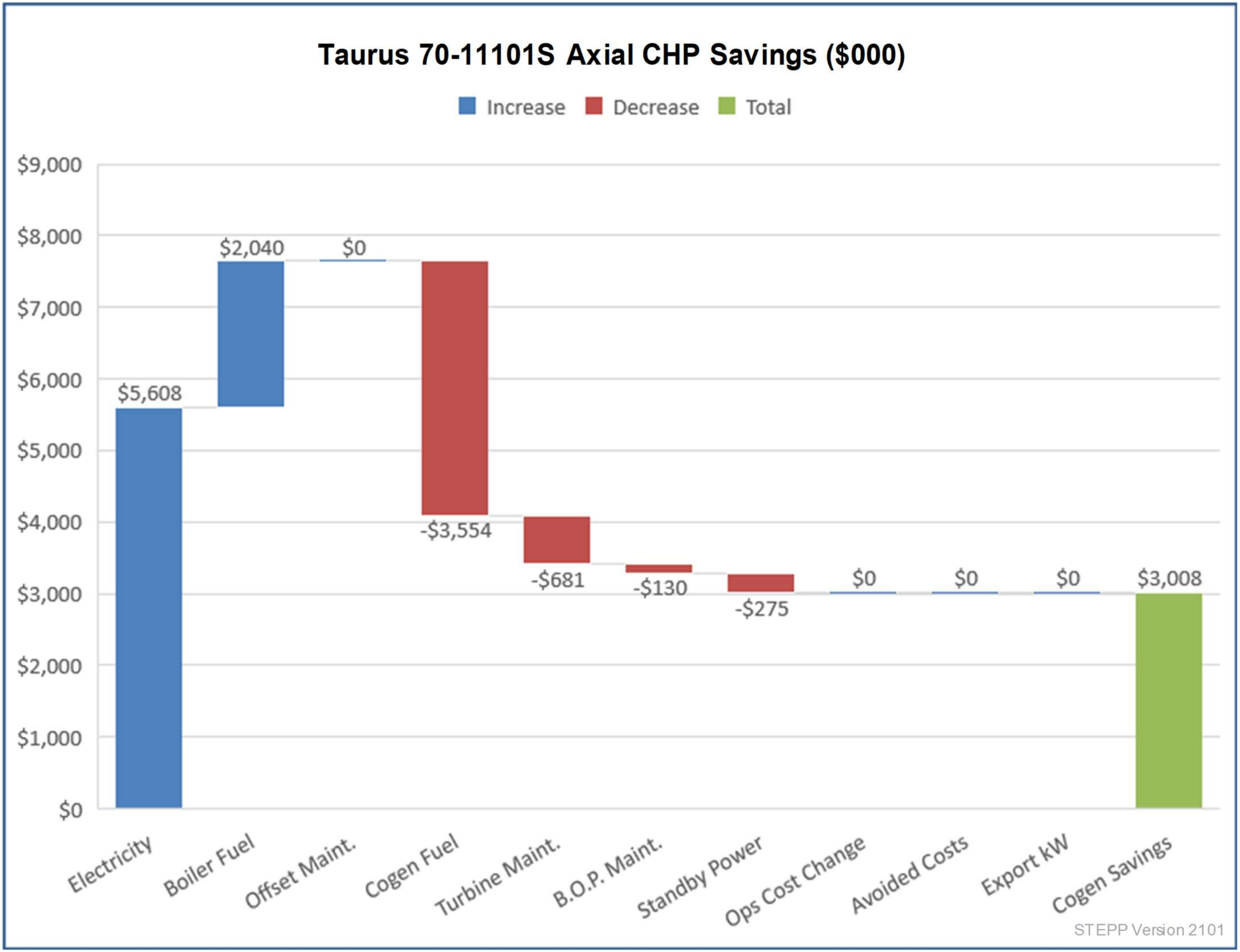
Cogeneration Plant Estimated Performance Summary

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


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

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**

WHAT WE WILL COVER TODAY

1 **GAS TURBINE BASICS (5 MIN)**

2. **COMBINED HEAT AND POWER (CHP) BASICS (5 MIN)**

3. **HEAT SINKS THE 1 THING TO REMEMBER**

4. **DRIVERS: ECONOMICS+RELIABILITY+SUSTAINABILITY**

5. **WHERE IT APPLIES**

6. **SIZE AND SELECTION OF GAS TURBINE (GT) & HEAT RECOVERY STEAM GENERATOR (HRSG)**

7. **TYPICAL PRELIMINARY CHP REPORT**

8. **SEIZE THE OPPORTUNITY**

9. **SUSTAINABILITY AND WHY CHP REALLY "MOVES THAT NEEDLE"**

10. **GREEN HYDROGEN.**

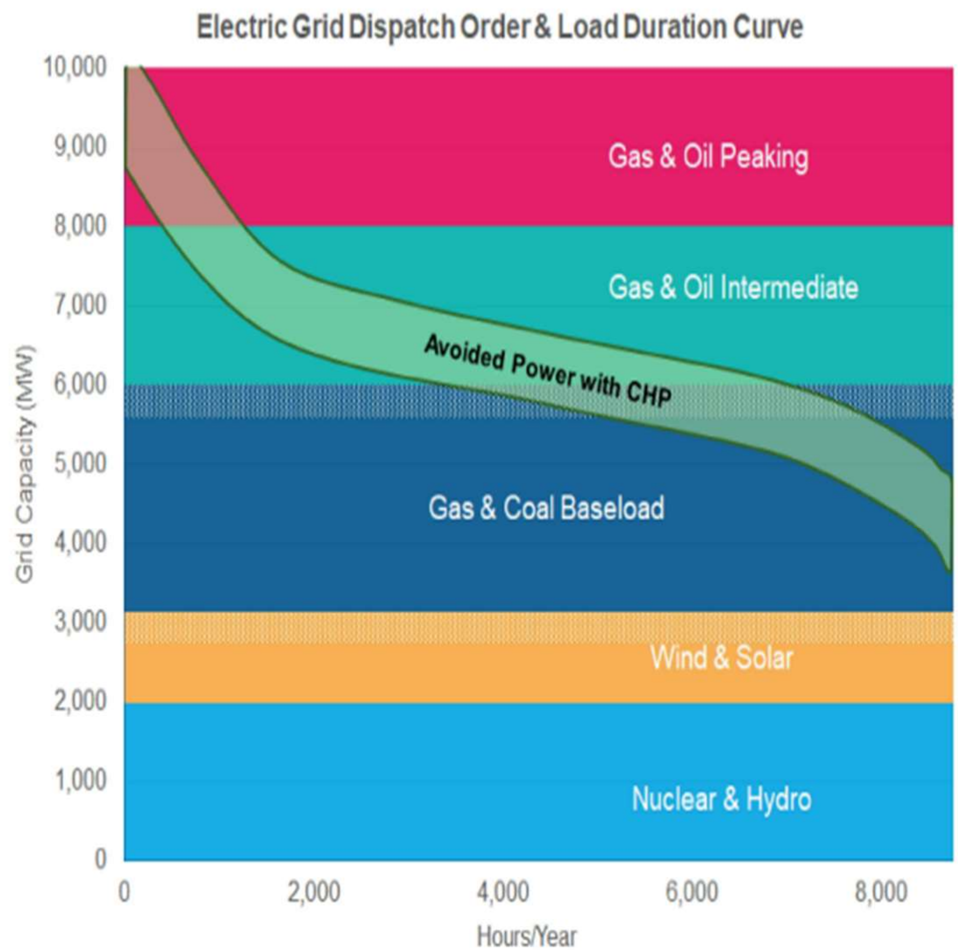
11. **Q&A SESSION**

Evaluating CHP Emission Impacts

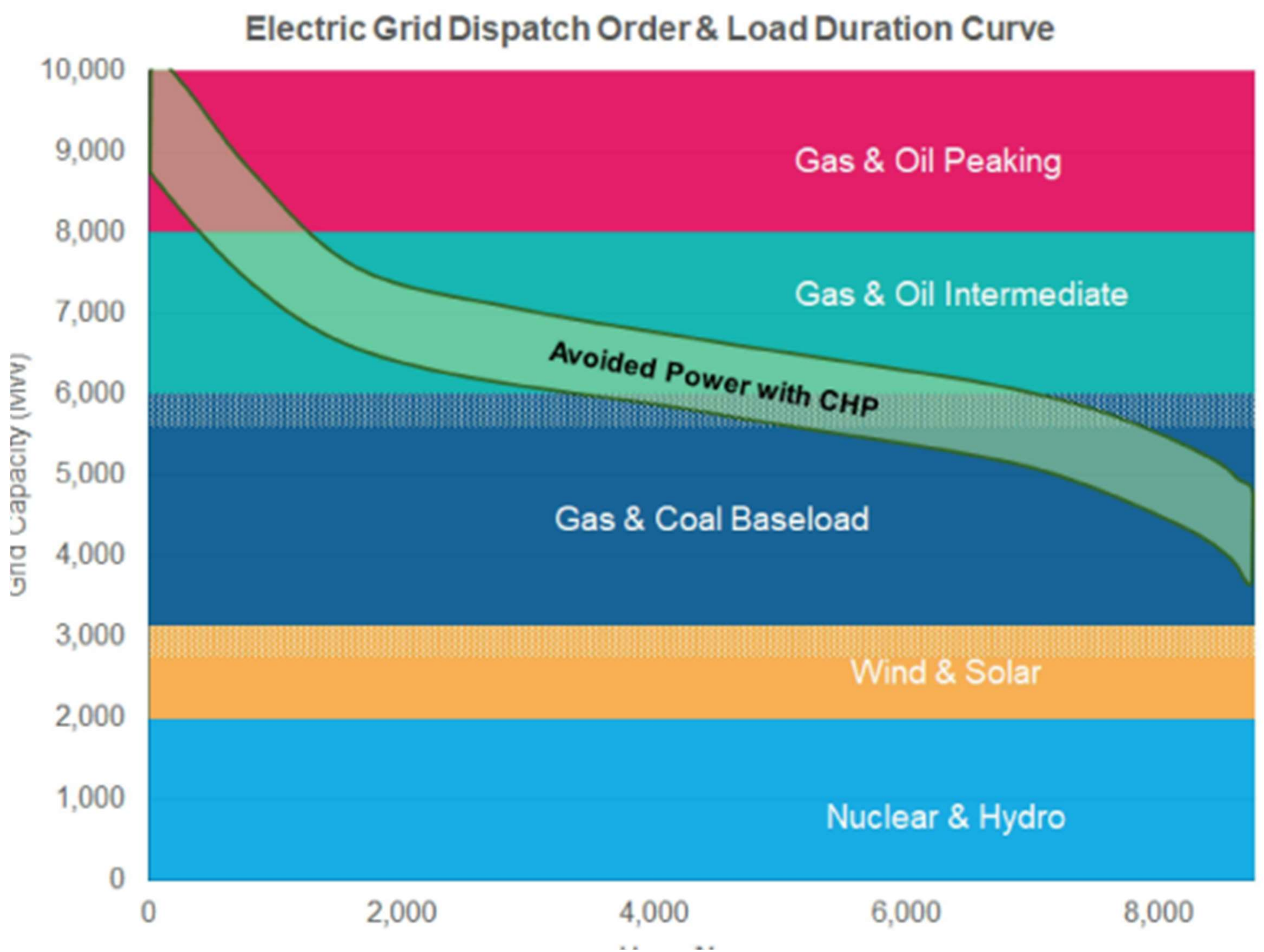
Displaced grid emissions for CHP are based on *marginal utility generation*

- 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



UIC ENERGY RESOURCES CENTER


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
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

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.

Map of eGRID Subregions

USEPA, eGRID, June 2018

Crosshatching indicates that an area falls within overlapping eGRID subregions due to the presence of multiple electric service providers. Visit Power Profiler to definitively determine the eGRID subregion associated with your location and electric service provider.
http://www.epa.gov/energy/power-profiler

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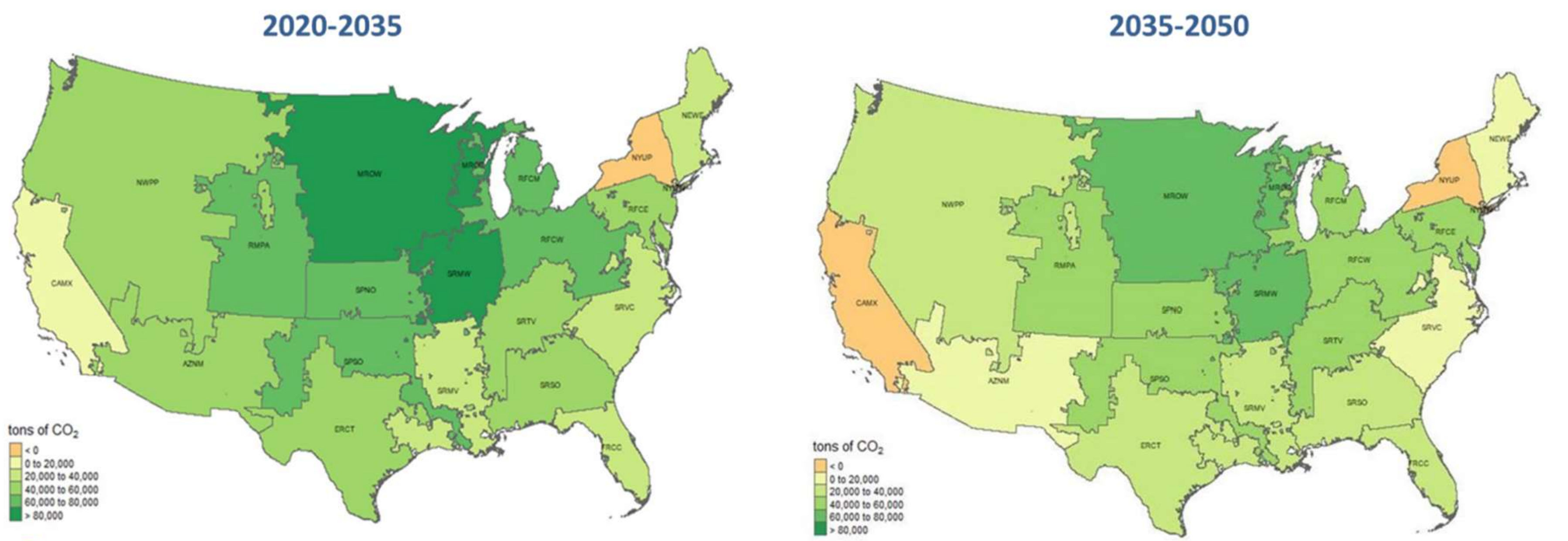
CHP REDUCES CARBON EMISSIONS ***DRASTICALY*** USING NATURAL GAS & REACHES ZERO EMISSIONS ON RNG & GREEN H2



Lifetime Carbon Emission Reductions for CHP Systems

ENERGY RESOURCES CENTER

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

(Average Fossil Generation)

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

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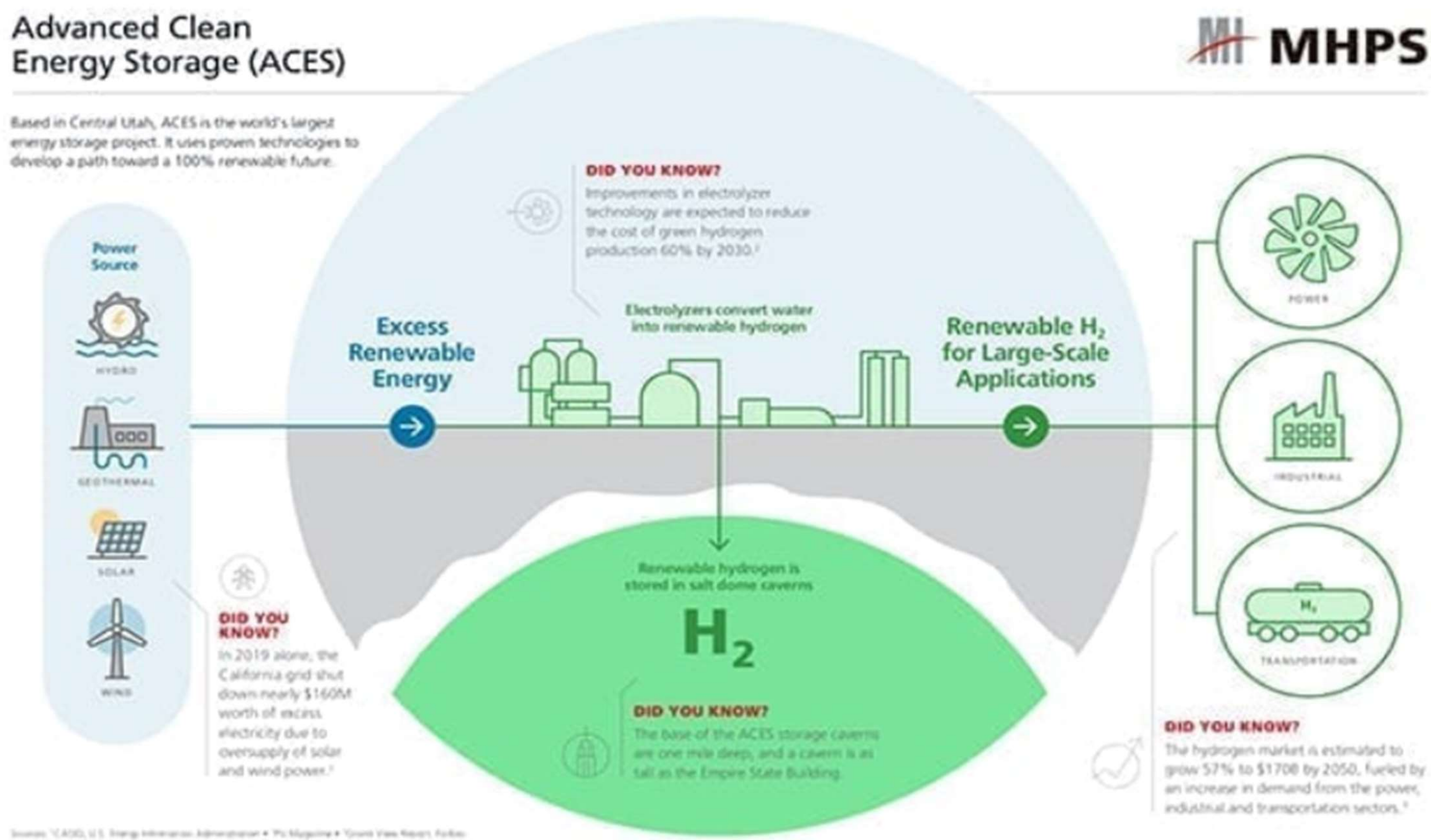
GREEN HYDROGEN

A KEY FACTOR IN REACHING ZERO EMISSIONS WITH CHP



High Hydrogen
Titan – 130 Units
burn 50% H_2

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

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

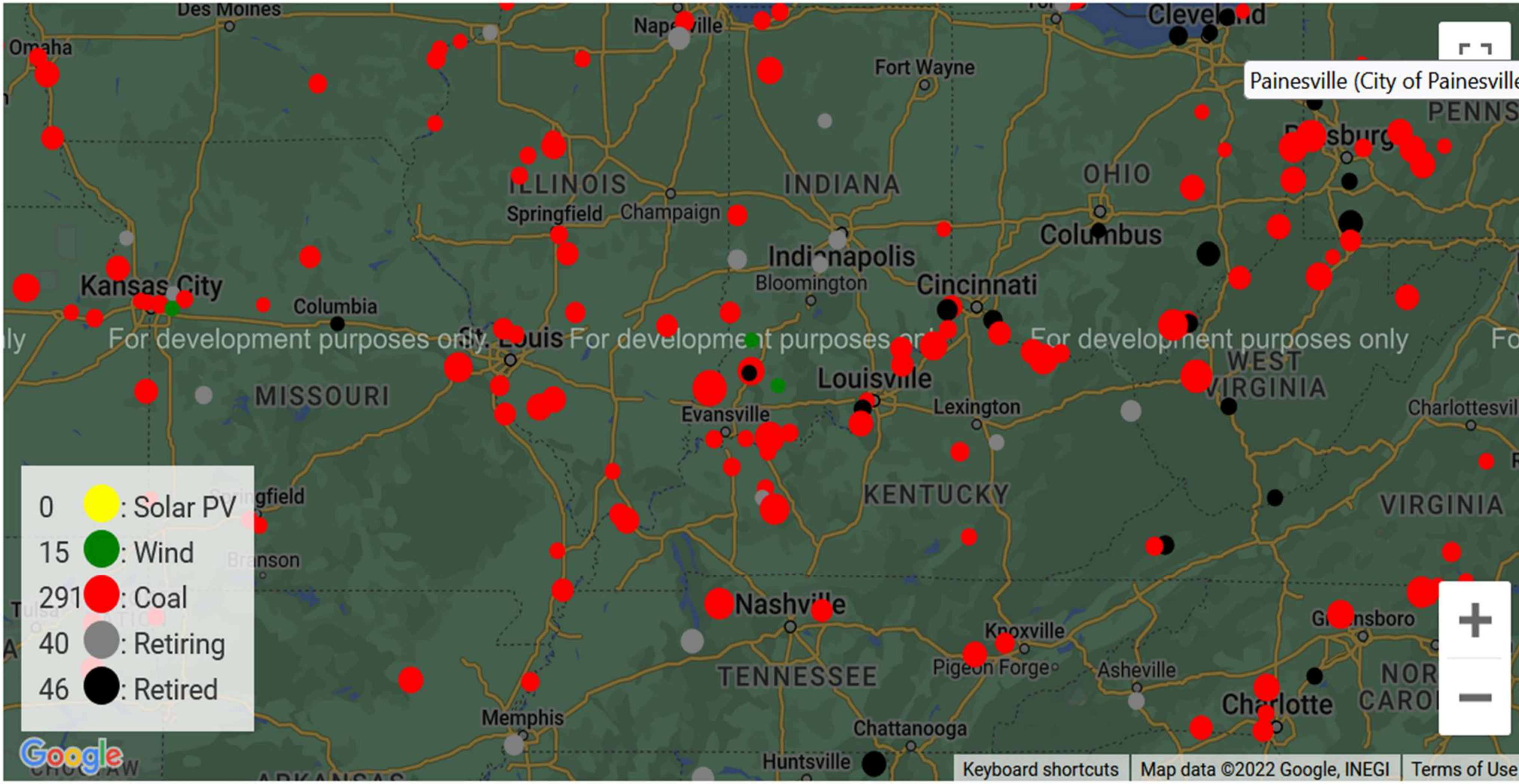
FROM 10% ITC TO 30% - 40% - 50%

- **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



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**

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LATHROP TROTTER Manufacturers Representatives

- **Gas Turbines (2-25MW):** Solar Turbines
- **Heat Recovery & Waste Hreat Boilers:** Superior Boiler Works
- **Gas Compressors:** Vilter / Emerson / Copeland
- **Deaerators and Feed Water Equipment:** Industrial Steam
- **Steam Turbine Gen Sets:** Dresser-Rand / Siemens (<300MW)

Thank you. Are there any questions?

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ed.stoermer@kochapplied.com
Craig Pleiman 513-713-3860 c
Craig.Pleiman@kochapplied.com

Biographical Information

Ed Stoermer
Cogen and CHP System Sales Engineer

Ed graduated from the University of Cincinnati with a B.S. in Mechanical Engineering and a minor in Business Administration. He later added an Executive Master of Business Administration from Xavier University.

Ed's primary focus is the design and application of combined heat and power systems, using gas and steam turbine generators with heat recovery steam boilers (1-200MW) to help industrial clients improve their plant's reliability and reduce overall emissions. The ultimate goal is to achieve sustainability goals while simultaneously improving the plant's bottom line profitability through improved energy efficiency. Current projects include refinery power and steam systems, standby power for data centers, specialty fuels, large central steam boilers, and complete steam plant upgrades for healthcare facilities.

In 1999, Ed merged the Stoermer Equipment Company with the RG Anderson Company to form Stoermer-Anderson Inc., a manufacturers rep firm, later selling this to the partners in 2007.

Ed currently lives in Northwest Montana but spends much time in the Midwest to work on power, steam, and special projects. He supports Lathrop Trotter with consulting and training for internal staff and clients and provides expertise in applying gas and steam turbines, boilers, burners, and the balance of plant systems. Ed has been involved in over 400 MWe of CHP projects since he joined the team in 2012.

In his free time, he enjoys backcountry biking, hunting, fishing, and wilderness adventures on horseback and hiking with family and friends.