Microturbine
Combined Heat and Power Systems

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AEE Northern Ohio Chapter

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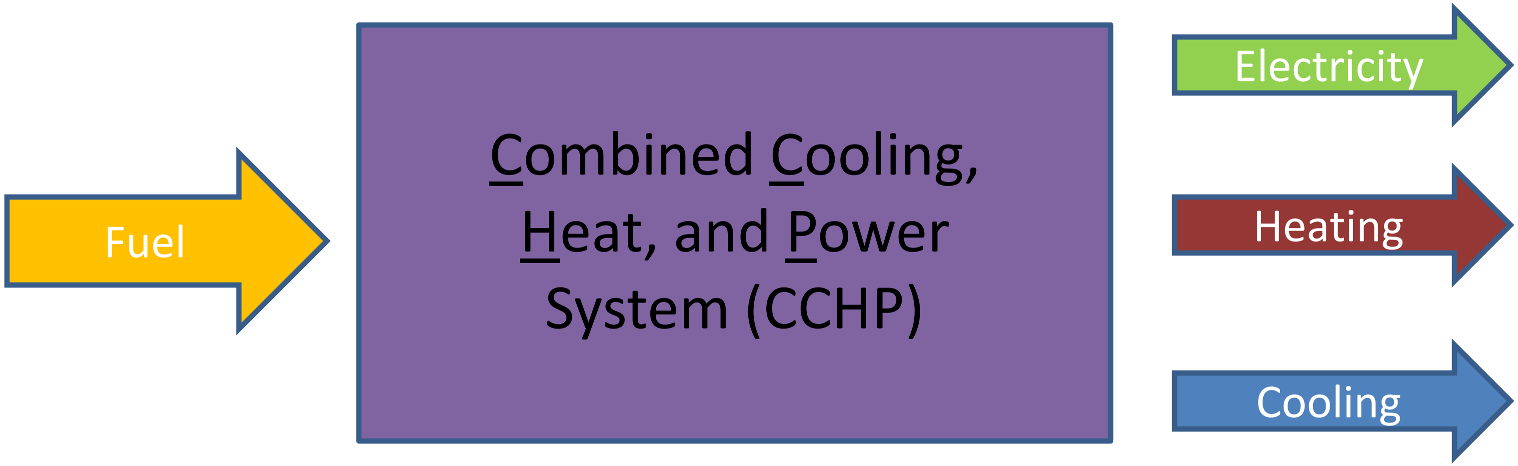
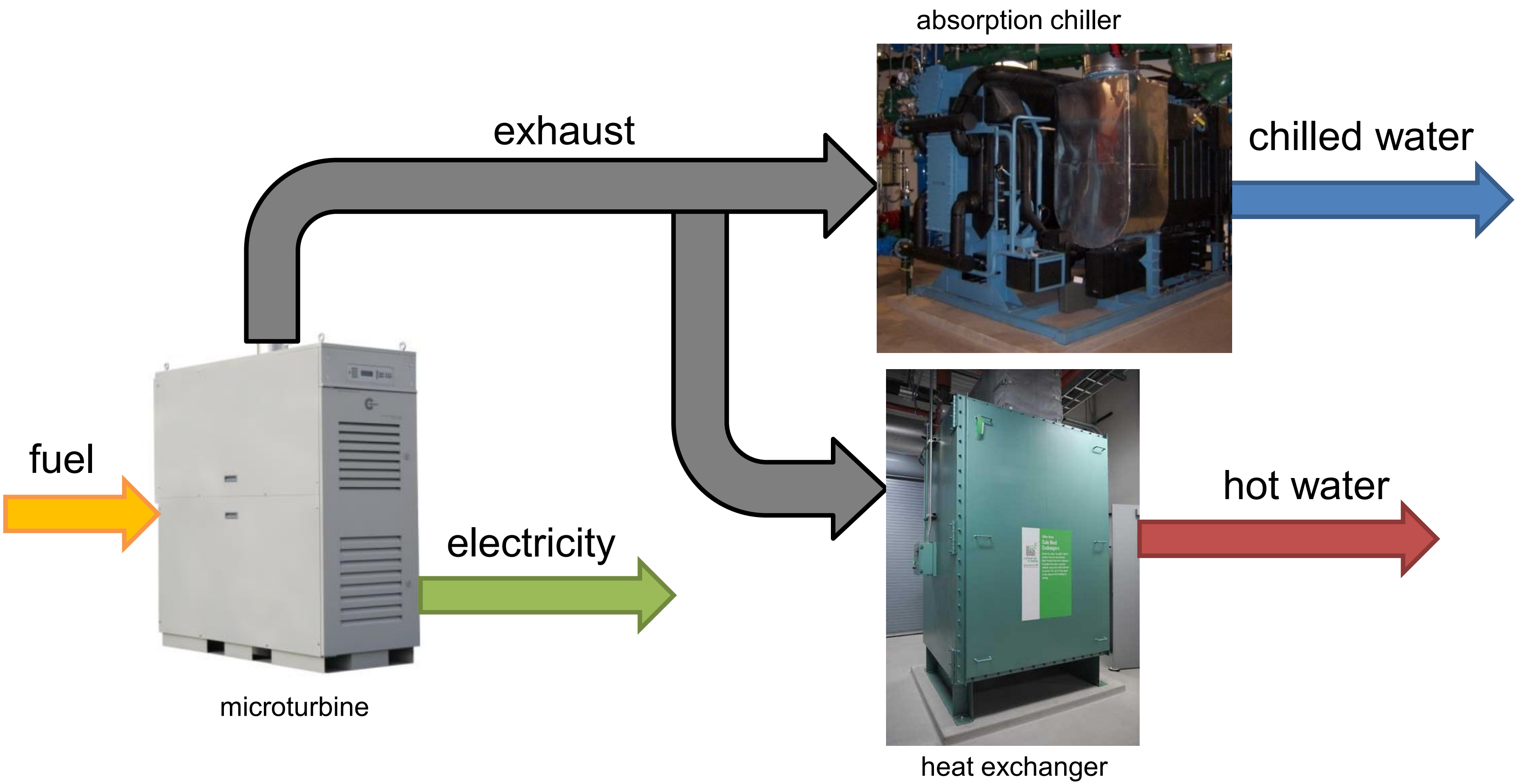
2017

CCHP Concept

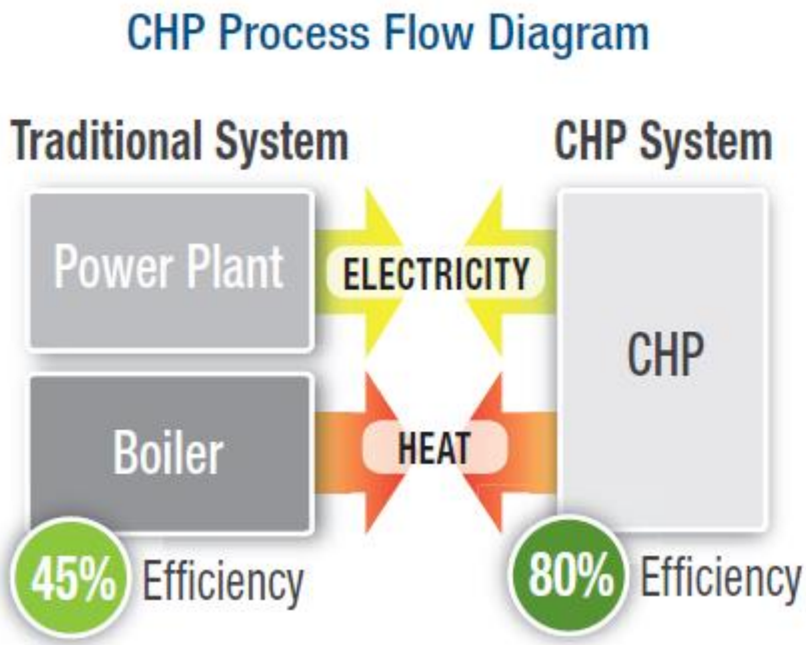


Energy Recovery Concept



What is CHP?

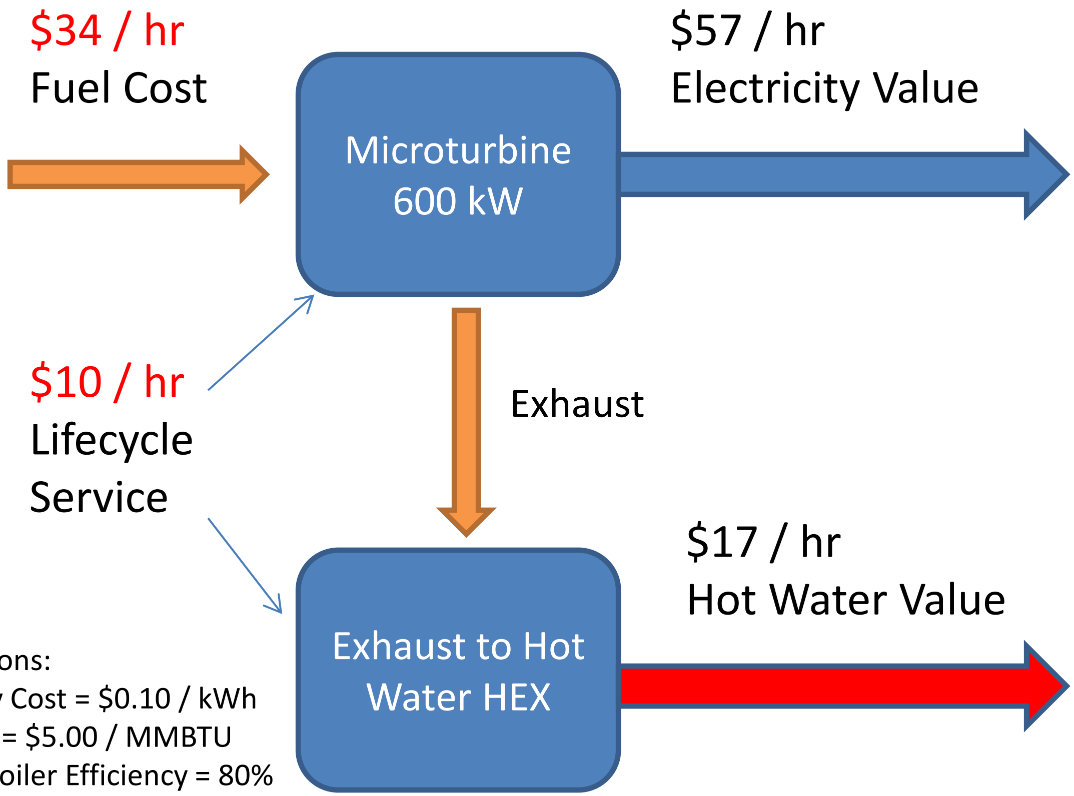
Combined Heat and Power
Also called Co-Gen



Source: U.S. DOE

- Distributed Generation
- Onsite Power Generation
- Energy Cost Savings
- Emissions Reduction

Reduction of Operational Costs
(Hot Water Example)

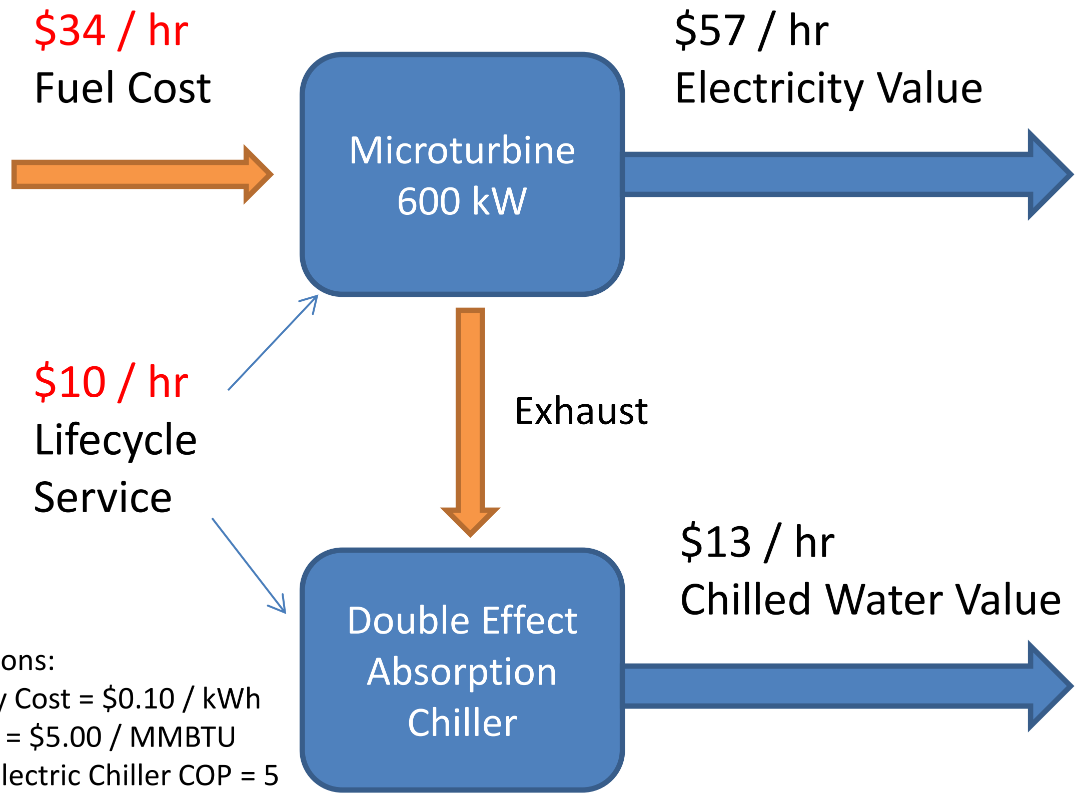


Assumptions:
Electricity Cost = $0.10 / kWh
Fuel Cost = $5.00 / MMBTU
Existing Boiler Efficiency = 80%

Electricity -	$57 / hr
Thermal -	$17 / hr
Fuel -	$34 / hr
Service -	$10 / hr
Savings =	**$30 / hr**

8750 Operating Hours per year = $262,500 annual savings

Reduction of Operational Costs
(Chilled Water Example)



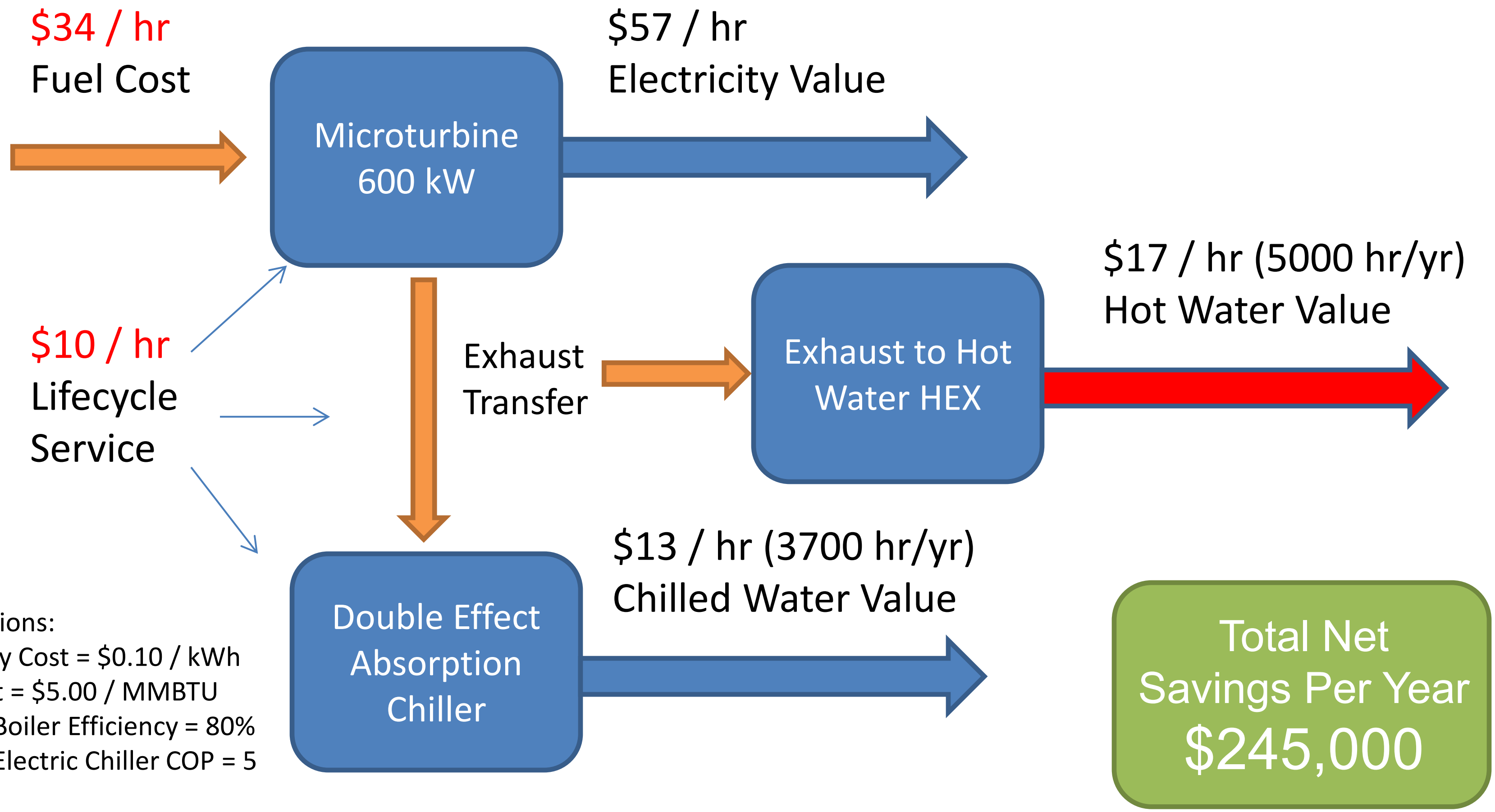
Assumptions:
Electricity Cost = $0.10 / kWh
Fuel Cost = $5.00 / MMBTU
Existing Electric Chiller COP = 5

Electricity -	$57 / hr
Thermal -	$13 / hr
Fuel -	$34 / hr
Service -	$10 / hr
Savings =	**$26 / hr**

4000 Operating Hours per year = $104,000 annual savings

Reduction of Operational Costs

(CCHP System Example)



Assumptions:
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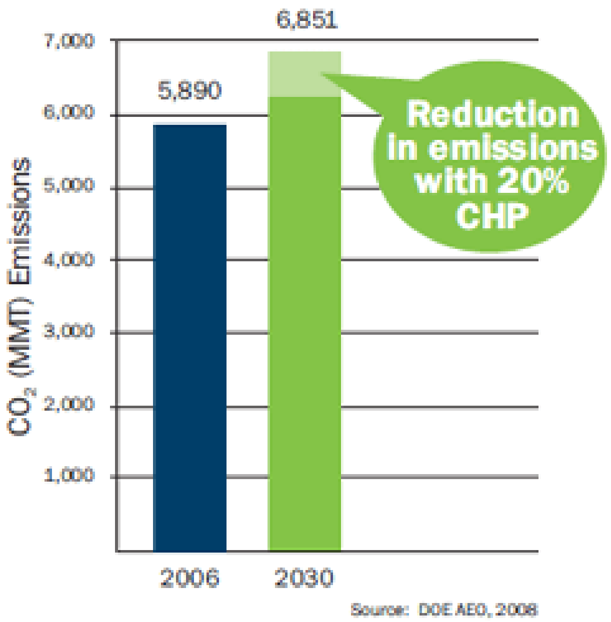
Existing Boiler Efficiency = 80%
Existing Electric Chiller COP = 5

Reduction of Emissions



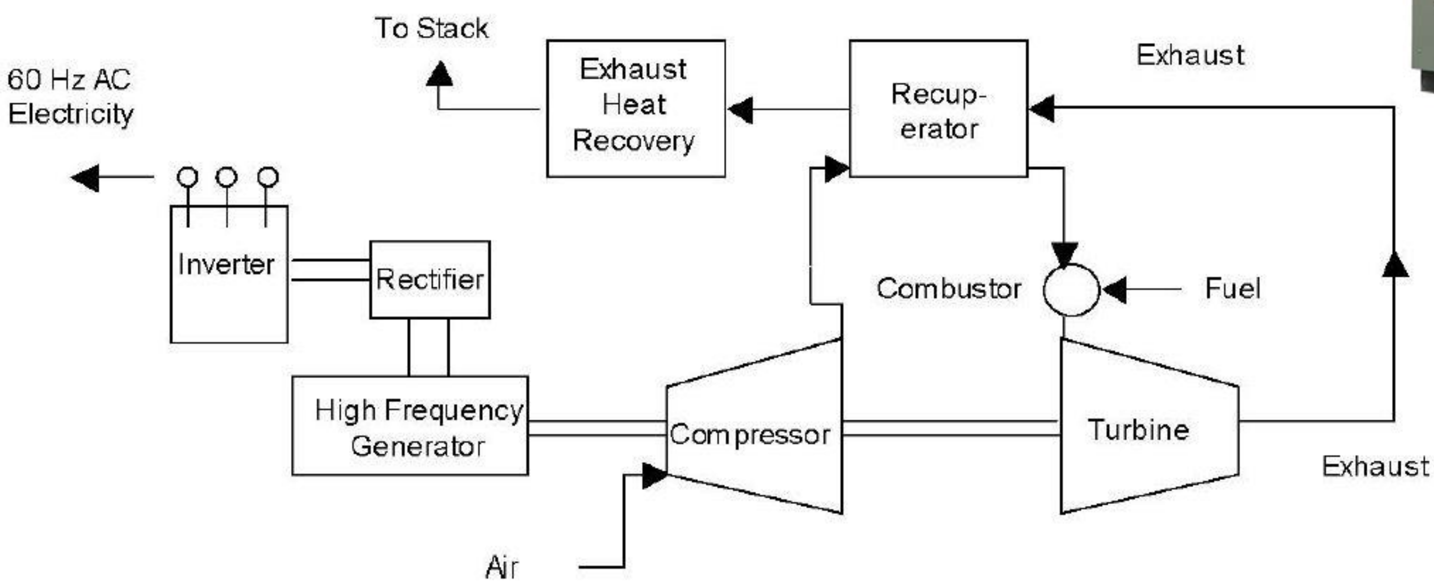
"CHP can avoid 60% of the potential growth in carbon dioxide emissions between 2006 and 2030."

→ Equivalent to removing 154 million cars from road

MICROTURBINE TECHNOLOGY

What is a Microturbine?

- Small gas turbine
- Brayton thermodynamic cycle

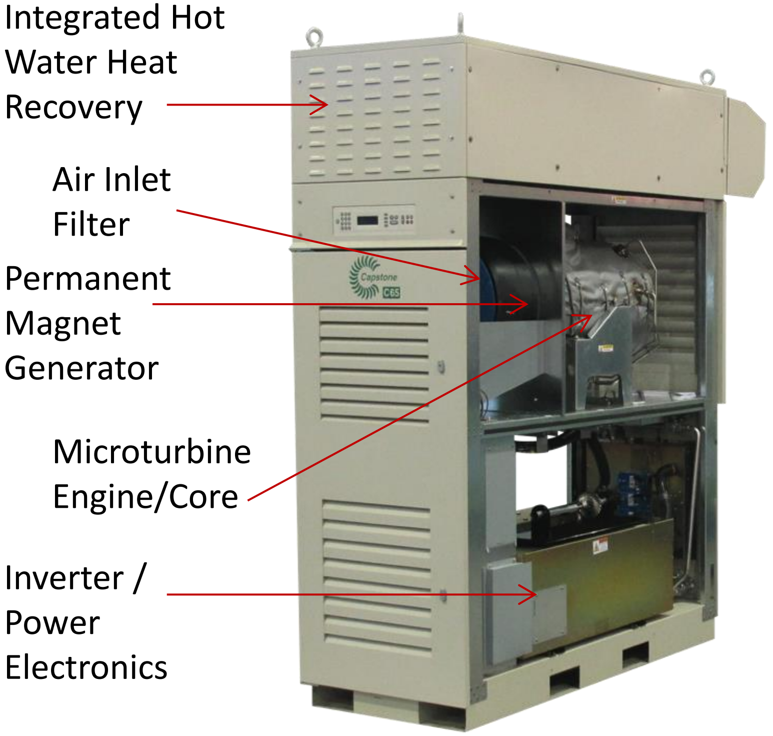


Capstone C30 MicroTurbine®

Source: EPA CHP Partnership Program,
Technology Characterization: Microturbines 2008

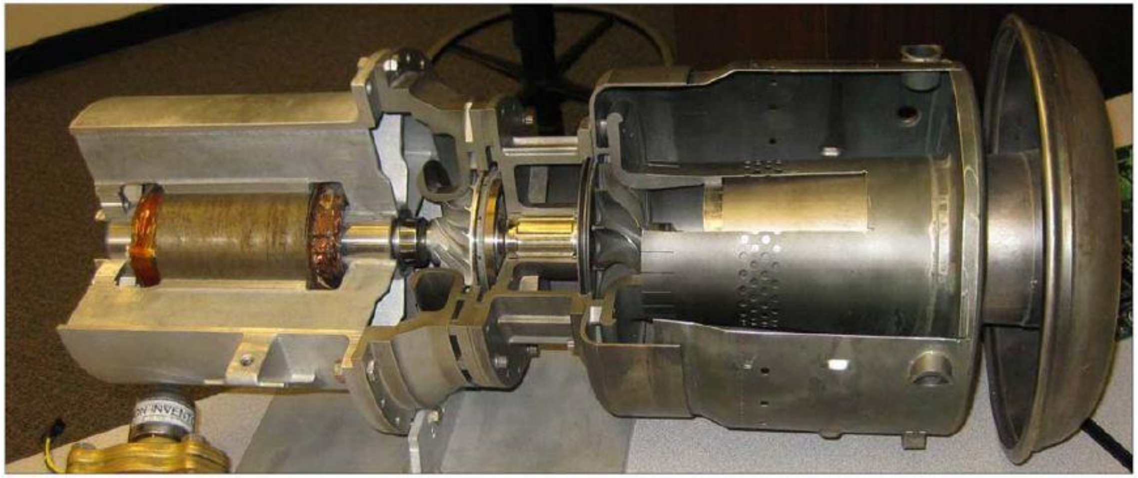
Capstone MicroTurbine® Technology

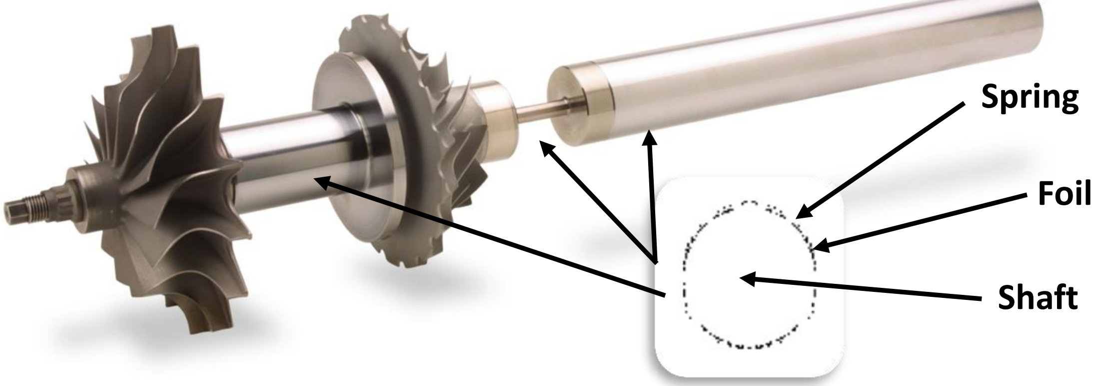
- One moving part
  - High reliability
  - Low total cost of ownership
- Air bearing technology & Air cooled
  - No oil, grease, coolant
  - Ultra low emissions
- Inverter power output
  - UL 1741 certified
  - Built-in protective relay functions & utility synchronization
  - IEEE 1547 compliant



Capstone C65 MicroTurbine®

Capstone MicroTurbine® "Turbogenerator"





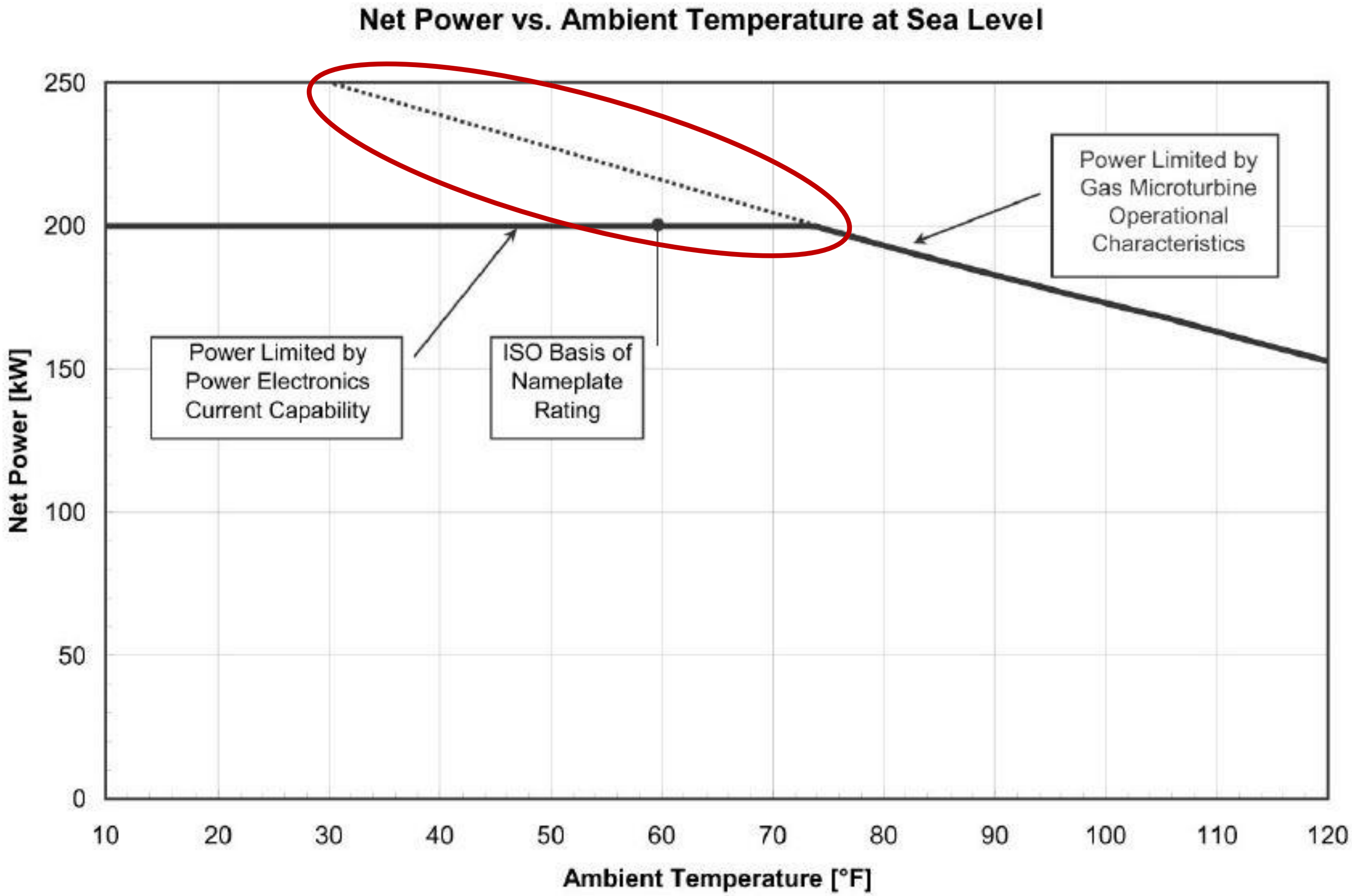
Microturbine Sizes

Electric Power Output	Manufacturer	Photo
30 kW	Capstone	
65 kW	Capstone	
200 kW	Capstone	
250 kW	FlexEnergy	
333 kW	FlexEnergy	
600, 800, 1000 kW	Capstone	

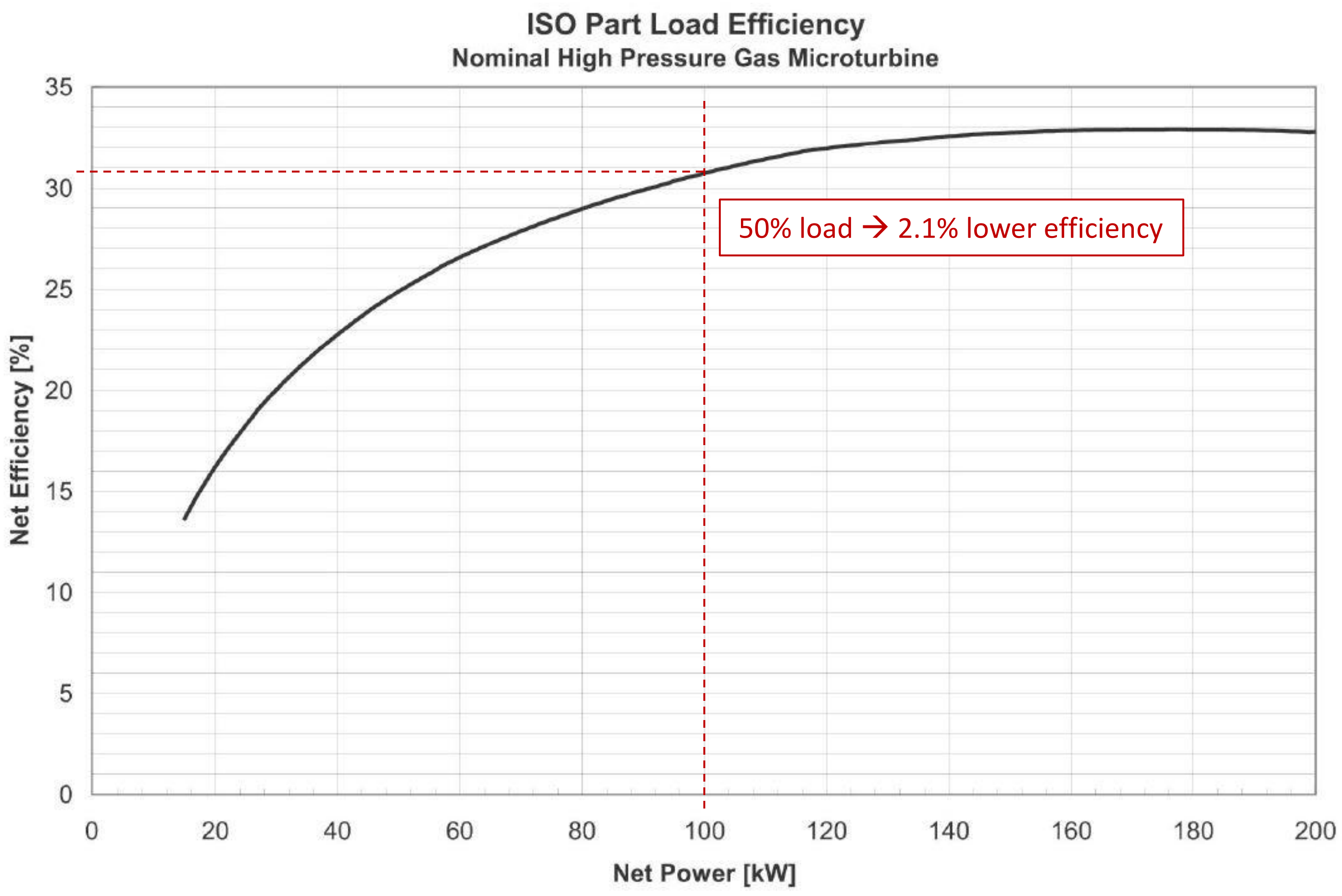
Engineering Considerations for Gas Turbines

- Ambient temperature
  - Maximum power output up to 70°F - 73°F
  - Remove heat rejected to space (indoor applications)
- Inlet and exhaust pressure drop
  - Maximum exhaust pressure loss: 8 in-WC
  - Heat recovery configuration
- Gas compression
  - For 0.5 psig inlet, 5 – 6% of rated power used for compression at full load
  - Variable frequency drive for reduced power consumption

Net Power Output vs. Ambient Temperature



Microturbine Part Load Efficiency

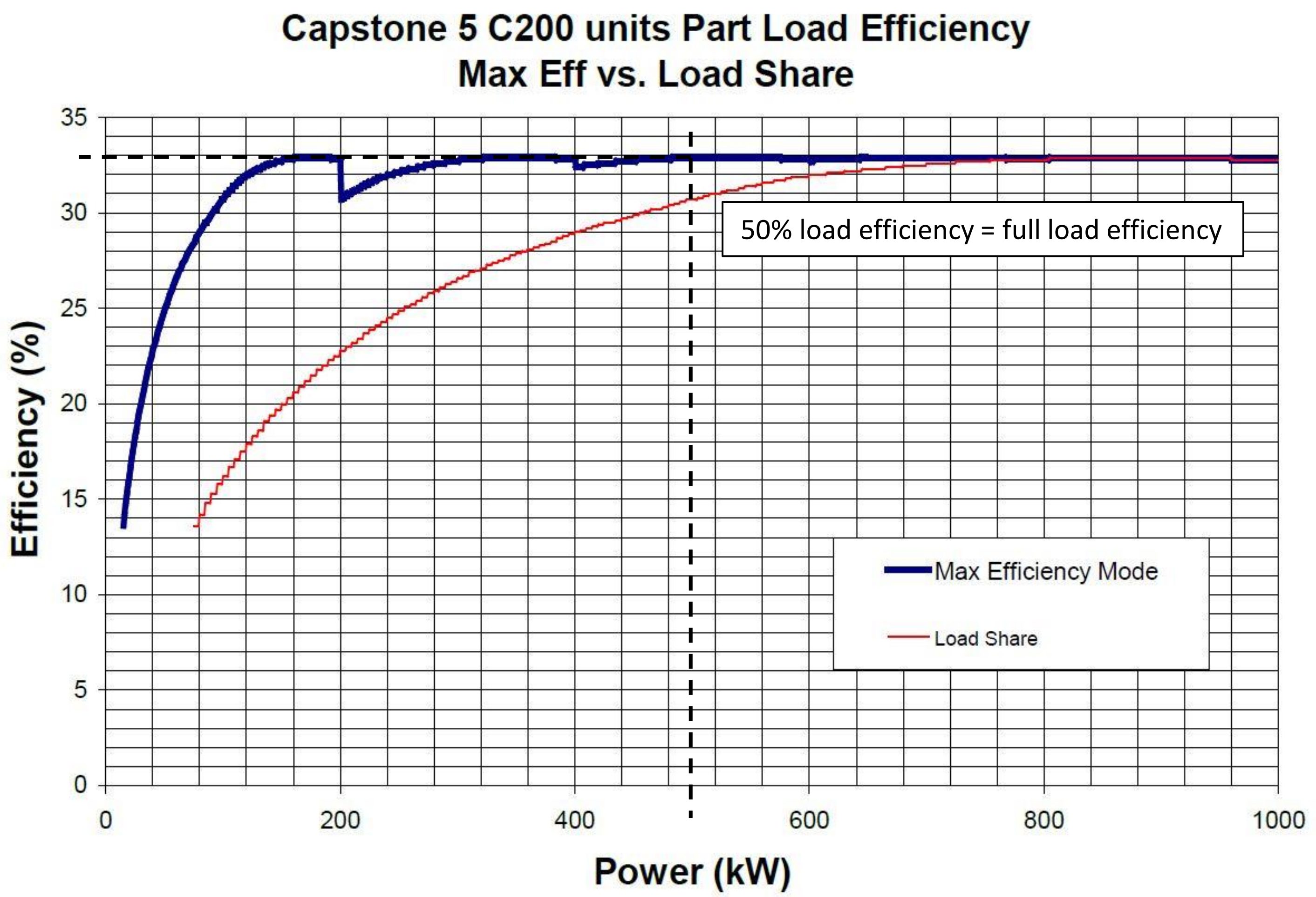


Multiple Prime Movers for CHP System

3 x C65 = 195 kW

C600/C800/C1000 =
600 kW / 800 kW / 1,000 kW

C600/C800/C1000 Microturbine Part Load Efficiency



Distributed Generation Technology Comparison

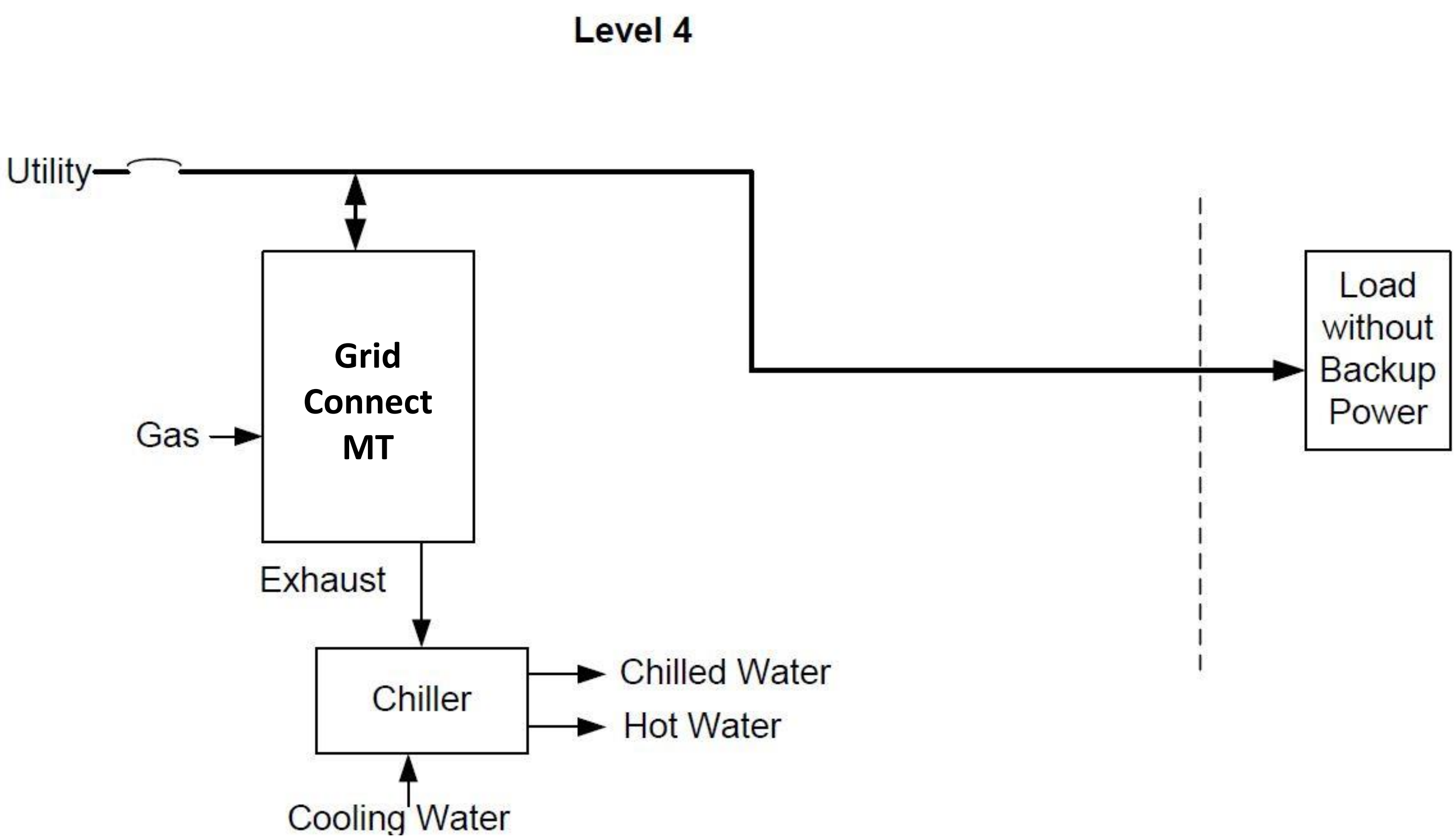
	Microturbine	Reciprocating IC Engine (RICE)	Fuel Cell	Wind Turbine	Solar Photovoltaic
Capital Cost to generate 2,000,000 kWh/year	1.0 (baseline)	0.85	2.0	3.5	5.0
Lifecycle O&M Cost ($/kWh)	0.016	0.025	0.035	0.010	0.002
Availability / Uptime	99.8%	92% - 94%	95%	98%	100%
Noise Level	Quiet	Needs Acoustic Enclosure	Quiet	Quiet	Quietest
Air Quality Impact: NOx (lb/MWh)	0.4 – 0.46	0.8 – 1.6 (without SCR treatment)	0.015	0.0	0.0
Oil Spill Hazard	None	Present	None	None	None

Table data obtained from EPA Catalog of CHP Technologies (2015) and NREL Distributed Generation Technologies (2012)

Microturbine CHP Systems

Power System Type	Ideal Customers
Integrated **P**ower **S**ystem (IPS)	• **Colleges/Universities** • **Health Care** • **Manufacturing** • **Large Hotels**
Mission **C**ritical **P**ower **S**ystem (MCPS)	• **Data Centers** • **Communication Facilities** • **Government** • **Military**
Renewable **P**ower **S**ystem (RPS)	• **Wastewater Treatment Plants** • **Agricultural** • **Food / Beverage** • **Landfills**

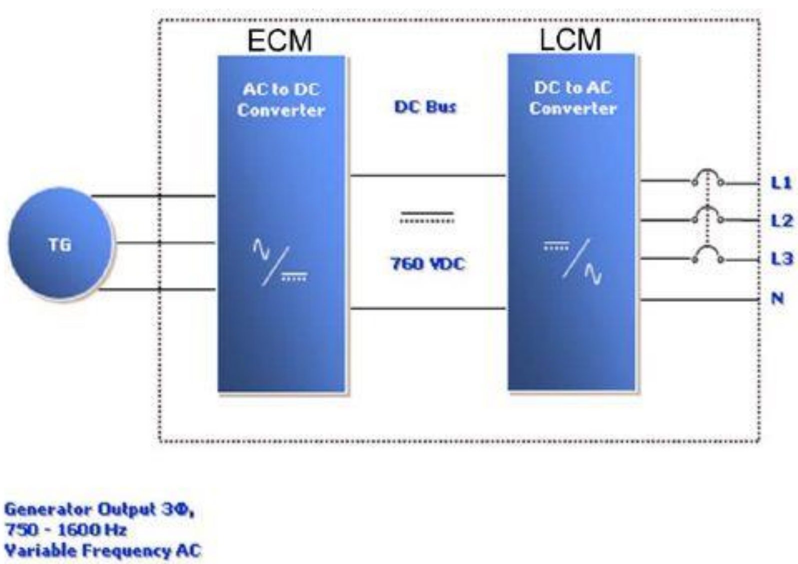
Grid Parallel Only Operation



Grid Parallel Only Microturbine

Power Electronics

Microturbine Operates as a Current Source while matching Utility's Voltage and Frequency

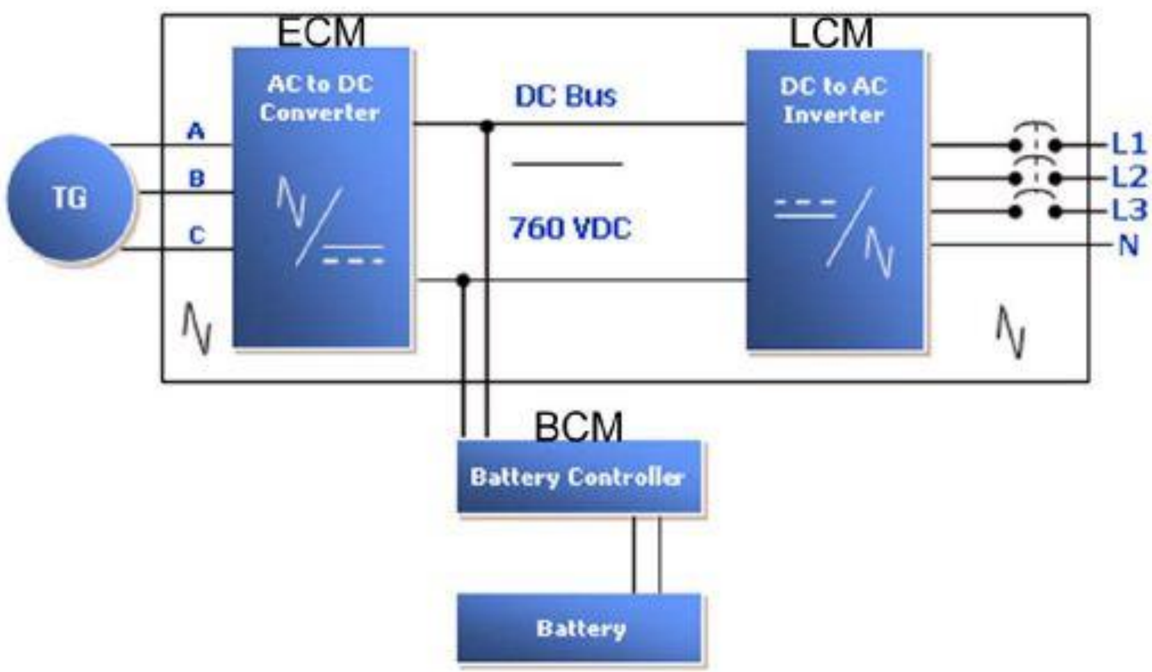


- If Utility has a fault, microturbine disconnects & powers down
- "Grid Connect" microturbine

Dual Mode Microturbine

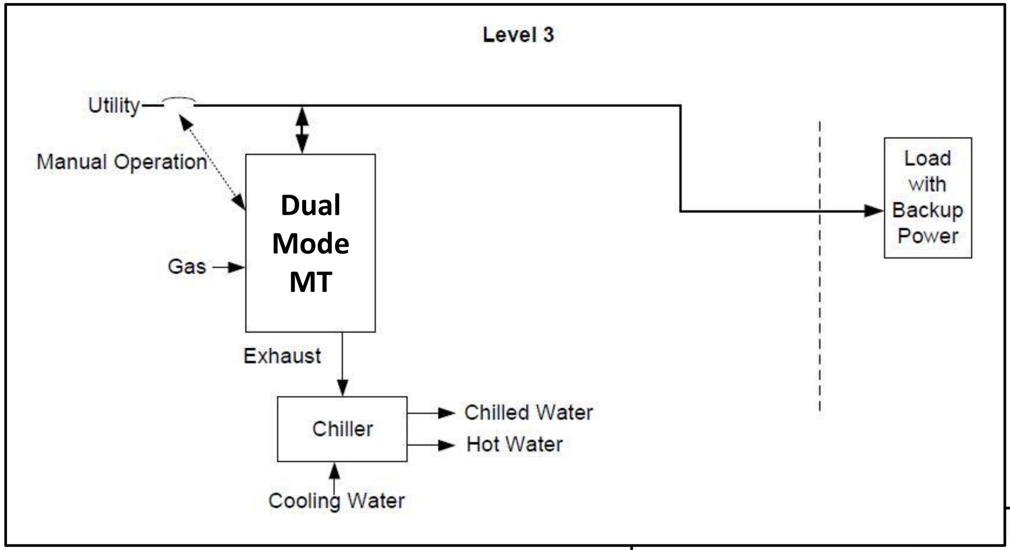
Power Electronics

Stand Alone Mode: Microturbine Operates as a Voltage Source

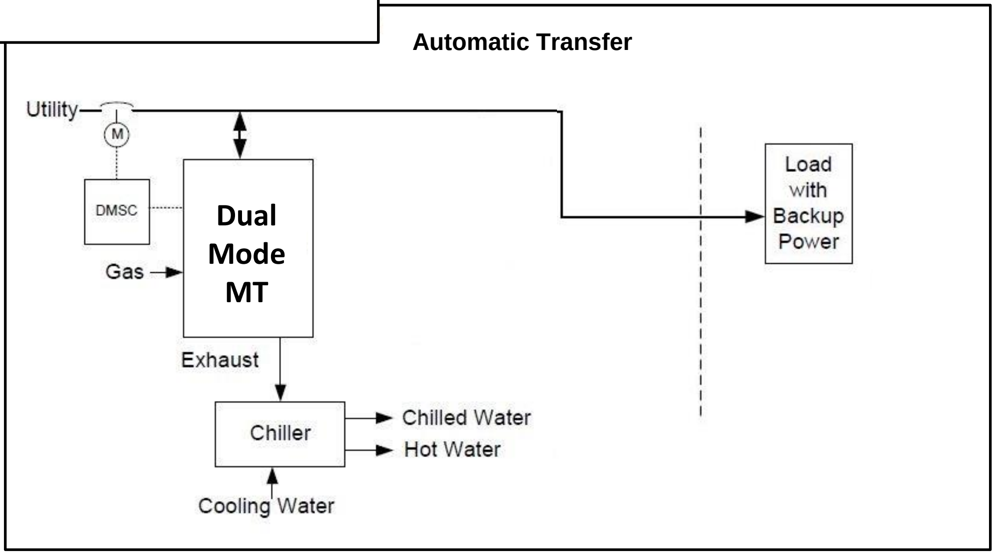


- Battery system sized to handle connected load variations
- “Dual Mode” microturbine provides both grid-parallel and stand-alone power generation

Grid Parallel and Stand Alone Power Generation

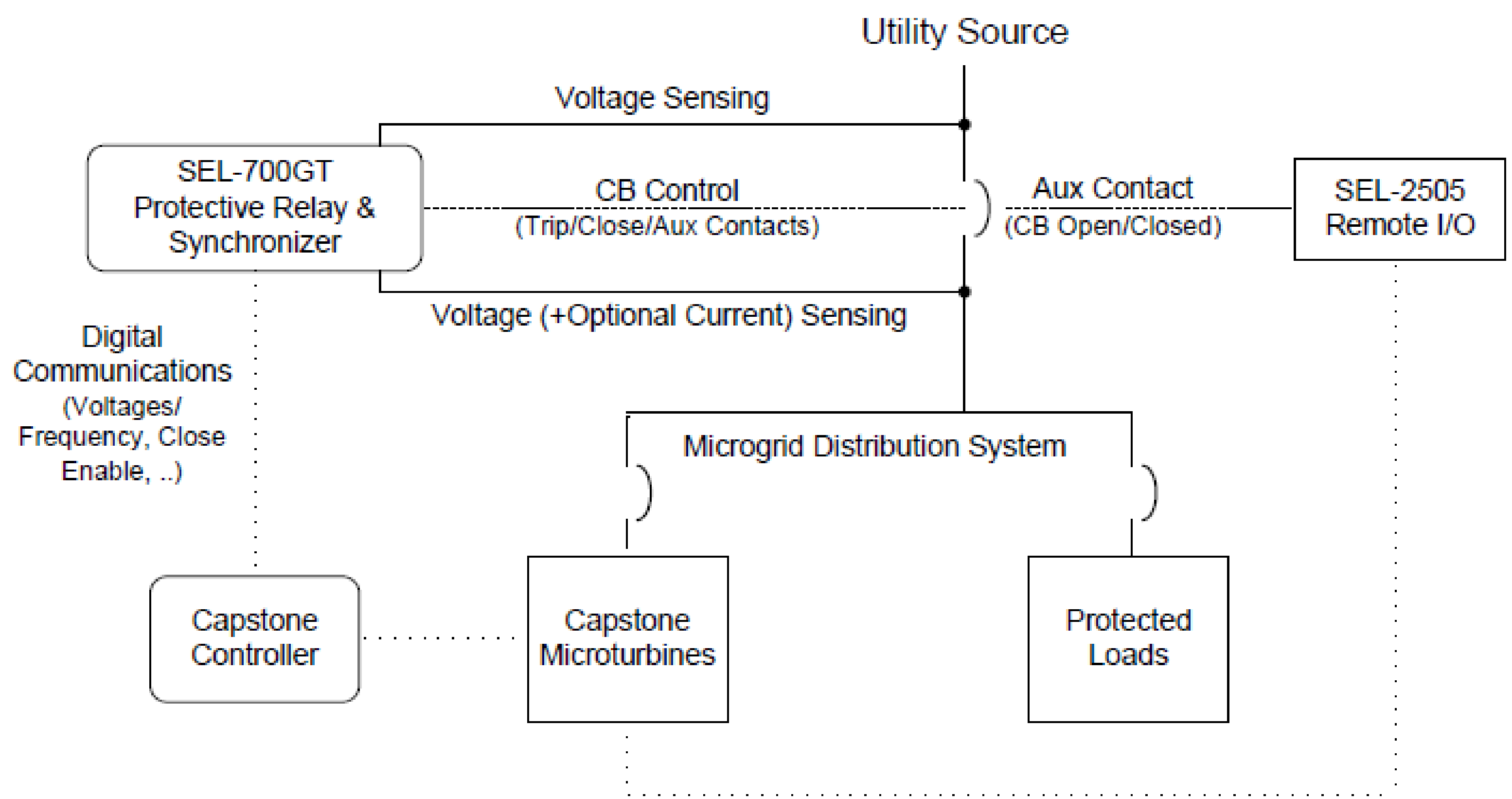


- Manual Transfer
  - Saves some cost
- Automatic Transfer
  - Power returns to MT-connected loads within 10 seconds after utility outage



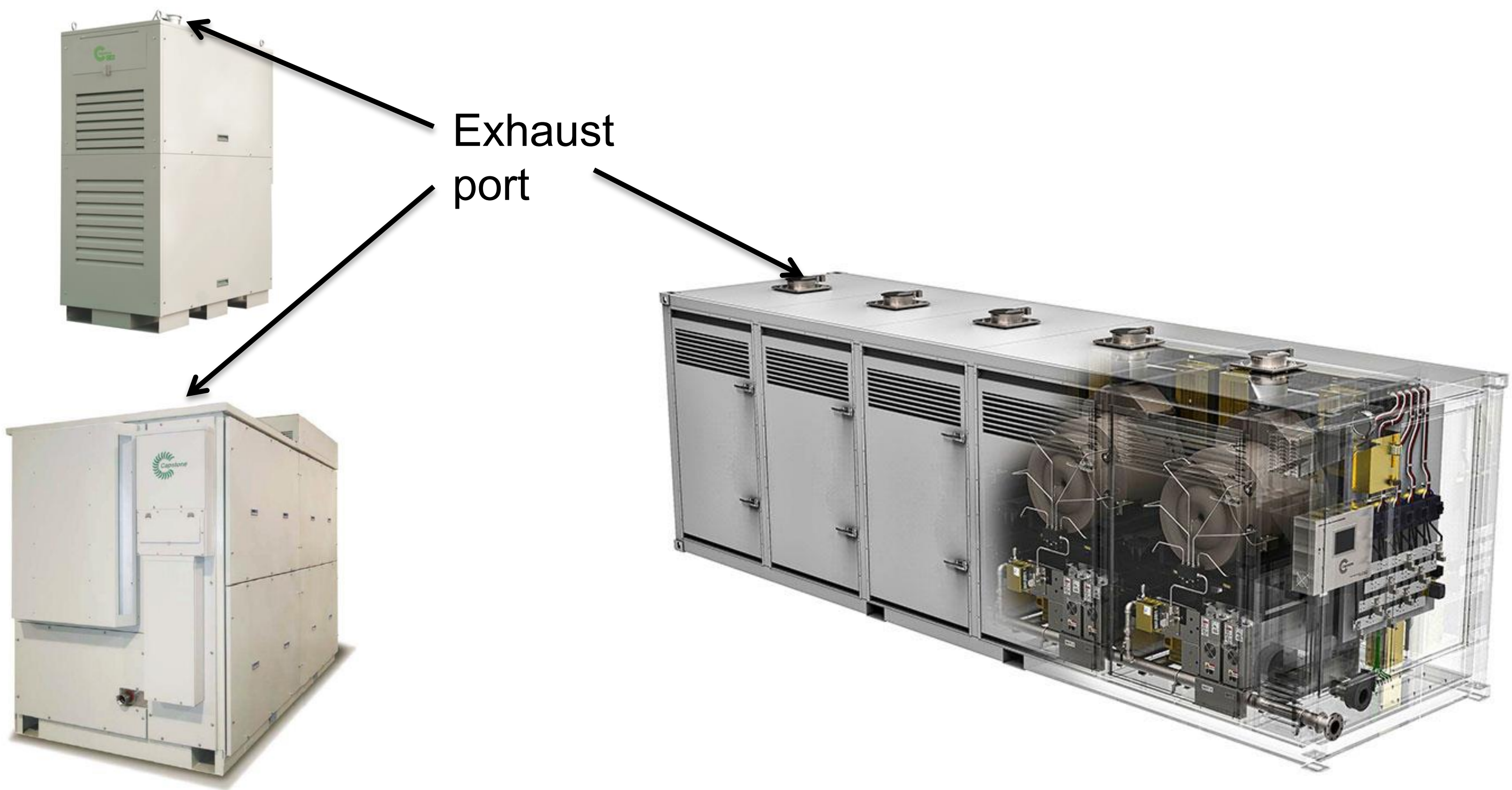
Grid Parallel and Stand Alone Power Generation

- Seamless Transfer
  - No interruption in power supply to building during utility brownout/blackout



Microturbine Heat Recovery

- One location to recover heat – exhaust outlet



Integrated Hot Water Heat Recovery

420,000 BTU/hr

- 160F supply temp
- 140F return temp
- 40 gpm flow

65 kW Microturbine-ICHP

Integrated Hot Water Heat Recovery

4,600,000 BTU/hr

- 160F supply temp
- 142F return temp
- 500 gpm flow

1,000 kW Microturbine-ICHP Package

Heat Recovery: Steam Generation

- 5 – 150 psig steam pressures
- Generate steam and hot water simultaneously

Heat Recovery Steam Generator

Exhaust to Hot Water HEX

Heat Recovery: Chilled Water Generation

Hot Water Fired Single Effect Absorption Chiller

Exhaust Fired Double Effect Absorption Chiller

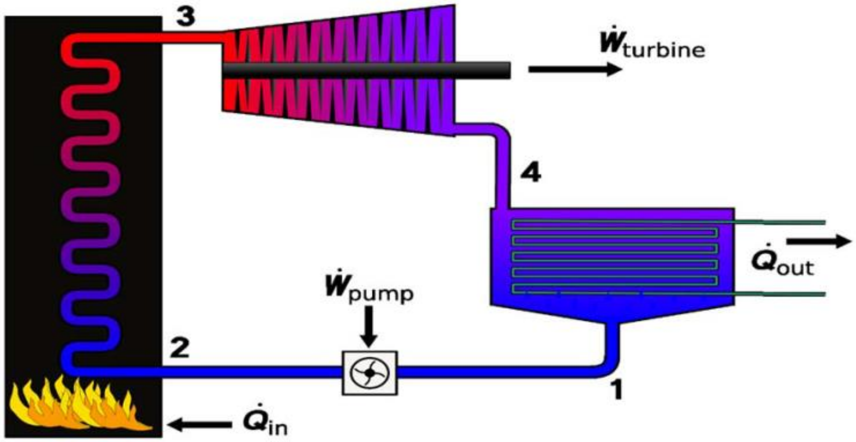
20 – 25% more chilled water output

Other Heat Recovery Options

Direct Exhaust Air

- Manufacturing process (e.g., drying)

Generate Additional Electricity - Organic Rankine Cycle (ORC)



Organic Rankine Thermodynamic Cycle

Huntington Center with Ice Arena

Case Study

Project Vitals	
Type	Sports Arena
Year	2009
Location	Toledo, Ohio
Function	CCHP
Reason	Cost Reduction
Electric	260kW
Heat	1.6 MMBTU
Cooling	82 - 100 Tons
Backup	Not implemented
Configuration	IPS-260-CCHP
Savings	$100,000/yr

Rome Memorial Hospital

Case Study

Project Vitals	
Type	Hospital
Year	2011
Location	Rome, NY
Function	CHP
Reason	Cost Reduction
Electric	260 kW
Heat	1.4 MMBTU HW
Cooling	N/A
Backup	Paralleled backup
Configuration	IPS-260-CHP
Savings	$90,000+/year

VAMC at Syracuse

Case Study

Project Vitals	
Type	Hospital
Year	2016
Location	Syracuse, NY
Function	CHP
Reason	Cost Reduction
Electric	520 kW
Heat	3.0 MMBTU HW
Cooling	N/A
Backup	N/A
Configuration	IPS-260-CHP (2)
Savings	$200,000+/year

The Toledo Museum of Art

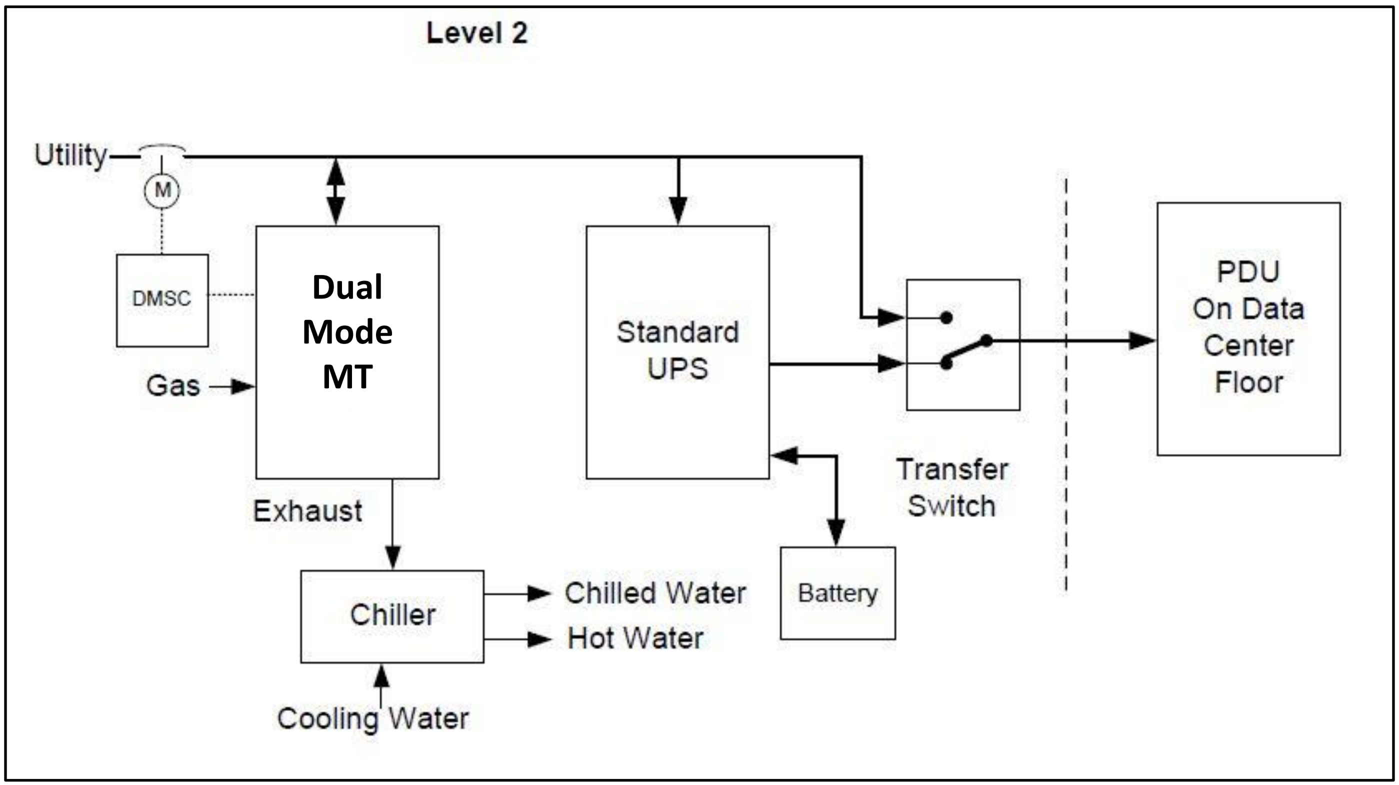
Case Study

Project Vitals	
Type	Museum
Year	2003
Location	Toledo, OH
Function	CHP, Backup Power
Reason	Cost Reduction
Electric	260 kW
Heat	1.6 MMBTU HW
Cooling	N/A
Backup	Level 3 - manual
Configuration	IPS-260-CHP
Savings	$100,000+/year

Microturbine CHP Systems

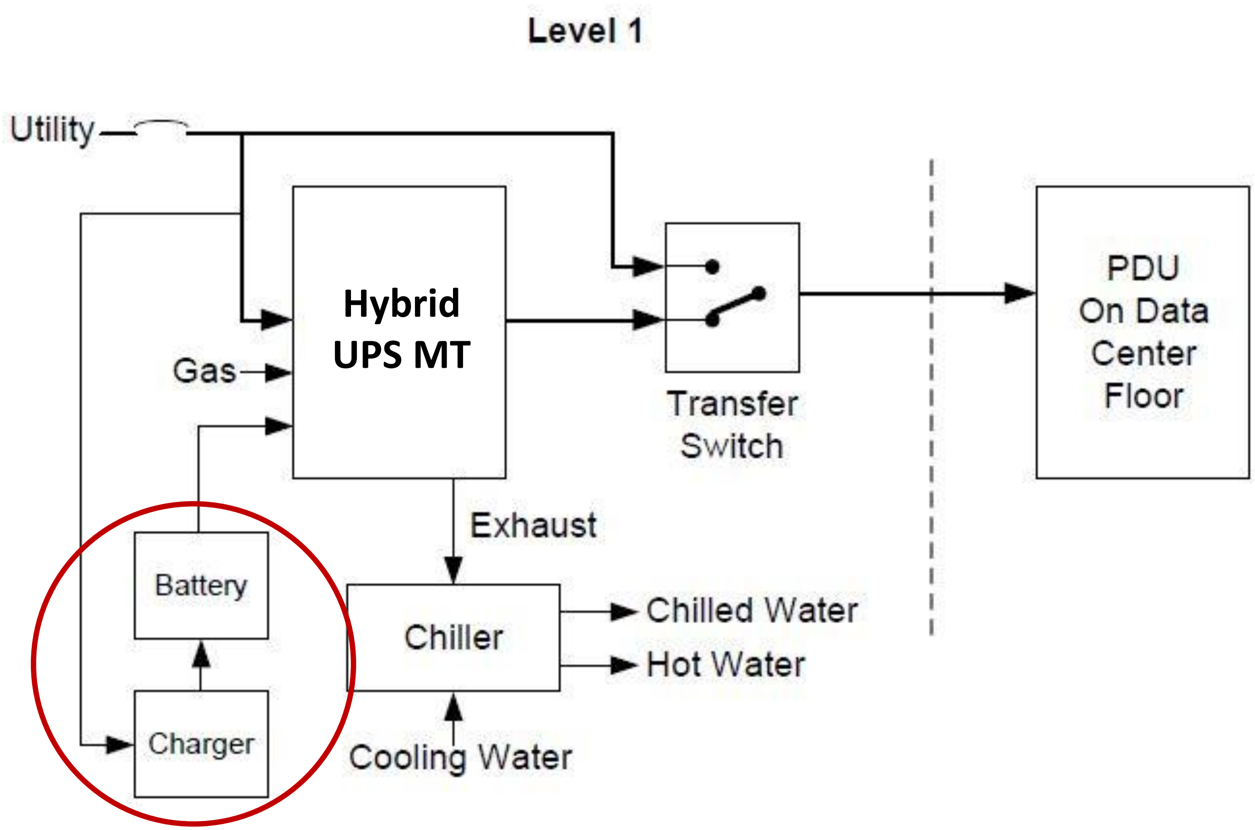
Power System Type	Ideal Customers
Integrated **P**ower **S**ystem (IPS)	• **Colleges/Universities** • **Health Care** • **Manufacturing** • **Large Hotels**
Mission **C**ritical **P**ower **S**ystem (MCPS)	• **Data Centers** • **Communication Facilities** • **Government** • **Military**
Renewable **P**ower **S**ystem (RPS)	• **Wastewater Treatment Plants** • **Agricultural** • **Food / Beverage** • **Landfills**

Mission Critical Power Systems (MCPS)
using Dual Mode Microturbine



Mission Critical Power Systems (MCPS)

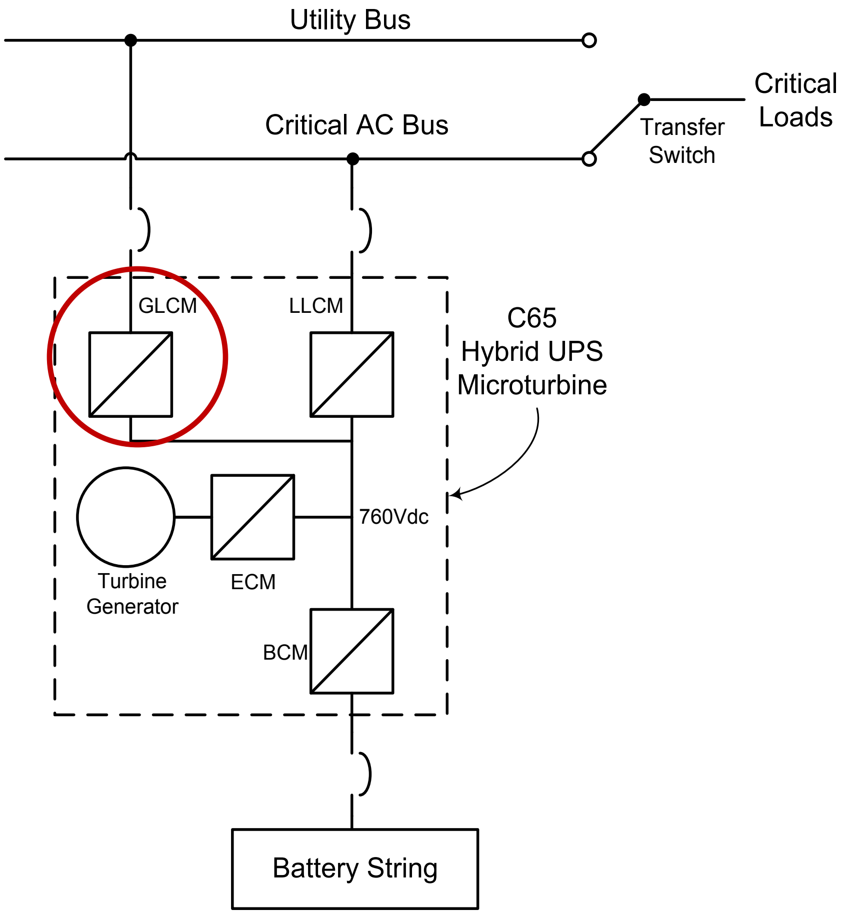
using Hybrid UPS Microturbine



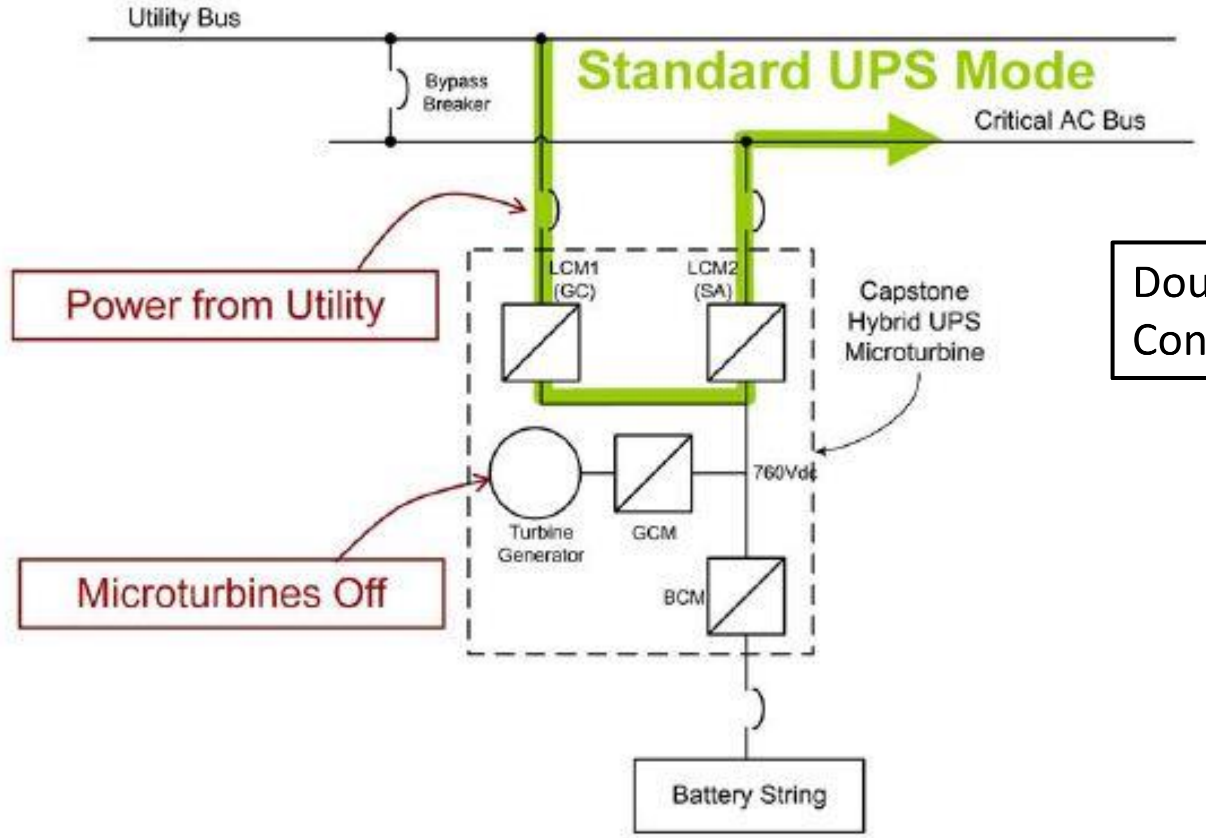
Hybrid UPS MicroTurbine

Power Electronics

- Double converted AC power
  - with or without combusting gas/generating electricity
- Reduction in power conditioning equipment

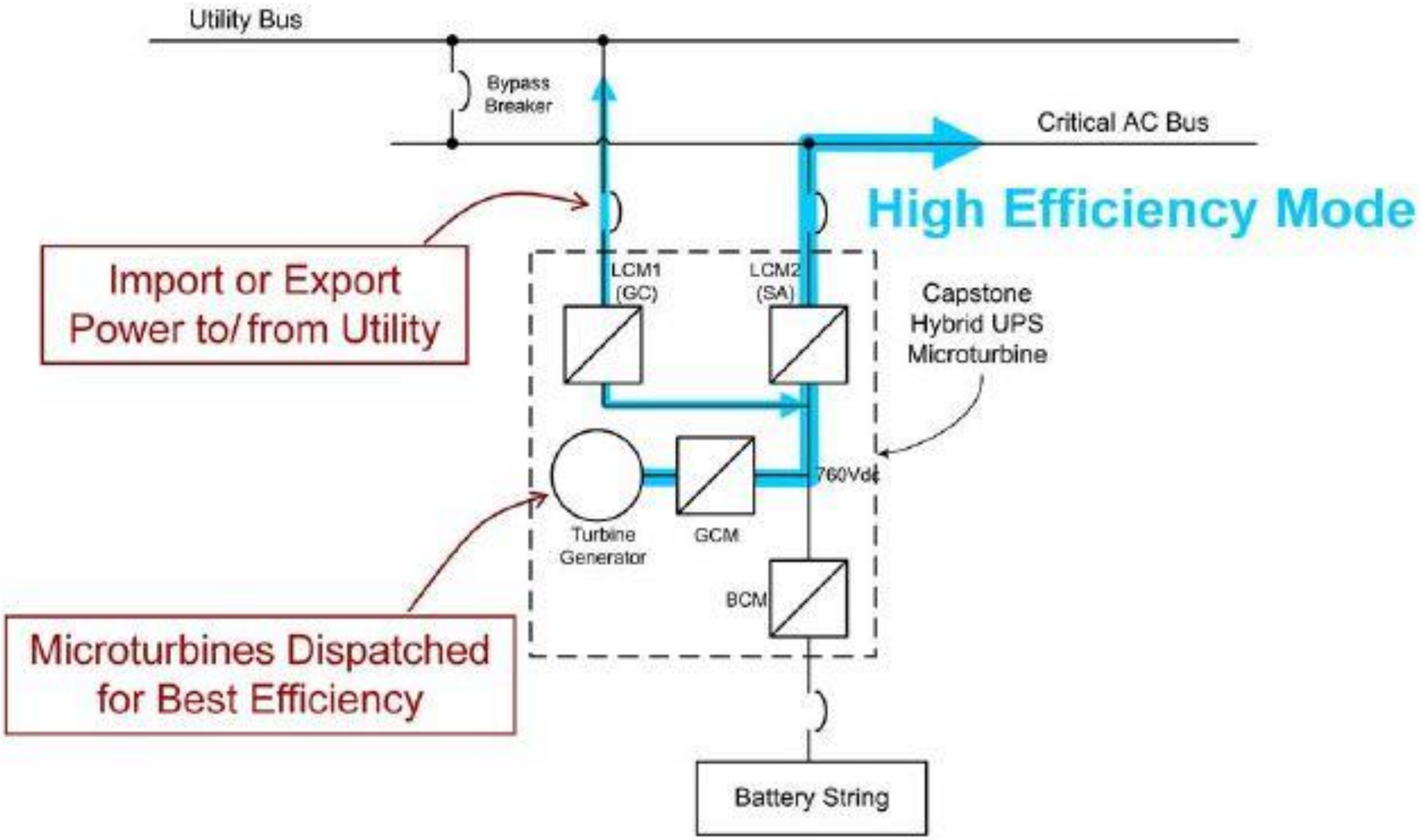


Hybrid UPS MicroTurbine

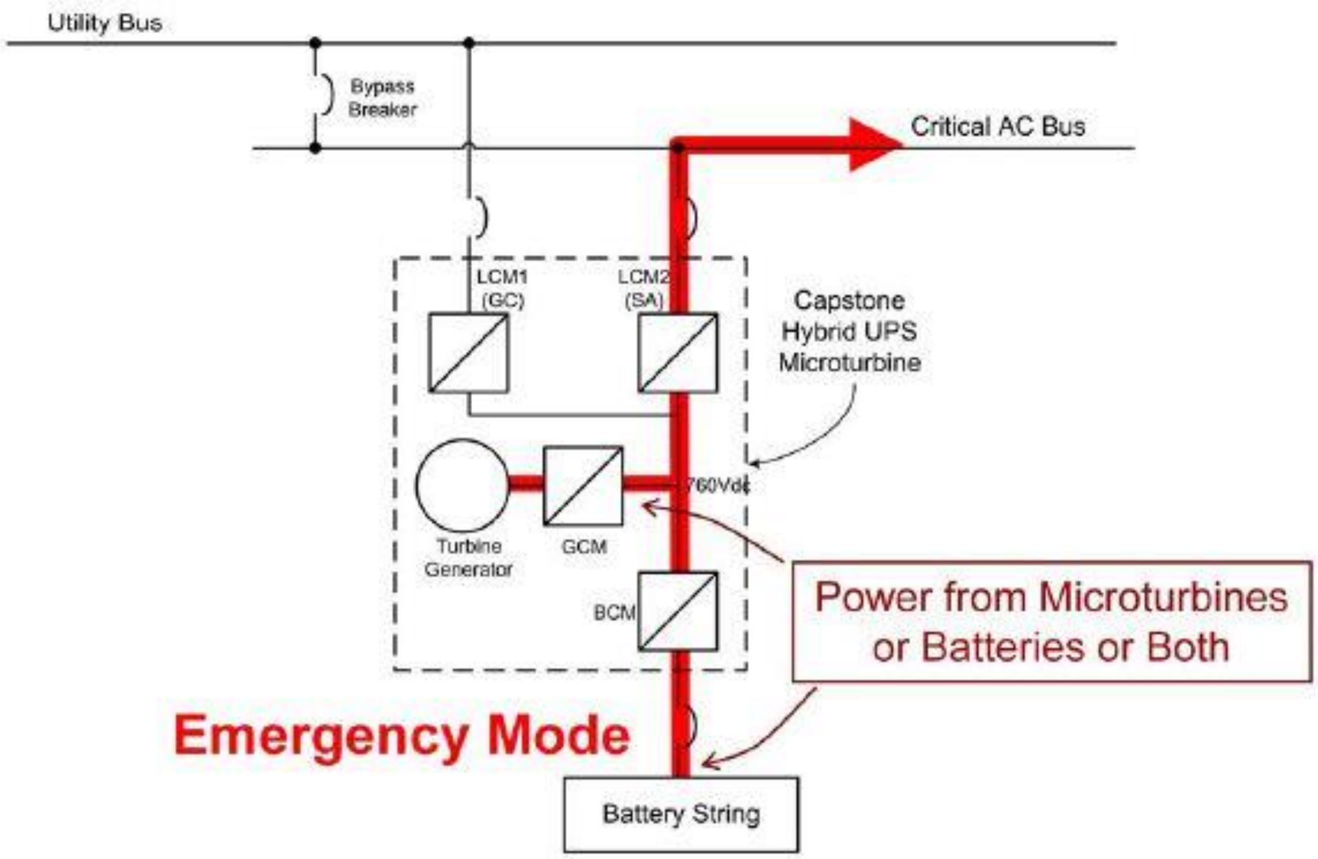


Double Conversion UPS

Hybrid UPS MicroTurbine

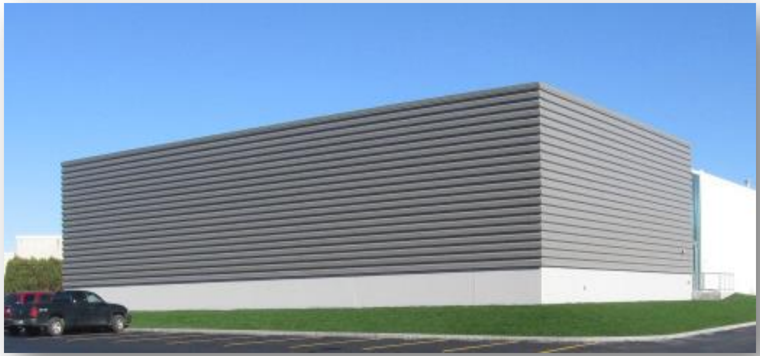


Hybrid UPS MicroTurbine



Syracuse University Green Data Center

Case Study



Project Vitals	
Type	Data Center
Year	2009
Location	Syracuse, NY
Function	Mission Critical
Reason	Cost Reduction
Electric	780 kW
Heat	4.0 MMBTU HW
Cooling	300 Tons
Backup	Level 1
Configuration	MCPS-390-CCHP (2)
Savings	$500,000+/year

University of Toledo

Project Summary

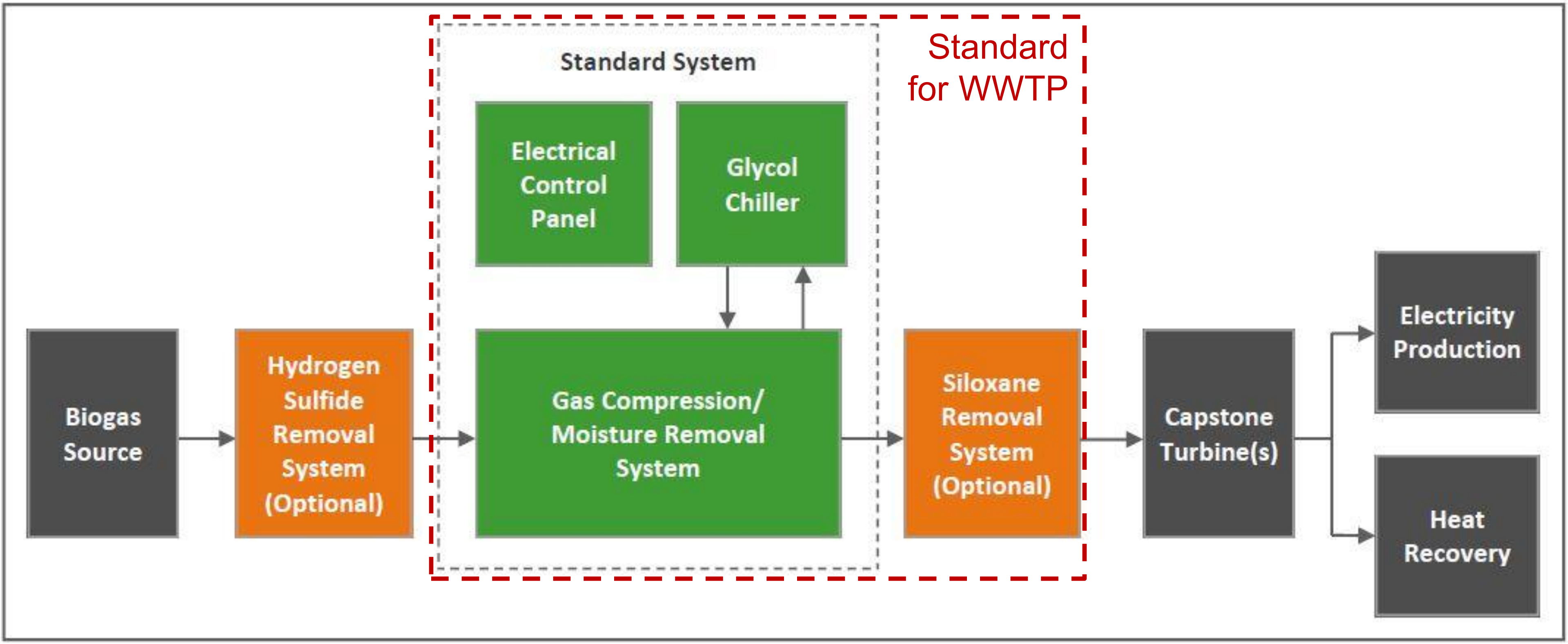
Project Vitals	
Type	Data Center
Year	2012
Location	Toledo, OH
Function	Mission Critical
Reason	Cost Reduction
Electric	260 kW
Heat	1.0 MMBTU HW
Cooling	100 Tons
Backup	Level 1
Configuration	MCPS-260-CCHP
Savings	$150,000+/yr

Microturbine CHP Systems

Power System Type	Ideal Customers
Integrated **P**ower **S**ystem (IPS)	• **Colleges/Universities** • **Health Care** • **Manufacturing** • **Large Hotels**
Mission **C**ritical **P**ower **S**ystem (MCPS)	• **Data Centers** • **Communication Facilities** • **Government** • **Military**
Renewable **P**ower **S**ystem (RPS)	• **Wastewater Treatment Plants** • **Agricultural** • **Food / Beverage** • **Landfills**

Digester Gas Conditioning System

- Hydrogen Sulfide Removal NOT required (typically); accepts <5,000 ppmv

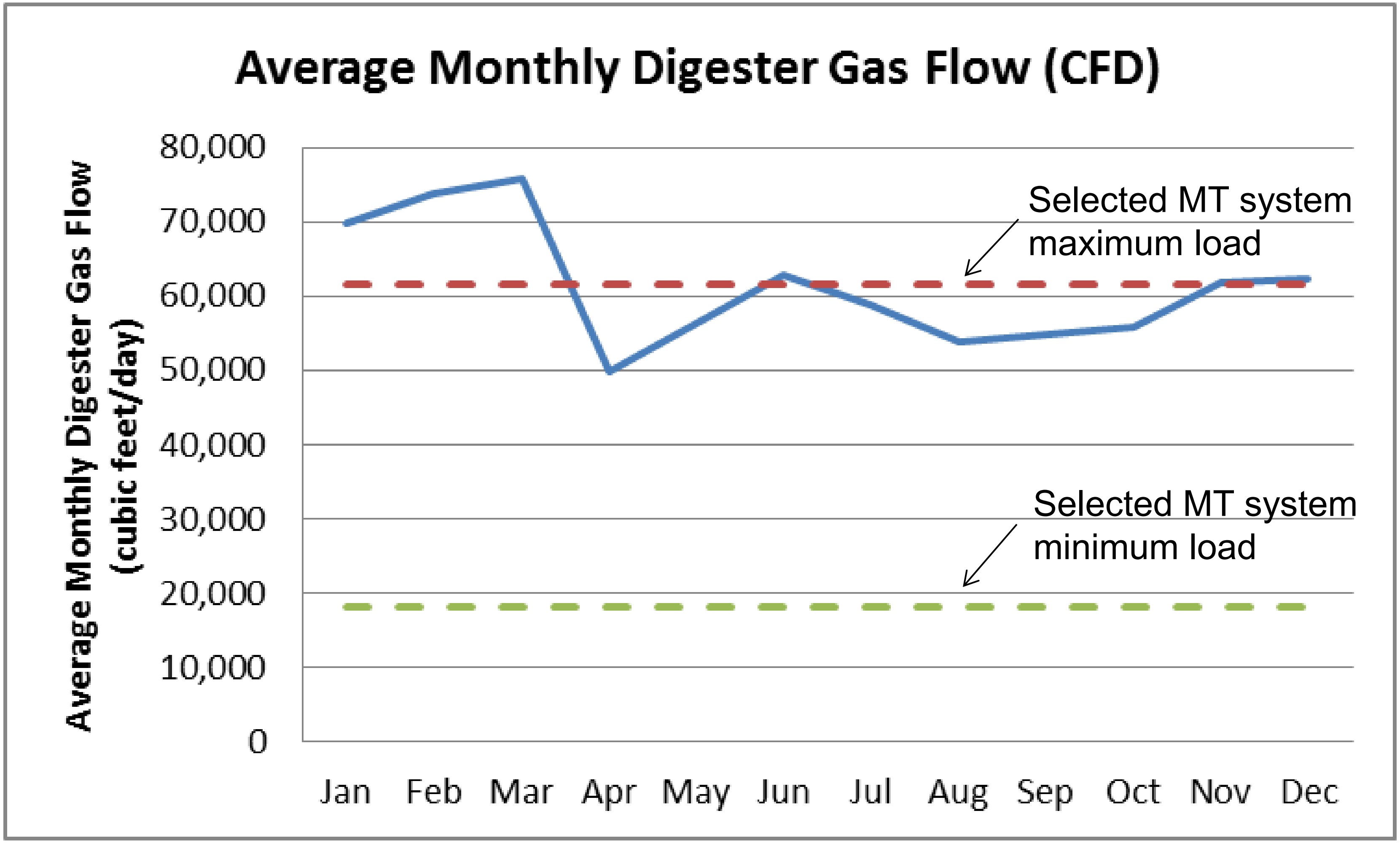


Comparison: Microturbines and RICE in Biogas Applications

	MicroTurbine	Reciprocating IC Engine (RICE)
Hydrogen Sulfide Removal	Not Required (typically)	Required
Siloxane Removal	Required	Required
Maintenance Interval	8,000 hours No inspection	1,000 hours* Daily inspection
Availability / Uptime	> 99%	92%
Heat Recovery	Simple	More complicated/costly

*Maintenance interval of engine depends highly on the level of H_2S and siloxane removal

Fuel Input Variation: Flow and Energy Content



Ithaca Area WWTF

Case Study

Project Vitals	
Type	Wastewater Treatment Plant
Average Flow	7 MGD
Characteristics	Additional Feedstocks/ Low H2S and Siloxanes
Year	2013
Location	Ithaca, NY
Function	Renewable Power
Reason	Energy and Cost Reduction
Electric	260 kW
Heat	1.0 MMBTU/hr

Lima OH WWTP

Case Study

Project Vitals	
Type	Wastewater Treatment Plant
Average Flow	14 MGD
Characteristics	Heavy Industrial Load/ High Siloxane Levels
Year	2002, 2012, 2013
Location	Lima, Ohio
Function	Renewable Power
Reason	Cost Reduction
Electric	90 kW, 130 kW
Heat	0.8 MMBTU/hr

Contact Information

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