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Online Community of Northeast Sustainable Energy Association

Building Energy 2016 Presentation

Small Scale Cogeneration

March 10, 2016

Today's agenda

- Introductions
- Cogeneration/CHP Overview
- Technologies Available to Market
- Incentives/Rebates and Credits
- What Do I Do Next? – Study?
- State Incentives and Renewable Attributes
- Resiliency/Case Study Discussion
- Questions and Answers

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Efficient By Design

Gregory S. Hester, PE, LEED AP
Managing Partner

- >20 Years of Energy Efficiency & 16 Years of Direct CHP Experience

- >$150m in CHP Projects Including Microturbines, Combustion Turbines, Reciprocating Engines and Fuel Cells

- >$31M in Incentives and Rebates

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Celtic Energy

Chris Lotspeich MPPM, MES
Director of Sustainability Services

- >20 Years of Energy Efficiency and Distributed Generation Experience

- Focus on Critical Facility Energy Surety, Microgrids and Retrofit for Resilience Projects

- Formerly at Rocky Mountain Institute and Second Hill Group

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Blue Delta Energy

Thomas Jacobsen
Executive Vice President

- Engages the environmental markets daily to provide revenue streams to clients
- At forefront of the CHP and clean energy markets, providing solutions via market access and regulatory services to commercial, industrial, health, educational and financial institutions

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Cogeneration Overview

- Also commonly called "combined heat and power" (CHP)
- Put simply, to generate electricity (and/or mechanical energy) and thermal energy in a single, integrated system to maximize total overall efficiency
- This contrasts with common practice in this country where electricity is generated at a central power plant, and on-site heating and cooling equipment is used to meet non-electric energy requirements
- The thermal energy recovered in a CHP system can be used for heating or cooling buildings. Because CHP captures the heat that would be otherwise be rejected in traditional separate generation of electric or mechanical energy, the total efficiency of these integrated systems is much greater than from separate systems. (On the order of 40% - 50% more efficient)

Cogeneration Overview

- The thermal energy output from a prime mover (Microturbine, Reciprocating Engine, Gas Turbine, Fuel Cell, Etc.) is most efficiently used if it can be delivered directly into a steam or hot water system. This delivers the highest overall system efficiency and results in the largest overall value proposition to end users

- The thermal output from these systems can also be used to provide cooling through absorption chillers, however, the financial benefit from these type projects often are lower than non-cooling projects due to the added infrastructure costs needed on these type jobs (i.e. chiller, towers, pumps, etc. unless they already exist on-site)

- The thermal energy recovery from CHP projects is one of the primary cash flow generators that creates the value to the owner and drives ROI

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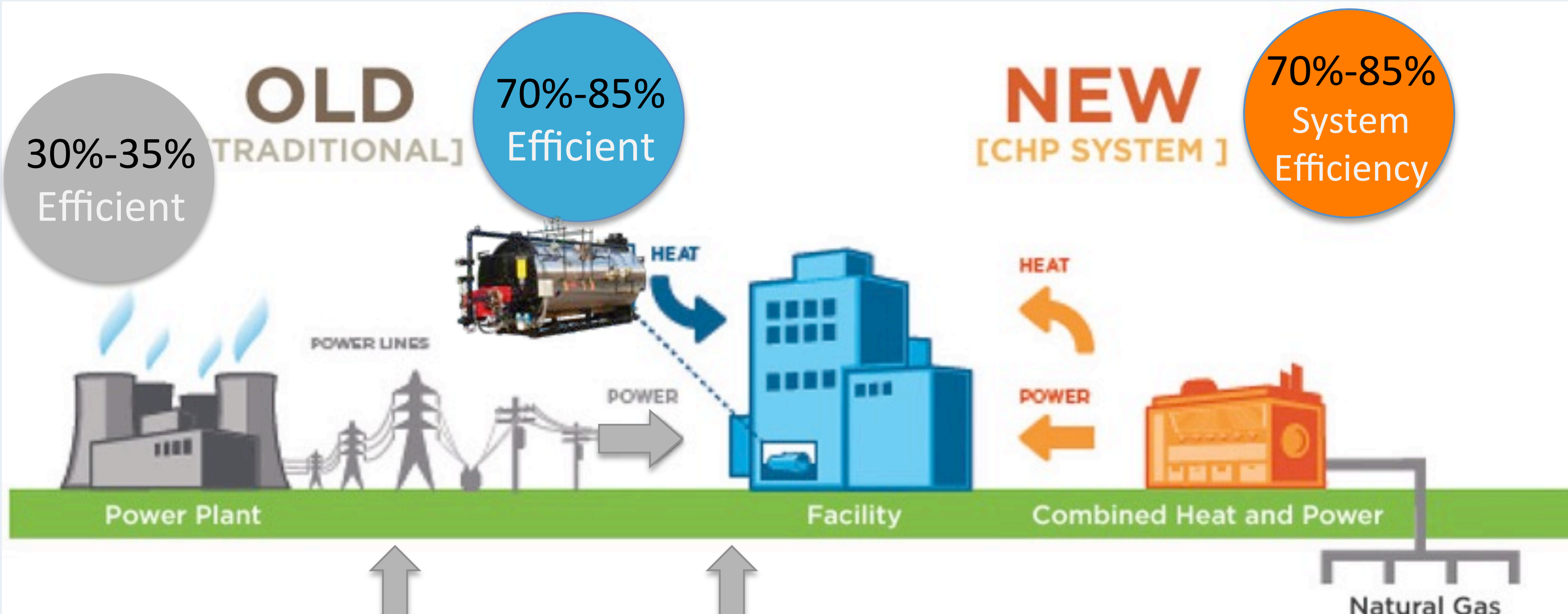
Cogeneration Overview



Line Losses

Transformer
Losses

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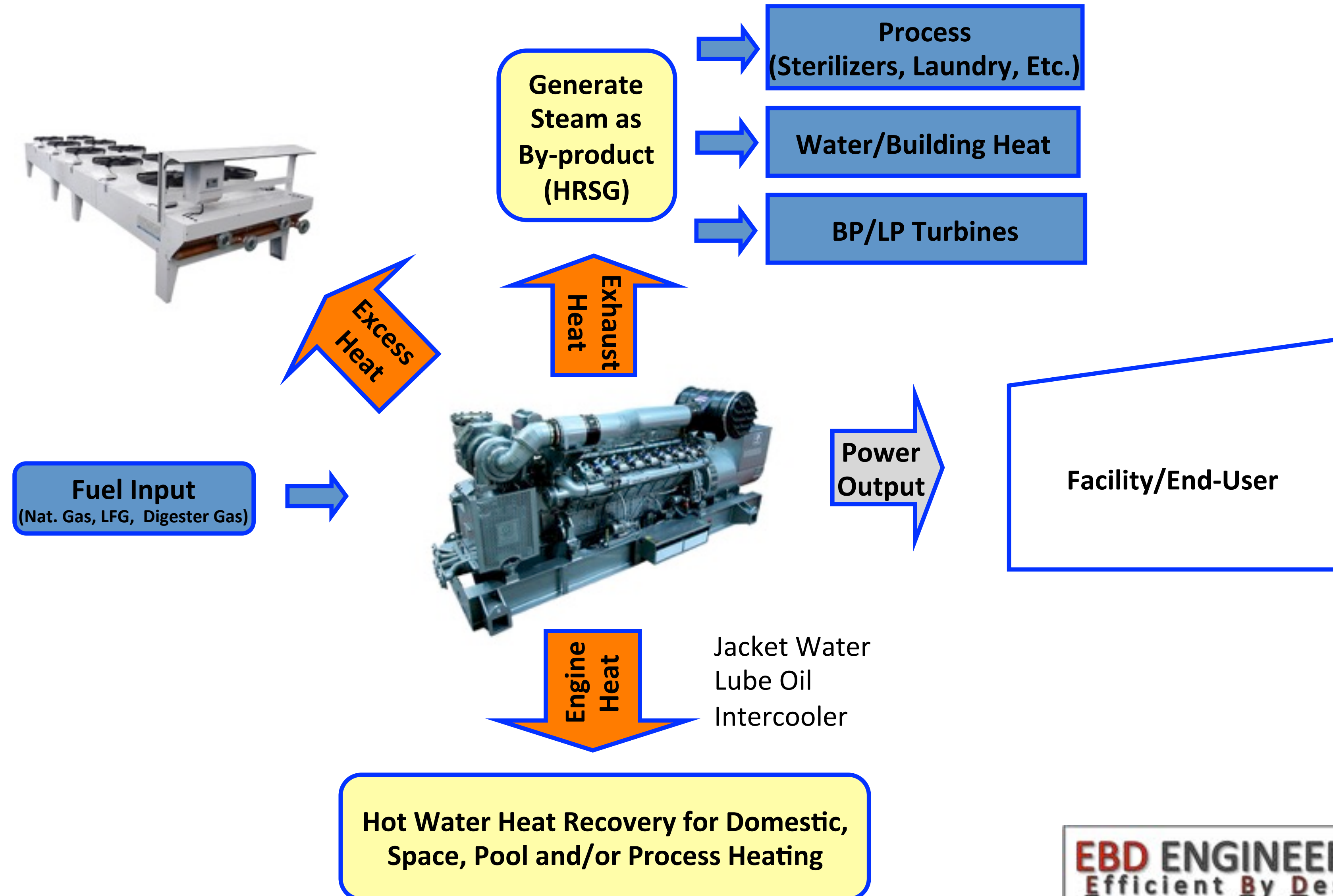
Cogeneration Overview



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Cogeneration Overview

Distributed Generation Technologies

Use for Thermal Energy

800°F

600°F

360°F

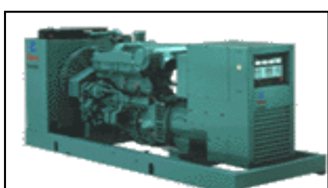
180°F

Gas-turbine

Solid Oxide Fuel Cell

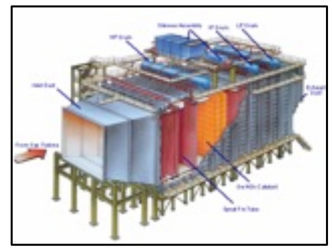
Micro-turbine

Commercial Phosphoric Acid Fuel Cell



I.C. Engine

Residential PEM Fuel Cell



Heat Recovery Steam Generator, ORC's

Double-Effect Absorption Water-Cooled Chiller

Single-Effect Absorption Chiller

Desiccant Technology

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Cogeneration Overview

Features

- Generate power onsite at a cost that is lower than can be purchased
- Utilize exhaust heat to produce steam for space heating, process loads and space cooling
- Utilize hot water waste heat for domestic hot water, condensate and space heating, process loads, absorption cooling, etc.
- Optimize the size of the system by matching the electric and heat profiles of the facility

Benefits

- Energy and Operational Cost Savings
- Improved Power Reliability
- Added Heating/Cooling System Redundancy
- Control of Customer's Utility Future
- Design in Future Site Expansion
- Societal Benefits: Reduced Total Emissions, Reduced Stress on Power Grid.
- Beneficial Grants/Incentives

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Cogeneration Overview

In general, the market for CHP includes:

- Hospitals, Nursing Homes
- Colleges & Universities
- Waste Water Treatment Plants
- Manufacturing
- Pharmaceuticals & Chemical Companies
- Pulp/Paper Mills
- Large Mixed Use Developments (Office & Residential Mix)

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Cogeneration Overview

Barriers to entry:

- Environmental Permitting
- Utility Interconnection Requirements
- Utility Rate Structure (Backup Demand Charges, Ratchets, etc.)
- Lack of Rebates and Incentives
- Lack of Benefit for Environmental Benefits of CHP (REC's)
- Depreciation schedules for CHP Investments Vary Depending on Ownership and May Not Reflect the True Economic Life of the Equipment

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Technology Summary

- Combustion Turbines – Natural Gas/Diesel Fuel/Landfill Gas
- (Including Microturbines)
- Reciprocating Engines - Natural Gas/Diesel Fuel/Landfill Gas
- Fuel Cells – Natural/Landfill Gas
- Steam Turbine/Combined Cycle Plant – Boilers can operate on Natural Gas/Landfill Gas/Biomass/Fuel Oil, Coal, Wood Chips, etc.

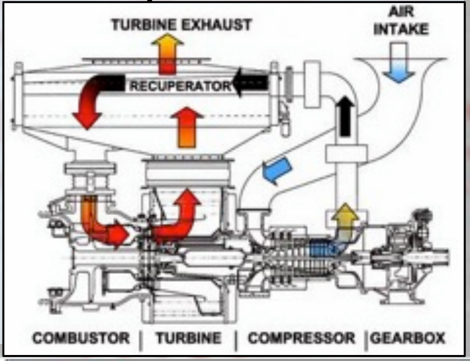
Technology Summary

Combustion Turbines

- Natural/Landfill Gas, Jet Fuel & Diesel Fuel
- Fuel to Electric Efficiencies – 21% - 40%
- Size Range – 30 kW – 100's of MW
- High Grade Waste Heat Used to Make Steam Through HRSG
- Turbines Can Be Recuperated and Non-Recuperated

(Recuperator Preheats Compressed Air Before Combustion to Increase Electrical Efficiency)

- HRSG Can be Duct Fired to Create More Steam Very Efficiently
- Handful of Manufacturers with Long History
- High Uptime Percentage
- Long Time Between Service Intervals
- Major Overhaul Required ~ 5 Years



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Technology Summary

Combustion Turbines (Continued)

- High Pressure Gas Requirements (Often Require Gas Compression)
- Noise Must be Considered
- Emissions Varies Greatly Between Manufacturers (5 ppm – 50 ppm NOX)
- Performance Degrades with Outdoor Air Temperature
- Performance Degrades with Cleanliness of Compressor/Turbine Blades
- Overall Net Efficiencies Can Reach > 80%

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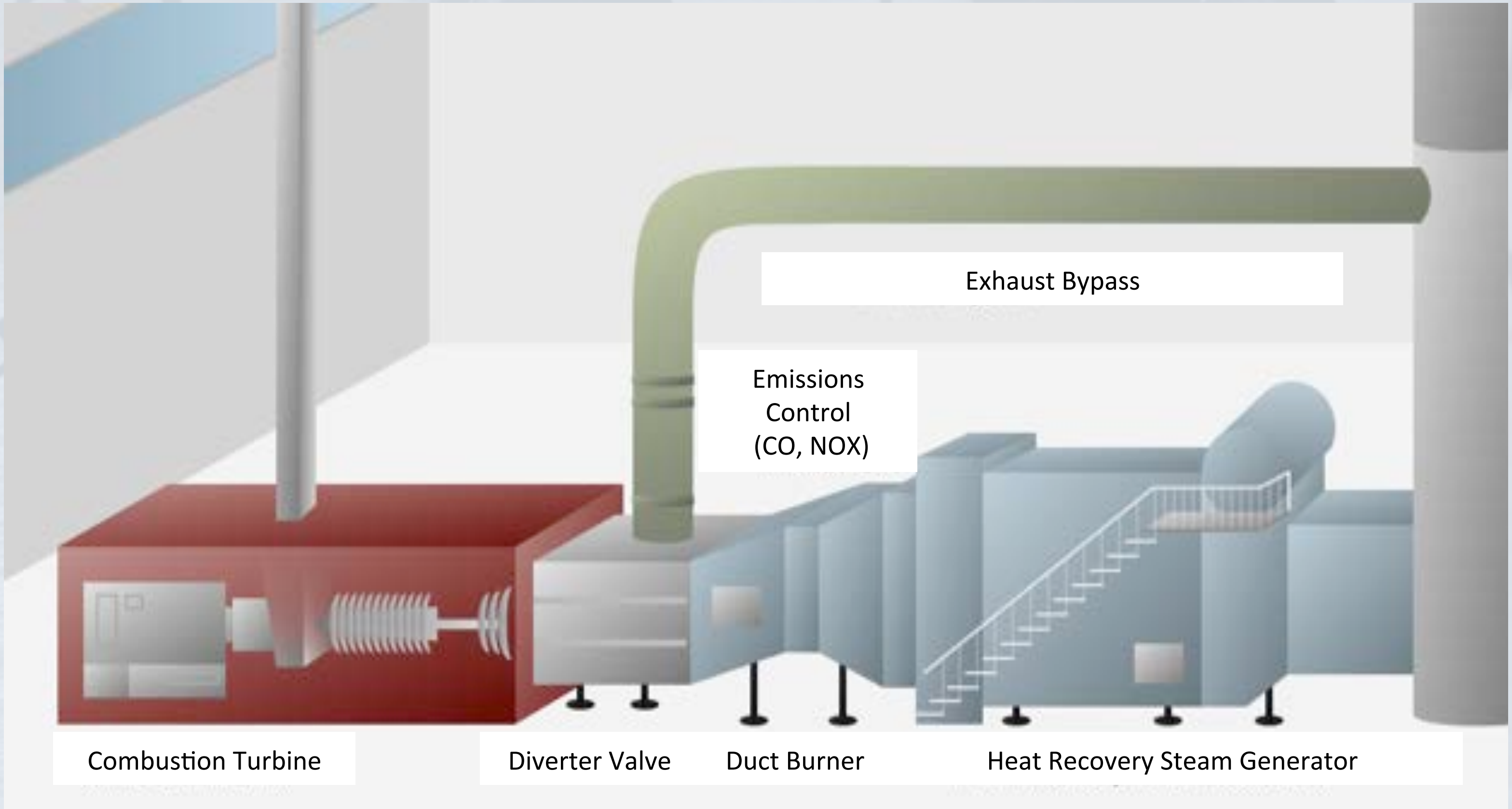
Technology Summary

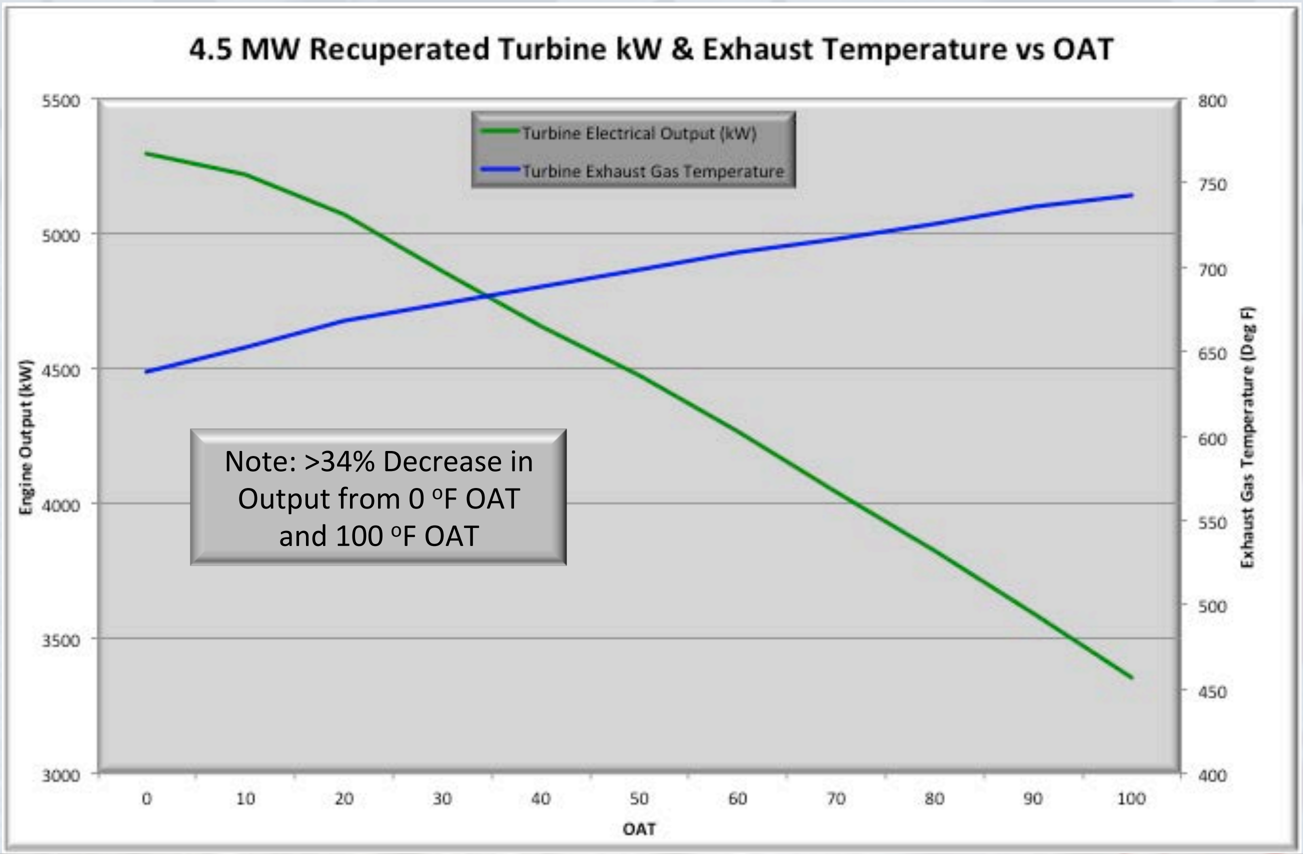
Combustion Turbines (Continued) – Typical Layout



Technology Summary

Combustion Turbines (Continued) – Performance VS OAT

- As OAT Rises, kW Output Drops and Exhaust Temperature Increases



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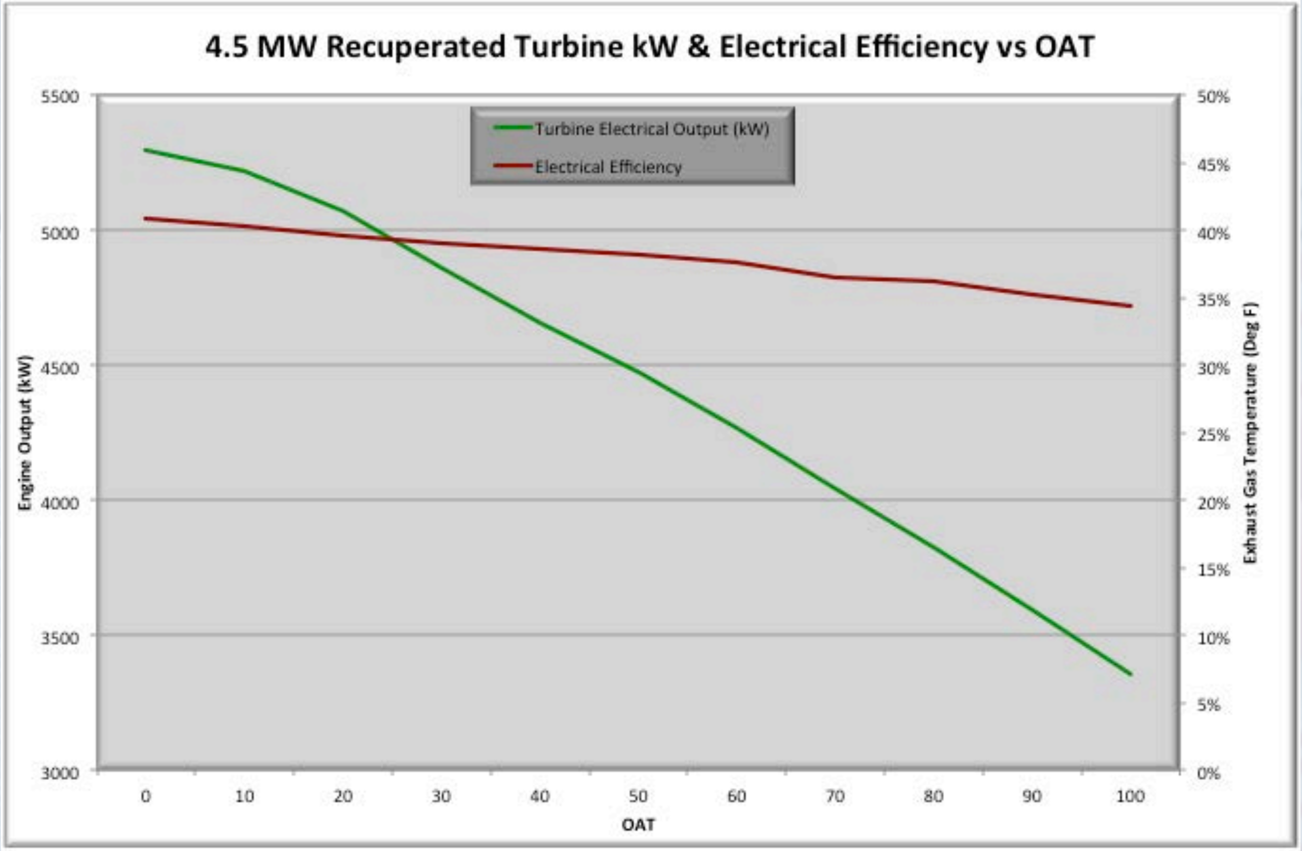
Technology Summary

Combustion Turbines (Continued) – Performance VS OAT``

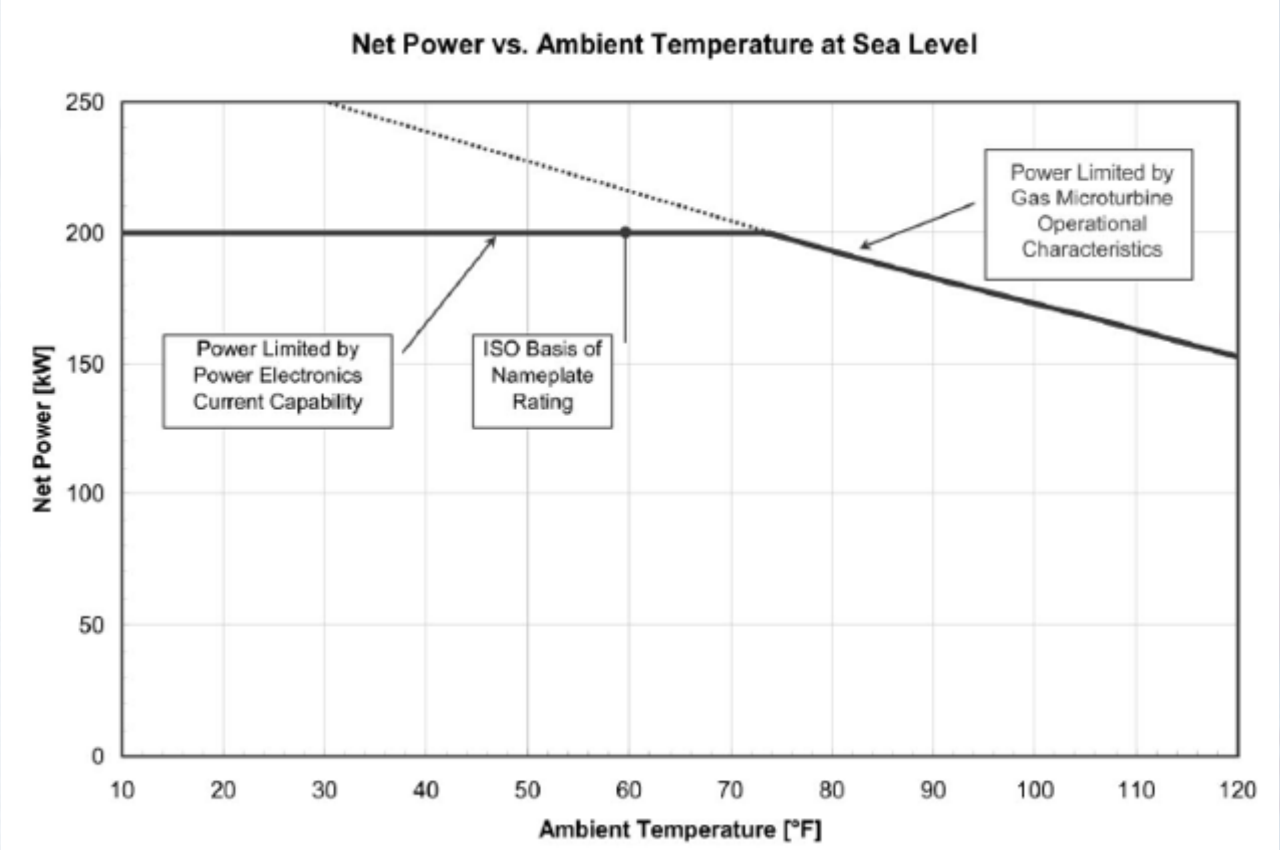
- As OAT Rises, kW Output Drops and Electrical Efficiency Decreases



Technology Summary

Combustion Turbines (Continued) - Microturbine

- As OAT Rises, kW Output Drops



Technology Summary

Combustion Turbines (Continued) - Manufacturers

- Capstone (30 kW, 60 kW, 200 kW Packages (Can Be Combined – 1 MW)
- GE (>25MW – 1500 MW)
- Kawasaki Gas Turbines Americas (600 kW – 18 MW)
- Opra Turbines (1.8 MW)
- PW Power Systems (30 MW – 140 MW)
- Siemens (4 MW – 400 MW)
- Solar Turbines (1.2 MW – 22 MW) – Division of Caterpillar

Technology Summary

Combustion Turbines (Continued)

- Turbine Waste Heat Boilers Are Used to Capture Exhaust Energy from Turbines to Generate Steam (HRSG) or High Temperature Hot Water
  - Rentech
  - Energy Recovery International
  - Deltak
  - Babcock Power
  - Cain

Technology Summary

Combustion Turbines (Continued)

- Size/Scale of 4.5 MW CHP Plant, 30 klb/hr HRSG, 700 Ton Absorber

Technology Summary

Combustion Turbines (Continued) -

- Size/Scale of 4.5 MW Unit

Turbine Size
10'-5" x 36'-6"

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Technology Summary

Combustion Turbines (Continued)

- Lube Oil Cooler & Combustion Air Inlet for 4.5 MW Unit

Technology Summary

Combustion Turbines (Continued)

- Duct Burner, Gas Meter and Scanner Blower

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Technology Summary

Combustion Turbines (Continued)

- Size/Scale of 1.0 MW CHP Plant, Chilled Water and Hot Water HR

320 Tons of Cooling

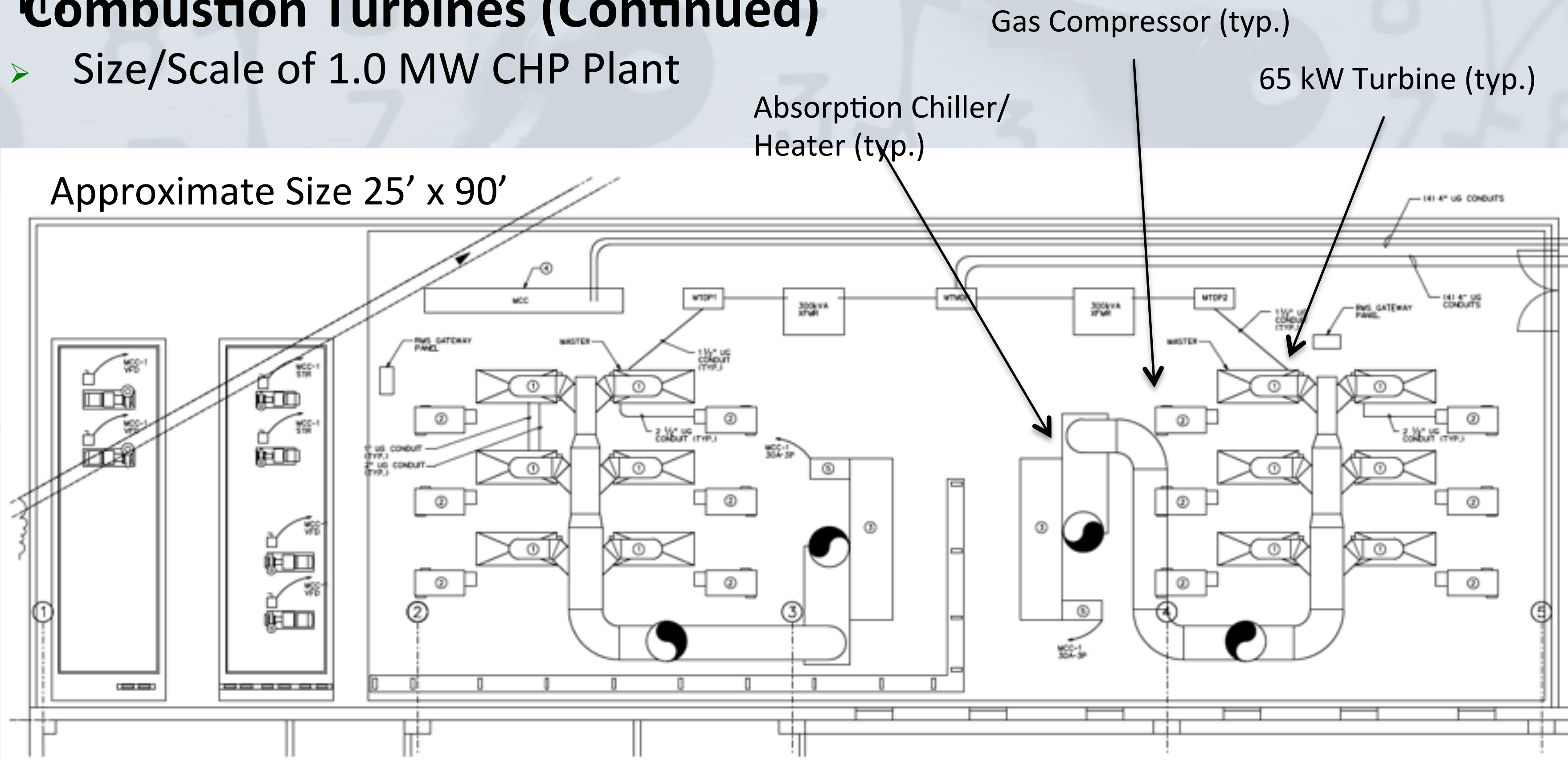
Up to 3,000 MBH Hot Water

Technology Summary

Tri

Combustion Turbines (Continued)

➢ Size/Scale of 1.0 MW CHP Plant



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Technology Summary

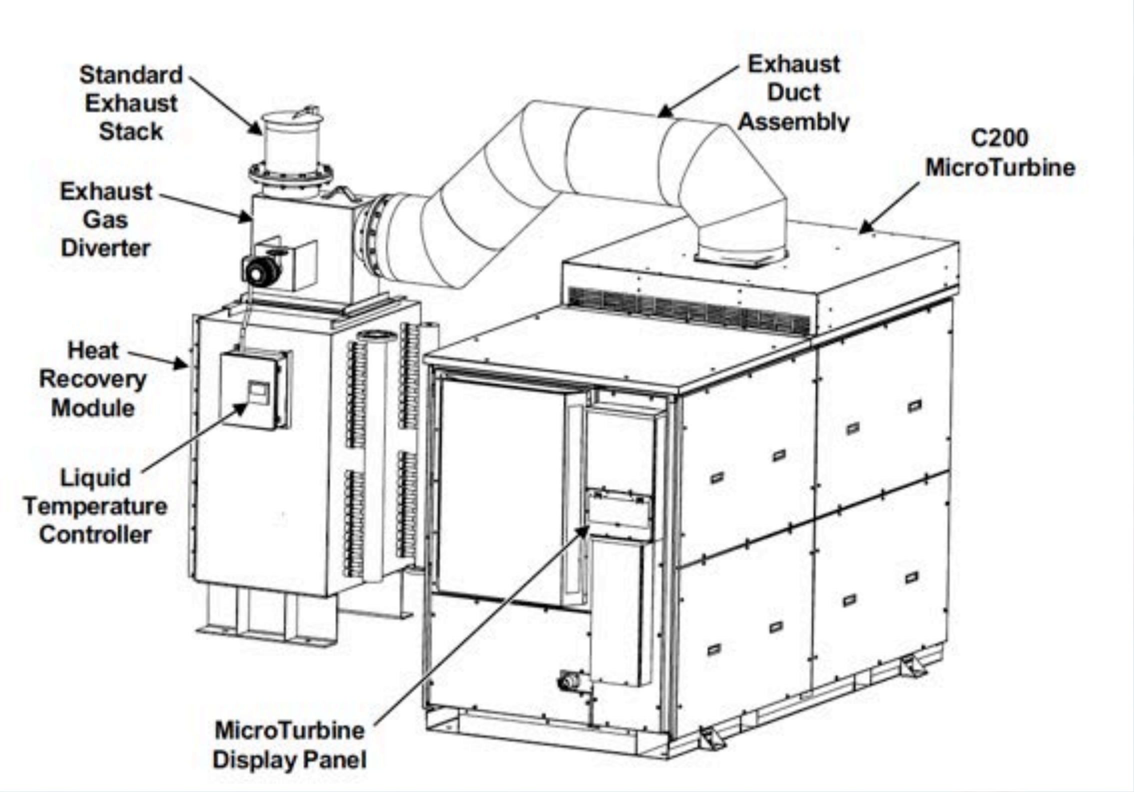
Combustion Turbines (Continued)

- Size/Scale of 1.0 MW CHP Plant

Technology Summary

Combustion Turbines (Continued)

- Microturbine Options



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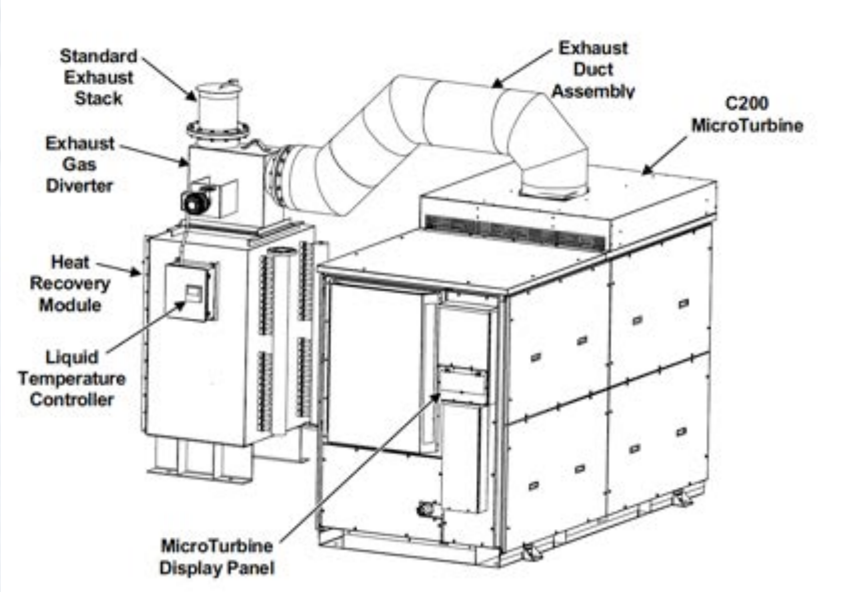
Technology Summary

Combustion Turbines (Continued)

- Microturbine Options
- Hot Water/Steam VS HW/CHW

Microturbine to HRSG



200 kW Turbine
(75 – 80 psig inlet gas pressure)

Microturbine(s) to Chiller/
Hot Water Heater

Technology Summary

Reciprocating Engines

- Natural/Landfill/Bio Gas & Diesel Fuel
- Fuel to Electric Efficiencies – 25% - 49%
- Size Range (60 kW – 15 MW)
- High Grade Waste Heat Used to Make Steam Through HRSG from Exhaust
- Low Grade Waste Heat from Jacket Water, Lube Oil and Inter/Aftercooler
- Handful of Manufacturers with Long History
- Good Uptime Percentage (>92%)
- Shorter Duration Between Service Intervals
- Maintenance Daily/Weekly/Monthly
- Major Overhauls Depend on Engine Speed (720, 900, 1200, 1800 RPM)

Technology Summary

Reciprocating Engines (Continued)

- Low Pressure Gas Requirements
- Quick Initial Startup to Full Load
- Noise/Vibration Must be Considered
- Emissions Varies Greatly Between Manufacturers
- Lean Burn Versus Rich Burn Options Depending on Application
- Performance Does Not Degrade with Outdoor Air Temperature
- Overall Net Efficiencies Can Reach > 80% If a Home Can Be Found for Low Grade Heat (Hot Water)

Technology Summary

Reciprocating Engines (Continued)

- Aegis (75 kW)
- Caterpillar (85 kW – 4 MW)
- Cummins (300 kW – 2MW)
- Gauscor (150 kW – 900 kW)
- Jenbacher (250 kW – 9.5 MW)
- Kawasaki (5MW – 7.5 MW)
- MAN (68 kW – 580 kW)
- Schmitt (100 kW – 500 kW)
- Tecogen (65 kW – 100 kW)

Note: Smaller Engines Typically Are Used Only to Heat Hot Water and Not to Provide Steam

Technology Summary

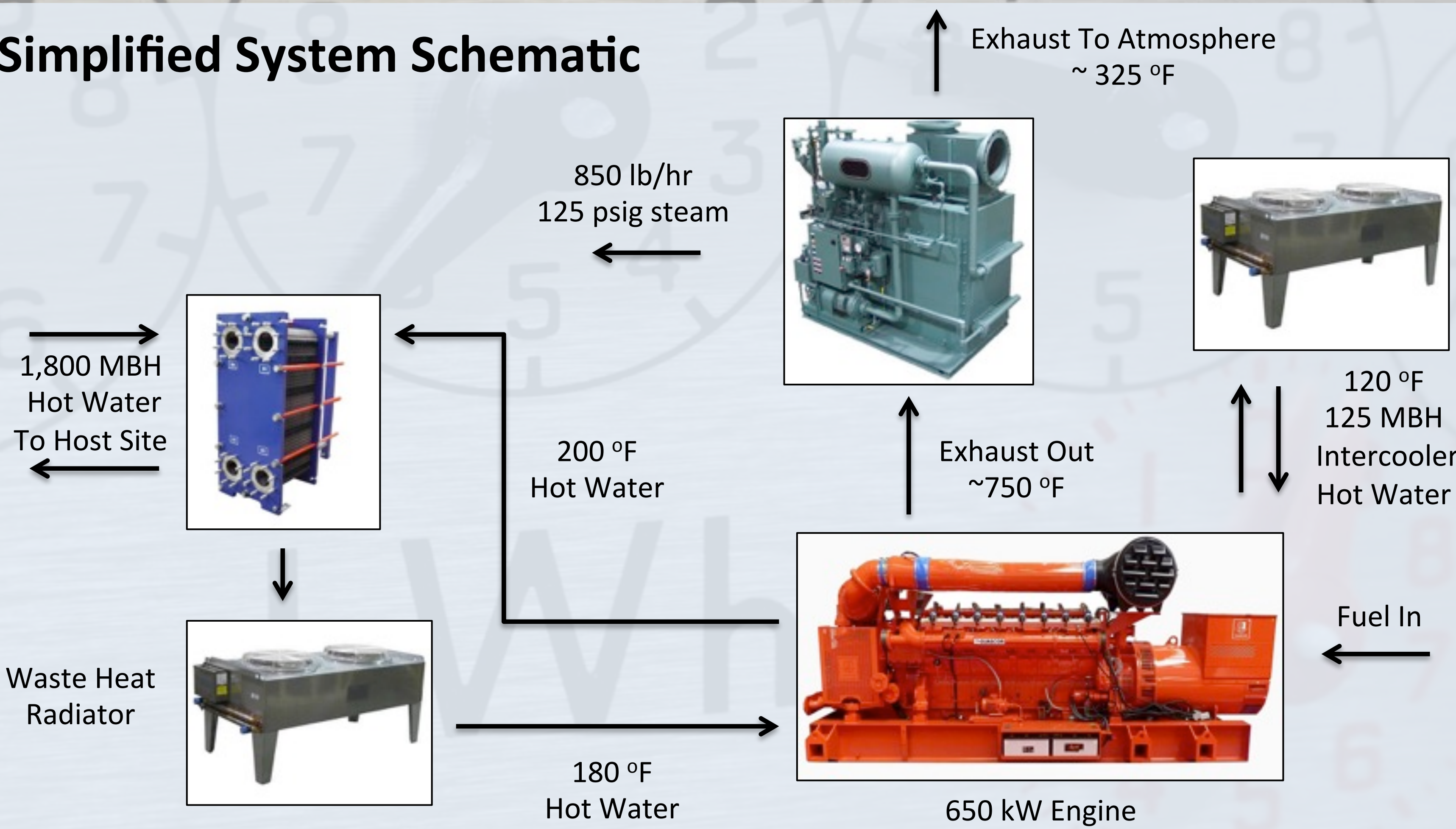
Reciprocating Engines (Continued)

Example of Reciprocating Engine Maintenance Activities

- Check Oil Level/Pressure (Daily)
- Check Battery Acid Levels (Monthly)
- Greasing of Generator Bearings (Every 1,000 Hours)
- Spark Plug Replacement (1,400 Hours on 1800 RPM Engine, 4,000 Hours on Slower Speed Engines)
- Check Valve Clearance (Every 2,000 Hours)
- Oil/Oil Filter Replacement (Every 2,000 Hours)
- Check Air Filters, Verify Ignition Timing (~4,000 Hours)
- Recondition Cylinder Heads, Change High Voltage Wires (~8,000 hours)
- Replacement of Generator Bearings, Pistons, Cylinder Linings (20,000 Hours)
- Turbo Replacement/Refurbishment, Change Connecting Rods (~ 20,000 hours)
- Engine Overhaul Including Cylinder Block, Crankshaft, Camshaft (48,000 - 60,000 hours)

Technology Summary

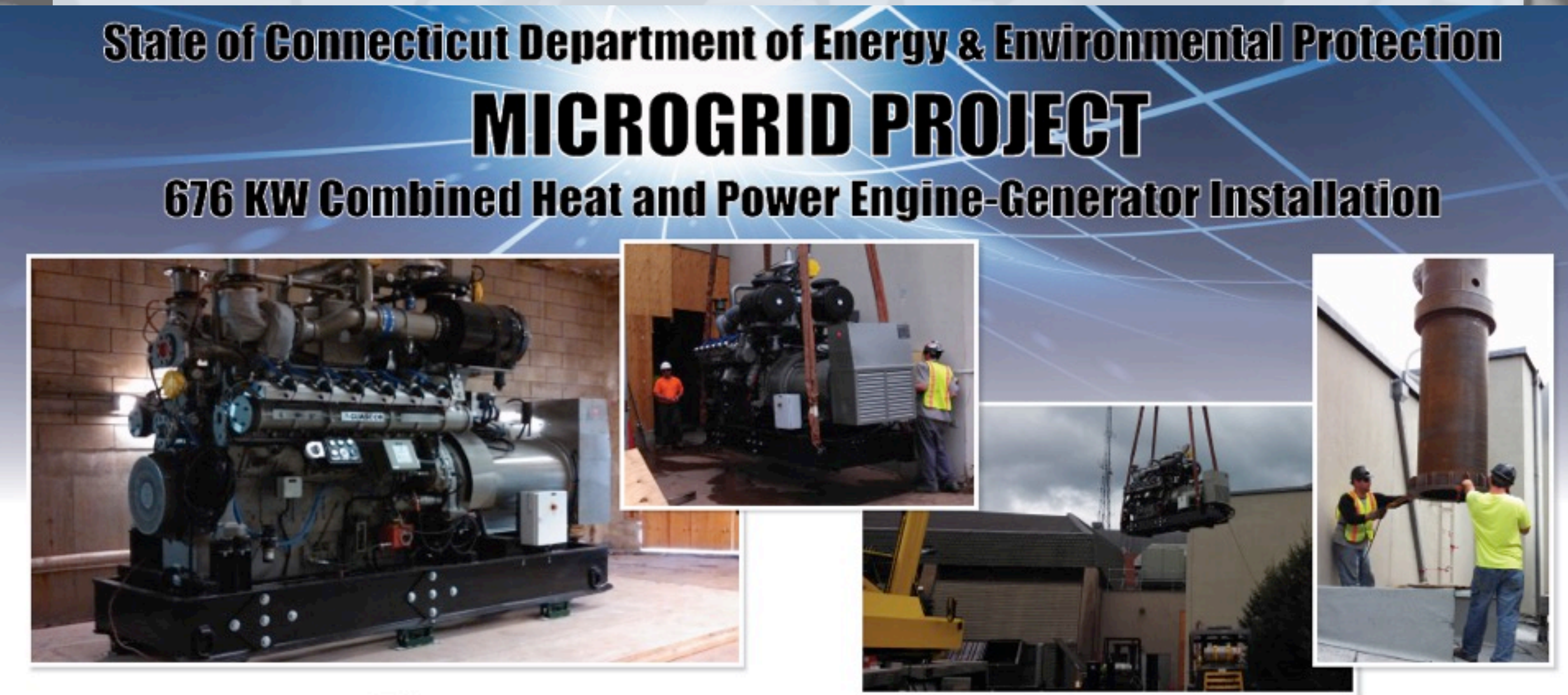
Simplified System Schematic



Technology Summary

Reciprocating Engines (Continued)

- Size/Scale of 670 kW CHP Plant, 840 lb/hr HRSG, 1,747 MBH HW



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Technology Summary

Reciprocating Engines (Continued)

- Size/Scale of 3,000 kW CHP Plant, 4,150 lb/hr HRSG, 4,416 MBH HW

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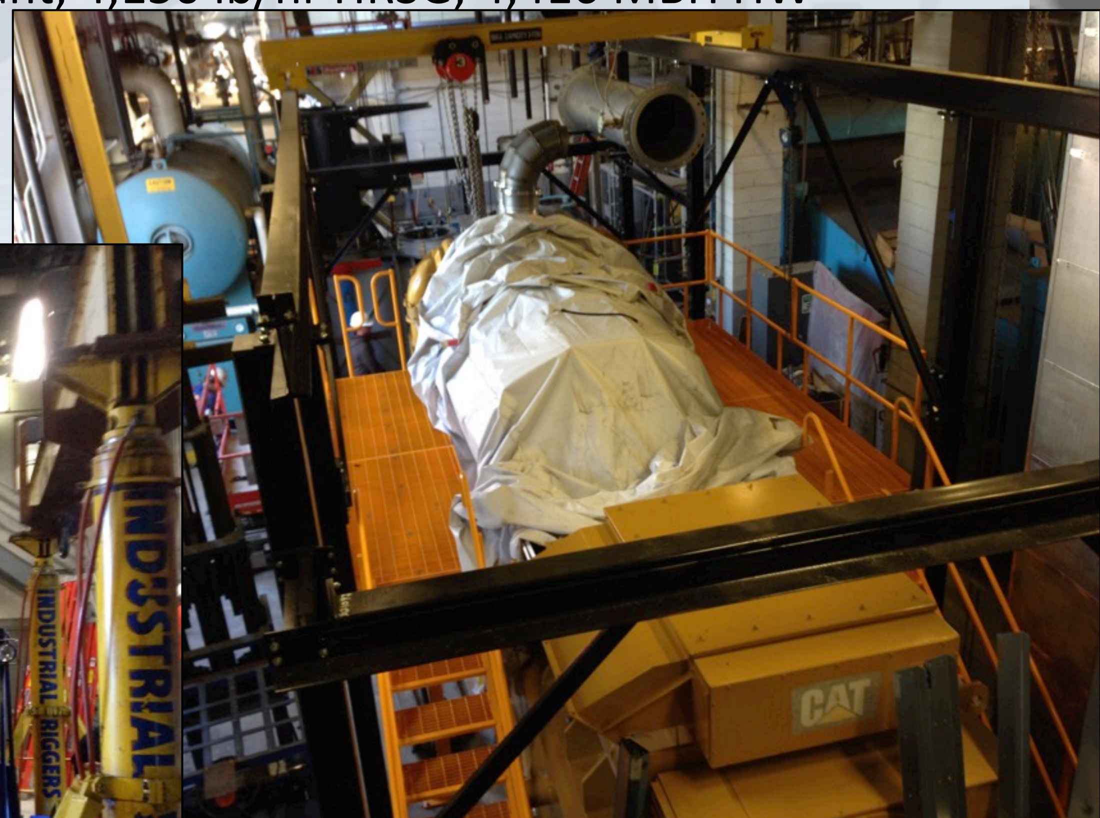
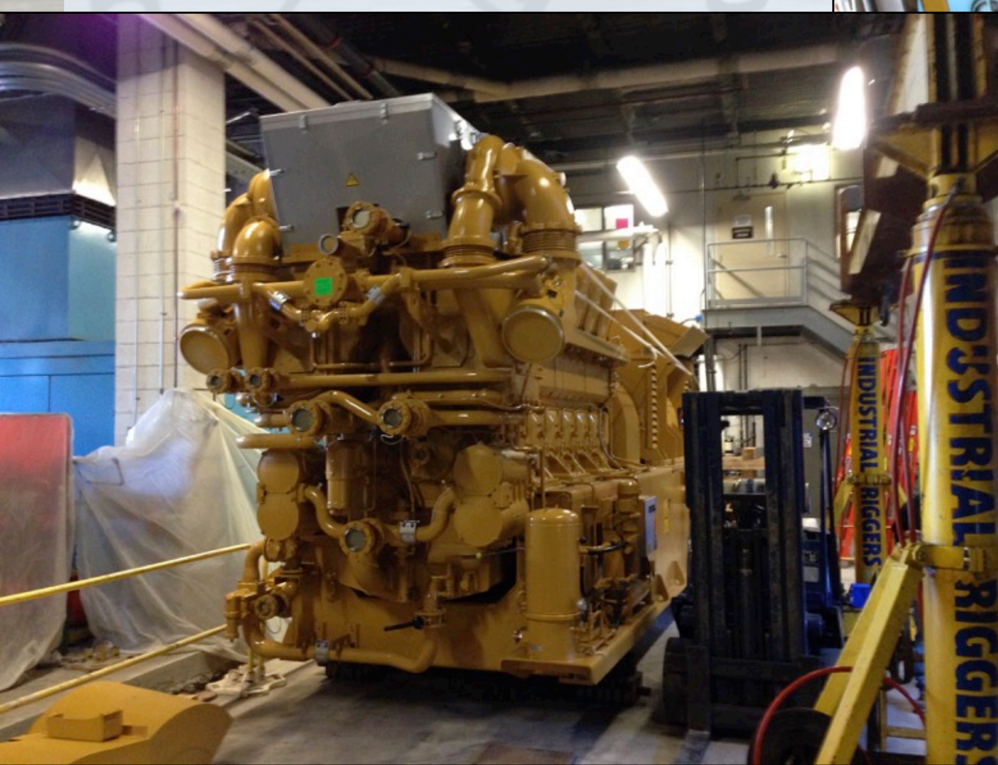
Technology Summary

Reciprocating Engines (Continued)

- Size/Scale of 3,000 kW CHP Plant, 4,150 lb/hr HRSG, 4,416 MBH HW





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Technology Summary

Fuel Cells

- Natural/Bio Gas
- Electrochemical Process (No Combustion)

- Molten Carbonate, Phosphoric Acid, Solid Oxide
- Fuel to Electric Efficiencies – 40% - 47%
- Size Range (400 kW – Multi MW Via Paralleling Units)
- Small Scale Units Heat Can Provide Both 200 ^{o}F and 120 ^{o}F Hot Water
- Larger Units (<1.4 MW) Produce Steam as Well as 200 ^{o}F and 120^{o}F Water
- Limited of Manufacturers (Bloom, Doosan, FCE)
- High Quality Power (DC to AC Conversion)
- Good Uptime Percentage (>92%)
- Reduced Output with Service Life

Technology Summary

Fuel Cells

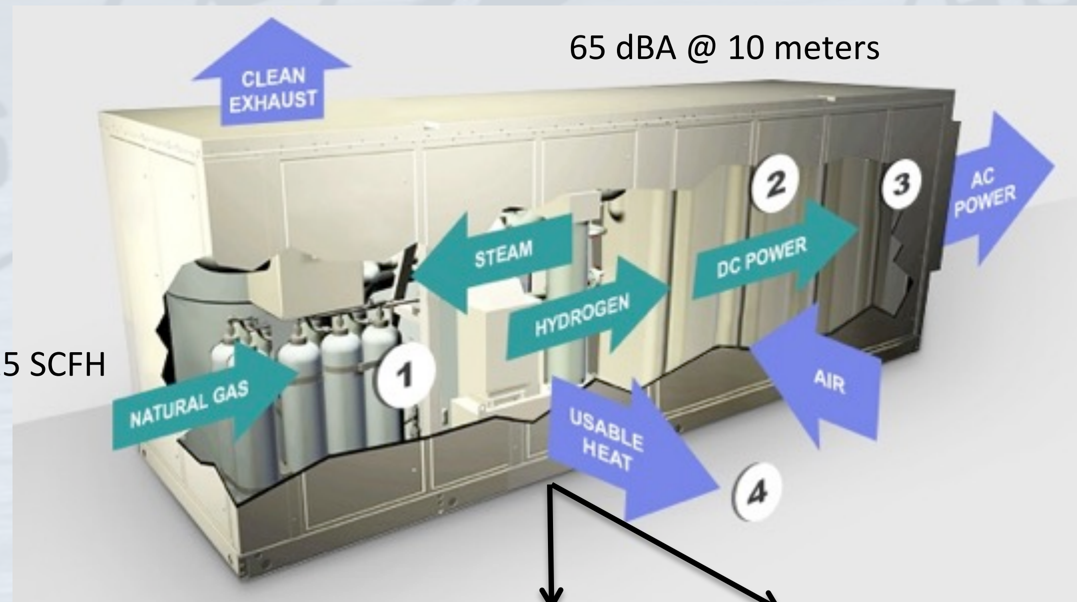
- Class I Renewable – Assists with Rebates/Incentives and Renewable/ Alternate Energy Credits (higher credit/mWh)
- Federal Tax Credits (30% Investment Tax Credit)
- Virtually Emissions Free
- Limited Water Usage Required
- High Material Costs
- Gas Must be Cleaned to Meet Certain Specifications if Biogas is Used. This Can Get Expensive
- High Maintenance Costs – Stack Life ~ 5 Years During Which Time Electrical Output Degrades and Heat Output Increases (10% Degradation)
- Typically More Expensive Than Other Technologies (Use Incentives/ Rebates, REC's to Help Bring Cost In-Line With Other Offerings)

Technology Summary

Doosan Fuel Cell Example – 400 kW

65 dBA @ 10 meters

3,515 SCFH



400 kW to Host Site

42% Electrical Eff.

640,000 BTU/HR (Up to 250 °F)

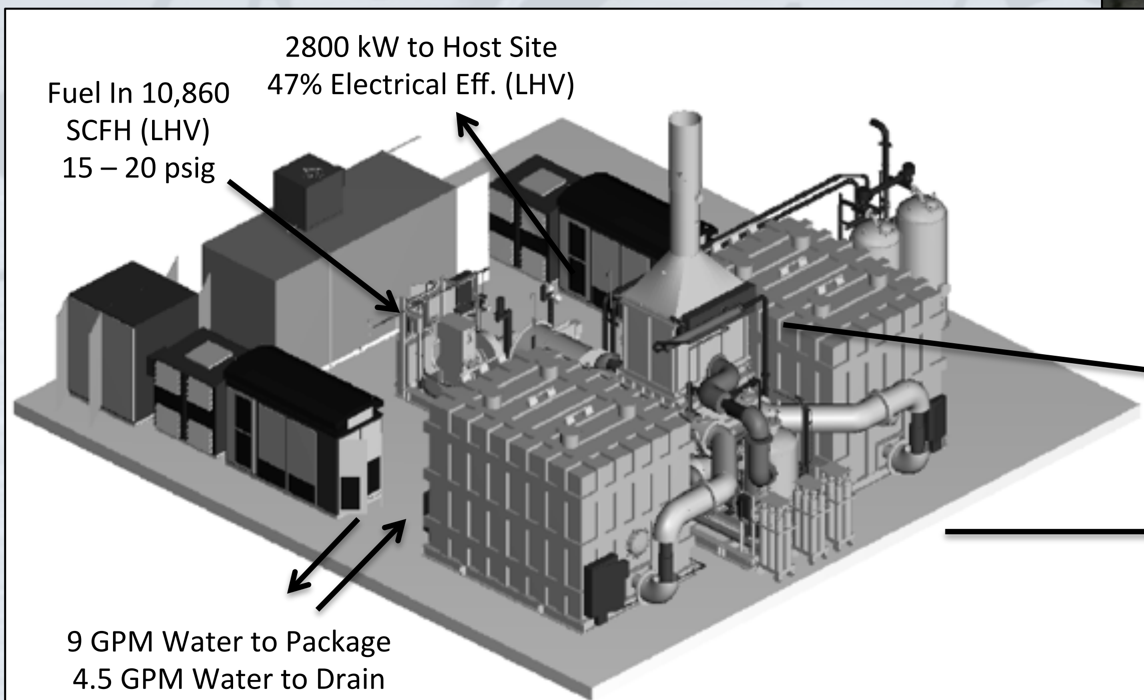
880,000 BTU/HR (Up to 140 °F)

Technology Summary

Fuel Cell Energy Example – 2.800 MW

Approximate Footprint – 44’W x 70’W x 26’H

72 dBA @ 10 feet



~700 °F Exhaust to HRSG
(~3,000 lb/hr)

4,433,000 BTU/H @ 250 °F
7,460,000 BTU/HR @ 120 °F

What Do I Do Next?

- The first step is typically to undertake a feasibility study. These studies are performed by qualified engineering teams with years of experience in the <u>design</u>, <u>construction</u> and <u>operation</u> of CHP plants
- These studies typically include:
  - Site Survey of Existing Systems and Equipment (Fuel Type, HW, Steam, CHW Loads, etc.)
  - Review of Existing Electrical and Fuel Delivery Infrastructure (Gas Pressure, Fuel Oil Tanks)
  - Detailed Interviews with Operations Staff to Understand Existing System Operations
  - Detailed Review of Utility Data (Tariffs, Interval Data, Chiller/Boiler Logs)
    - Identify Hour to Hour, Day to Night and Weekday to Weekend Changes in Load
  - Review of Existing Air Permitting
  - Review of Planning and Zoning Requirements (Siting, Acoustics, etc)
  - Discussions Regarding Master Planning (Future Site Needs)
  - Reliability/Redundancy Requirements
  - Operational Requirements of New System (Grid Parallel, Island Mode – Extended Outage)
  - Investigation Into Incentives/Rebates and REC's/AEC's
  - Discussions With Utility Company Regarding High Level Interconnection Concepts

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What Do I Do Next?

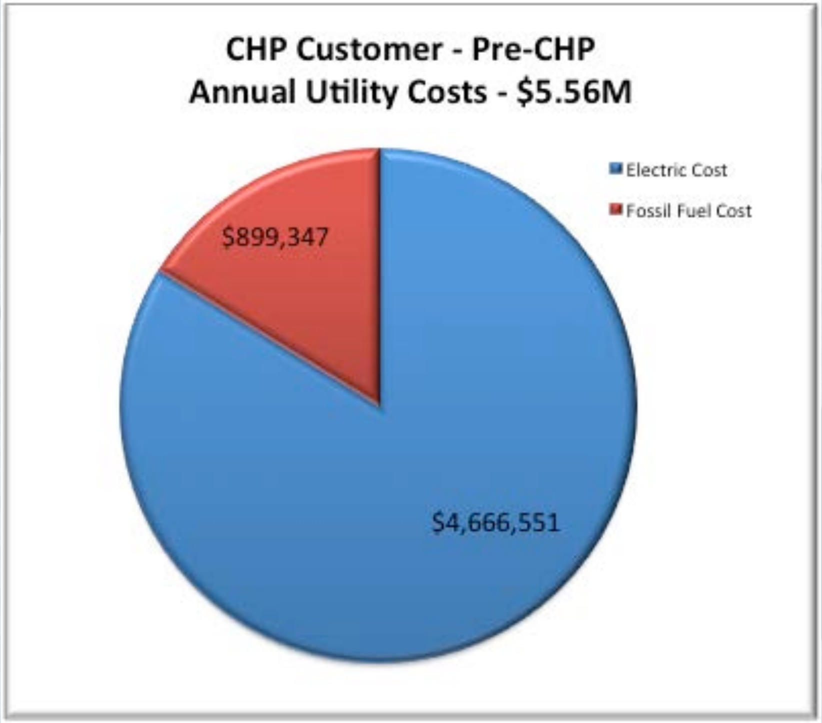
Feasibility Study (Continued)

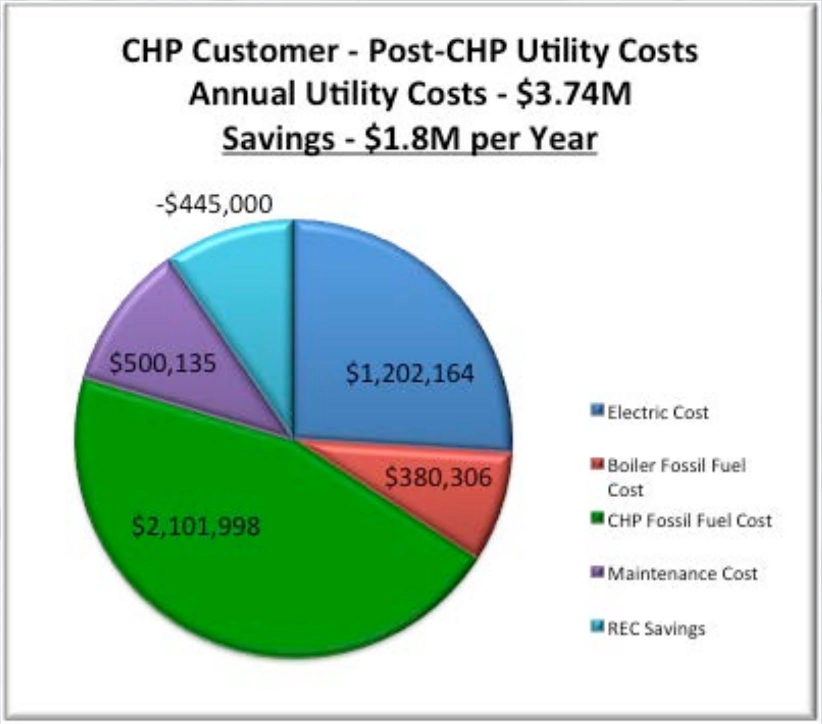
- These studies typically include:
  - Development of Alternatives and Detailed Scenario Modeling – Different Prime movers
  - Review With Decision Makers and Tune Concepts
  - Creation Conceptual Drawings
  - Development of Probable Cost Estimates From Previous Project Work, Major Equipment Cost Estimates and By Working With Contractors Experienced in CHP Installations
  - Review Financing/Construction Alternatives with Customer
  - Development of Financial Models Based on Customer Feedback for Utility Rates

    (Existing Commodity Contracts, Escalation Rates Assumed, etc), Site Growth Estimates and Financing Options Chosen
  - Modeling Also Includes Rebates/Incentives, REC's, Probable Estimates of Cost, Utility Cost Savings, Maintenance Costs, Construction Interest, etc.
  - Illustrate Sensitivity Analysis Based on Key Variables
  - Discuss Next Steps (Schematic/Design Development Package to Verify Pricing)

What Do I Do Next?

Feasibility Study (Continued) – Data Example





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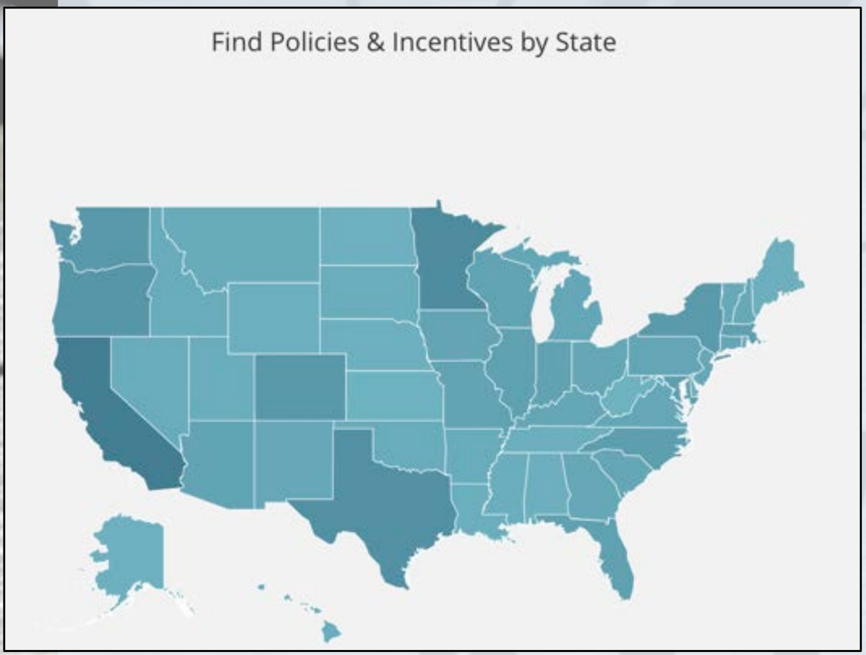
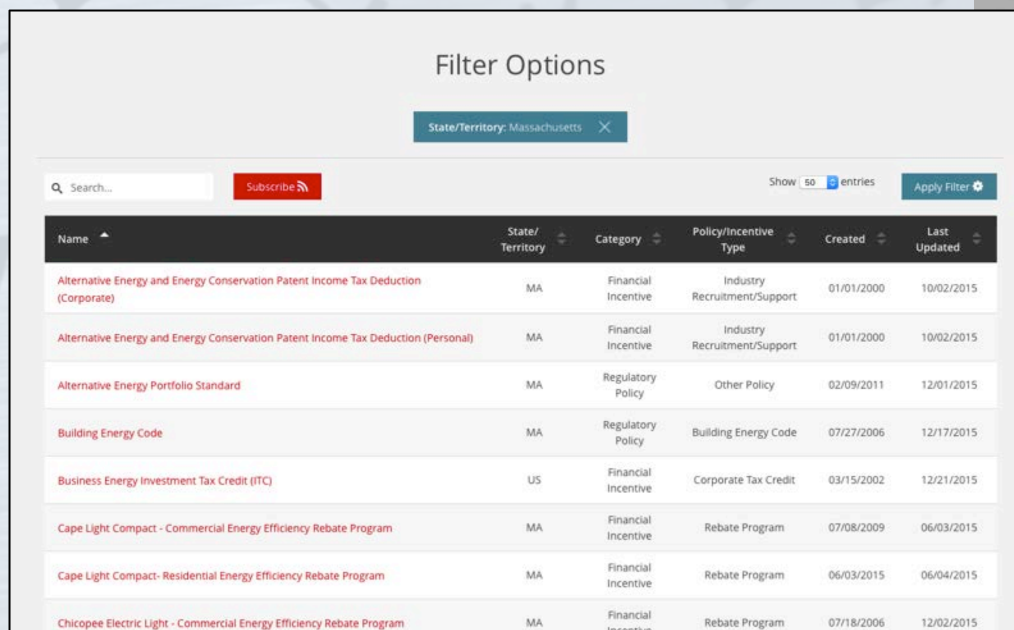
What Do I Do Next?

Feasibility Study (Continued) – Rebates/Incentives

- DSIRE Website: WWW.DSIREUSA.ORG





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Alternative Energy and Energy Conservation Patent Income Tax Deduction (Personal)	MA	Financial Incentive	Industry Recruitment/Support	01/01/2000	10/02/2015
Alternative Energy Portfolio Standard	MA	Regulatory Policy	Other Policy	02/09/2011	12/01/2015
Building Energy Code	MA	Regulatory Policy	Building Energy Code	07/27/2006	12/17/2015
Business Energy Investment Tax Credit (ITC)	US	Financial Incentive	Corporate Tax Credit	03/15/2002	12/21/2015
Cape Light Compact - Commercial Energy Efficiency Rebate Program	MA	Financial Incentive	Rebate Program	07/08/2009	06/03/2015
Cape Light Compact- Residential Energy Efficiency Rebate Program	MA	Financial Incentive	Rebate Program	06/03/2015	06/04/2015
Chicopee Electric Light - Commercial Energy Efficiency Rebate Program	MA	Financial Incentive	Rebate Program	07/18/2006	12/02/2015

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What Do I Do Next?

Feasibility Study (Continued) – Rebates/Incentives

- MassSave: Between $750/kW and $1200 per Kw Depending on Capacity & Efficiency
http://www.masssave.com/business/eligible-equipment/combined-heat-and-power

- Maine – up to $1M per project
http://www.efficiencymaine.com/opportunities/program-opportunity-notice/

- New York – NYSERDA – up to $2.5M per project
http://www.nyserda.ny.gov/All-Programs/Programs/Combined-Heat-and-Power-Program.aspx

- Connecticut – up to $450/kW plus financing options
http://www.energizect.com/your-business/solutions-list/Combined-Heat-Power

What Do I Do Next?

Feasibility Study (Continued) – Other Important Items to Consider

- Design Should Be Based on Failure Analysis
- Emergency Rentals – Contingency – CHP is an Economic Engine but Depending On Site/Process, Rentals or Backup Diesel Gensets May be Appropriate
- Availability & Efficiency Guarantees
- Equipment with Local Support and Track Record
- Service Agreements and Critical On-Site Spares
- Hire Operators with Experience Operating High Availability Plants

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EBD History/Background of CHP Projects

Partial List of EBD Projects

Customer	System Description
Danbury Hospital	4.5 MW Gas Turbine
Sikorsky Aircraft	10 MW Gas Turbine
Pratt & Whitney	7.5 MW Gas Turbine
Fairfield University	4.5 MW Gas Turbine
Data Center	1 MW MicroTurbine
Norwalk Hospital	3 MW Reciprocating Engine
Wesleyan University	650 kW Reciprocating Engine
Industrial Facility in Rhode Island	5 MW & 7.5 MW Reciprocating Engines
Industrial Facility in Florida	22.5 MW Gas Turbine

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Q&A