The "process" aspect of cogeneration

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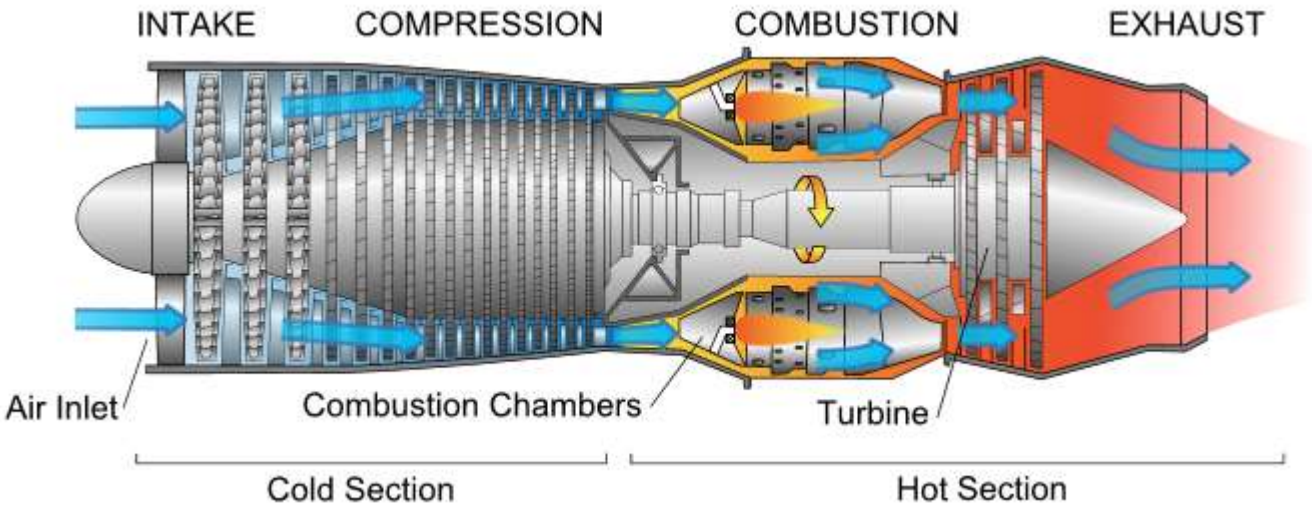
Gas Turbine Power Generation



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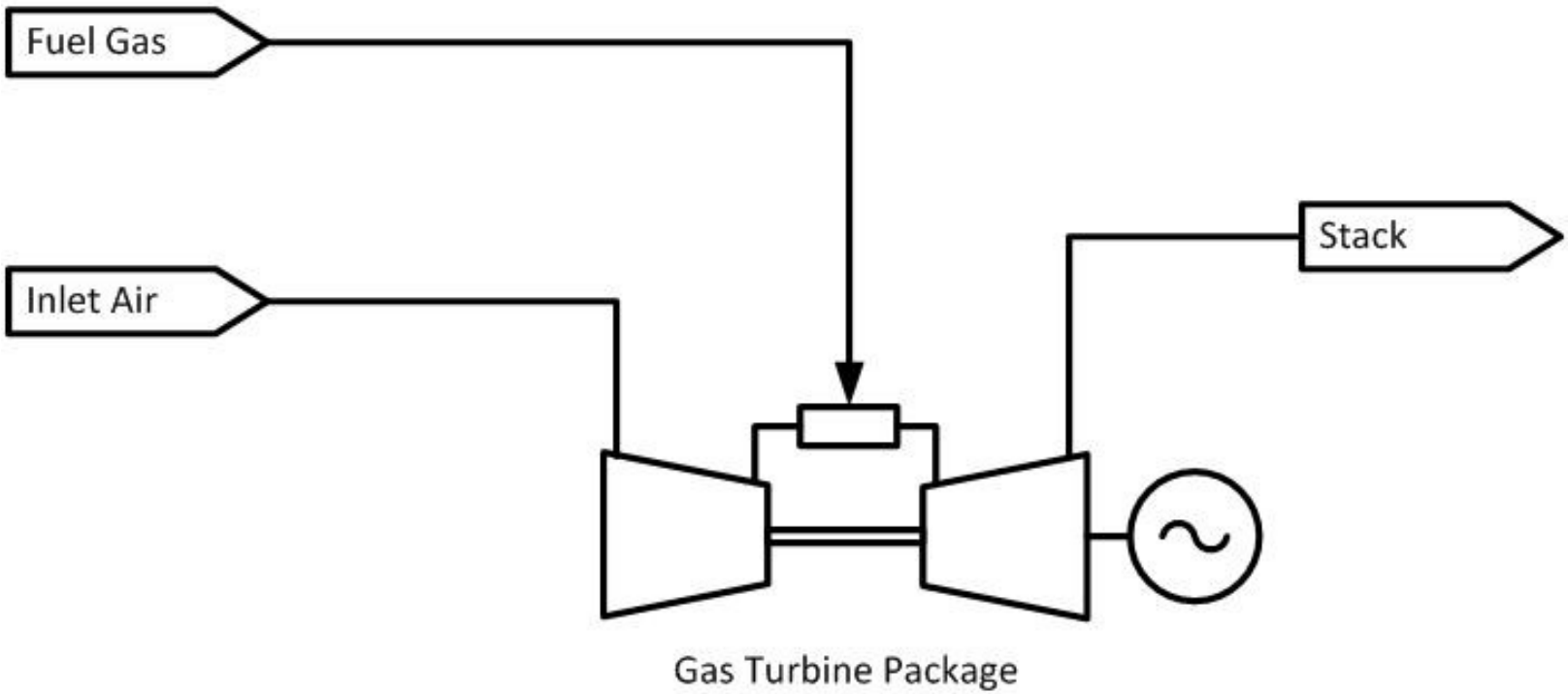
Simple Cycle



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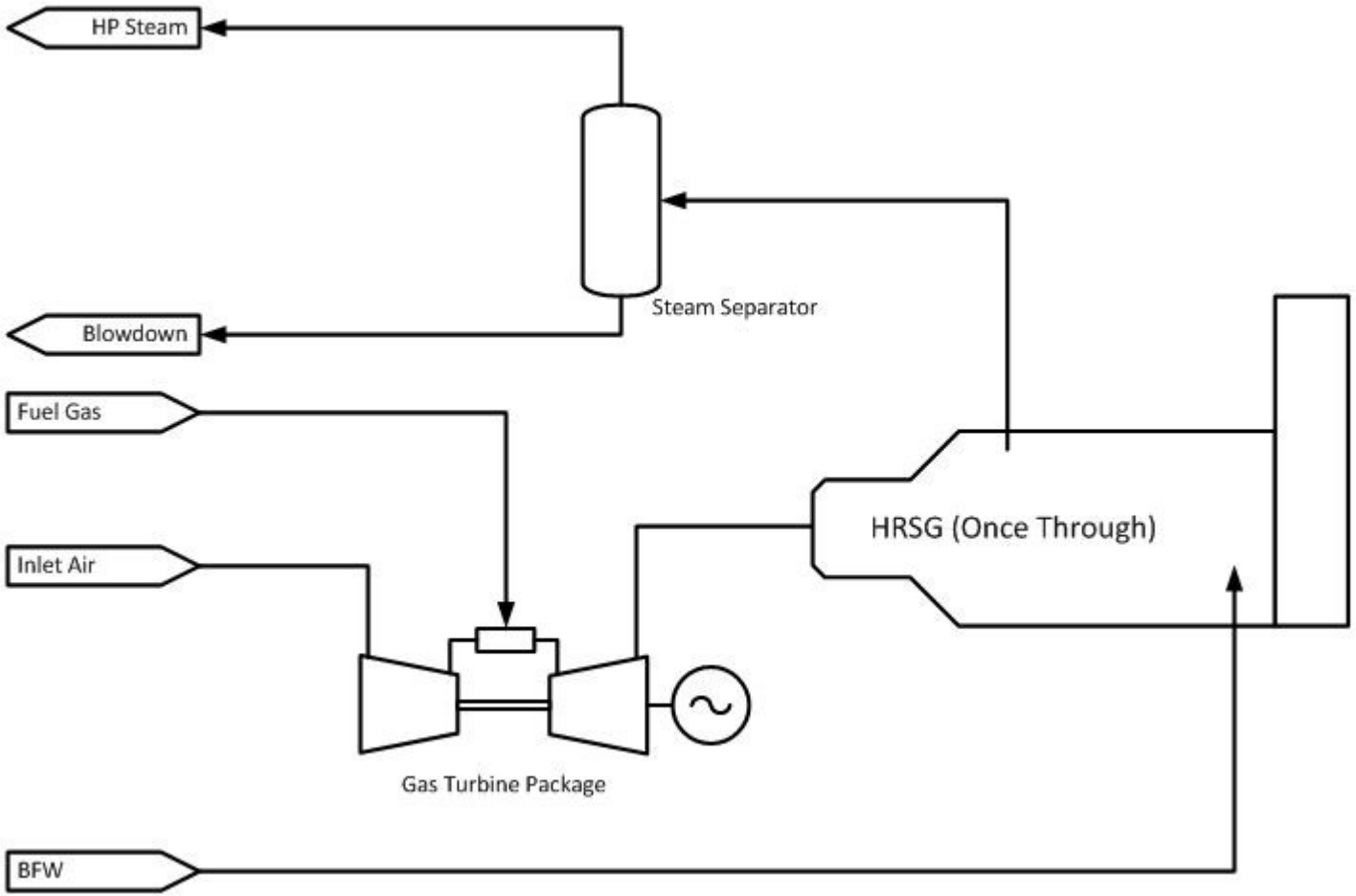
Cogeneration (SAGD Example)



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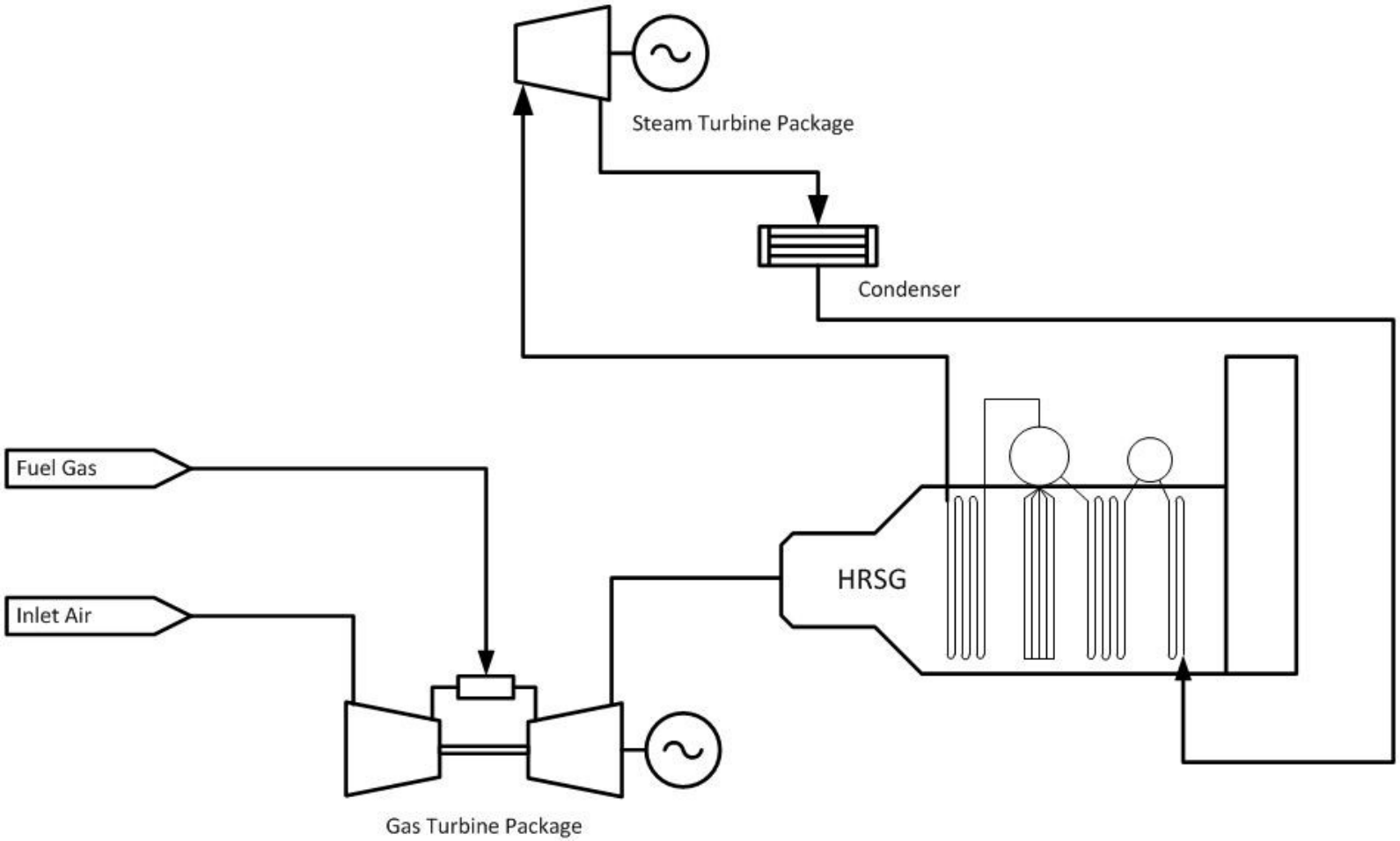
Combined Cycle



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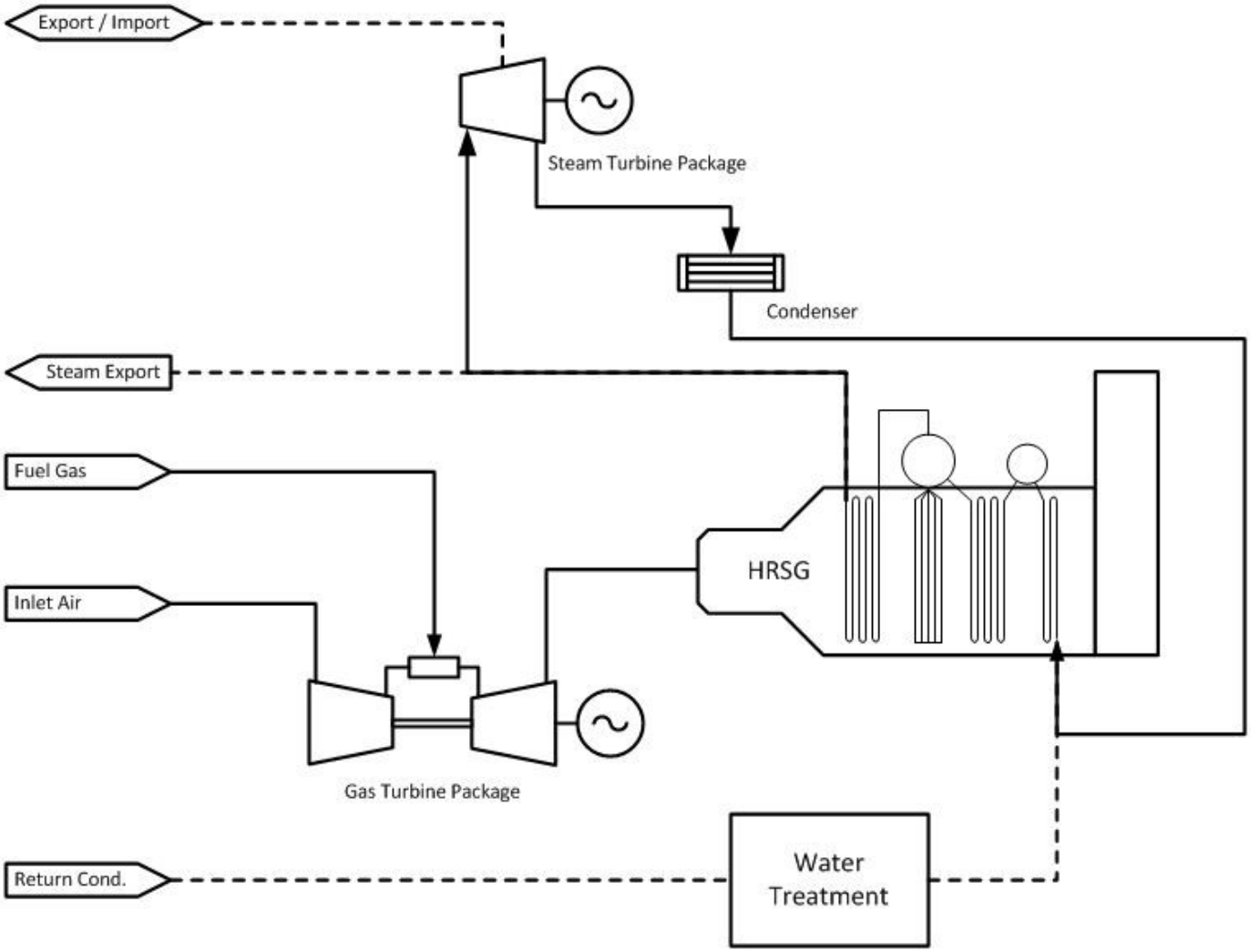
Combined Cycle Cogeneration



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Configuration Efficiencies

- LM6000PH Gas Turbine
- One Pressure Level (30 bar, 450°C)
- No Supplemental Firing

Configuration	Output [kW]	Heat Rate [kJ / kWh]	Electrical Efficiency [%]	Class 43 Heat Rate [Btu / kWh]
Simple Cycle	47,800	8821	40.8	-
Cogeneration	47,600	8858	40.6	5110
Combined Cycle	61,600	6844	52.6	7594
CC Cogen (50% extracted at 15 bar)	56,500	7460	48.3	6353

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Aeroderivative vs Frame Turbine

- GE LM6000PH vs GE Frame 7E.03
- One Pressure Level (30 bar, 450°C)
- No Supplemental Firing

Configuration	Heat Rate [kJ / kWh]	Electrical Efficiency [%]	GT Exhaust Temp [°C]
Simple Cycle			
LM6000	8821	40.8	479
7E.03	10624	33.9	550
Combined Cycle			
LM6000	6844	52.6	479
7E.03	7256	49.5	550

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Impact of Ambient Conditions

GE LM6000PH Operating in Simple Cycle

Ambient Temperature (@101.3 kPa)	Power Output
-20ºC	54700 kW
15ºC	47800 kW
35°C	38500 kW

Ambient Pressure (@15°C)	Power Output
101.3 kPa (0 m)	47800 kW
93.8 kPa (645 m)	44100 kW
87.0 kPa (1265 m)	40600 kW

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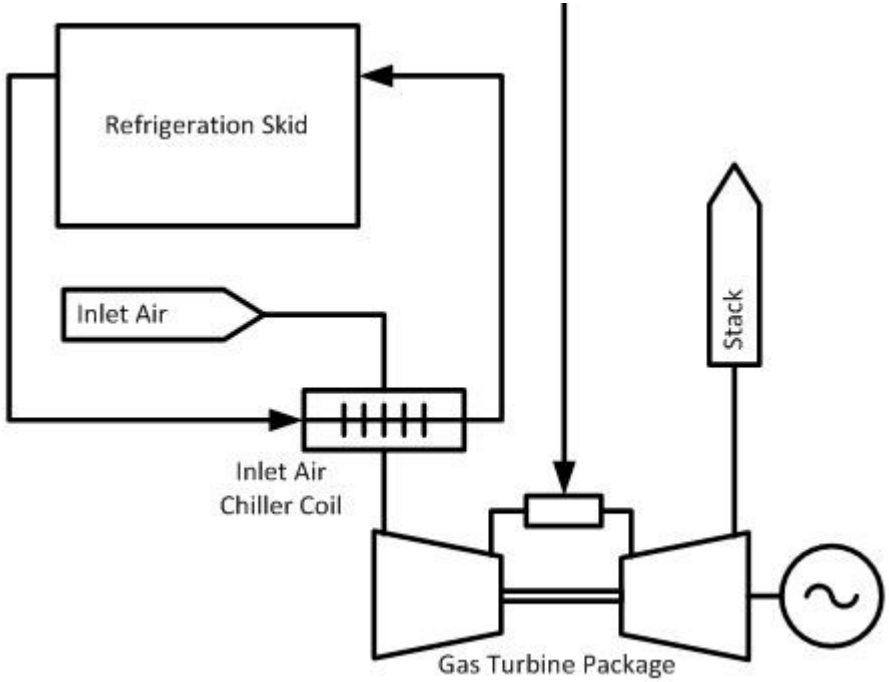
Impact of Ambient Conditions

What can be done to “overcome” power output changes due to ambient conditions?

Inlet Air Cooling

- Cooling water
- Evaporative
- Chiller
- Fogger

The denser the air,
The higher the power.



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Other Ways to Increase Power

In a Combined Cycle configuration (i.e. with a Steam Turbine), more steam gives you more power.

How to maximize steam in a Heat Recovery Steam Generator (HRSG)?

- *Surface Area*
  - HRSGs are massive heat exchangers but more surface area is more expensive.
- *Multiple Pressure Systems*
  - By increasing the number of steam pressure levels, more efficient heat recovery can be attained and thus produces more power.
- *Duct Firing*
  - Largest impact on steam generation and makes power generation more customizable.

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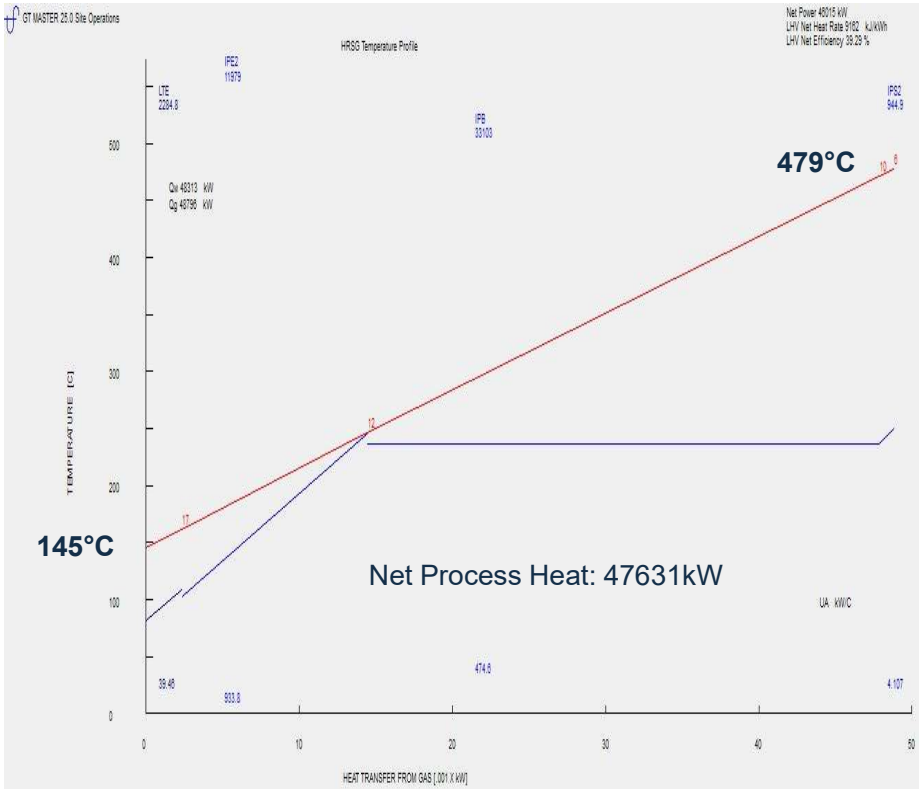
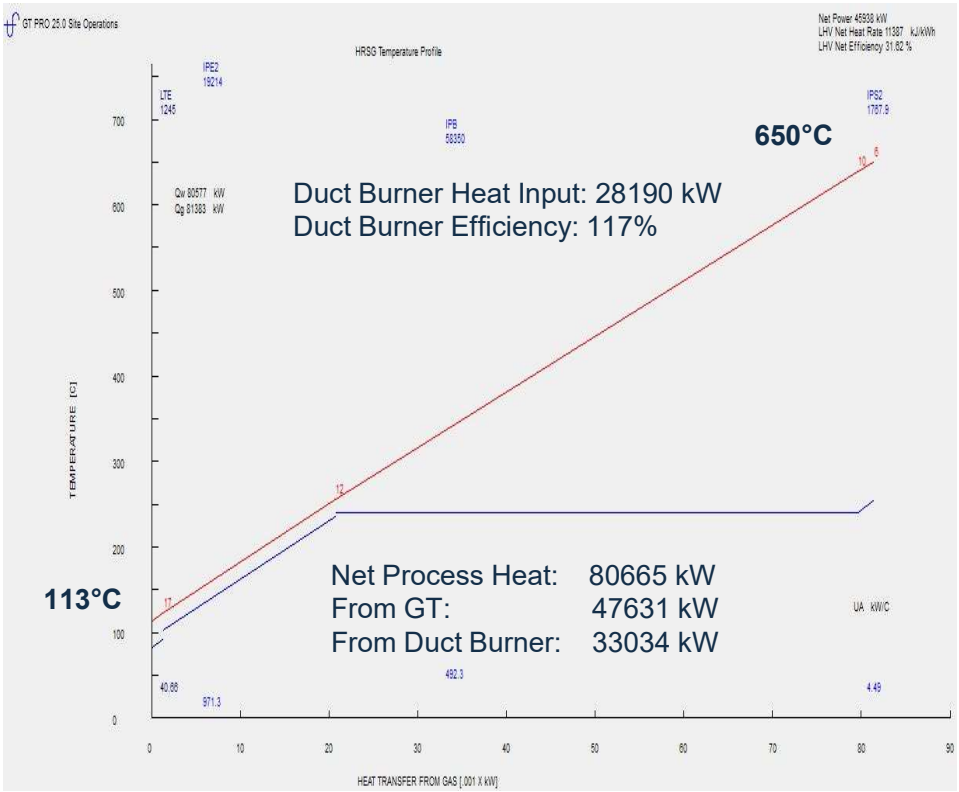
The “Magic” of Duct Firing

- Duct Firing can make an HRSG more efficient





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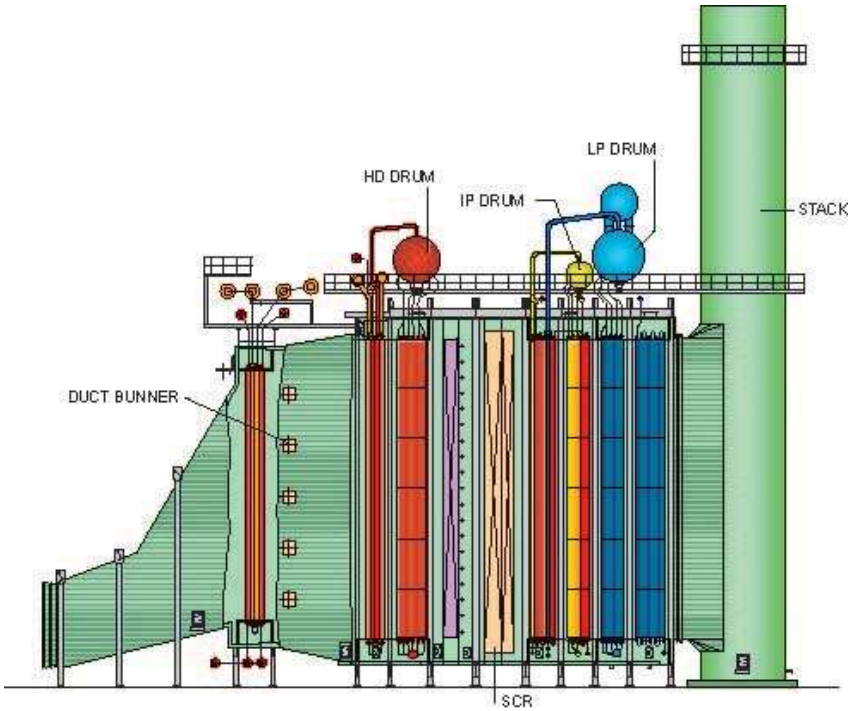
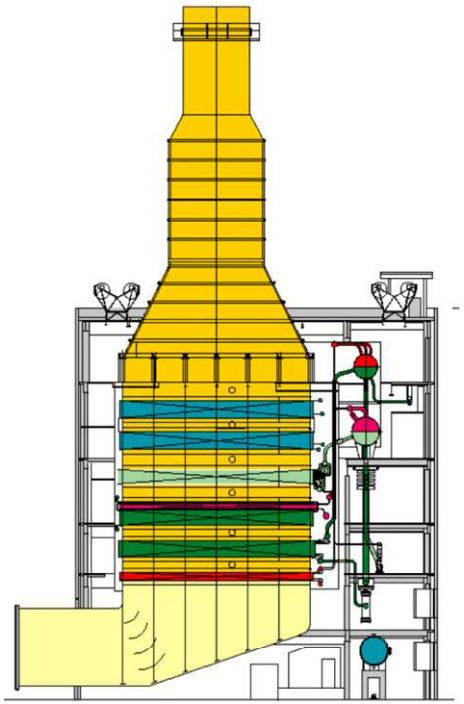
Equipment Options and Considerations

Heat Recovery Steam Generators – Drum Style

- Can be horizontal (North America) or vertical (Europe)





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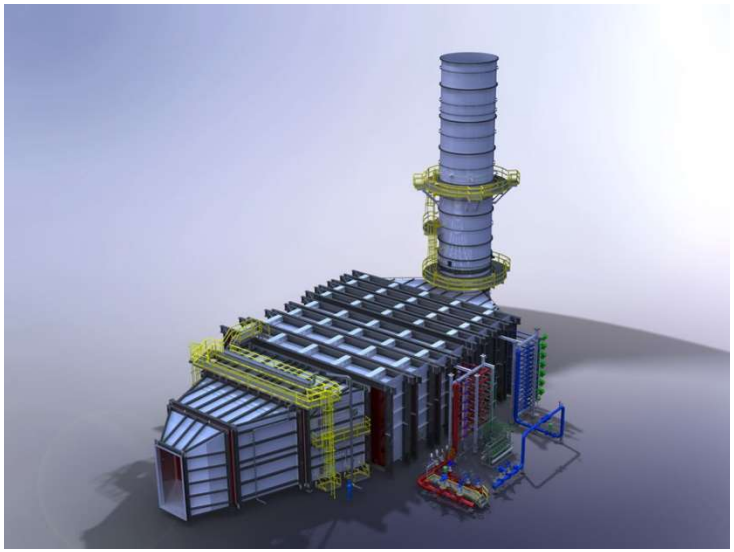
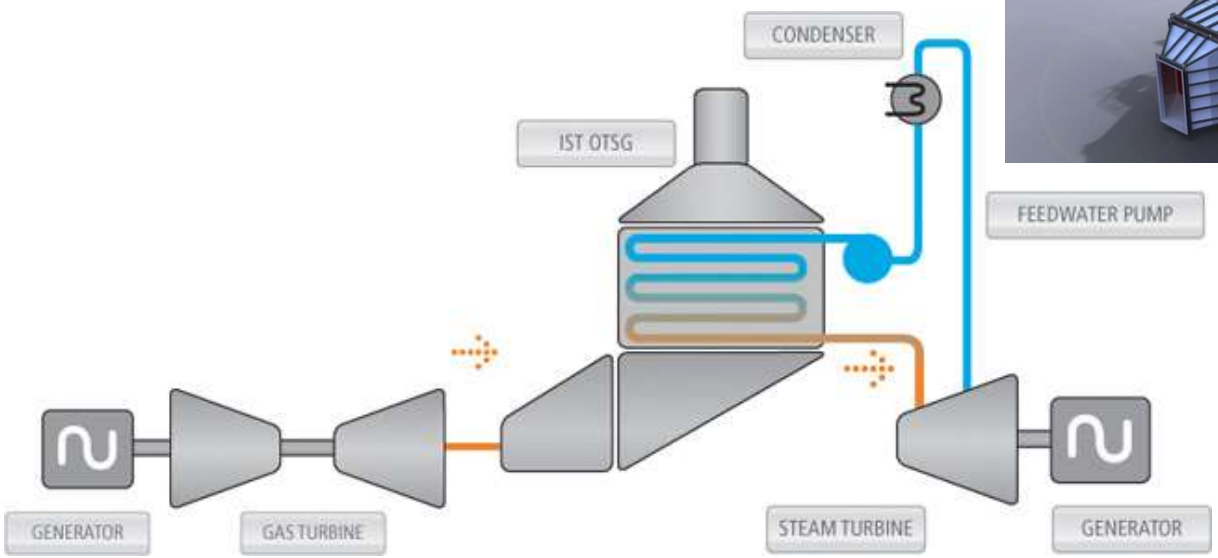
Equipment Options and Considerations

Once Through Steam Generators



- Used in Heavy Oil facilities
- Used in Combined Cycle applications



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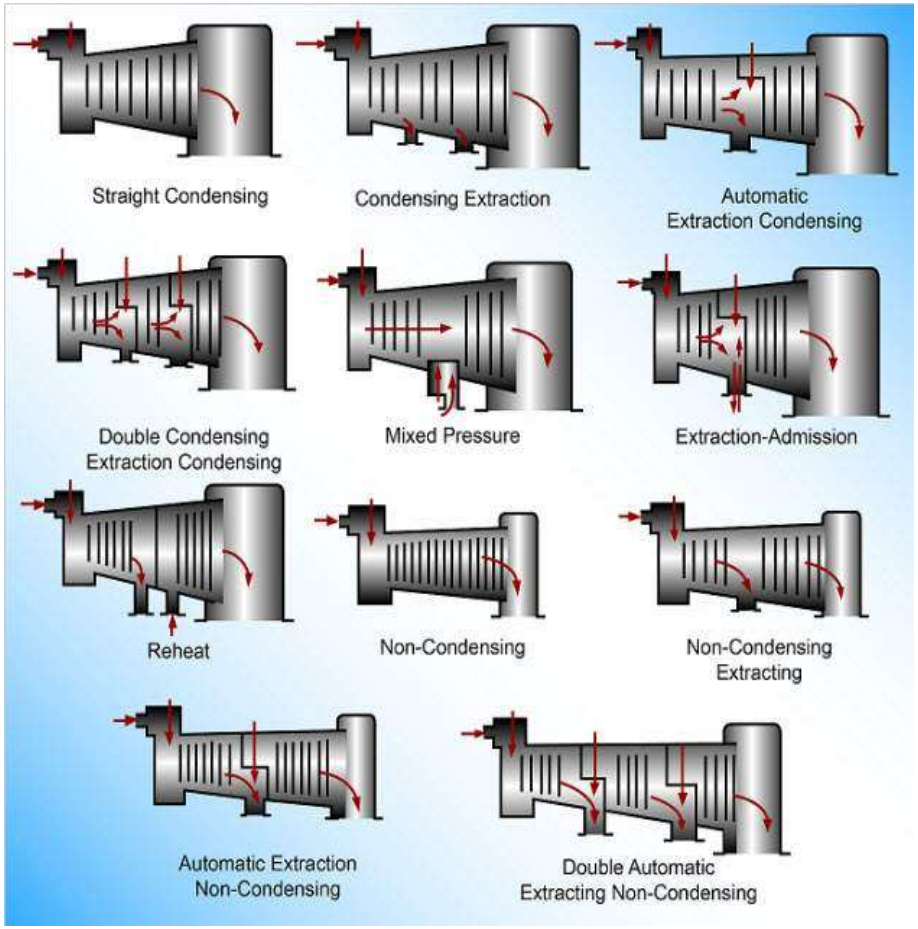
Equipment Options and Considerations

Steam Turbine

- Very flexible in cogeneration applications.
- The lower the exit pressure, the higher the power generation.

Condensing Pressure	Condensing Temperature
2.34 kPaa	20°C
4.24 kPaa	30°C
7.38 kPaa	40°C



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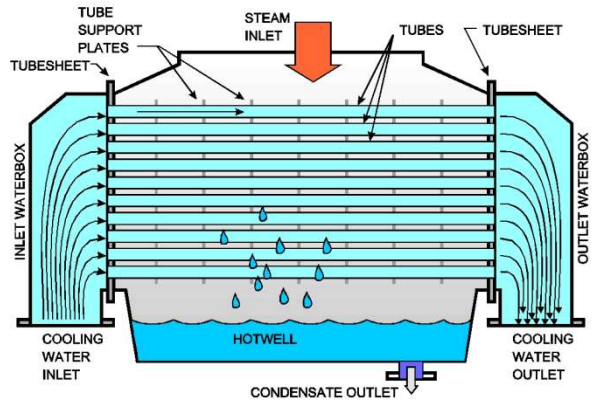
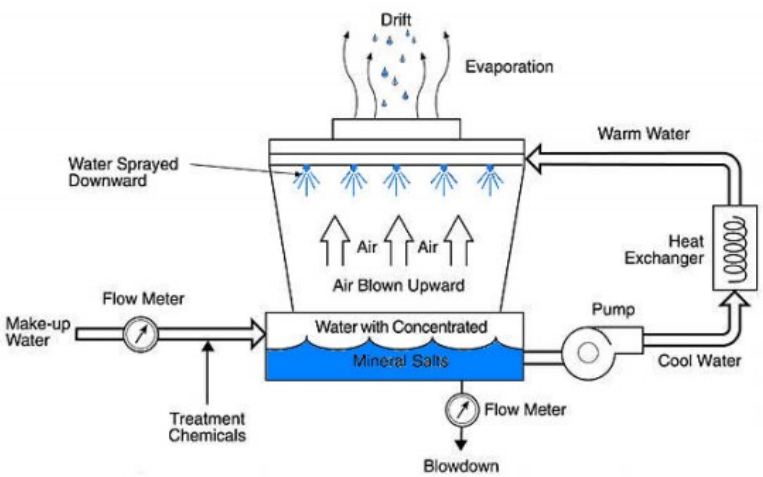
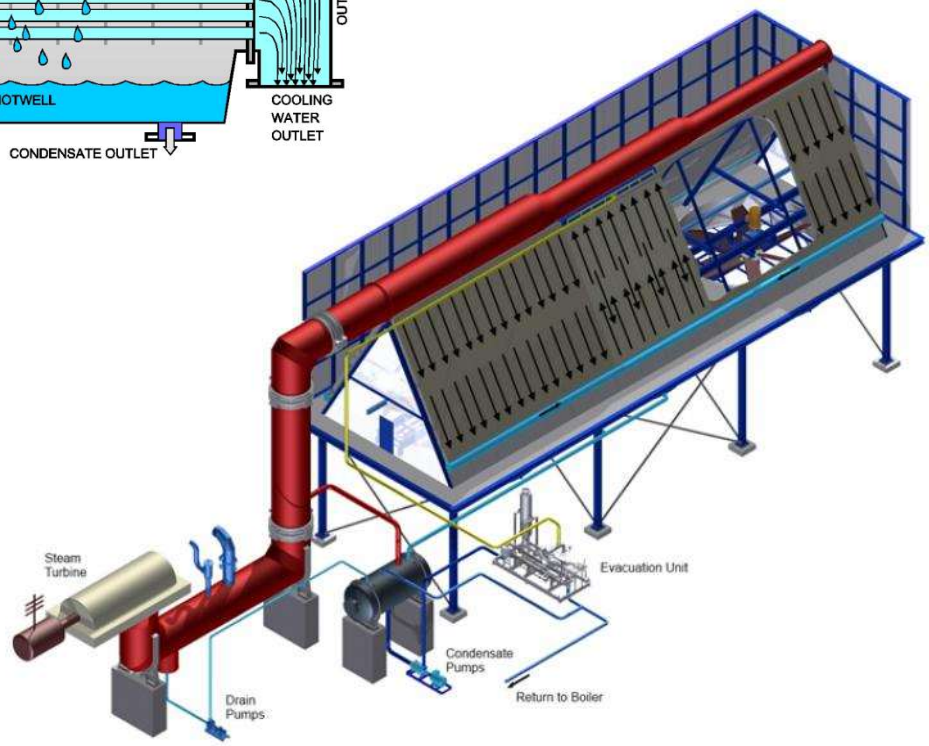
Equipment Options and Considerations

Condensers

- Direct Cooled
- Cooling Tower
- Air Cooled







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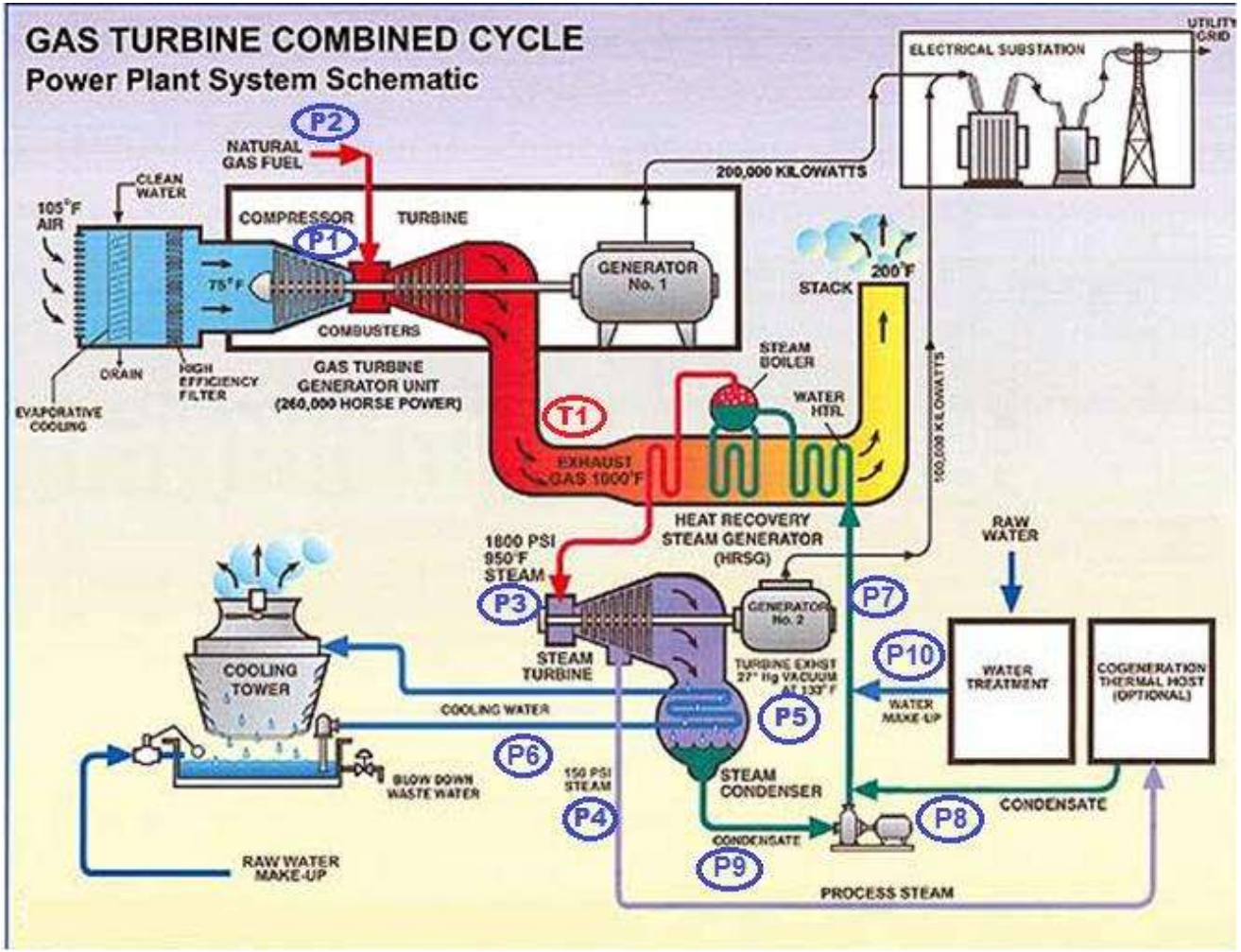
Efficient Power Generation



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