Lecture 13: Gas Power Plant Modifications

Course: MECH-422 – Power Plants

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BUITEMS – DEPARTMENT OF MECHANICAL ENGINEERING

What we have done so far…

- Steam Power Plants
- Gas Power Plants

What's next?

- Combined Cycle Power Plant (Brayton + Rankine)

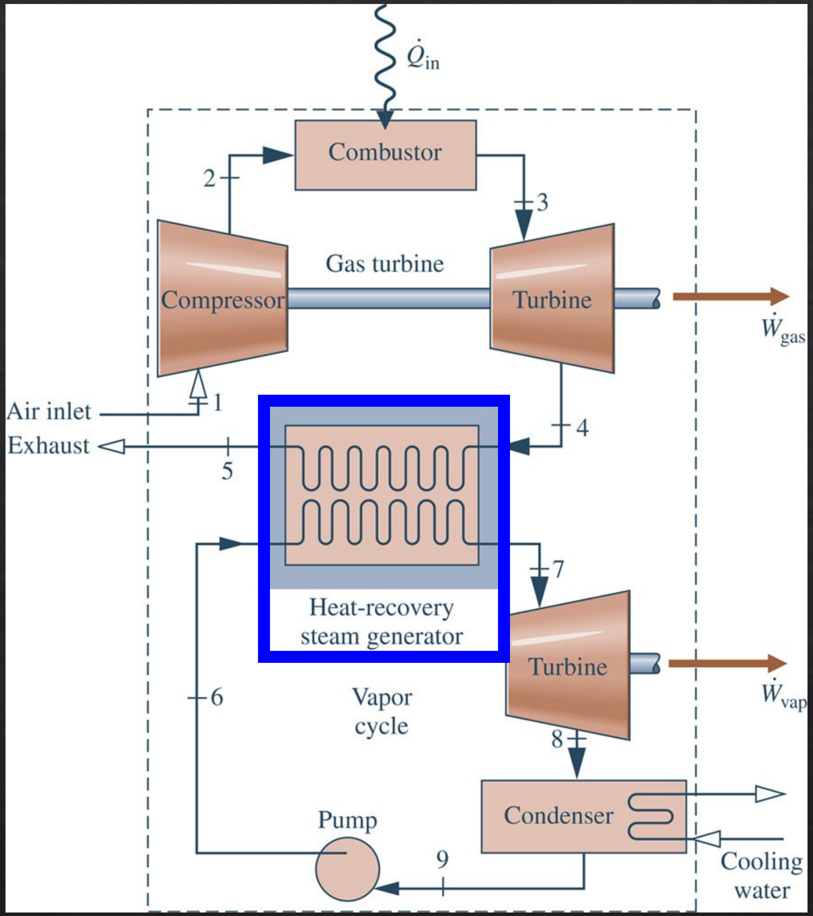
Gas Turbine-Based Combined Cycle

- ►The exhaust temperature of the simple gas turbine is typically well above the ambient temperature, and thus the hot gas exiting the turbine has significant thermodynamic utility (exergy) that can be used cost-effectively.
- ►***Ways*** to utilize this potential include:
  - ►The ***regenerative cycle*** previously considered.
  - ►A ***combined cycle*** – namely, a cycle that couples two power cycles such that the energy discharged by heat transfer from the higher-temperature cycle is used as a heat input for the lower-temperature cycle.

Combined Gas Turbine-Vapor Power Cycle (1 of 2)

- ►Illustrated here is a combined cycle involving gas and vapor power cycles:
  - ►The cycles are combined using an interconnecting ***heat-recovery steam generator*** that serves as the boiler for the vapor power cycle.

The overall electrical efficiency of a combined-cycle power system is typically in the range of 50–60% — a substantial improvement over the efficiency of a simple, open-cycle application of around 33%.

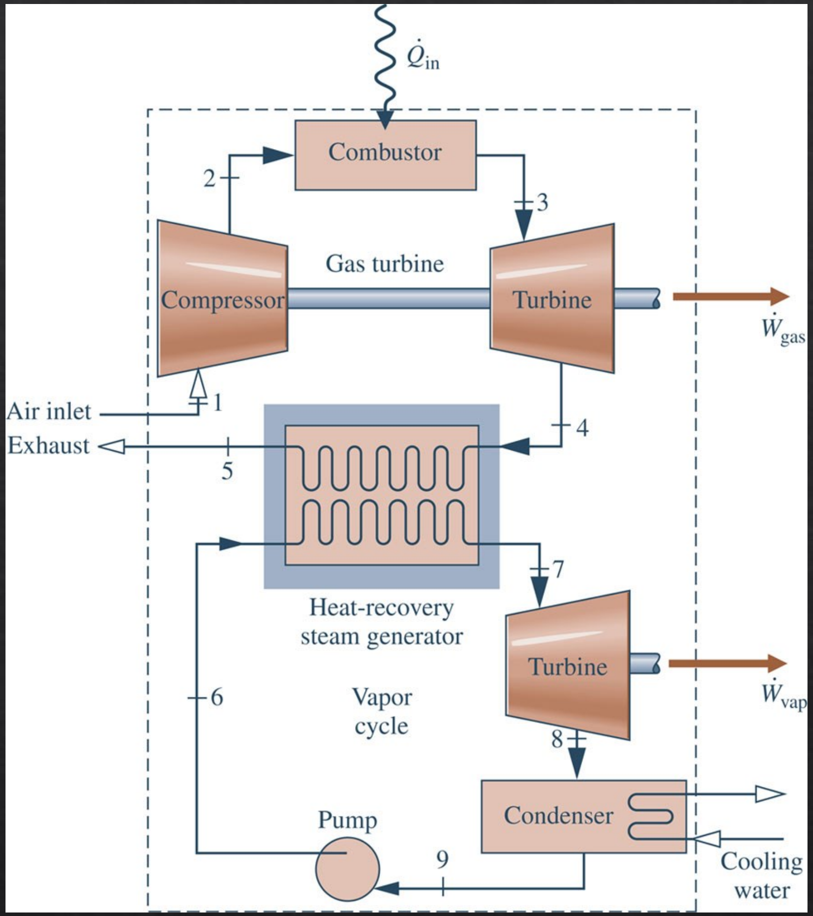


Combined Gas Turbine-Vapor Power Cycle (1 of 2)

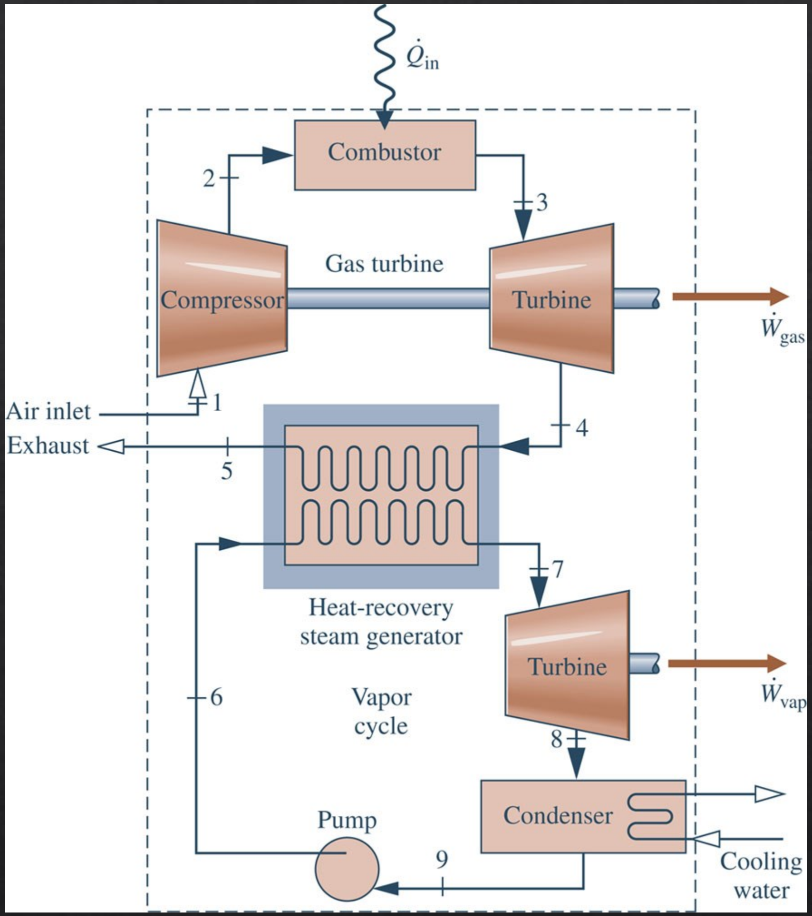
- The combined cycle has the gas turbine's high average temperature of heat addition and the vapor power cycle's low average temperature of heat rejection.

- Thermal efficiency is greater than either cycle would have individually.

- Increasingly, combined gas turbine-vapor power plants are being used world-wide for electric power generation.



Combined Gas Turbine-Vapor Power Cycle (2 of 2)

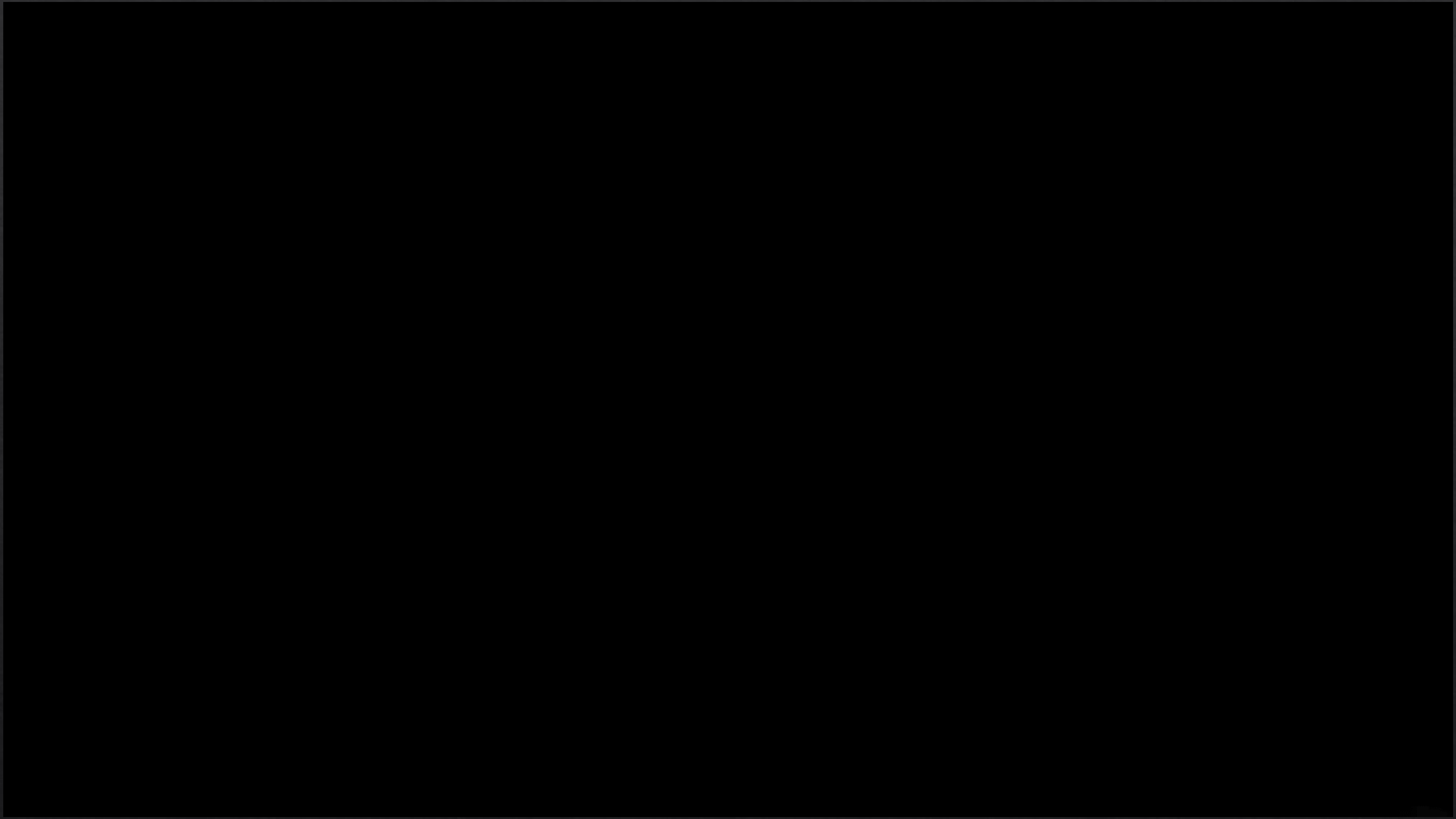


- The net power developed by the combined cycle is the sum of the net power developed by each cycle.
- The thermal efficiency of the combined cycle is the net power output divided by the rate of heat addition.

$$\eta = \frac{\dot{W}_{gas} + \dot{W}_{vap}}{\dot{Q}_{in}}$$

- For an adiabatic heat recovery steam generator, mass and energy rate balances reduce to give the following relationship involving the mass flow rates of the two cycles:

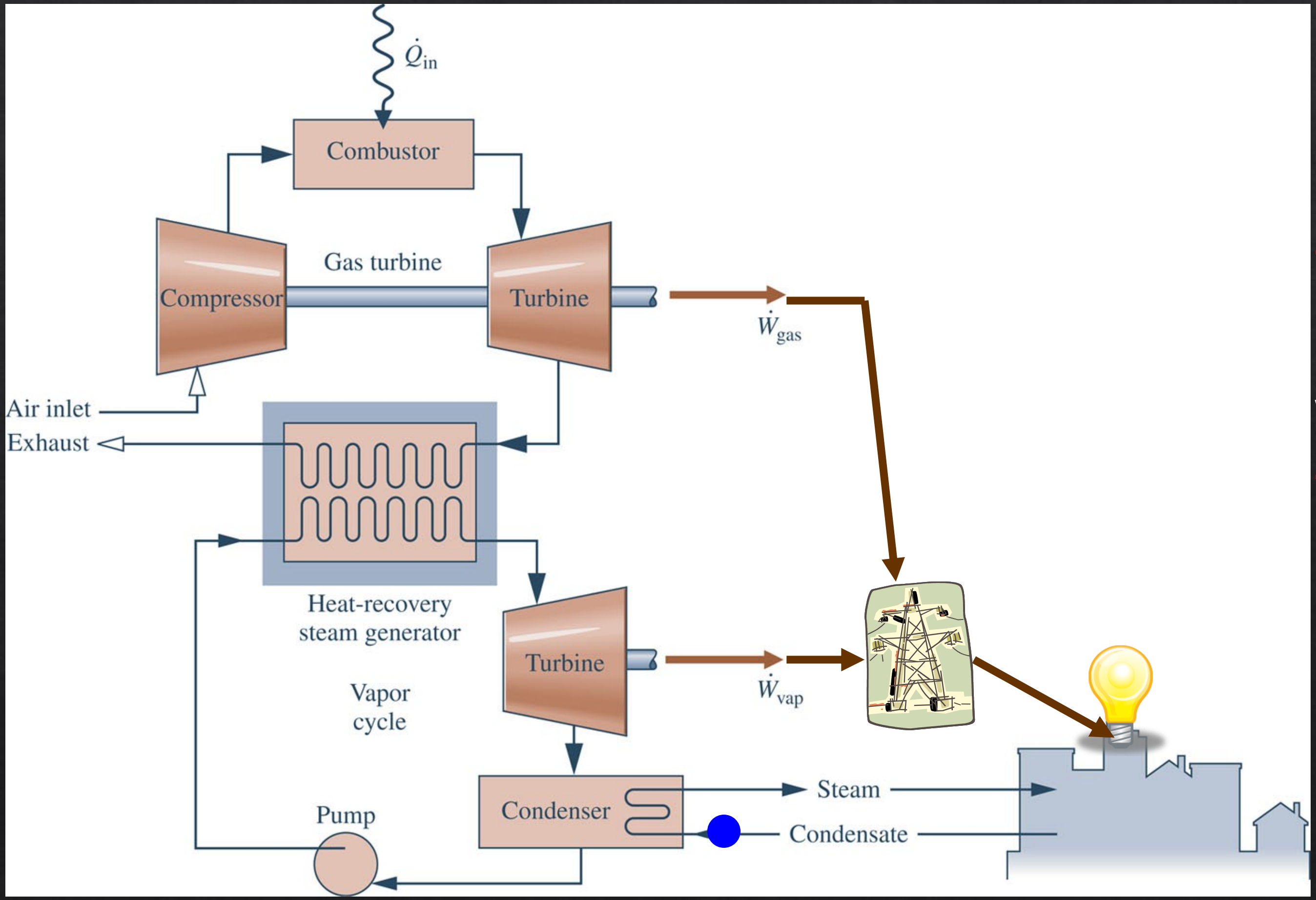
$$\dot{m}_v(h_7 - h_6) = \dot{m}_g(h_4 - h_5)$$



- https://www.youtube.com/watch?v=eeiu-wcyEbs

Combined-cycle District Heating

►Shown here is a combined gas turbine-vapor power cycle applied for ***district heating***. District heating plants are located within communities to deliver steam or hot water together with electricity for domestic, commercial, and industrial use.



►Alternatively, steam exiting the turbine may be sent directly to the community while its condensate returns to the pump, thereby eliminating the condenser.

Heat Recovery Steam Generators (HRSGs)

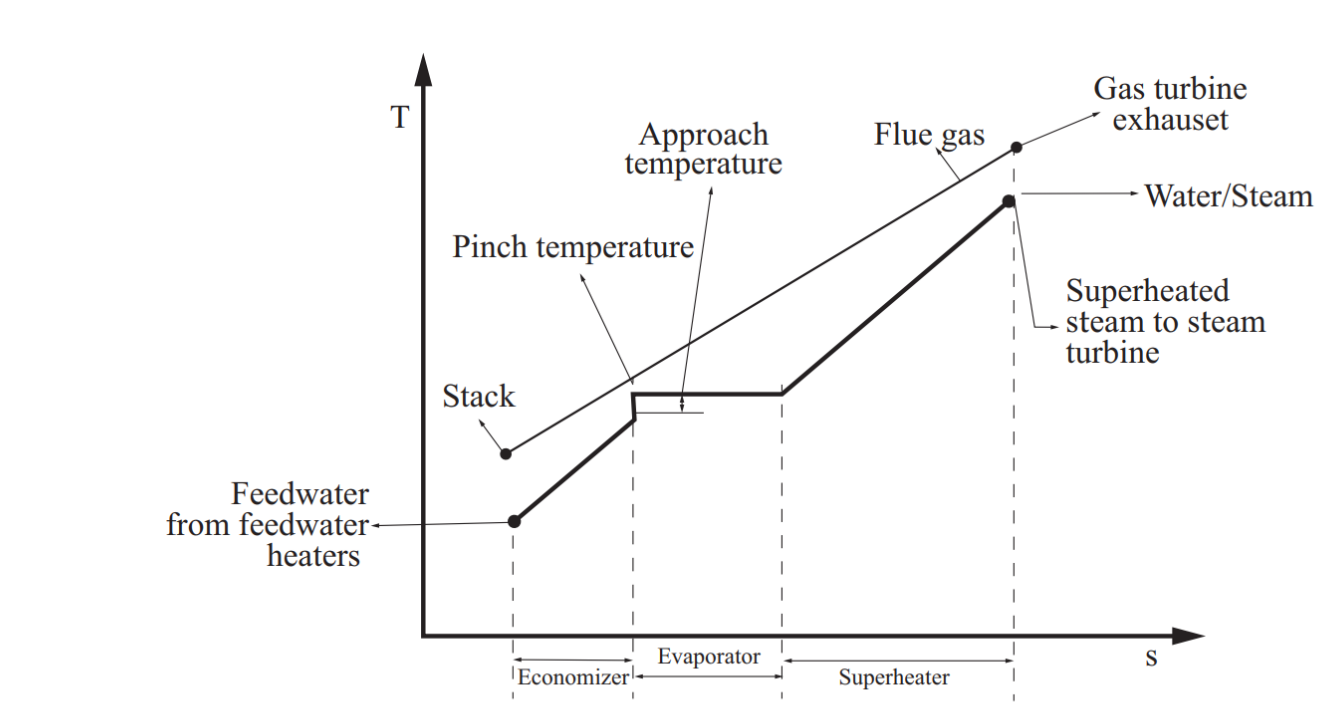
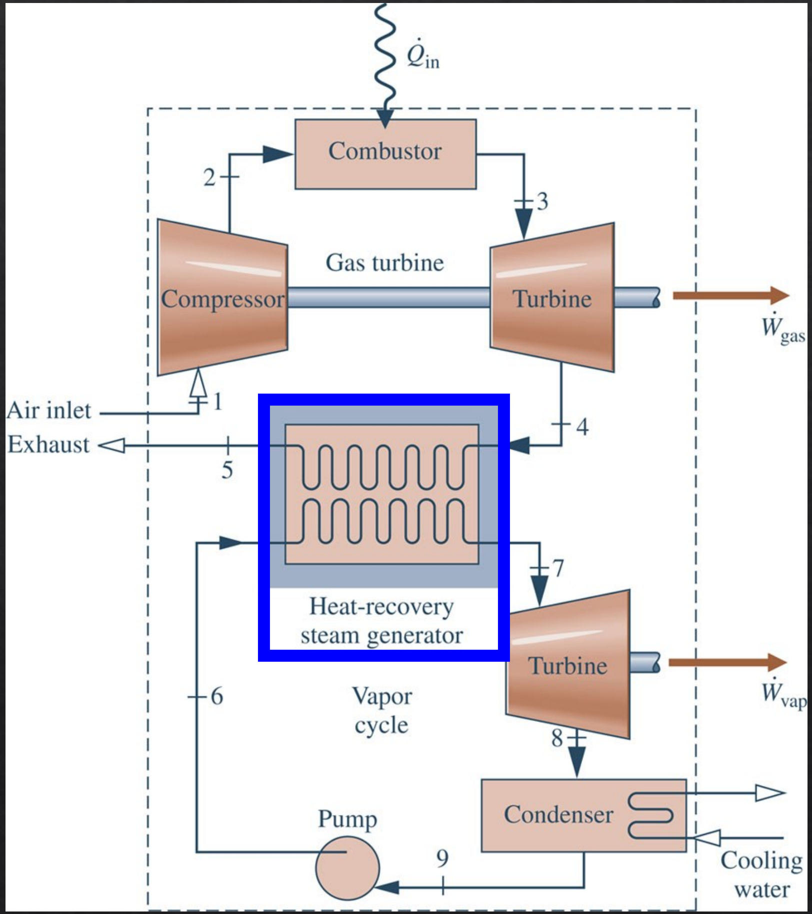
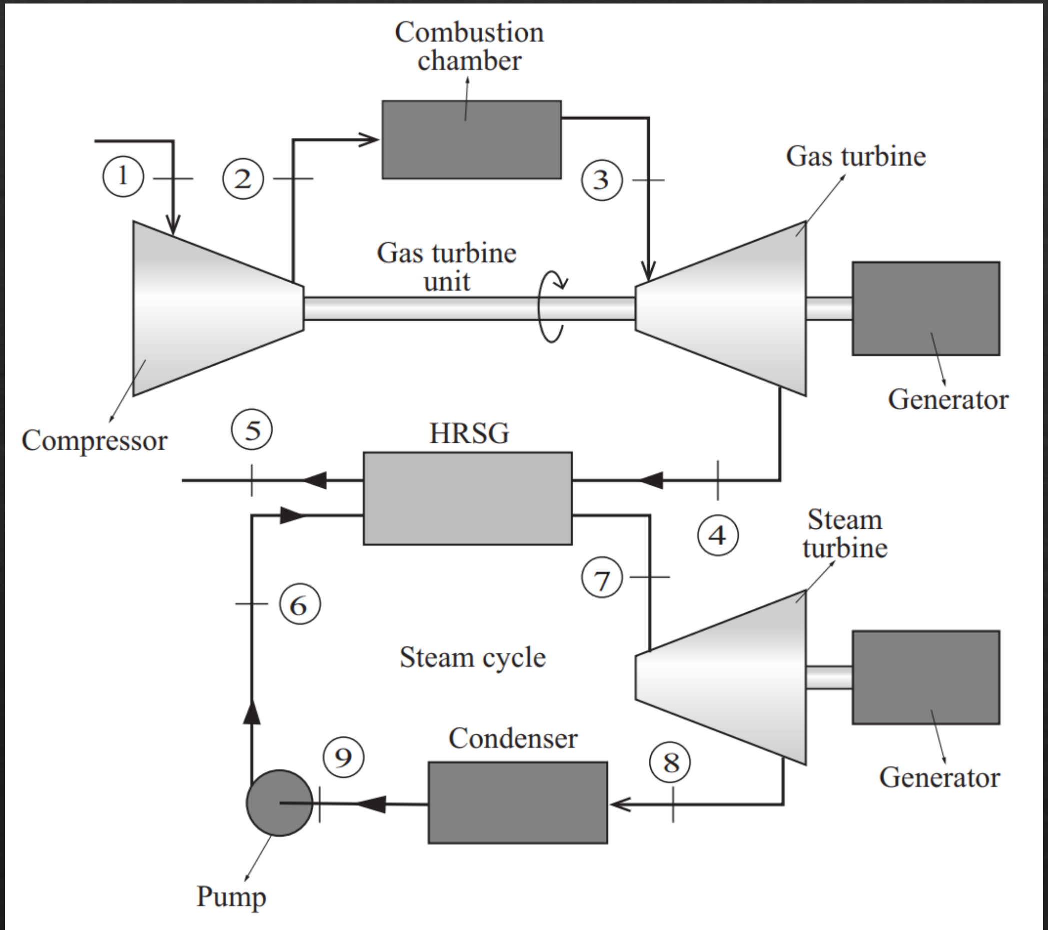
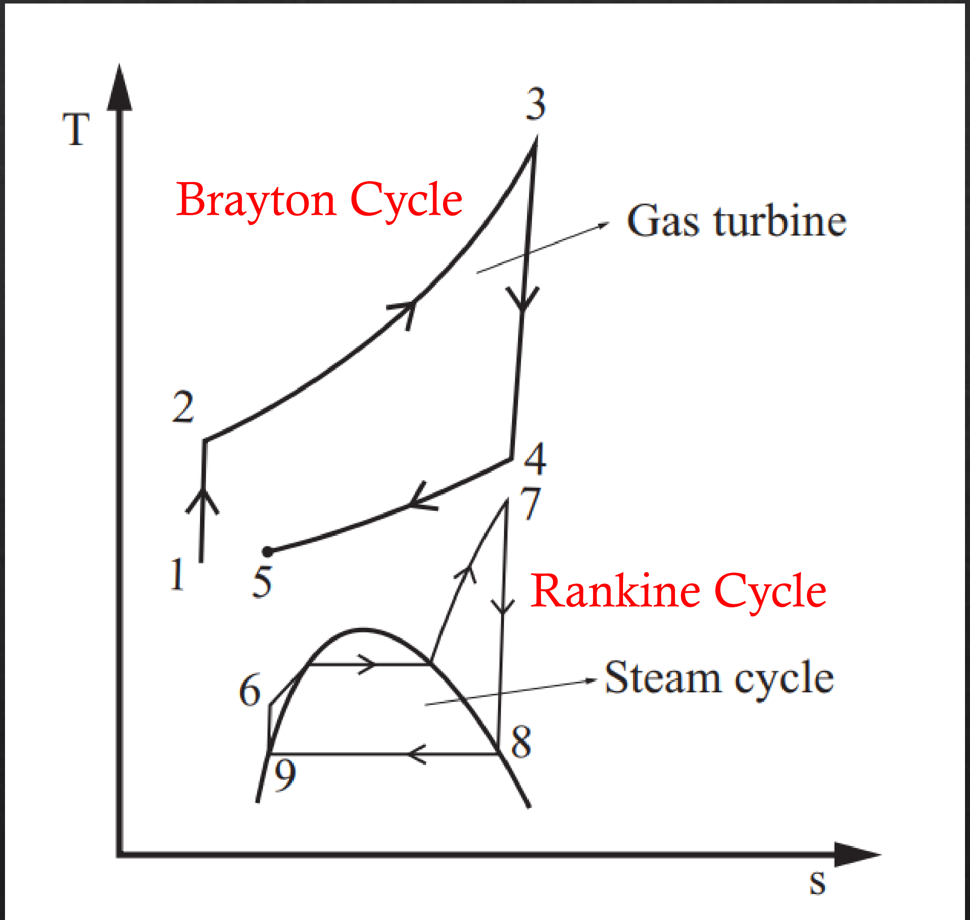


FIGURE 10.5
T-s diagram of a single-pressure HRSG.



Combined Cycle Power Plant





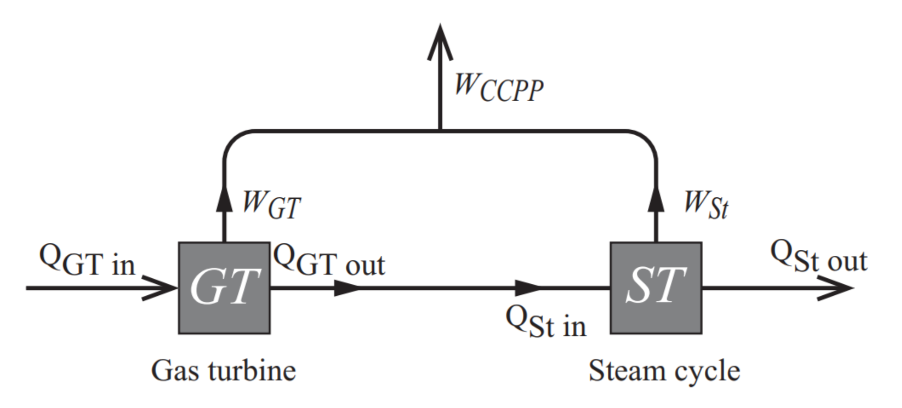
Efficiency of Combined Cycle Power Plants

$$\eta_{CCPP} = \frac{\dot{W}_{CCPP}}{\dot{Q}_{GT,\,in}} = \frac{\dot{W}_{GT} + \dot{W}_{St}}{\dot{Q}_{GT,in}} \tag{10.1}$$

The efficiency of the gas turbine and steam cycle are

$$\eta_{GT} = \frac{\dot{W}_{GT}}{\dot{Q}_{GT,\,in}} \tag{10.2}$$

$$\eta_{St} = \frac{\dot{W}_{St}}{\dot{Q}_{St,\,in}} \tag{10.3}$$



Example 10.2

A 500 MW CCPP has an efficiency of 55%. If the efficiency of the gas turbine cycle is 36%, determine the power output of the gas turbine and the steam cycle (in MW), the mass flow rate of natural gas burned in the combustion chamber of the gas turbine (in kg/s), and the thermal energy exhausted by the HRSG (in MW). The heating value of natural gas is 45 MJ/kg.

- One of the limitations of gas turbine units is that they cannot be fueled by solid fuels,
  - such as coal, biomass, solid municipal waste, or even a mixture of solid fuels.

- Integrated gasification combined cycles (IGCC)
  - are a way to overcome this limitation

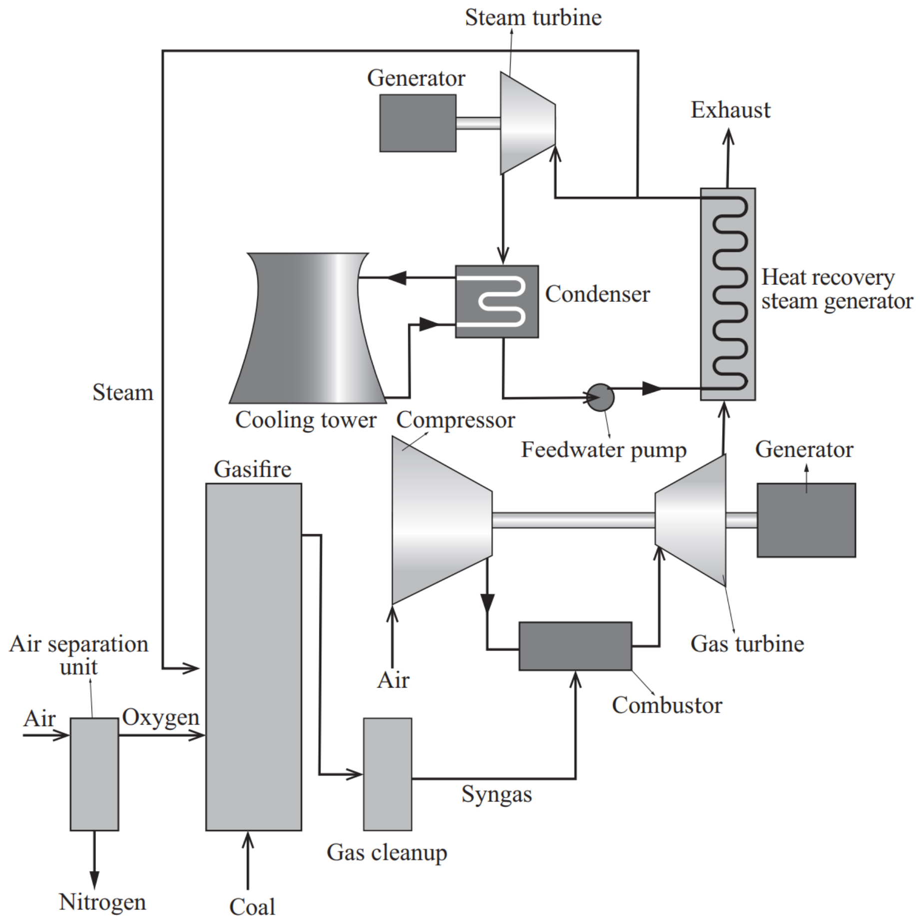


FIGURE 10.8
Schematic of an integrated gasification combined cycle (IGCC).

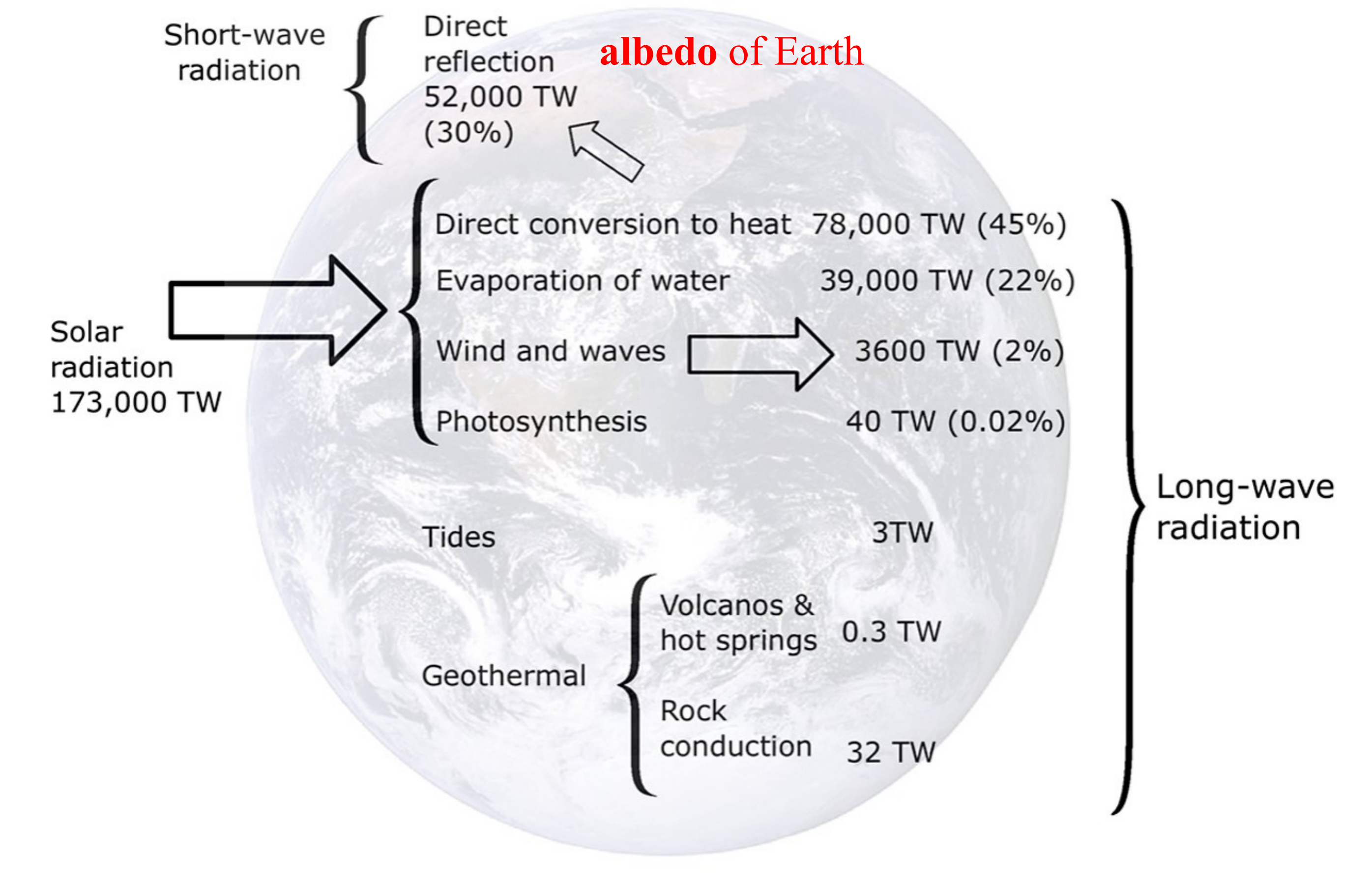
What we have done so far…

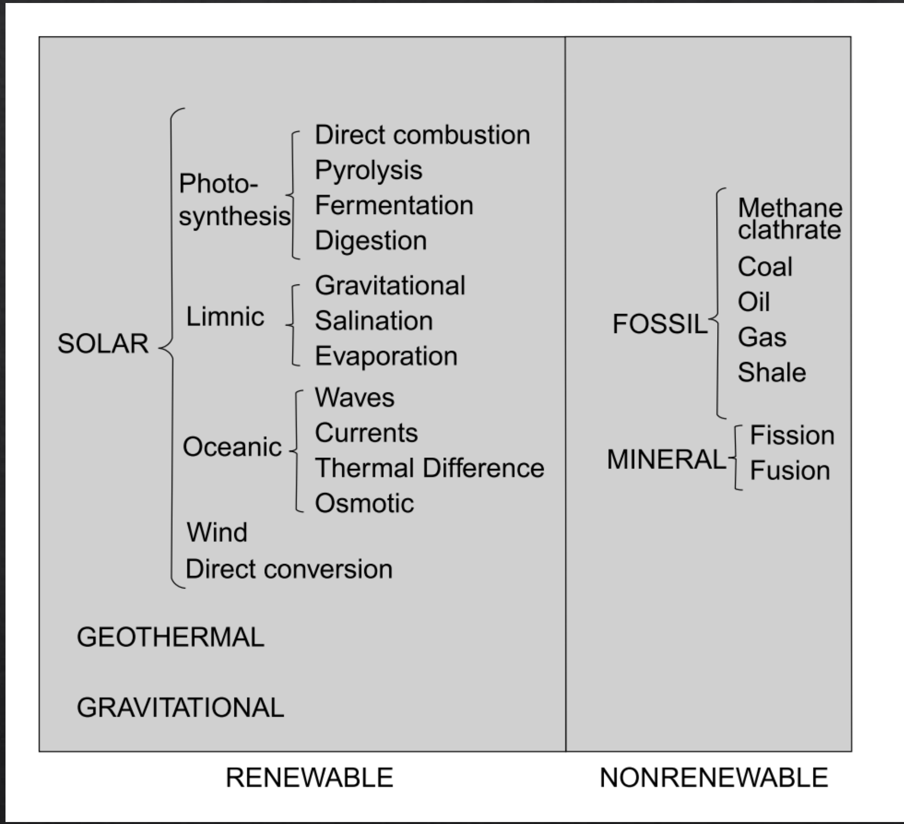
1. Electricity and Energy
2. Conventional Power Plants
   - Steam Power Plants
   - Gas Power Plants
   - Combined Cycle Power Plant

What's next?

►Renewables (Solar, Wind, etc.)

Planetary Energy Balance





End of Lecture!