Electric Generation Technologies

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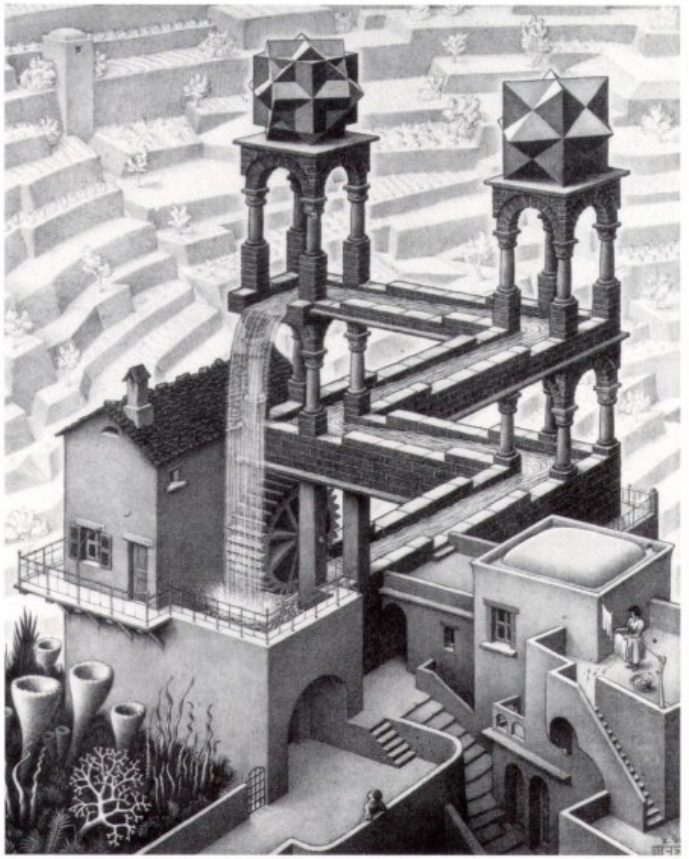
HDR

Pesky Laws of Thermodynamics

First Law -Conservation of Energy: Energy can neither be created nor destroyed. It can only be converted from one form to another.

Second Law – There is no such thing as 100% efficiency. There are always losses.

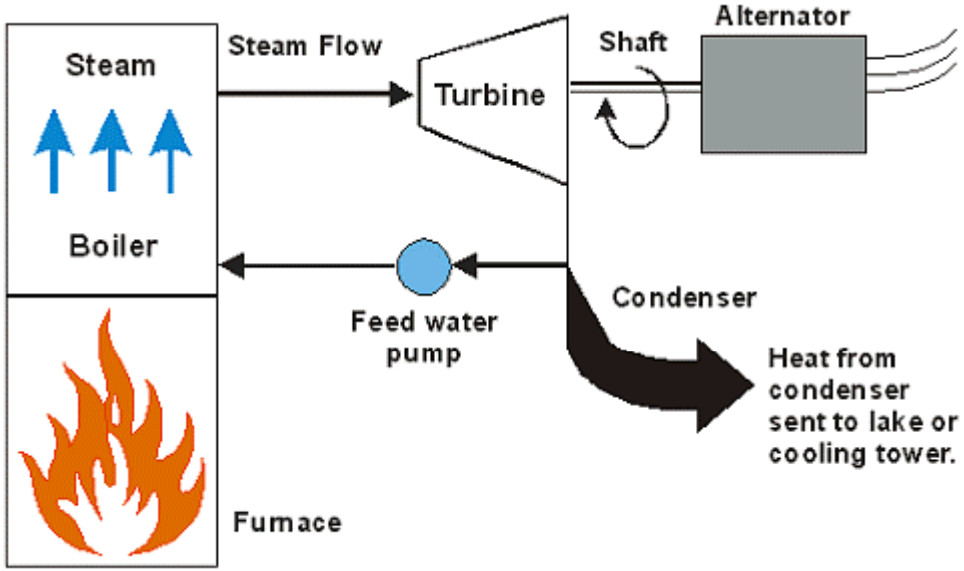


Conventional Steam Power Plants

Steam Power Plants

Sources of Thermal Energy:

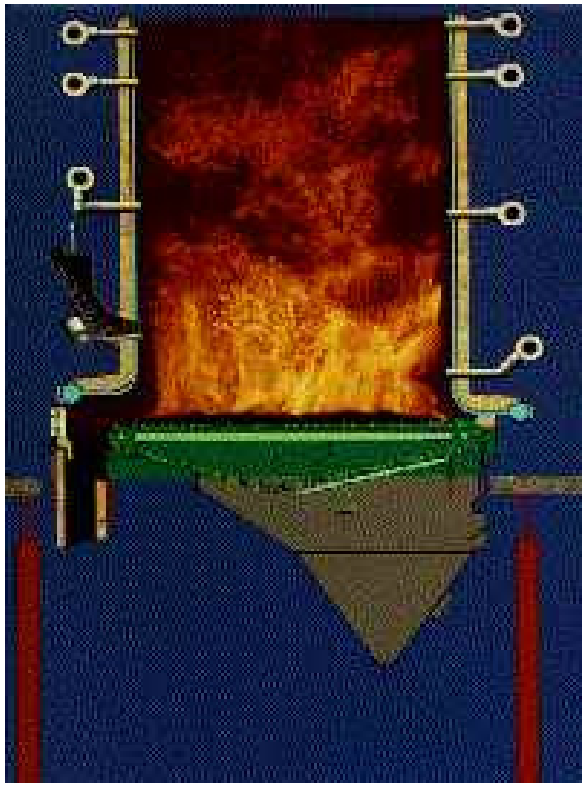
- Coal
- Natural Gas
- Oil
- Biomass
- Nuclear
- Solar Thermal



Roughly 90% of all electrical power generated in the world is via a Rankine Cycle.
Typical large power station efficiency 30-40%

Solid Fuel Boiler Types

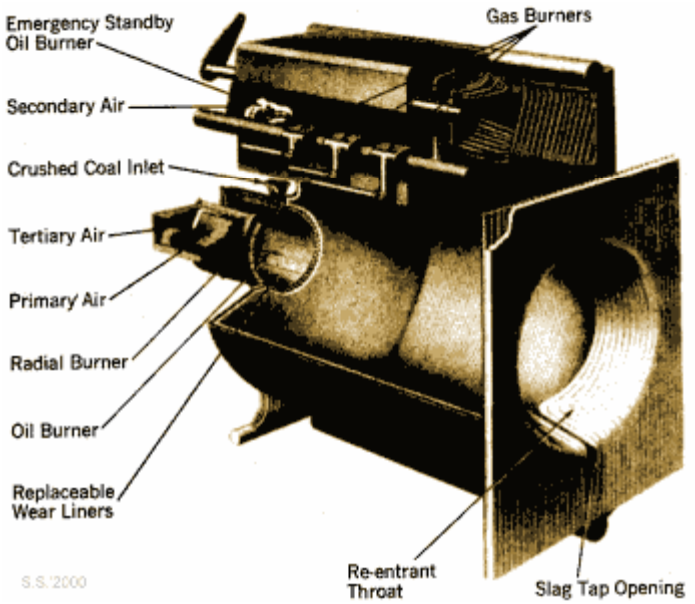
- Stoker / Grate



Fuel is combusted primarily on top of a grate

Solid Fuel Boiler Types

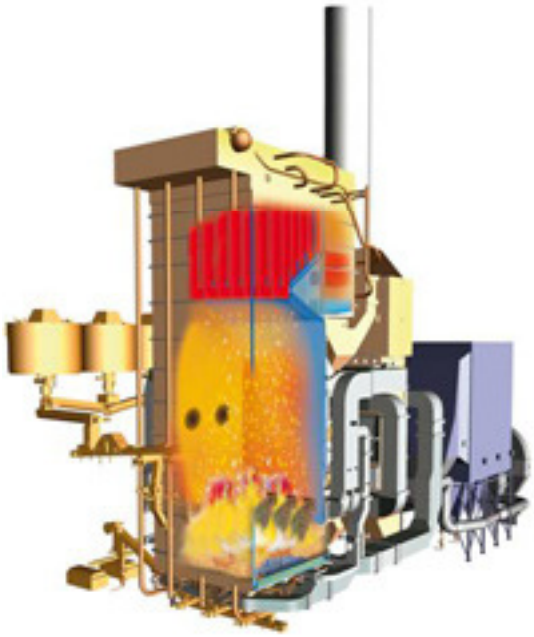
Pulverized Coal (PC)

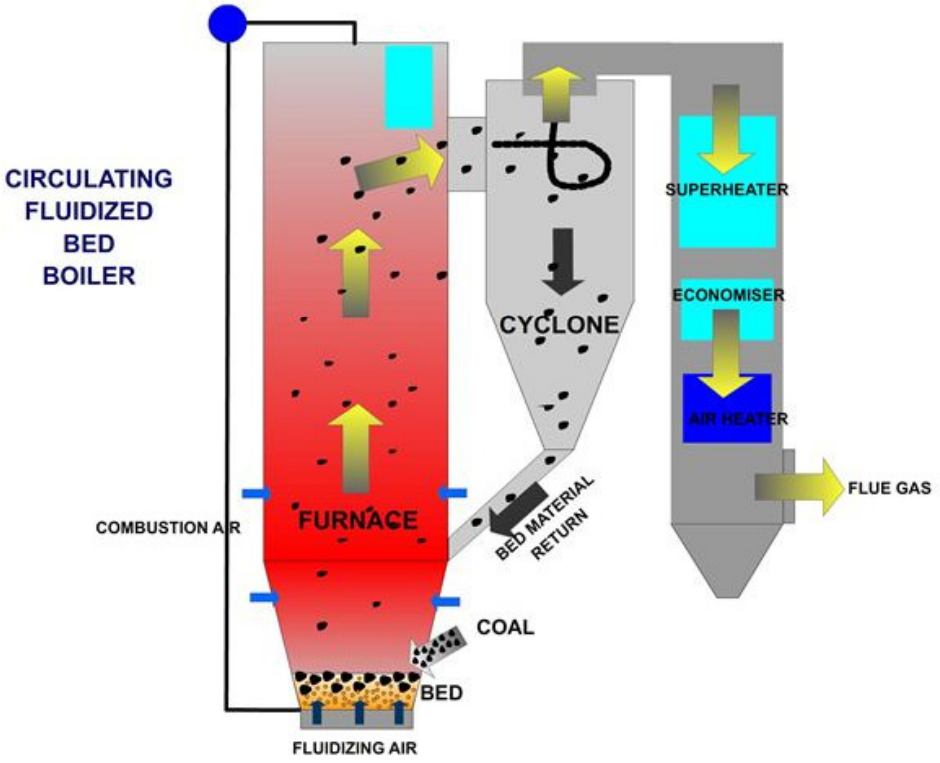


PC Boilers are more efficient than stokers

Solid Fuel Boiler Types
Fluidized Bed Combustion

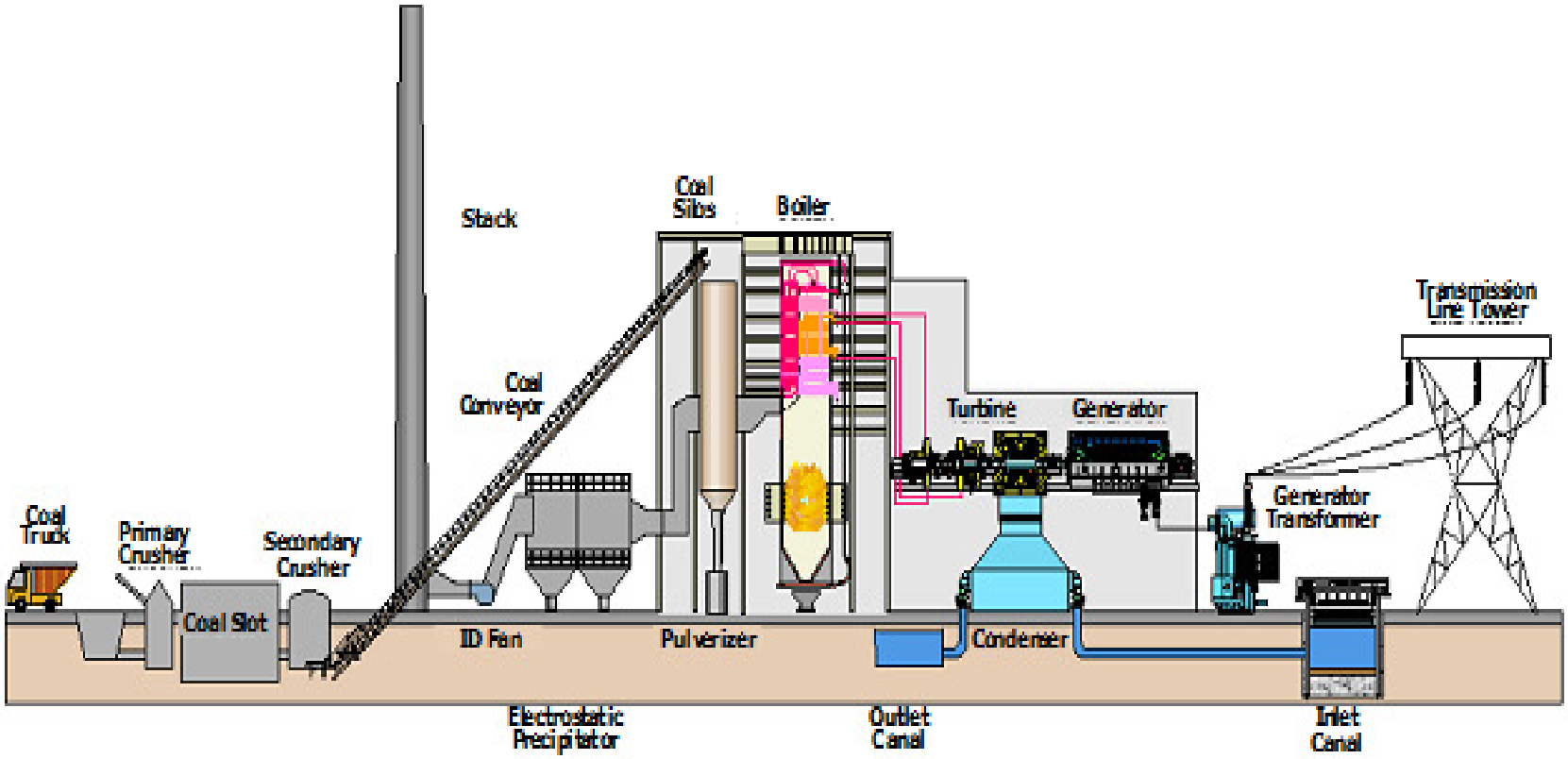
Bubbling
Fluidized
Bed
Boiler





Fluidized bed boilers – fuel flexibility & lower NOx/SOx formation.

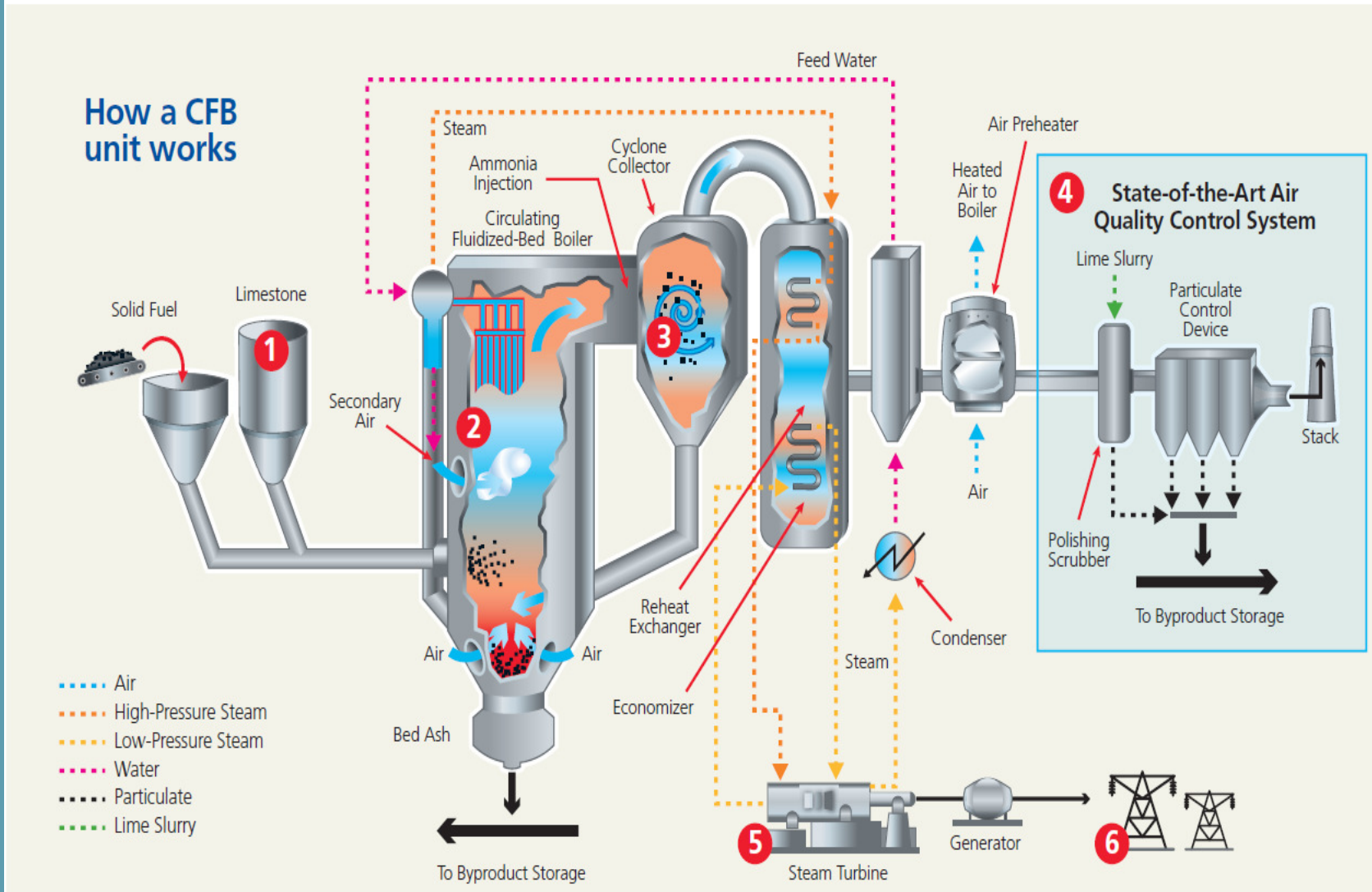
Conventional Steam Plant Overview



In Real Life …

Nebraska City Station

Circulating Fluidized-Bed (CFB) Boiler



CFB Boiler Characteristics

- Fuel flexibility - ability to utilize a wide range of fuels, better able to incorporate renewable & opportunity fuels
- SOx removal as part of combustion process with limestone addition >95%
- Lower combustion temperatures result in substantially lower NOx, ~ 50%

CFB Boilers

Pros:

- Good fuel flexibility, lower fuel costs & incorporation of renewables
- Potentially lower fuel cost risk
- Reliable baseload electric capacity
- Opportunity to provide thermal output (CHP)

Cons:

- Capital intensive
- Lower efficiency than some natural gas plants
- Higher emissions than other options (i.e., gas, wind, solar)

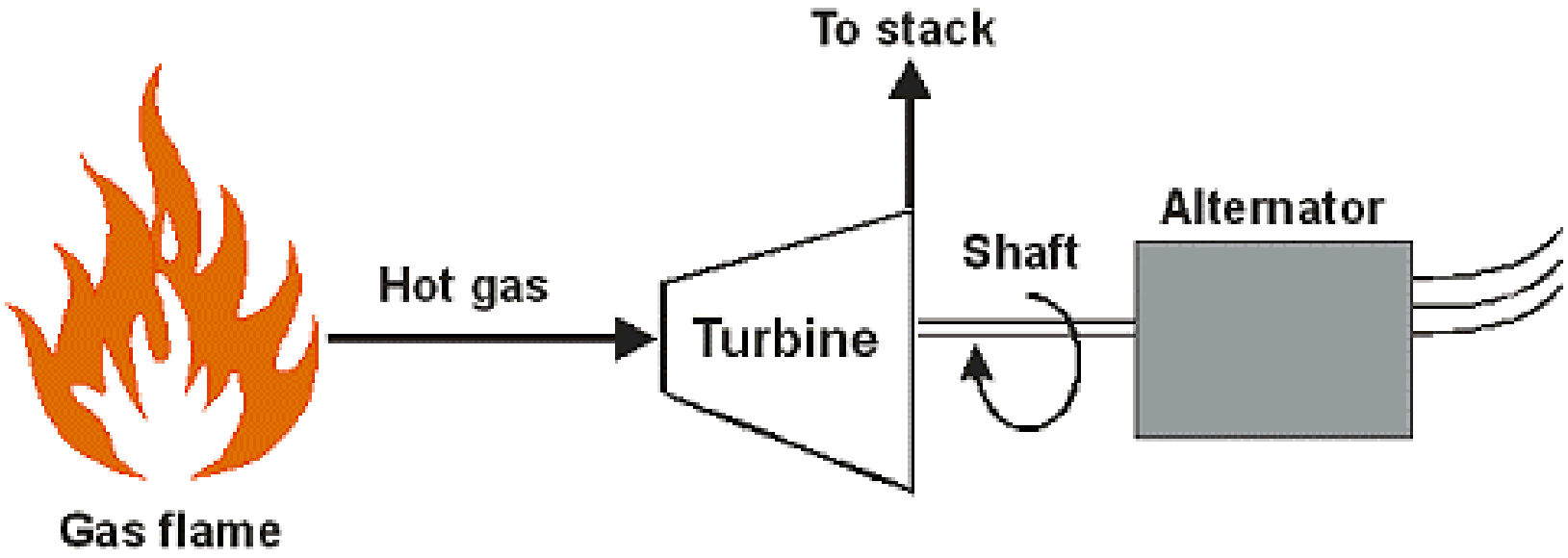
Combustion Turbine Power Plants

Optional Message Placement

Gas Turbine Applications

- Simple Cycle
- Combined Cycle
- Cogeneration

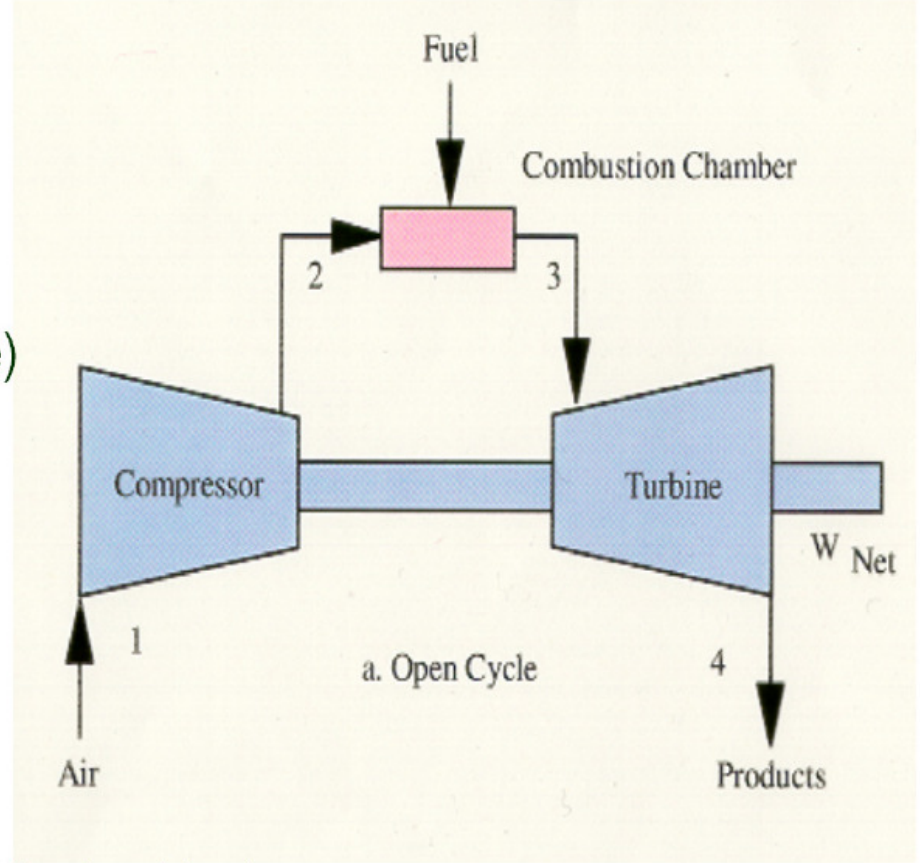
Combustion Turbine Generators … AKA Gas Turbines



Principles of Operation

- Open Cycle

Also referred to as simple cycle)

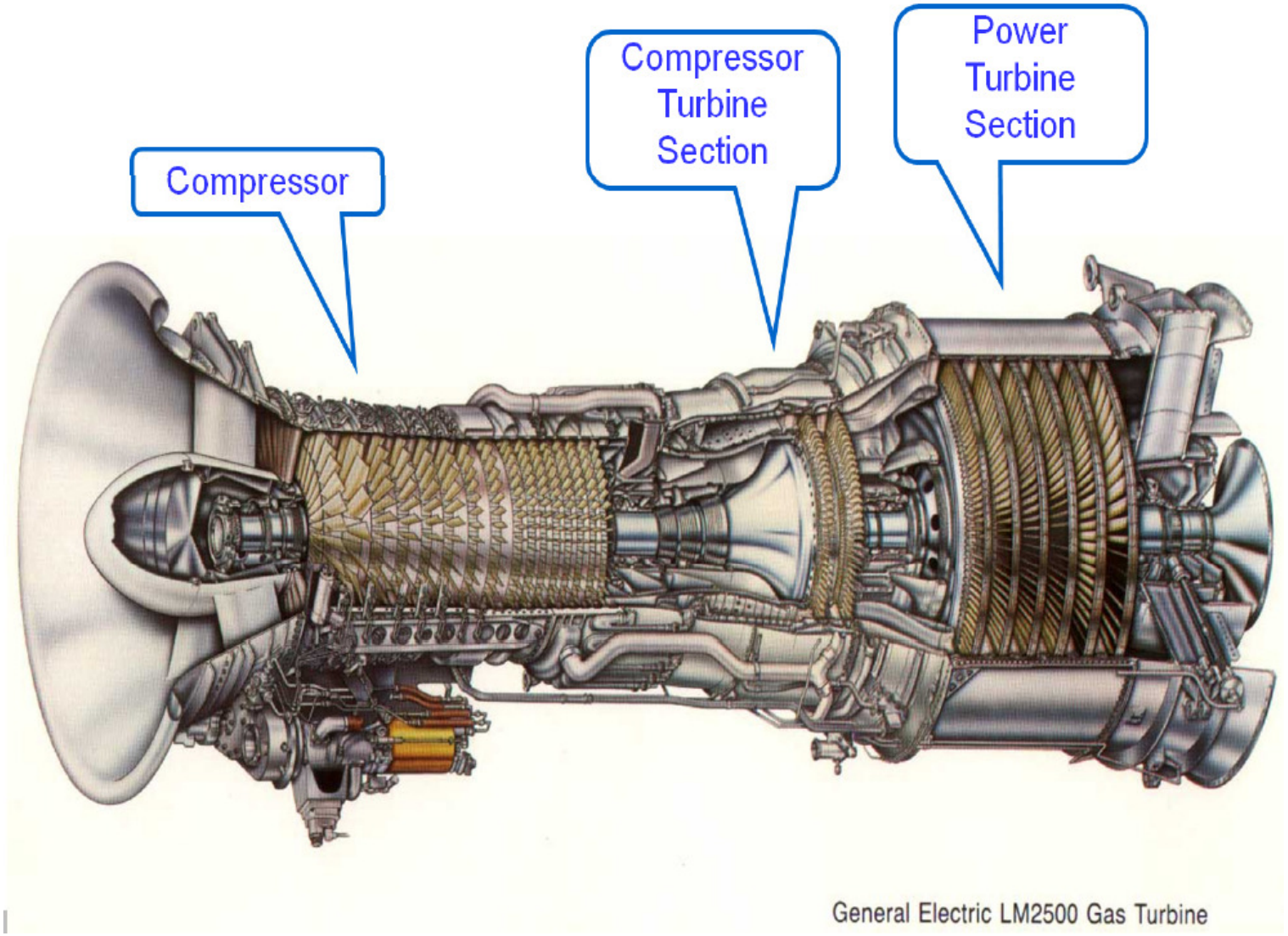


- The energy contained in a flowing ideal gas is the sum of enthalpy and kinetic energy.
- Pressurized gas can store or release energy. As it expands the pressure is converted to kinetic energy.

Combustion Turbine Fuels

- Conventional Fuels
  - Natural Gas
  - Liquid Fuel Oil
- Nonconventional Fuels
  - Crude Oil
  - Refinery Gas
  - Propane
- Synthetic Fuels
  - Chemical Process
  - Physical Process

GE LM2500 Aeroderivative Gas Turbine



General Electric LM2500 Gas Turbine

Derived from GE CF-6 Jet Engine – First used on DC-10: 25-30MW, 38%

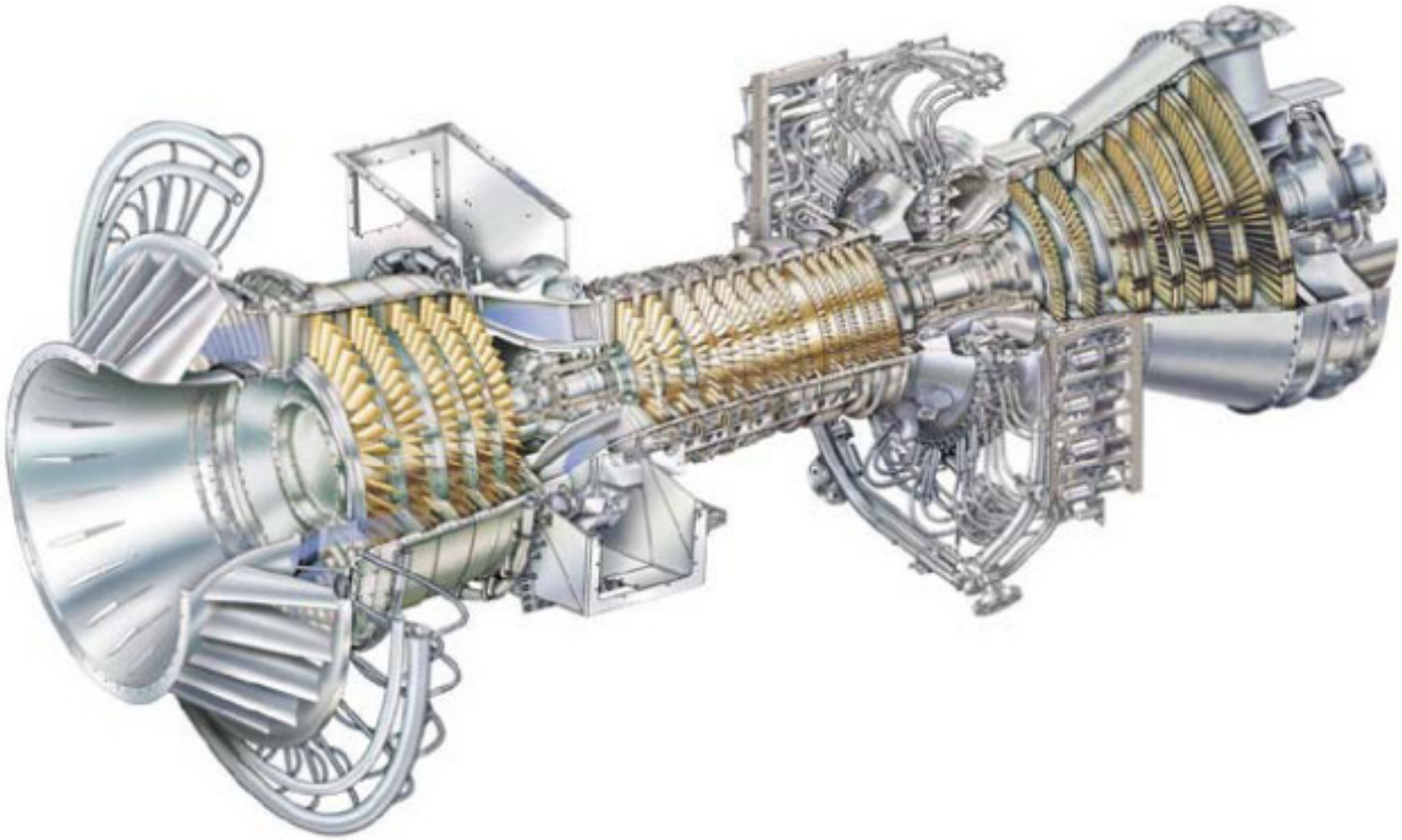
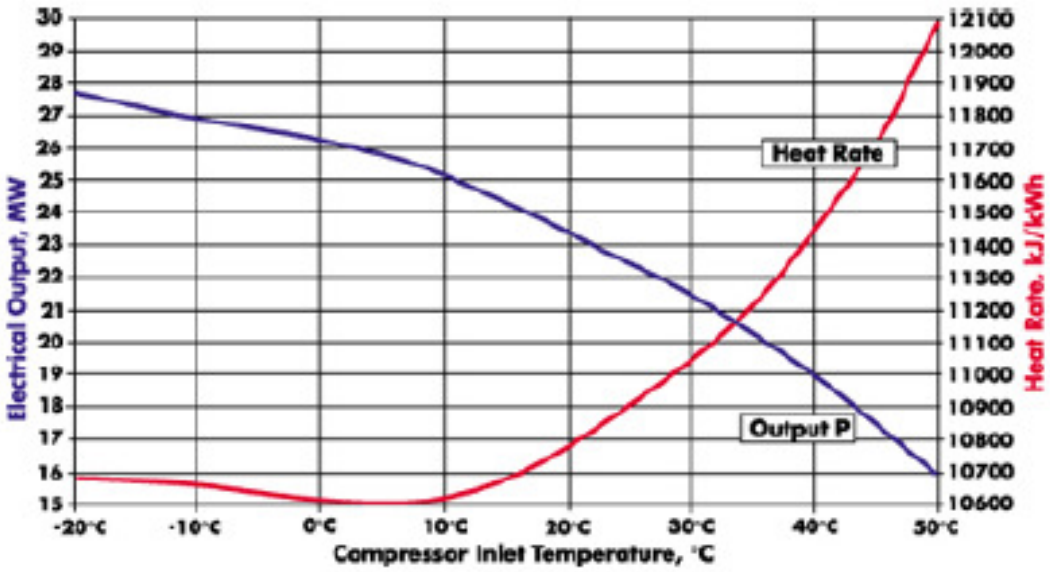
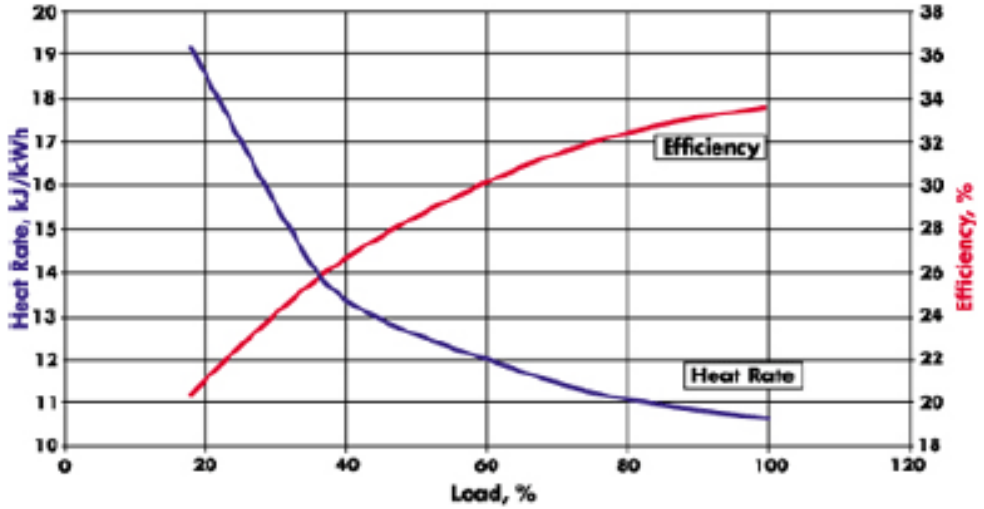


Fig. 13. The GE LM6000 (aeroderivative of the CF6-80C2). (Source: GE Power Systems)

45-50MW, 41%



a) Generator output and heat rate versus compressor inlet air temperature



b) Heat rate and efficiency versus load

GE Combustion Turbine Comparisons

Generator Drive (ISO conditions - natural gas - electrical generator terminals)

	ISO RATED POWER kW	HEAT RATE kJ/kWh	EFFIC. %	PRESSURE RATIO	EXHAUST FLOW kg/sec	EXHAUST FLOW lbs/sec	TURBINE SPEED RPM	EXHAUST TEMPERATURE °C	EXHAUST TEMPERATURE °F
 GE10-1	11,250	11,489	31.4	15.5	47.5	104.7	11,000	482	900
 PGT16	13,720	10,295	35.0	20.2	47.3	104.3	7,900	491	919
 PGT20	17,464	10,238	35.2	15.7	62.5	137.7	6,500	475	887
 PGT25	22,417	9,919	36.3	17.9	68.9	151.9	6,500	525	976
 PGT25+	30,226	9,084	39.6	21.5	84.3	185.9	6,100	500	931
 PGT25+G4	33,057	9,047	40.0	23.2	89.6	197.7	6,100	510	950
 LM6000*	42,262	8,787	41.1	28.0	125.0	275.0	3,600	455	851
 LMS100*	98,196	7,997	45.0	40.0	206.9	456.0	3,600	417	782
 MS5001	26,830	12,687	28.4	10.5	125.2	276.1	5,094	483	901
 MS5002E*	31,100	10,285	35.0	17.0	102.0	225.0	5,714	511	952
 MS6001B	42,100	11,230	32.1	12.2	141.1	311.0	5,163	548	1,026
 MS7001EA	85,400	10,990	32.7	12.6	292.0	643.0	3,600	537	998
 MS9001E	126,100	10,650	33.8	12.6	418.0	921.0	3,000	543	1,009

(*) DLE Combustion

Typical Simple Cycle CT Plant Components

- Prime Mover (Combustion Turbine)
- Fuel Supply & Preparation
- Emissions Control Equipment
- Generator
- Electrical Switchgear
- Generator Step Up Transformer
- Starting System (Combustion Turbines)
- Auxiliary Cooling
- Fire Protection
- Lubrication System

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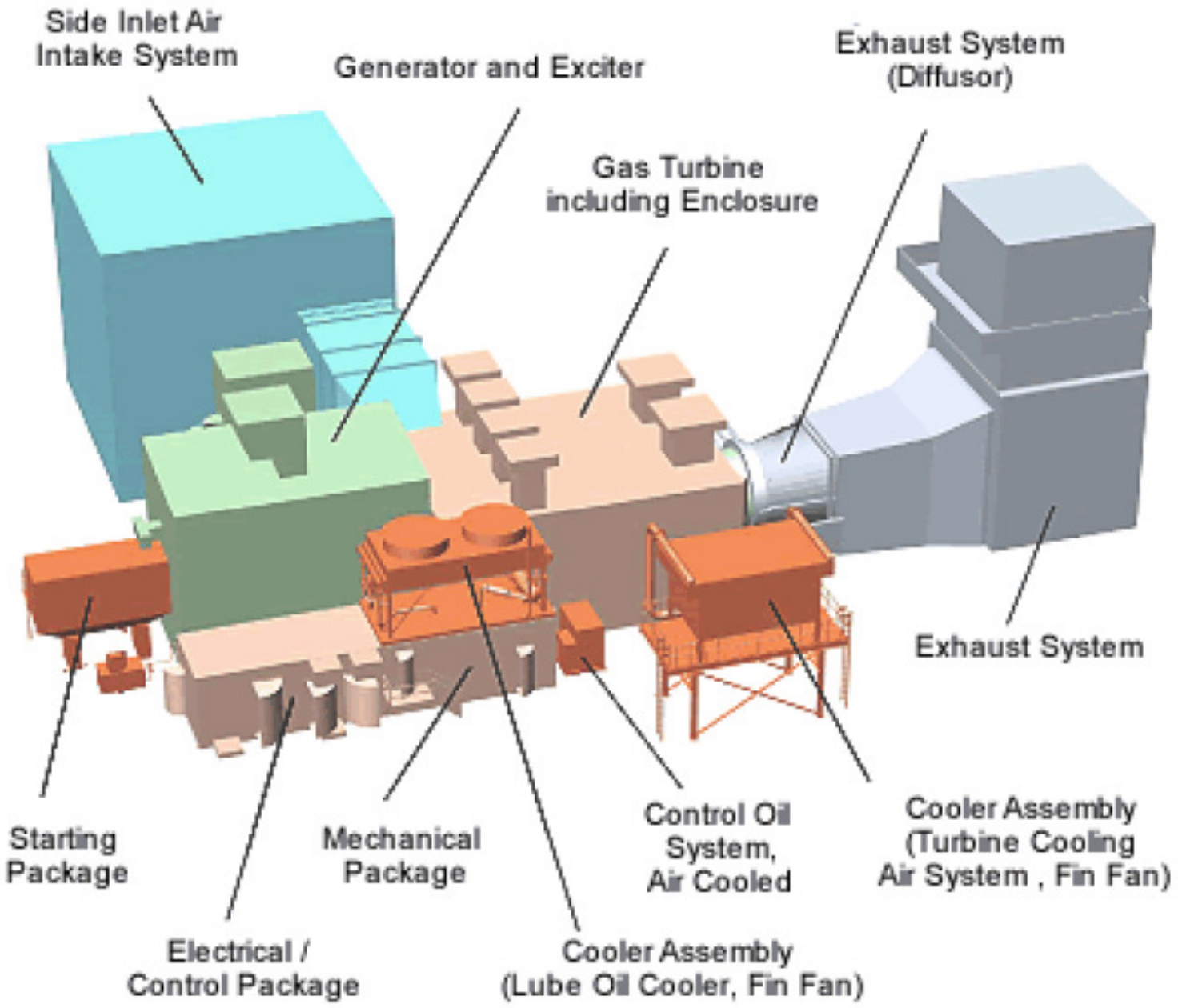
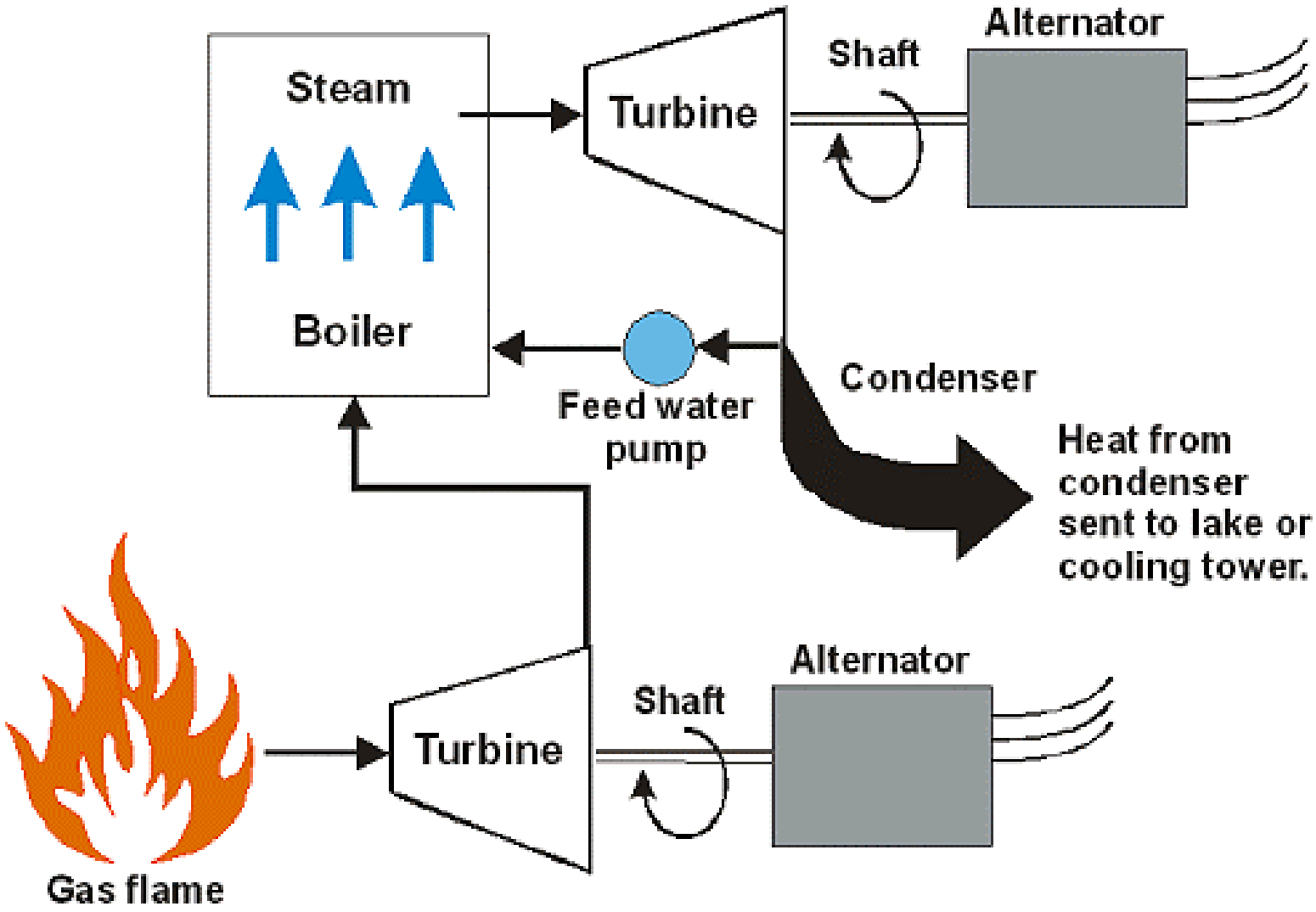

Side Inlet Air
Intake System
Generator and Exciter
Exhaust System
(Diffusor)
Gas Turbine
including Enclosure
Exhaust System
Starting
Package
Electrical /
Control Package
Mechanical
Package
Cooler Assembly
(Lube Oil Cooler, Fin Fan)
Control Oil
System,
Air Cooled
Cooler Assembly
(Turbine Cooling
Air System , Fin Fan)

In Real Life …

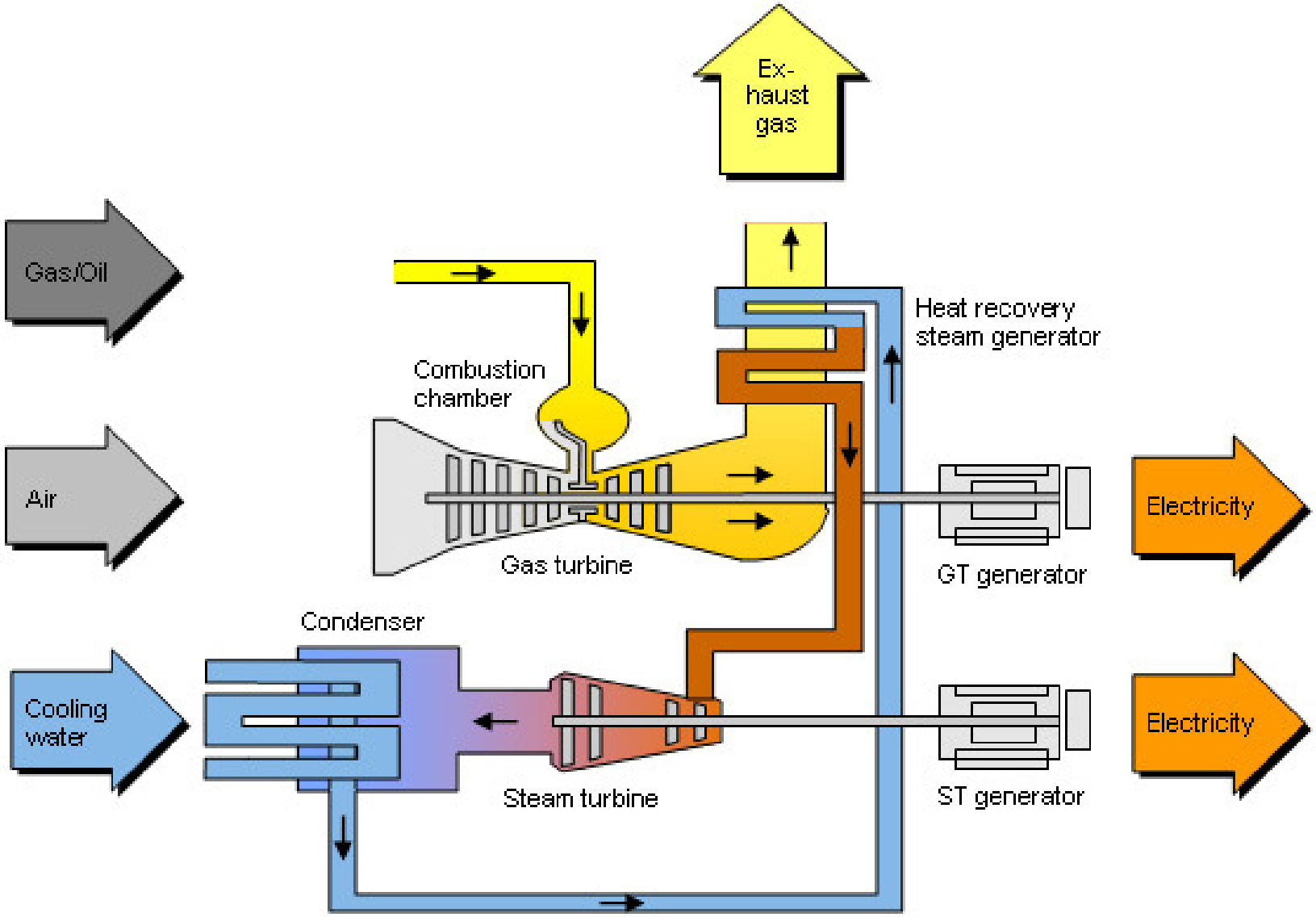
2 – LMS 100, 200MW

Combined Cycle Power Plants

Optional Message Placement



Brayton + Rankine Cycle = Combined Cycle

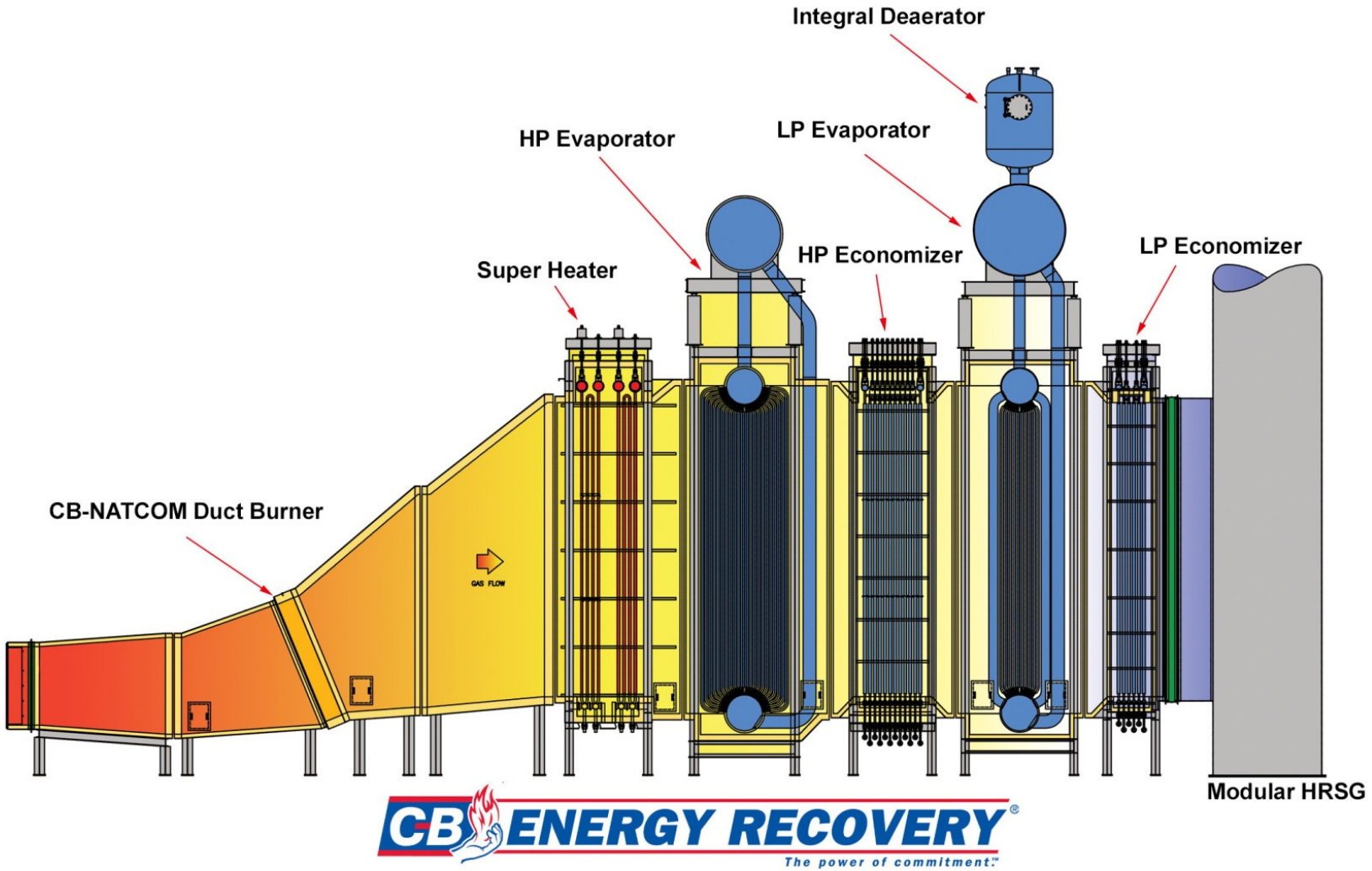

Ex-
haust
gas
Gas/Oil
Air
Cooling
water
Combustion
chamber
Heat recovery
steam generator
Gas turbine
GT generator
Electricity
Condenser
Steam turbine
ST generator
Electricity

Combining the Brayton and Rankine Cycles

- Gas Turbine Exhaust used as the heat source for the Steam Turbine cycle
- Utilizes the major efficiency loss from the Brayton cycle
- Advantages:
  - Relatively short cycle to design, construct & commission
  - Higher overall efficiency
  - Good cycling capabilities
  - Fast starting and loading
  - Lower installed costs
  - No issues with ash disposal or coal storage
- Disadvantages
  - High fuel costs
  - Uncertain long term fuel source
  - Output dependent on ambient temperature

Combined Cycle Efficiencies 50-60%

Modular HRSG



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Major Combined Cycle Plant Equipment

- Combustion Turbine (CT/CTG)
- Steam Generator (Boiler/HRSG)
- Steam Turbine (ST/STG)
- Heat Rejection Equipment
- Air Quality Control System (AQCS) Equipment
- Electrical Equipment

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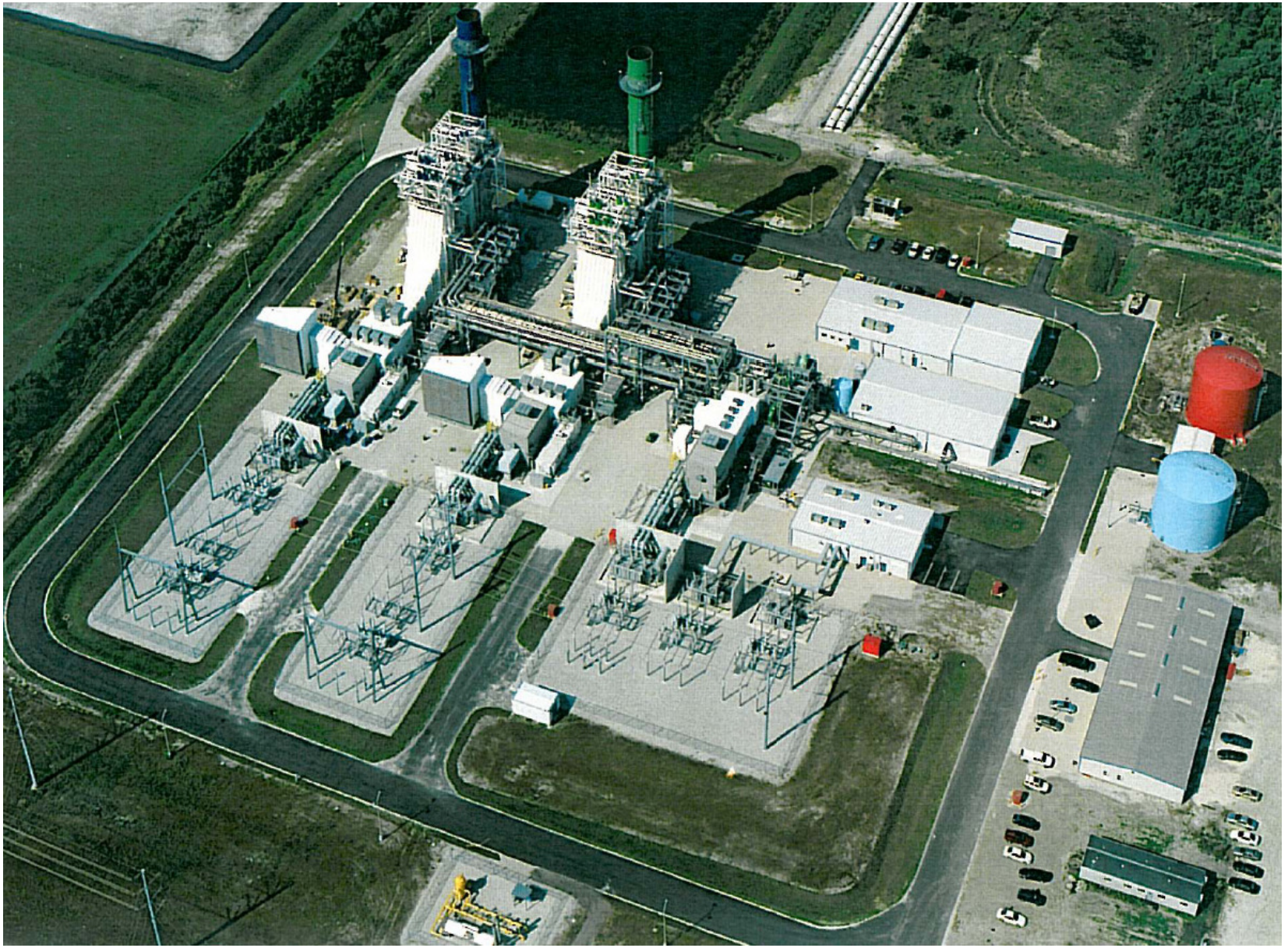

2x1 501F Combined Cycle in Florida, 500MW

Characteristics

Simple Cycle

- Operate to meet Peak Demand
- Designed for Quick Start-up
- Not as Efficient, but Reliable Peaking Power
- Little to no water consumption

Combined Cycle

- Reliable - Operate for Intermediate or Base Load
- Highest Fossil Fuel Efficiency
- Can be designed to operate in Simple Cycle Mode

Combined Cycle Repowering

Optional Message Placement

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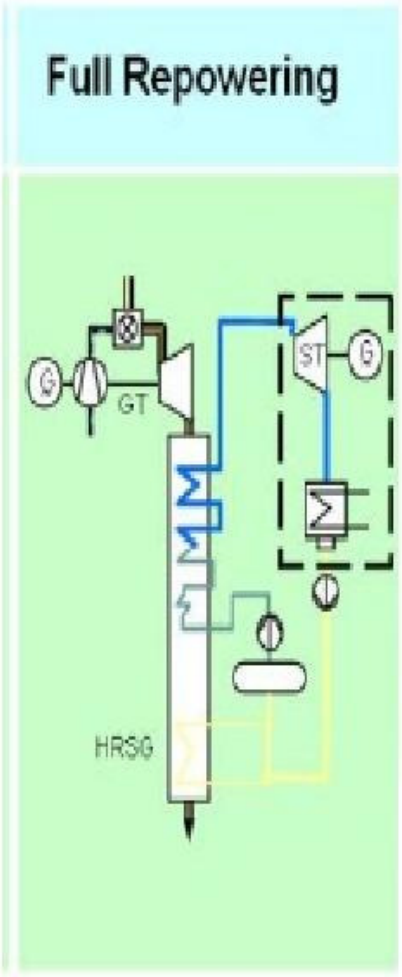
Combined Cycle Repowering



Using a combustion turbine generator & HRSG to replace an existing boiler. The existing steam turbine generator and auxiliaries are re-used.

Significant increase in electrical output & plant efficiency.

When replacing a coal fired boiler with a natural gas fired combustion turbine, significant reductions in emissions are realized.

Less capital cost than a new combined cycle plant due to the re-use of existing equipment and systems.

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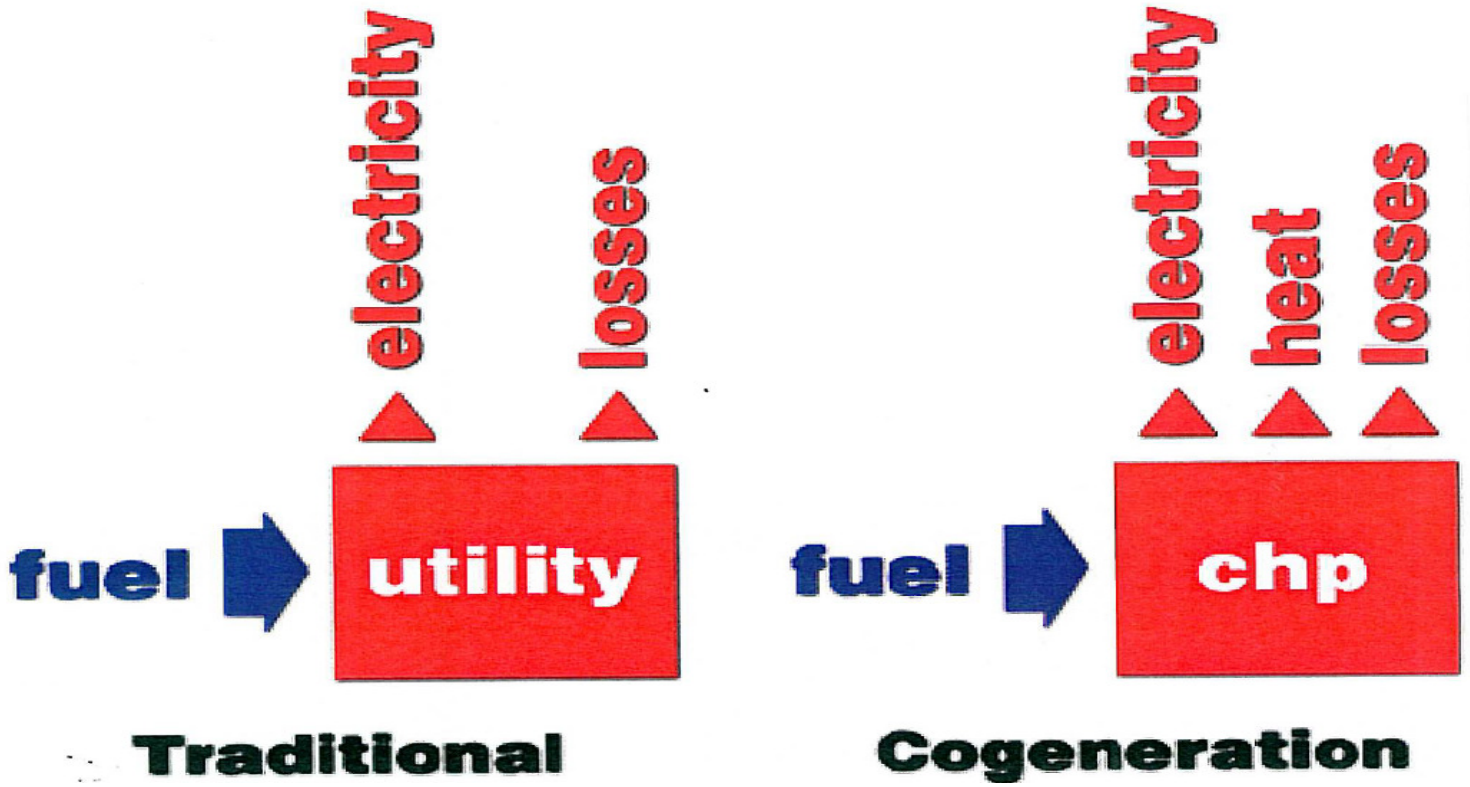
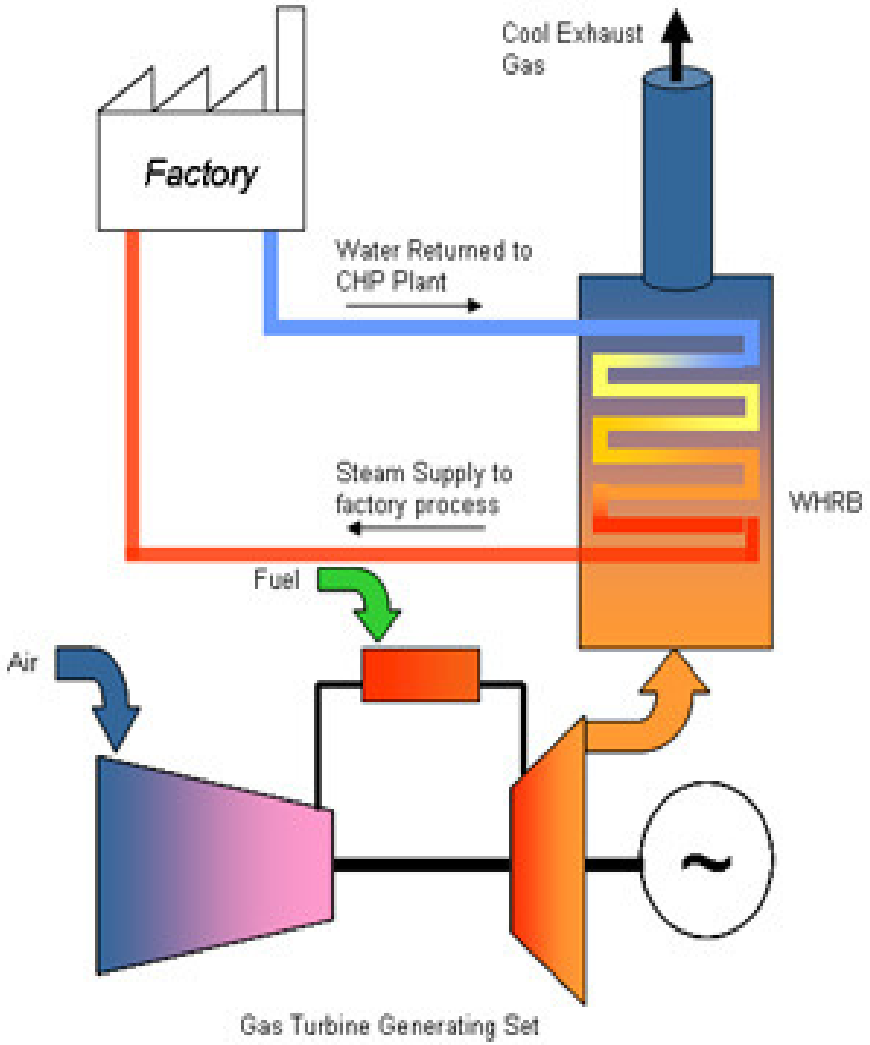
Cogeneration / Combined Heat & Power (CHP)



- By utilizing otherwise rejected or wasted heat from the electricity generation process (losses) to produce a useful form of thermal energy (hot water, steam, etc.), the overall efficiency can be dramatically increased.
- Increased energy efficiency can save money!
- Increased energy efficiency can reduce environmental effects.



The Gas Turbine based Combined Heat & Power Cycle

Combined Heat & Power is the simultaneous production of Power and Heat from a single fuel source.

The Gas Turbine generates electricity to power the plant.

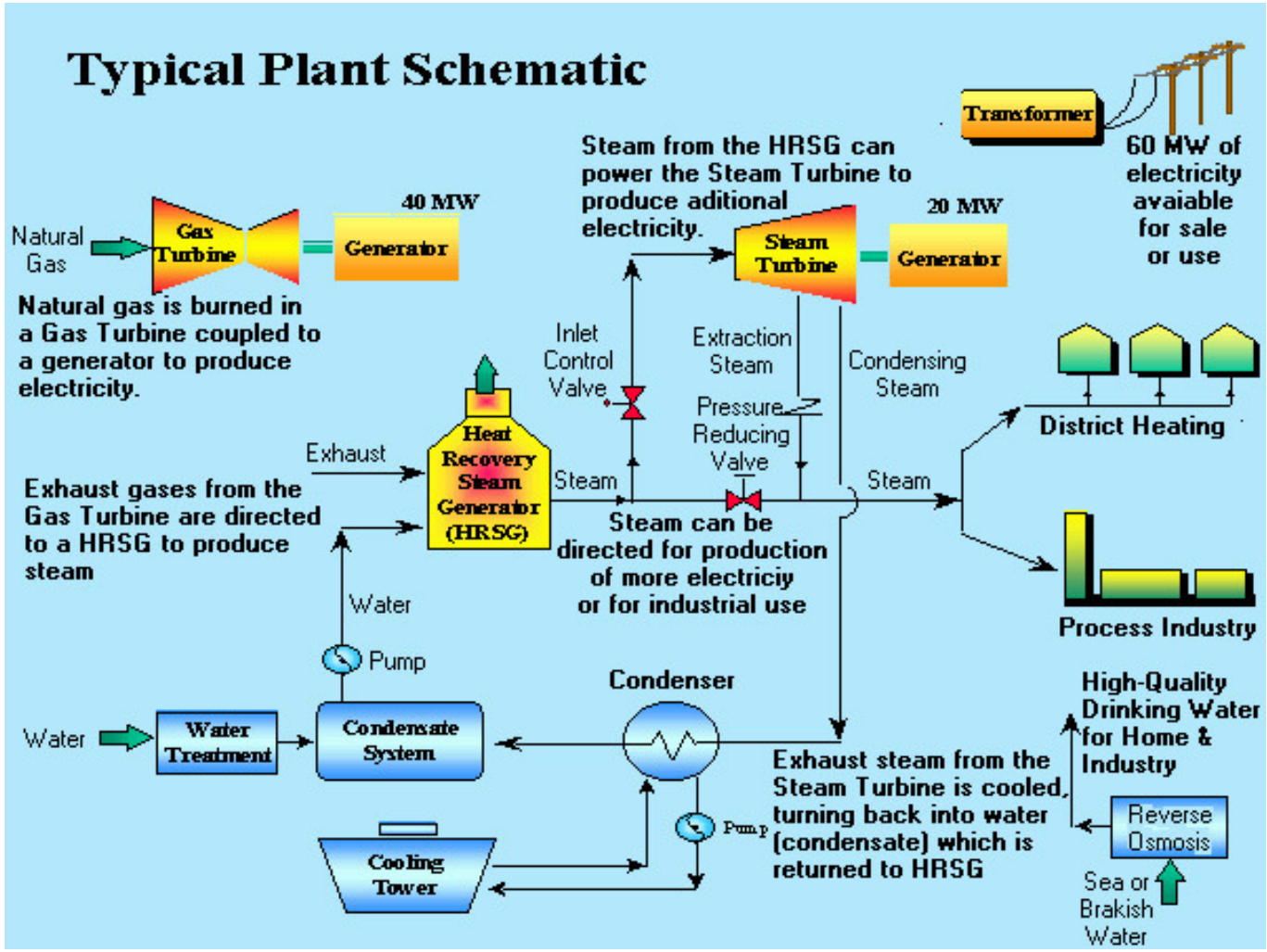
The hot exhaust gases are passed through a Waste Heat Recovery Boiler*

The hot gases heat water which is supplied either as hot water or steam to the factory/facility processes.

* Waste Heat Recovery Boilers are also known as Heat Recovery Steam Generators (HRSG)

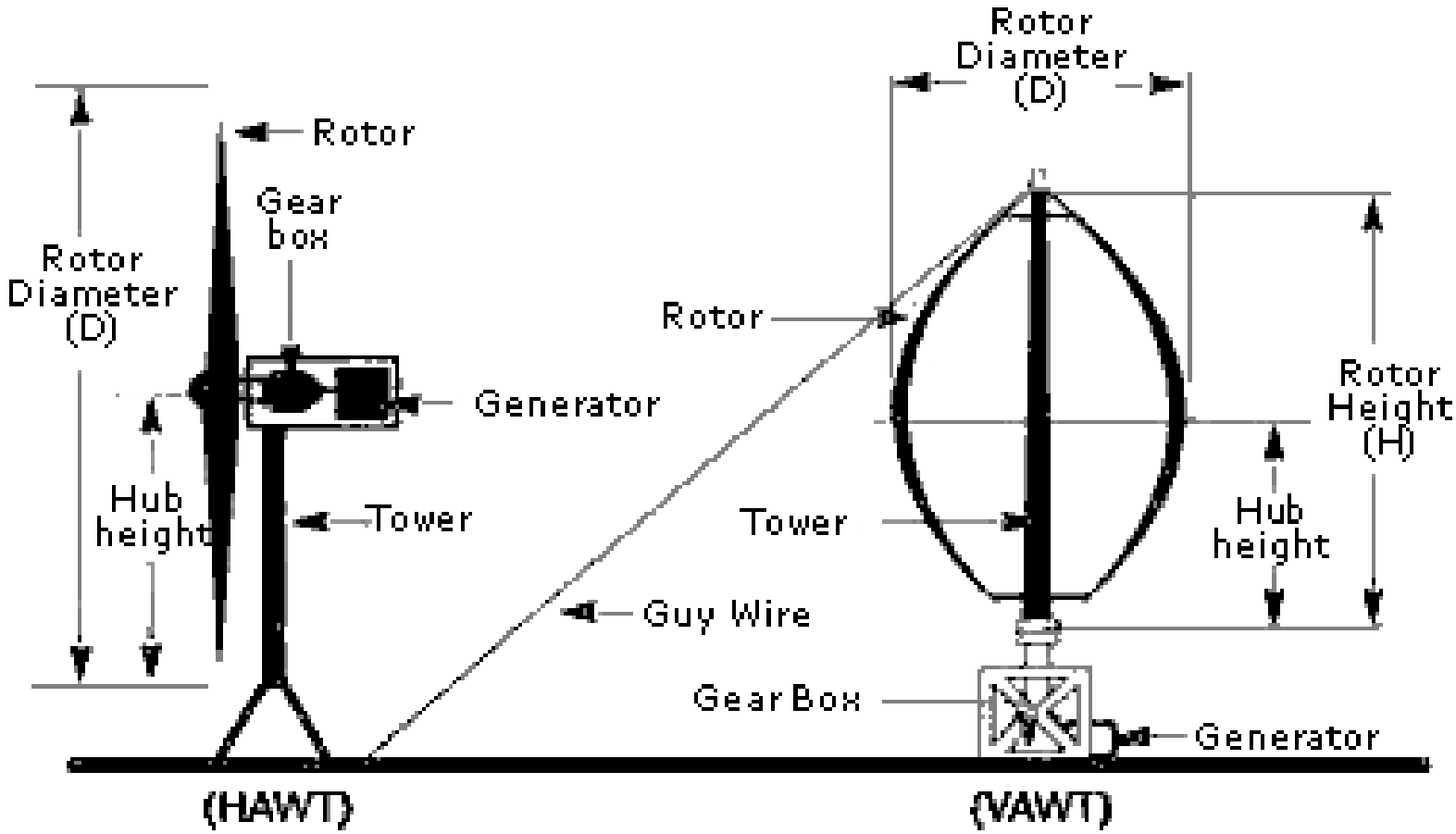
Overall Cogeneration Efficiencies can reach 70-80%

Combined Cycle Cogeneration

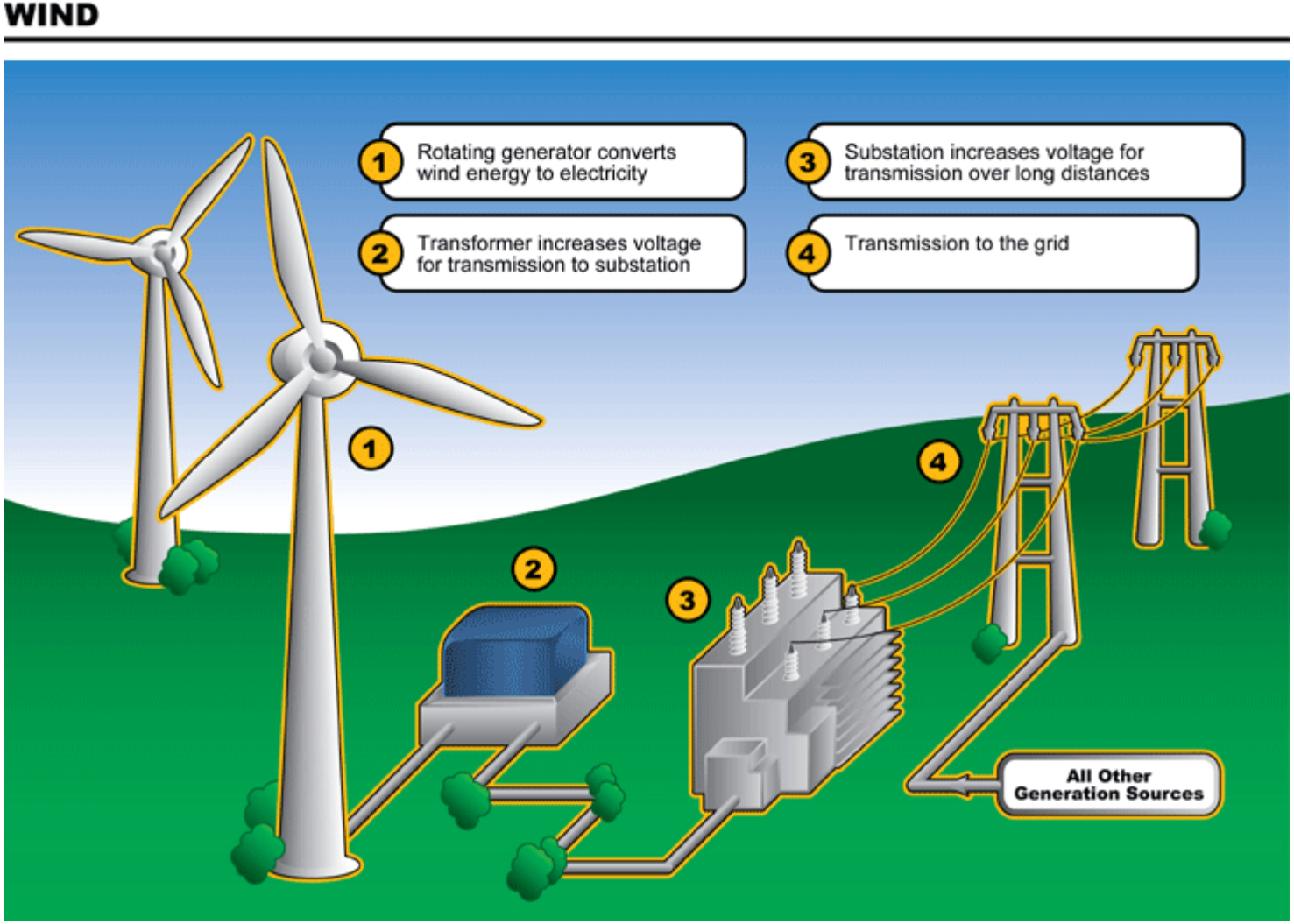


Wind Power

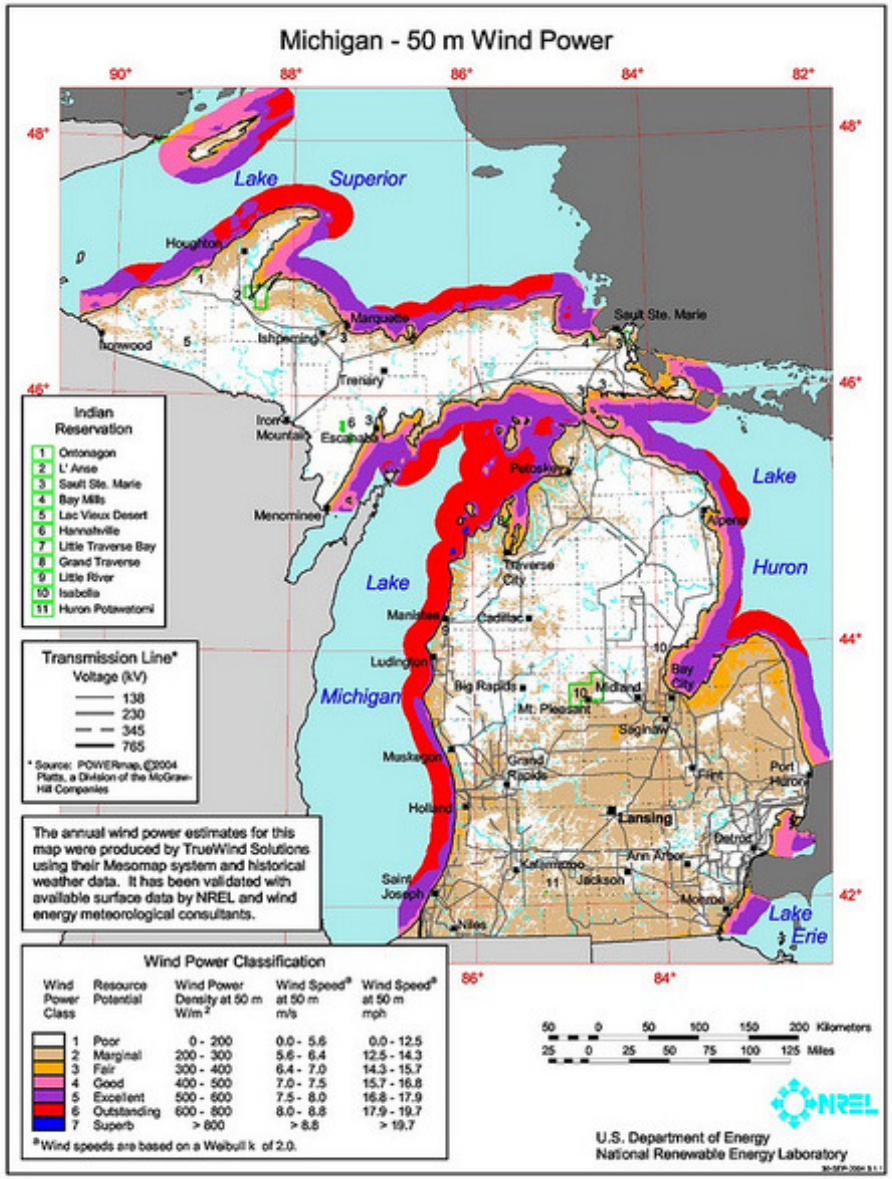
Wind Turbine Types



Wind Farm Components



Michigan Wind Power Resources



Typical “rule of thumb” is that an average annual wind speed of 15-16mph at the turbine hub height is desirable.

Wind Power Characteristics

- Renewable energy resource – wind is free!
- No toxic air emissions – Sox, Nox, Hg, PM, CO2, etc.
- Proven technology
- Intermittent resource – Low capacity factor, typ. 25-35%
- Very large land area required – 20-80 acres/MW
- Potential environmental impacts – noise, bird/bat mortality, aesthetics, shadow flicker

Solar Power

Solar Power

- Photovoltaic – PV
  - Crystalline Silicon, 17-20%
  - Crystalline Silicon (ribbon), 12%
  - Thin Film, 8-12%
  - Tracking – fixed, single axis and double axis
- Concentrated Solar Power – CSP
  - Linear fresnel – 400-500F
  - Parabolic trough – 750F
  - Power tower – 1000F
  - Stirling Engine

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