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CHP Lower Emissions Technologies

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Prime Mover Technology

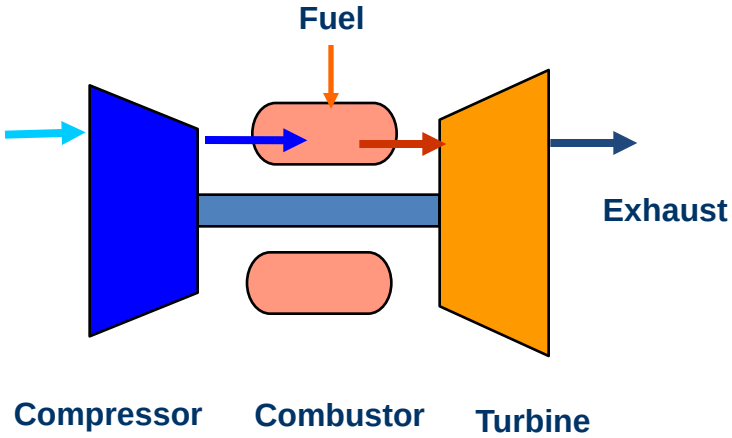
High Efficiency – Low Emissions
Gas Turbine Technology

High Efficiency Gas Turbine Origins

- Part of the U.S. Department of Energy's Advanced Turbine Systems (ATS) Program
- ATS Program Objectives
  - Achieve Single-Digit NOx Emissions
  - Improve Thermal Efficiency by 15%
  - Reduce Cost of Electricity by 10%

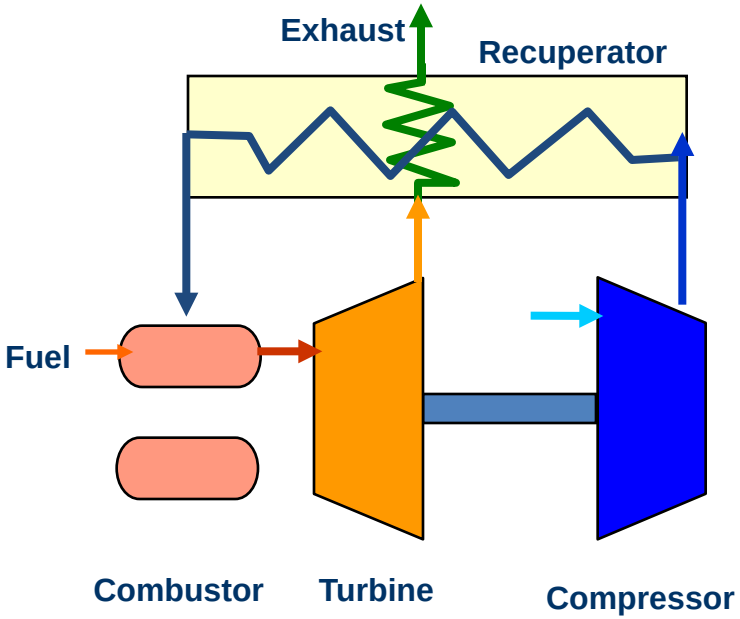
Design Options

Simple Cycle



- Increase Pressure Ratio
- Increase Firing Temperature
- Reduce Cooling Flow
- High Efficiency Components

Recuperated Cycle



- Improved Thermal Efficiency
- Lower Emissions

Selected

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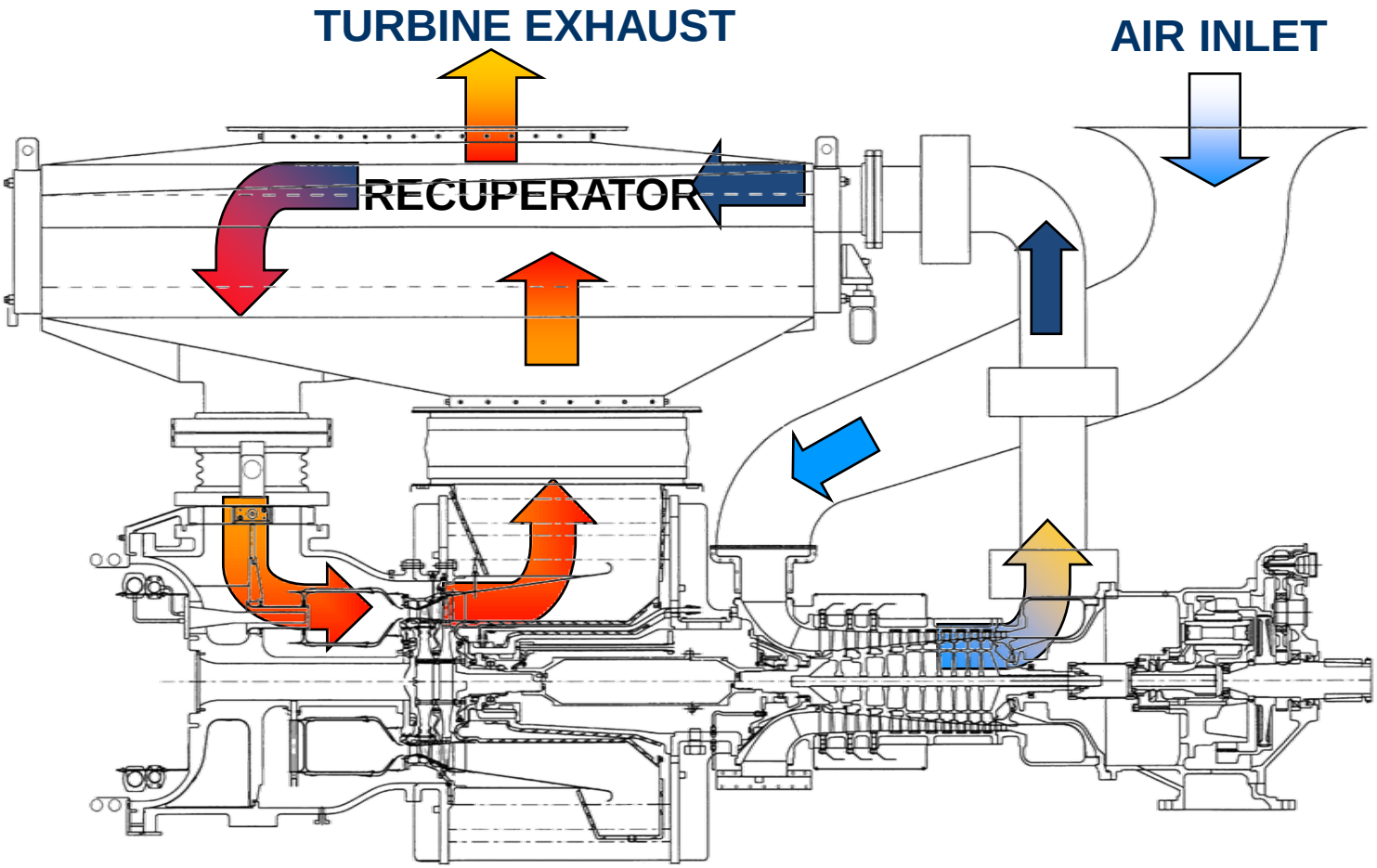
Advanced Gas Turbine Flow Path



COMBUSTOR | TURBINE | COMPRESSOR | GEARBOX

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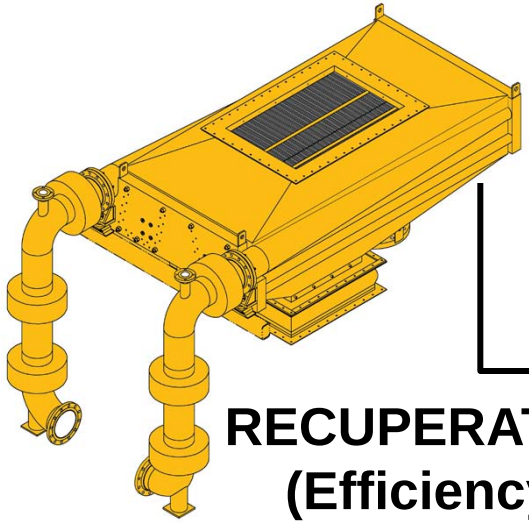
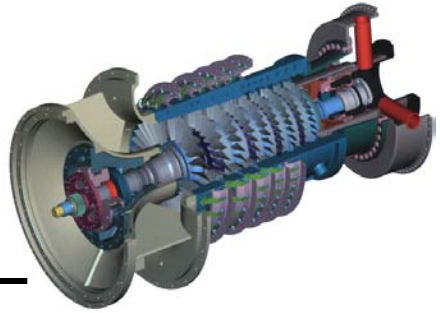
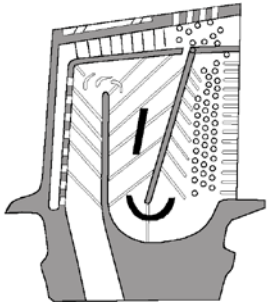
Technology Advancements

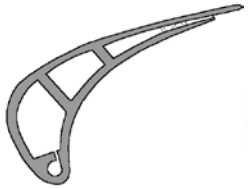


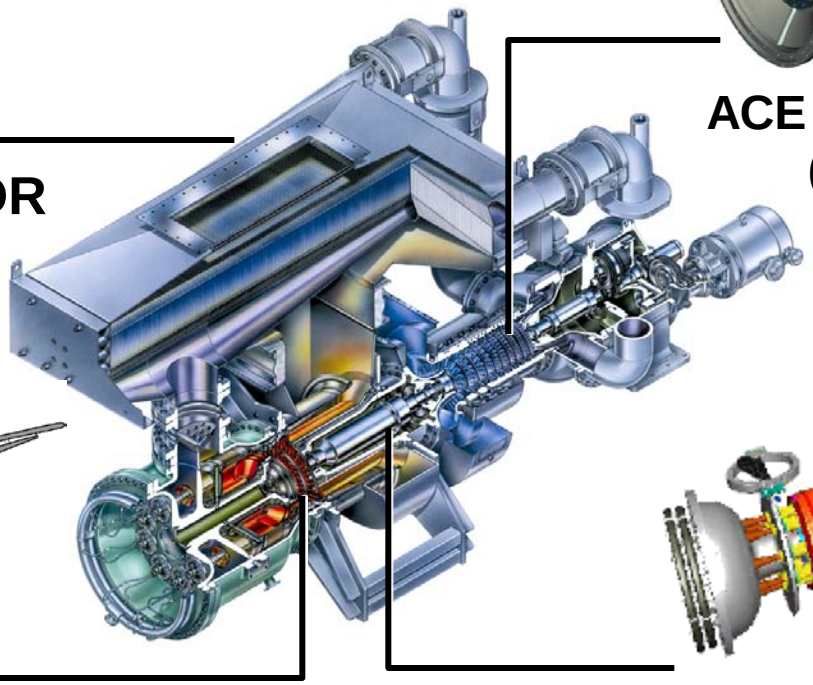
RECUPERATOR
(Efficiency)

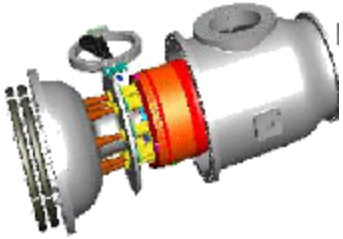


ACE COMPRESSOR
(Efficiency)









ADVANCED
BLADE COOLING
(Durability)

COMBUSTOR
(Low Emissions)

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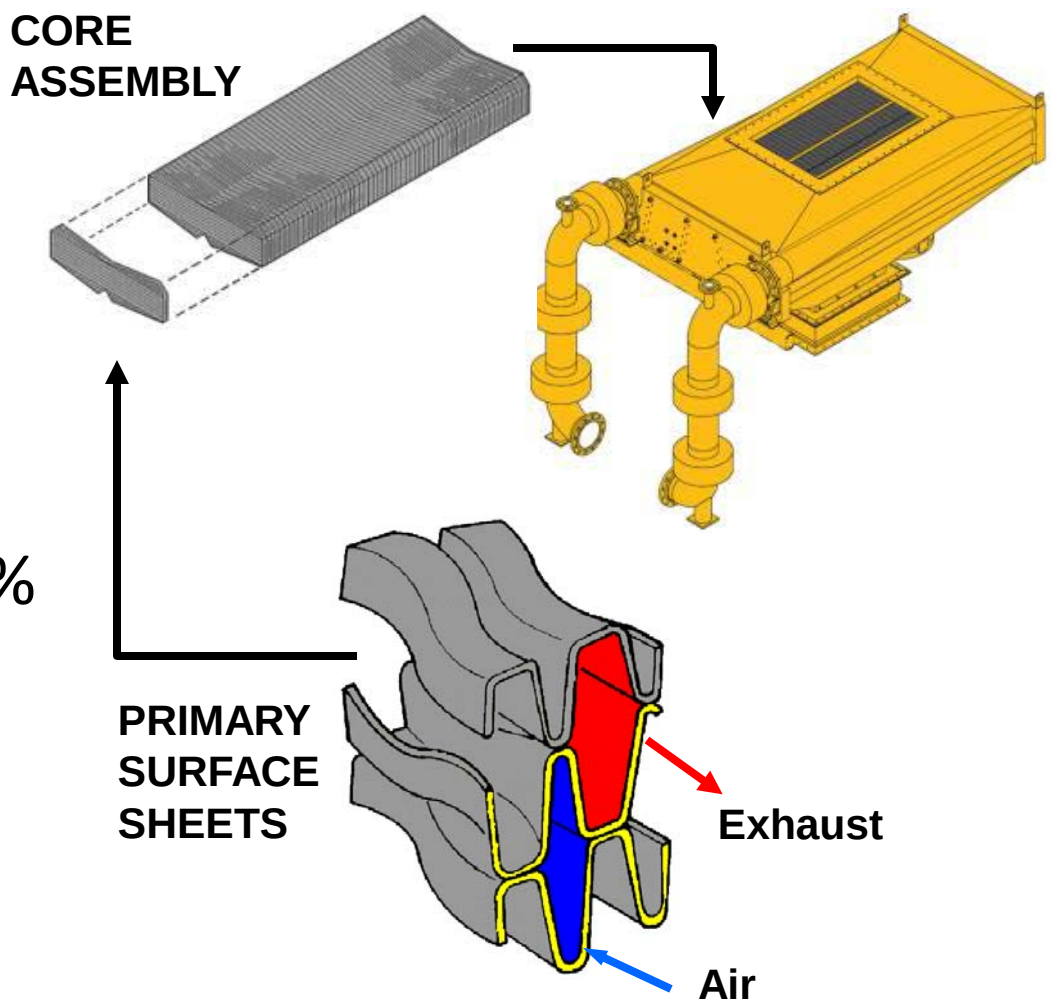
Recuperator Assembly

- Patented
- Fully Integrated with Gas Turbine Cycle Design
- High Efficiency >90%
- High Durability



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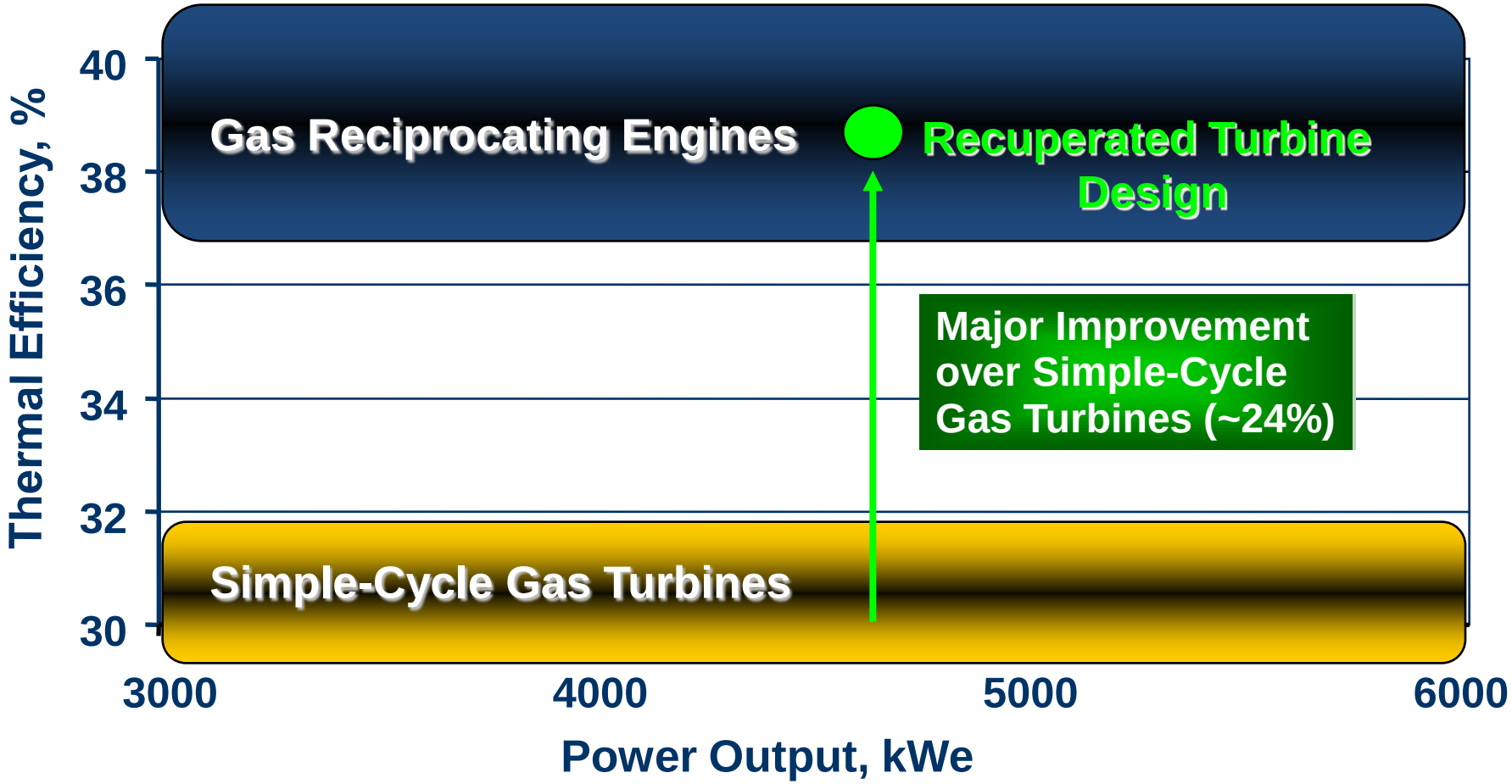
Efficiency Comparisons



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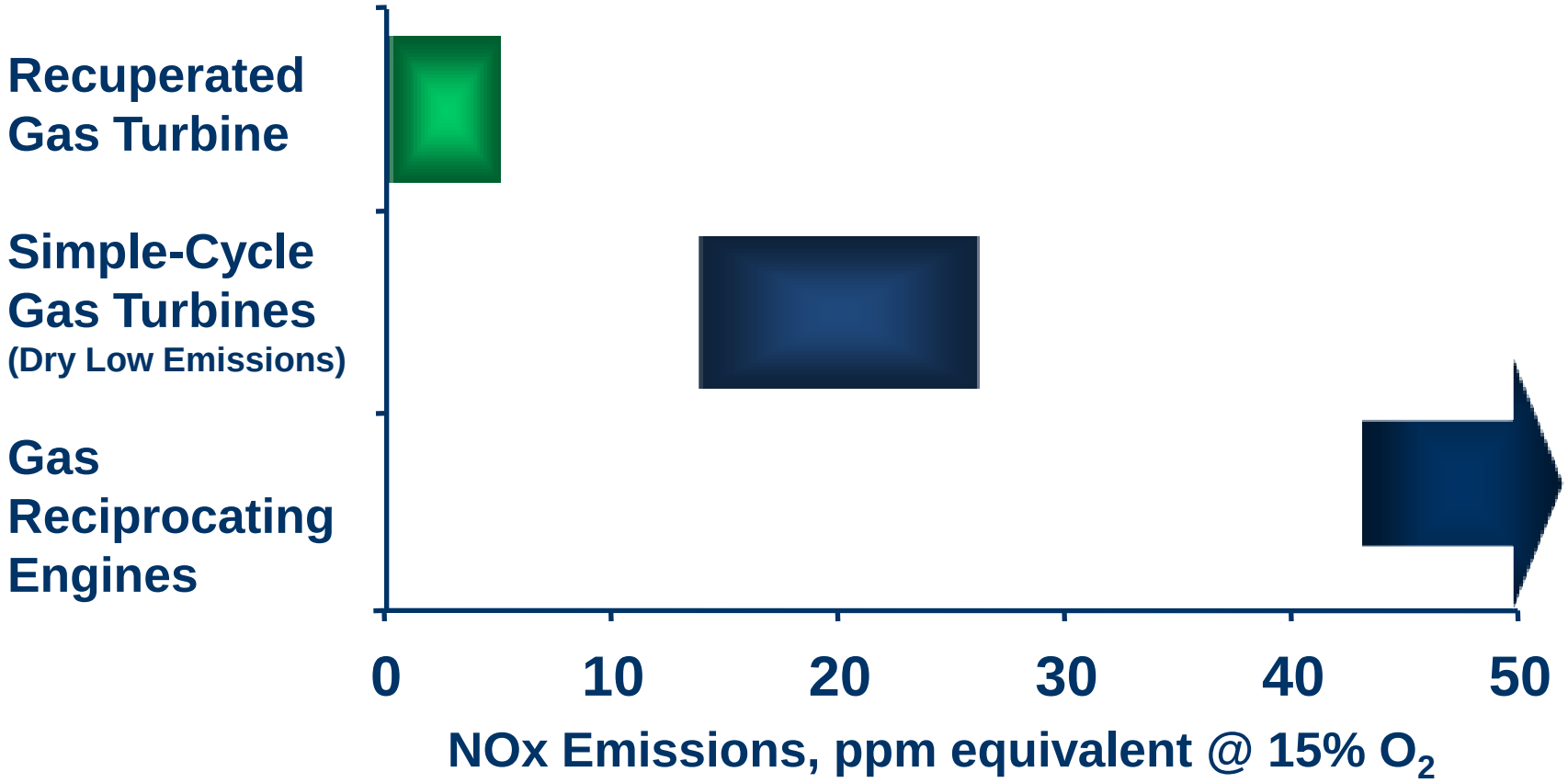
Emissions Comparisons



Note: emissions shown here on natural gas for mid-size CHP applications

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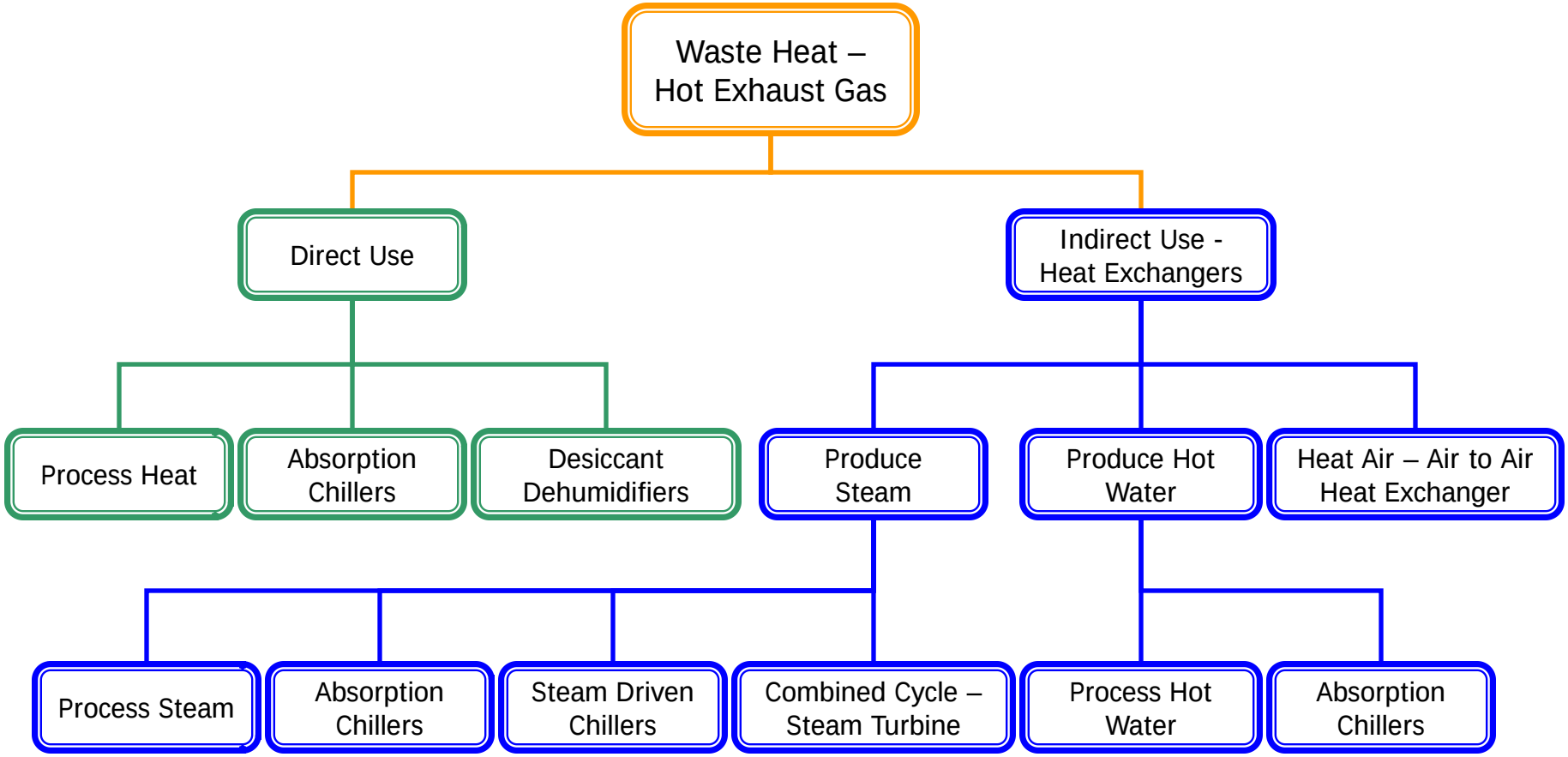
Waste Heat Recovery Technology

Absorption Chilling

Waste Heat Recovery Options



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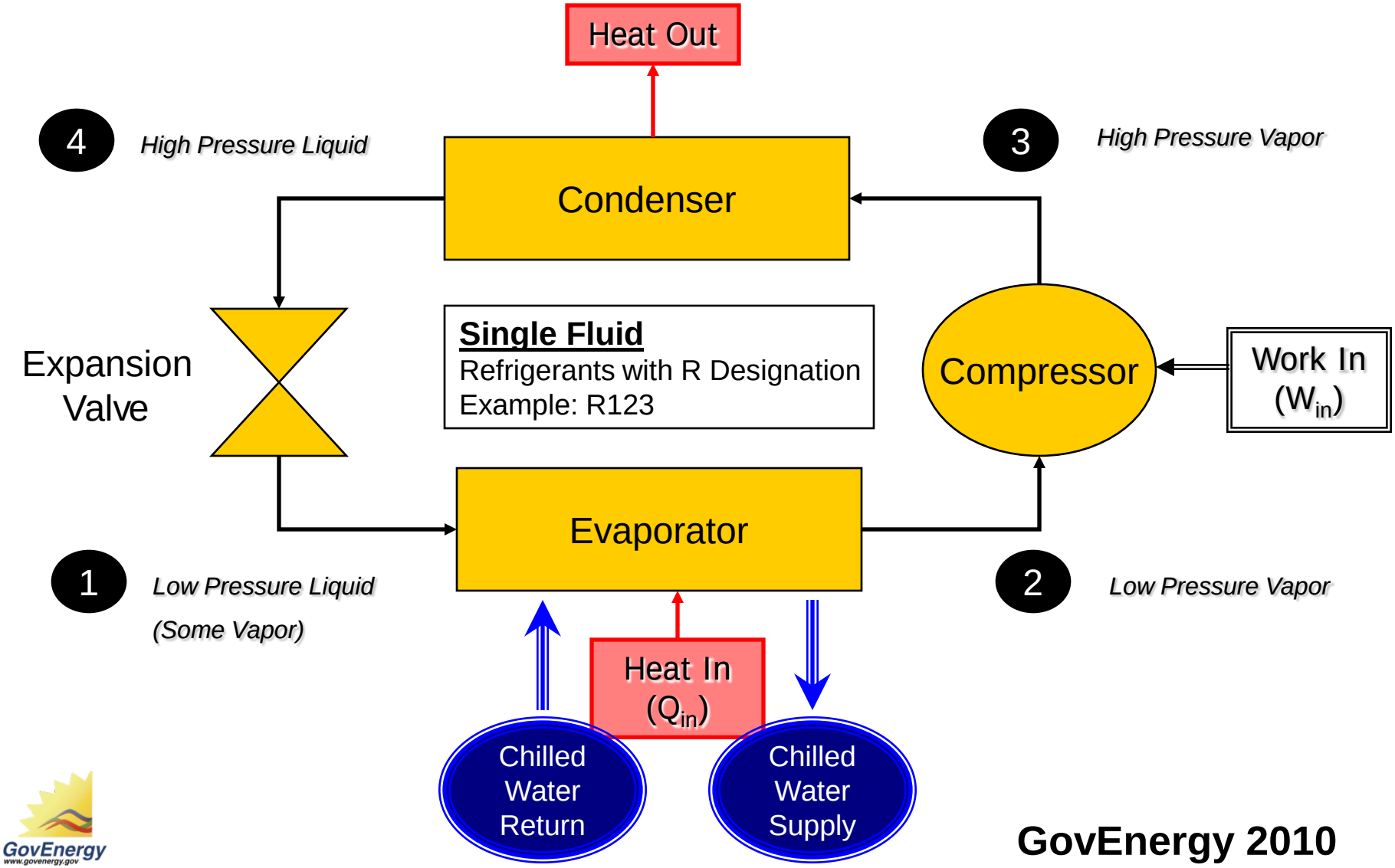
General Refrigeration Diagram



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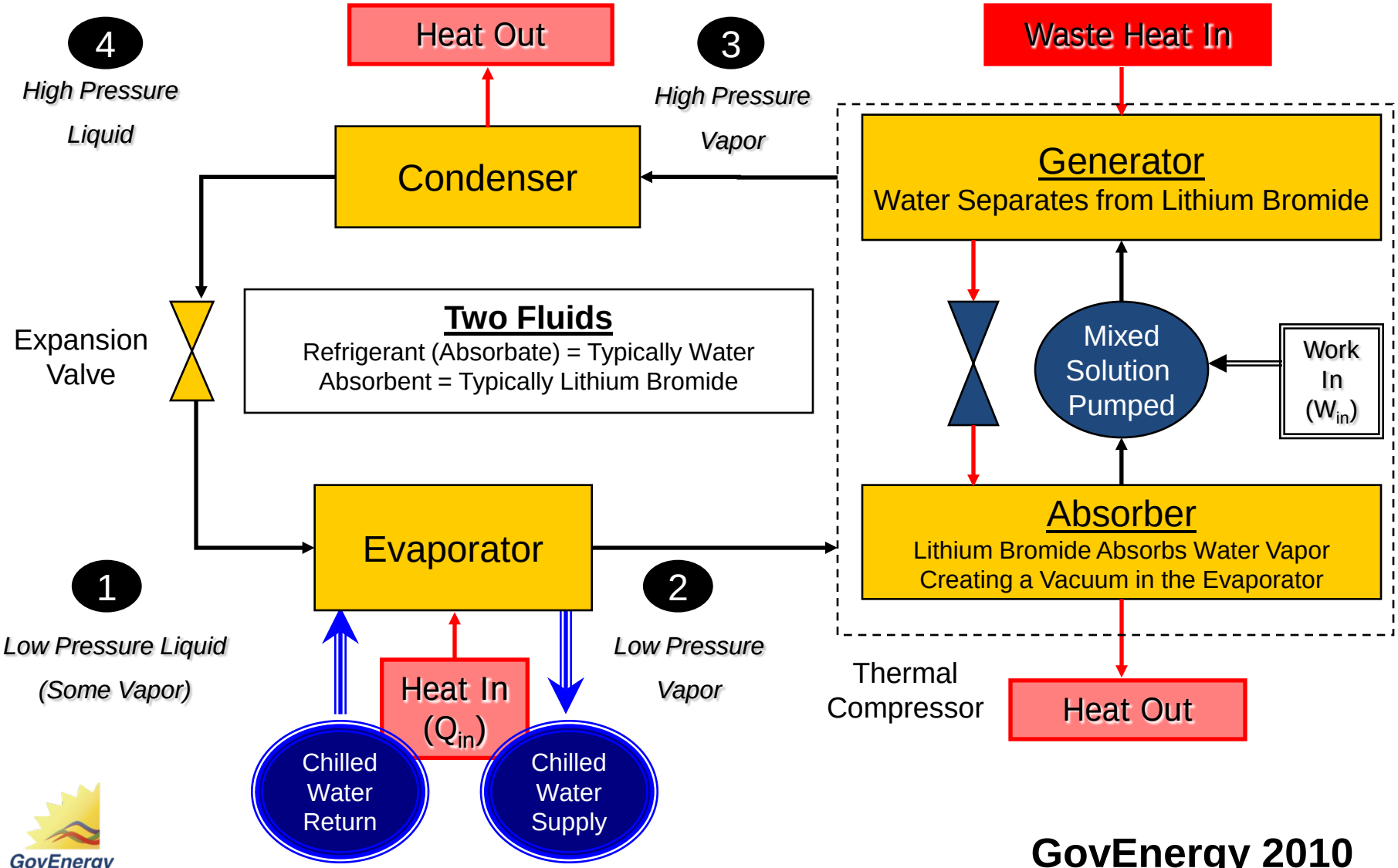
Absorption Chiller (Single Effect - Indirect Firing)



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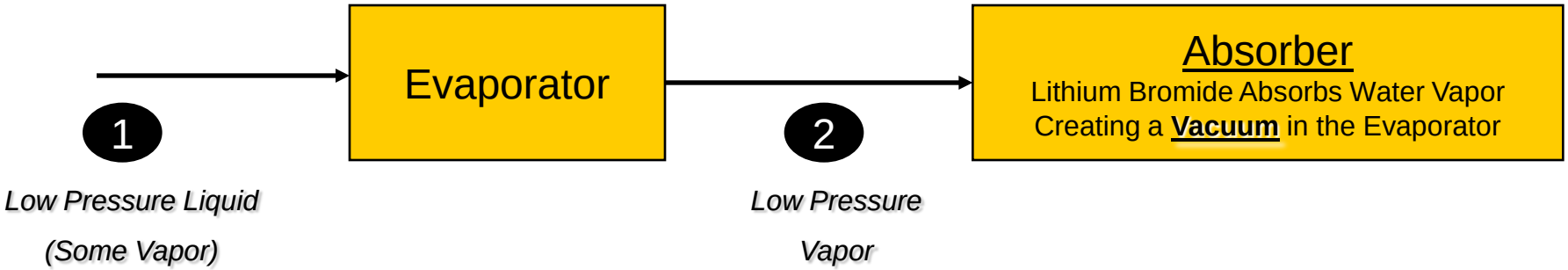
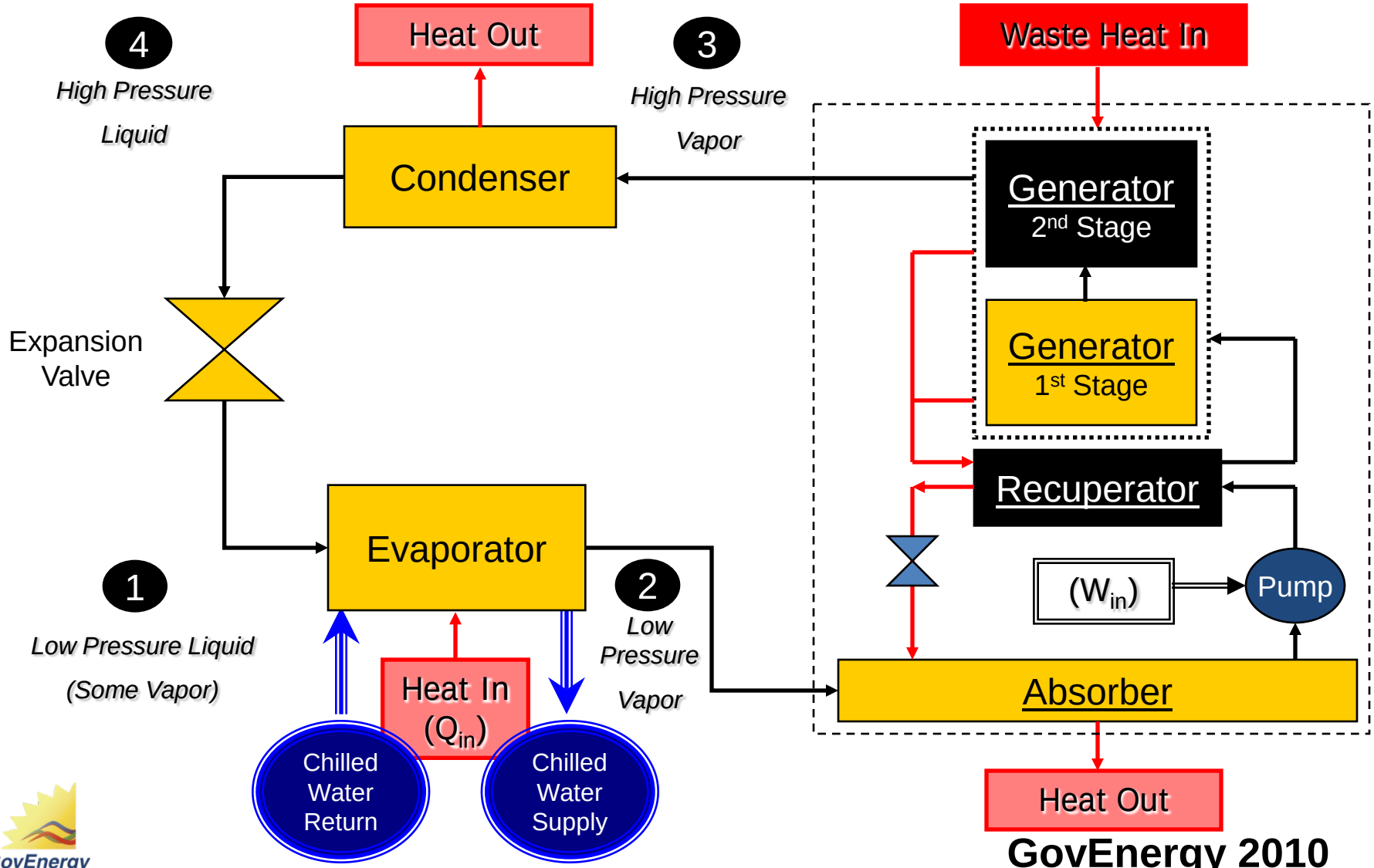
Refrigeration Effect



Absolute Pressure (PSIA)	Water Boiling Point (F)
14.69	212
1.50	115
0.11	37.5

Most Lithium Bromide chillers can only supply chilled water down to approximately 40 degrees F

Absorption Chiller (Double Effect - Indirect Firing)



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Waste Heat Requirements

- Absorption Chiller Capacity
  - Generally available in 100 to 1500 tons
- Absorption Chiller Steam Pressure Requirements
  - Single Effect Chiller
    - Low grade steam requirement: Approximately 15 PSIG
    - Low pressure applicable to most prime movers in CHP applications
    - 1 Refrigeration Ton requires 18.7 lb/hr of steam
  - Double Effect Chillers
    - Higher grade steam requirement: Approximately 100 to 150 PSIG
    - Higher pressure will limit prime mover options in CHP applications
    - 1 Refrigeration Ton requires 9.9 lb/hr of steam
- Water Temperature Requirement: Approximately 260 F
  - Water temperature applicable to most prime movers in CHP applications

Chiller Efficiencies

- Coefficient of Performance COP (Q_{in}/W_{in}) = Heat Removed / Supplied Energy
  1) Electric Driven Chiller = 1 Refrigeration Ton / 0.6 kW
     - COP (Electric Driven Chiller) = 5.9
  2) Double Effect Absorption Chiller = 1 Refrigeration Ton / (9.9 lb/hr of Steam)
     - COP (Double Effect Absorption Chiller) = 1.2
  3) Single Effect Absorption Chiller = 1 Refrigeration Ton / (18.7 lb/hr of Steam)
     - COP (Single Effect Absorption Chiller) = 0.67

Why use absorption chilling?

<u>Conversion Factors</u>

1 Refrigeration Ton = 12,000 BTUs/Hr

1 kW = 3,412 BTUs/Hr

1 lb/hr of steam = 1000 BTUs/Hr

Chiller Selection Criteria

- Electrical Power Input Considerations
  - 325 Ton electric driven mechanical chiller requires approximately 195 kW
  - 325 Ton absorption chiller requires approximately 8 kW (96% less)
    - Advantageous when electrical power is expensive or unreliable.
- Waste Heat is Available – Free Source of Fuel
- Emissions Considerations
  - Site Example (Hospital):
    - 4.5 MW Electrical Load (Electrical Load Excludes Chiller Loads)
    - 1600 Ton Chilling Load (2000 hrs – Summer Months)
    - 13,500 Lbs/Hr Steam Load (Water Heating, Sterilization, Etc.)

What is the emissions impact of CHP versus a grid power/gas fired boiler option?

Emissions Analysis

CHP Results

The results generated by the CHP Emissions Calculator are intended for eductional 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)	3.43	50.39	4.81	51.76	94%
SO2 (tons/year)	0.00	103.40	0.12	103.52	100%
CO2 (tons/year)	22,097	30,582	5,624	14,109	39%
Carbon (metric tons/year)	6,027	8,341	1,534	3,848	39%
Fuel Consumption (MMBtu/year)	377,729	327,878	96,139	46,287	11%
Acres of Forest Equivalent				3,848	
Number of Cars Removed				2,405	

es 2005

4,109 tons per year

E) per year

This reduction is equal to emoving the carbon emissions of 2,405 cars

Annual Emissions Analysis

NOx = 94% Reduction

SO2 = 100% Reduction

CO2 = 39% Reduction (3,848 Metric Tons)

CO2 Reduction is the equivalent of removing the annual carbon emissions of 2,405 cars!

Case Study – Dell Children's Hospital, Austin TX

- Prime Mover – Recuperated 4.6 MW Gas Turbine
- Heat Recovery – Heat Recovery Steam Generator (22,000 lbs/hr) and 1000 Ton Steam Driven Absorption Chiller
- Thermal Storage – 8000 Ton-Hour
- CHP Efficiency in Excess of **85%**.

Awards & Notes

- First U.S. LEED Platinum Hospital
- 2007 Pacesetter Plant Award by Combined Cycle Journal
- Partially Funded by DOE

Thank you for your attention!

Marco Perez

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