Basic Course on

Renewable Energy & Energy Efficiency

Capacity Building to Bangladesh Power Sector
April/May 2018

European Investment Bank

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Module Topics

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Session No.	Topics	Speaker
Session 1	Policy Landscape & Incentive Mechanisms for Promoting Renewable Energy and Energy Efficiency in Bangladesh	Mr. Mohammad Alauddin Joint Secretary (Renewable Energy) Power Division
Session 2	Solar PV Design, Installation and Operation	Engr. Shahriar Ahmed Chowdhury Director, Centre for Energy Research United Intl. University(UIU), Dhaka
Session 3	Solar Mini-grid	Engr. Shahriar Ahmed Chowdhury Director, Centre for Energy Research, UIU, Dhaka
Session 4	Guidelines for Net Energy Metering in Bangladesh	Md. Abdur Rouf Miah Director (Sustainable Energy), Power Cell
Session 5	Commercial & Financial Aspects of Renewable Energy • Solar Water Pumping • Minigrid	Mr. Md. Enamul Karim Pavel Head of Renewable Energy, IDCOL
Session 6	Wind Energy	Mr. Md. Atiqur Rahman XEN Wind Resource Mapping in Bangladesh
Session 7	Grid integration challenge for distributed RE	Mr. Al Mudabbir Bin Anam Programme Coordinator Renewable Energy and Energy Efficiency Programme (REEEP), Bangladesh
Session 8	Energy Efficiency & Conservation: Bangladesh's Roadmap	Mr. Siddique Zobair Member (Additional Secretary) SREDA
Session 9	Energy Efficiency : Thermal	Dr. Md. Zahurul Haq Professor, Department of Mechanical Engineering, BUET
Session 10	Energy Efficiency : Electrical Power	Dr. Md. Ziaur Rahman Khan Professor, Department of Electrical and Electronic Engineering, BUET

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Energy Efficiency: Thermal

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Presentation Outline

- Review of Thermodynamics and Thermal Efficiency
- Performance parameters of Simple Thermal Power Plants
- Gas turbine (GT) based power plants
- Combined cycle (CC) power plants
- Combined Heating-Cooling-Power (CHP) Plants

Energy: Primary, Delivered & Useful

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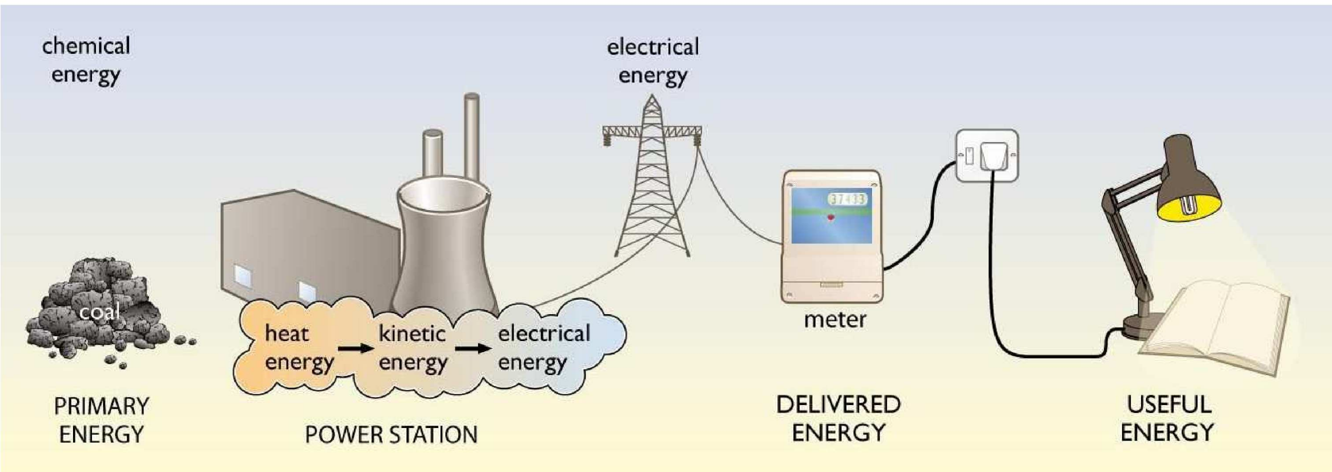

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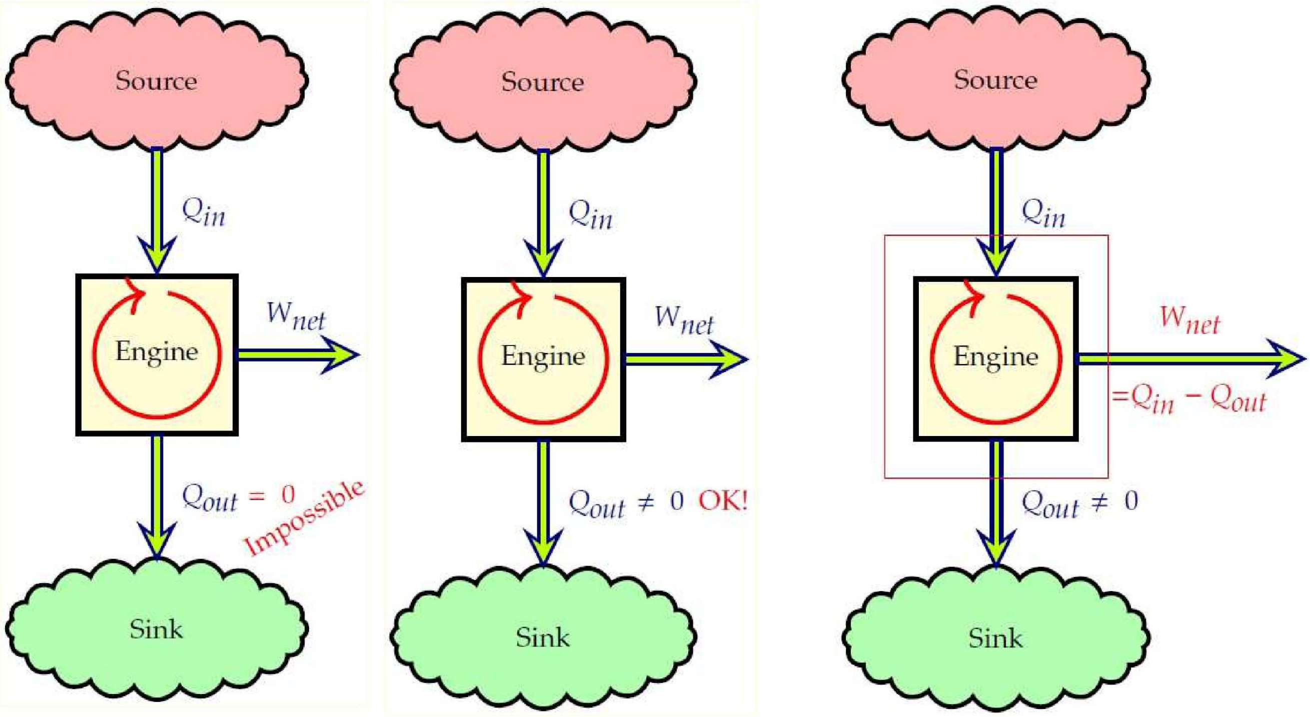
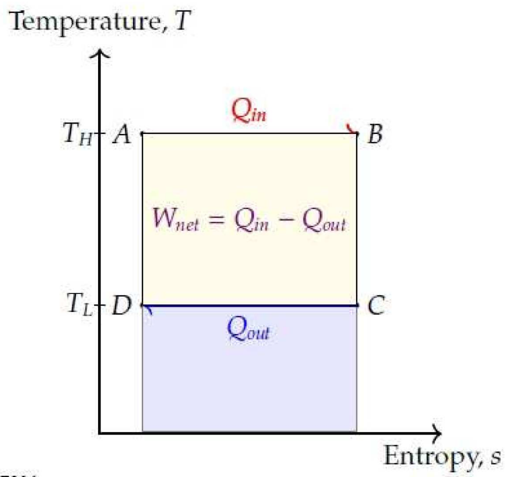
Laws of Thermodynamics: Second Law & First Law

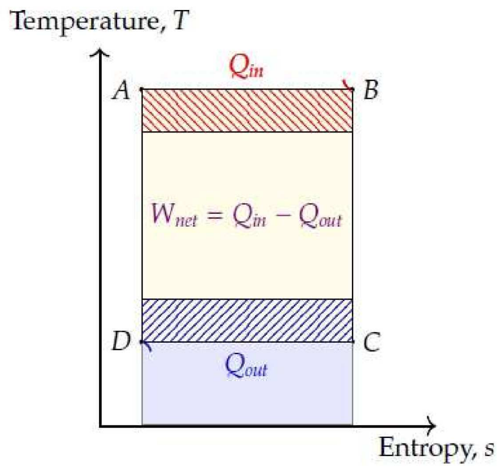


Thermal Efficiency: Effects of Source & Sink Temperatures

$$\text{Thermal efficiency, } \eta_{th} \equiv \frac{W_{net}}{Q_{in}} < 1.0$$



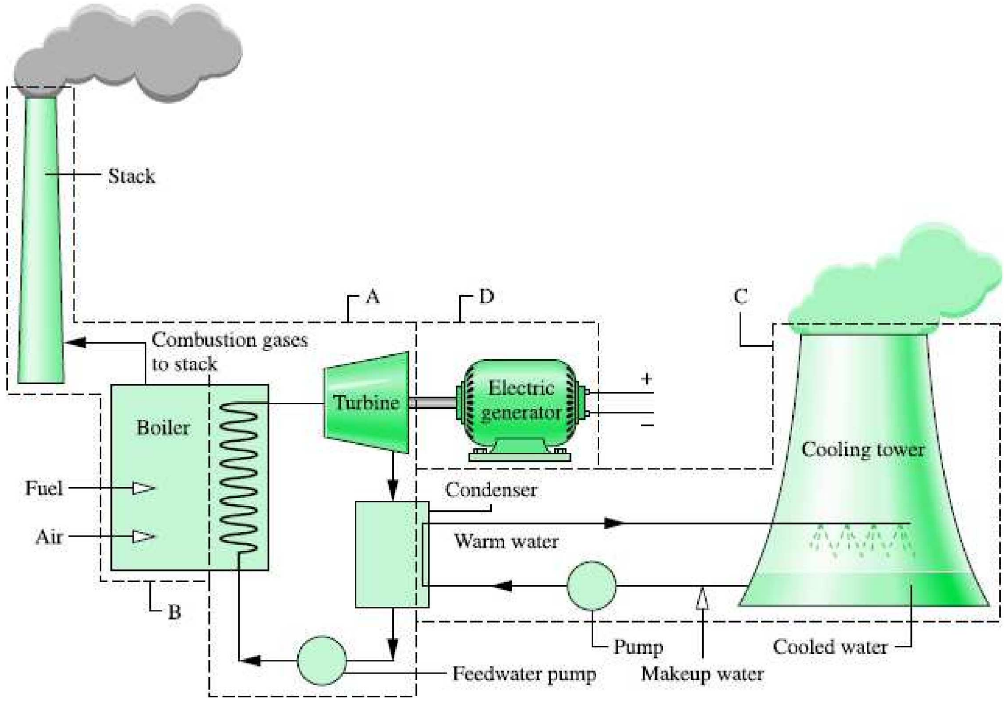
F004



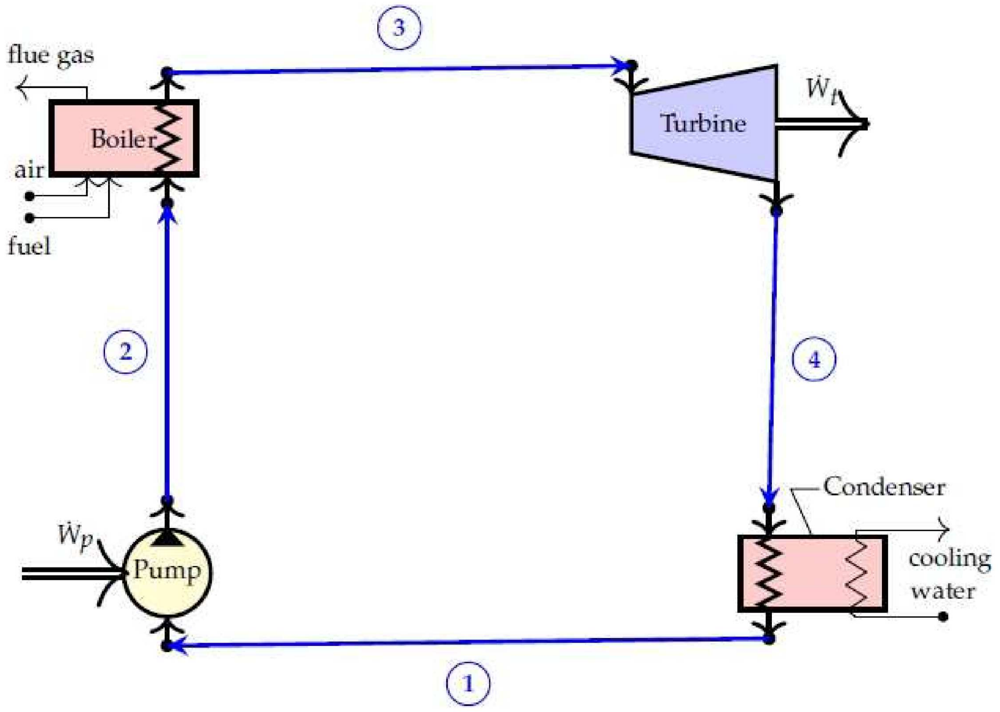
F005

- $T_H \uparrow \mapsto \eta_{th} \uparrow$
- $T_L \downarrow \mapsto \eta_{th} \uparrow$

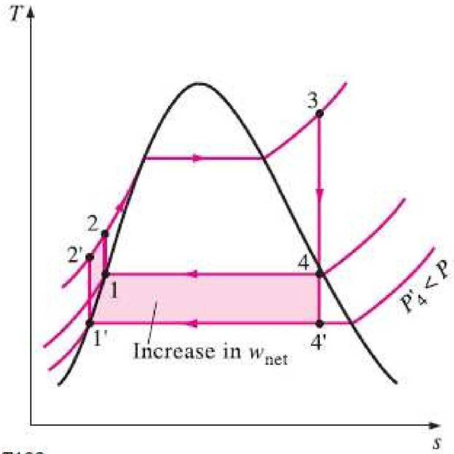
Components of a Simple Vapour Power Plant



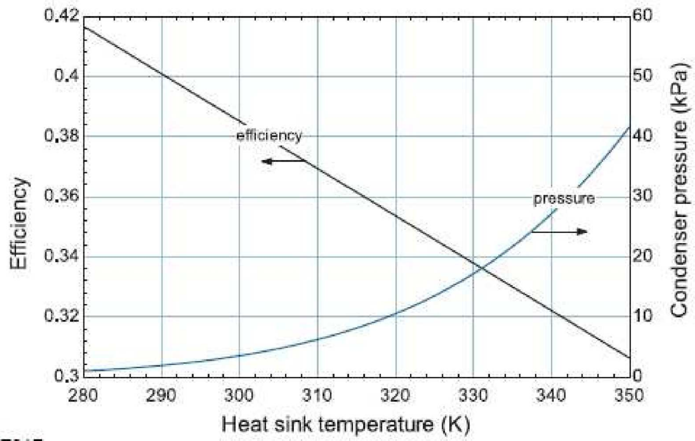
Schematic of a Simple Rankin Cycle



Thermal Power Plants: Effect of Condenser Pressure



T199



T217

- $P_{cond} = P_{sat}(T_{cond})$: $T_{cond} - T_{atm} \simeq 10 - 15^oC$.
- $P_{cond} \downarrow :\Longrightarrow w_{net} \uparrow$, $\eta_{th} \uparrow$ & $x_4 \downarrow$. Higher moisture decreases turbine efficiency and erodes its blades. In general, $x_4 \geq 0.9$ is maintained. Lower P_{cond} promotes leakage.

Thermal Power Plants: Effect of Steam Super-heating

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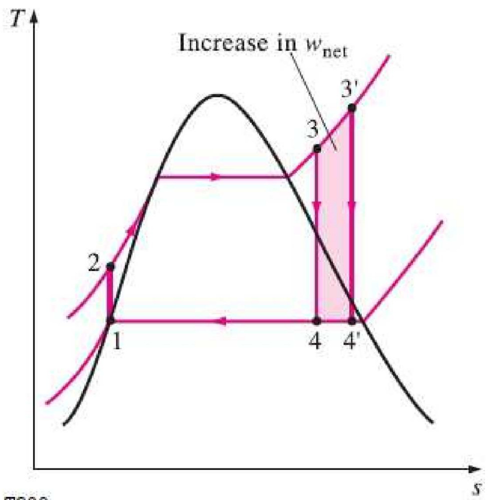
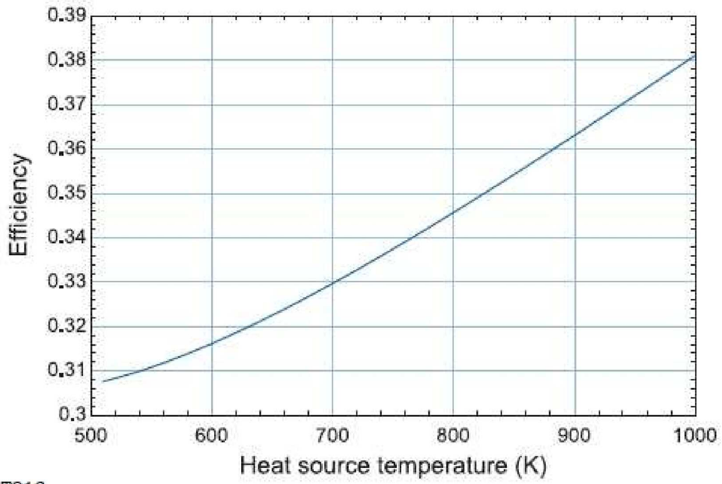


T200



T216

- $T_{max} \uparrow :\Longrightarrow w_{net} \uparrow$, $\eta_{th} \uparrow$ & $x_4 \uparrow$.
- Higher average temperature of heat addition increases η_{th}. T_{max} is limited by metallurgical considerations. In general, $T_{max} = 620^oC$.

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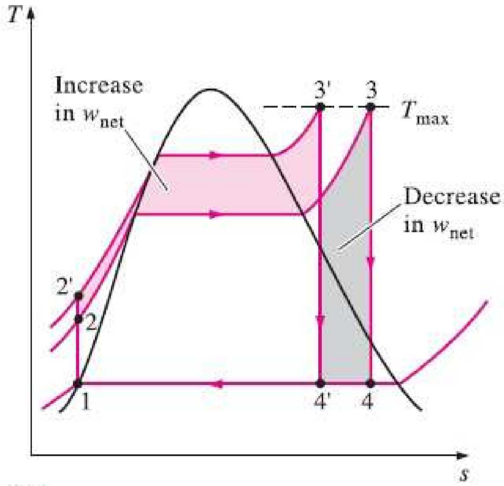
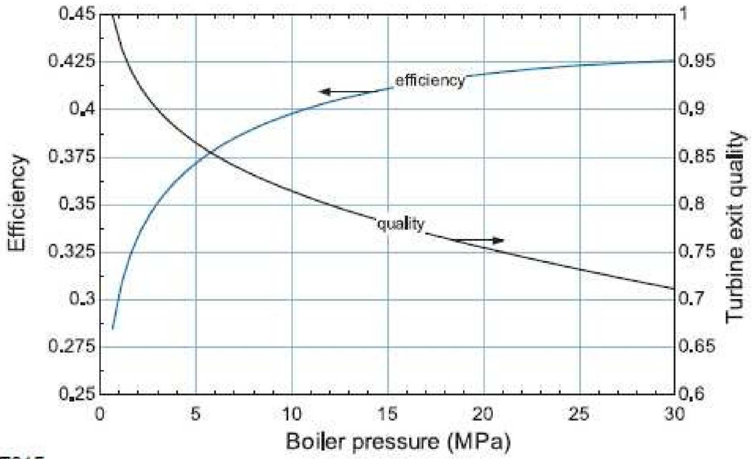
Thermal Power Plants: Effect of Boiler Pressure



T201



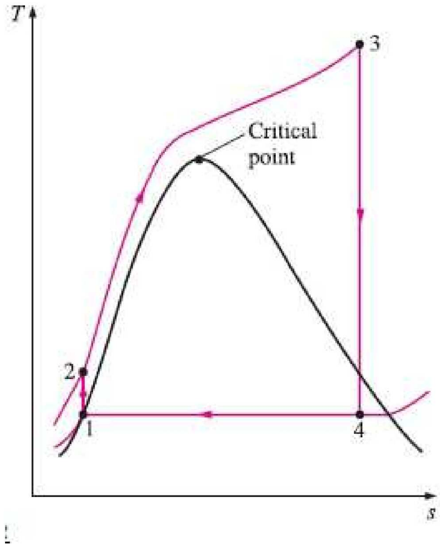
T215

- For fixed T_{max} : $P_B \uparrow :\Longrightarrow \eta_{th} \uparrow$ & $x_4 \downarrow$. Higher η_{th} is achieved because of higher average temperature of heat addition.

Effects of Operating Parameters on Cycle Efficiency

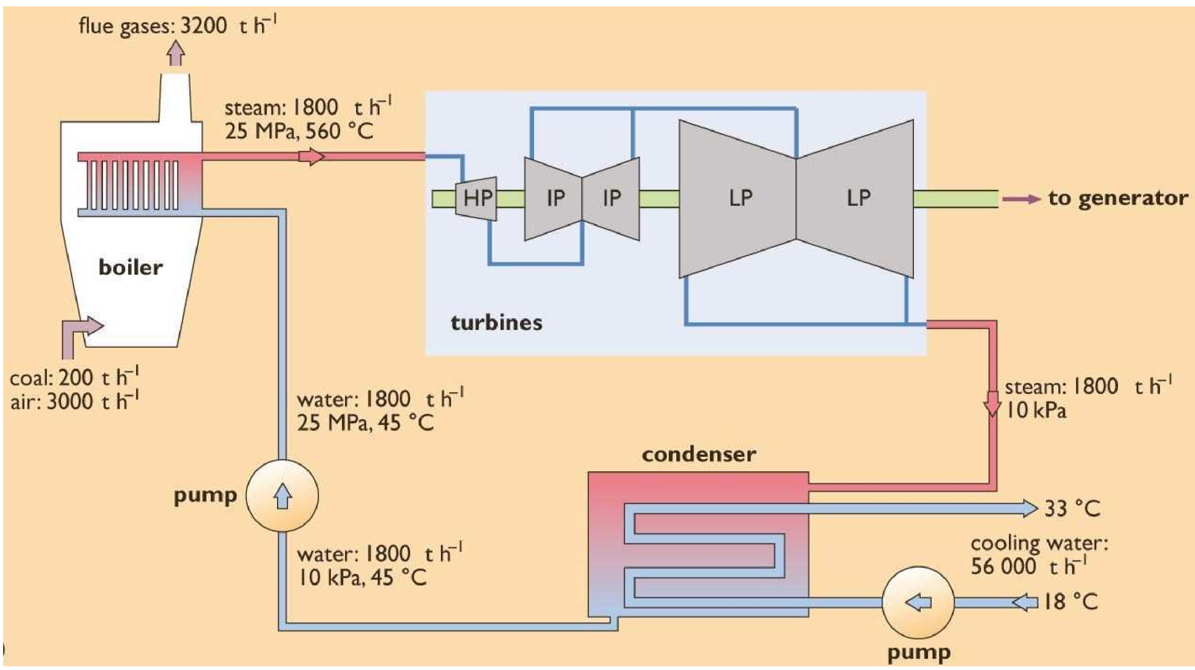
Boiler Pressure	[MPa]	3.0	3.0	**3.0**	**15.0**
Max. Temperature	[°C]	350	**350**	**600**	600
Cond. Pressure	[kPa]	**75**	**10**	10	10
Heat added	[kJ/kg]	2727	2920	3487	3375
Turbine work	[kJ/kg]	713	979	1302	1467
Pump work	[kJ/kg]	3.03	3.02	3.02	15.1
Thermal efficiency	[%]	26.0	33.4	37.3	43.0
x_4	[-]	0.886	0.812	0.914	0.804

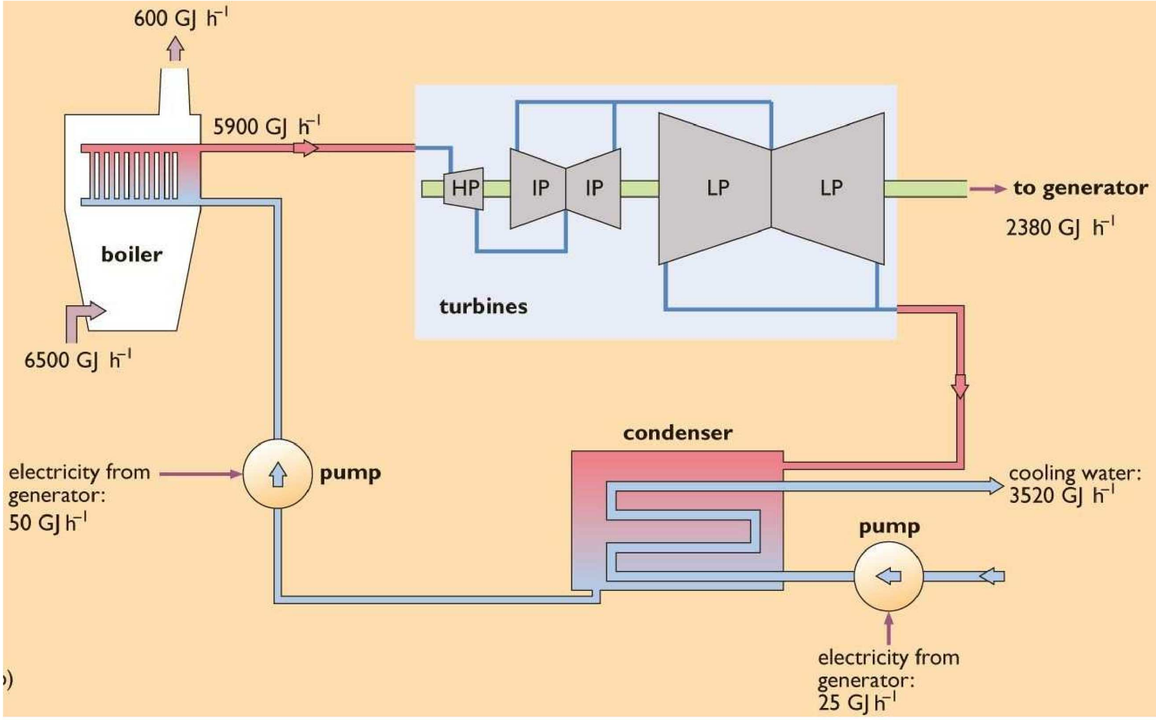
A supercritical Rankine cycle



- Some modern power plants operate at supercritical pressure ($P \approx 30$ MPa $> P_C = 22.06$ MPa) and have $\eta_{th} \sim 40\%$ for fossil-fuel plants and $\eta_{th} \sim 34\%$ for nuclear power plants.
- Lower η_{th} of nuclear power plants are due to lower maximum temperatures used due to safety reasons.

Mass & Energy Flow in a 600 MW ST System





Typical Boiler Accessories & Losses

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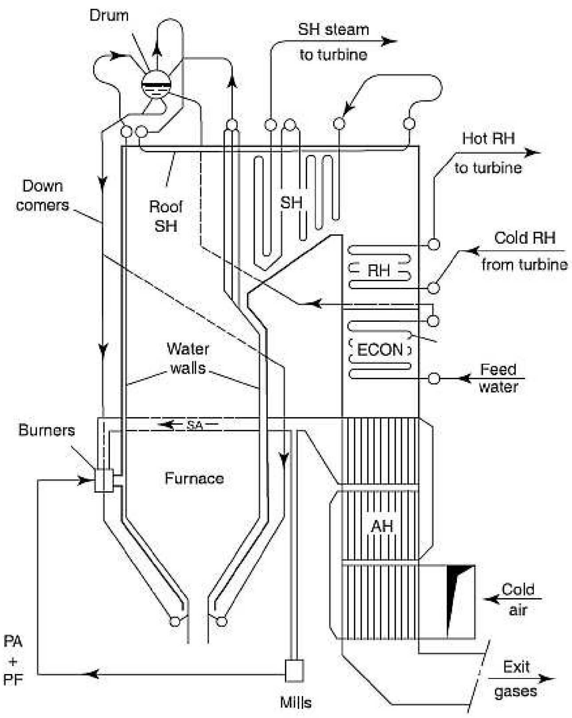
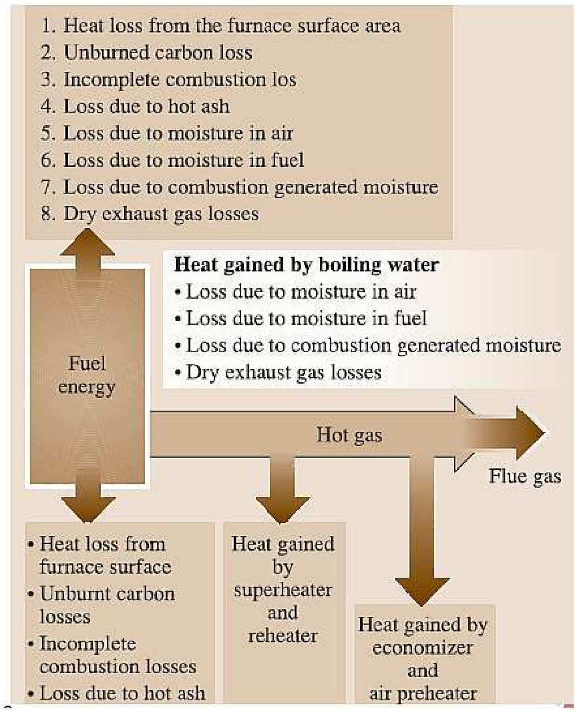
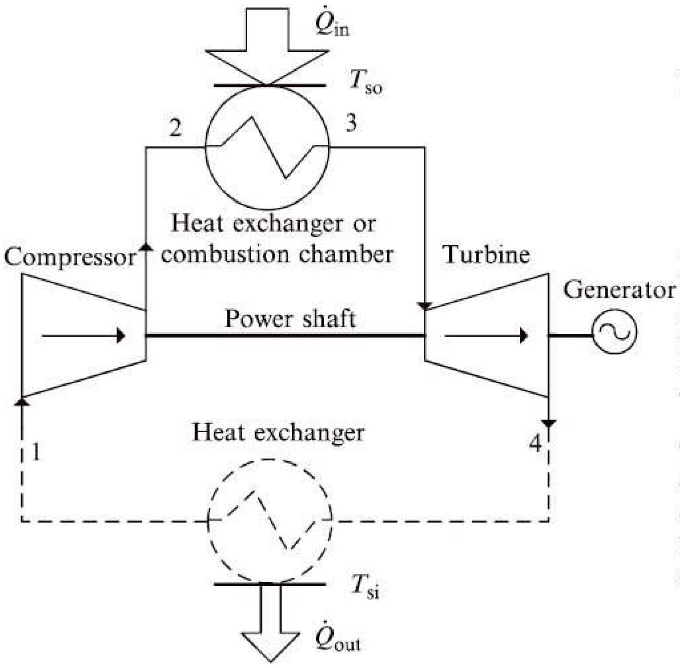




Gas Turbine Cycle: Brayton Cycle



Legend
$\dot{Q}_{in}$ — input heat (e.g., combustion)
$\dot{Q}_{out}$ — heat rejected
T_{so} — source temperature
T_{si} — sink temperature

Ideal processes
1 – 2: isentropic compression
2 – 3: isobaric heat addition
3 – 4: isentropic expansion
4 – 1: heat rejection

Type of the cycle
Open: 1 – 2 – 3 – 4
Closed: 1 – 2 – 3 – 4 – 1
Note: thermodynamically open and closed cycles are equivalent

An Intercooled, Reheat and Regenerative Cycle

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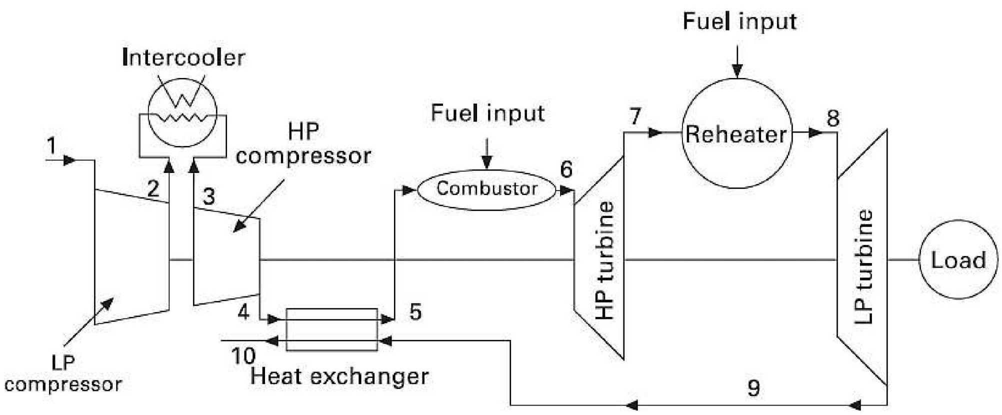

1–2 Isentropic LP compression
2–3 Intercooling
3–4 Isentropic HP compression
4–5 Constant pressure heat addition via heat exchanger
5–6 Constant pressure heat addition via external heat source
6–7 Isentropic HP turbine expansion
7–8 Reheat (heat addition – external heat source)
8–9 Isentropic LP turbine expansion
9–10 Constant pressure heat transfer for heating process 4–5

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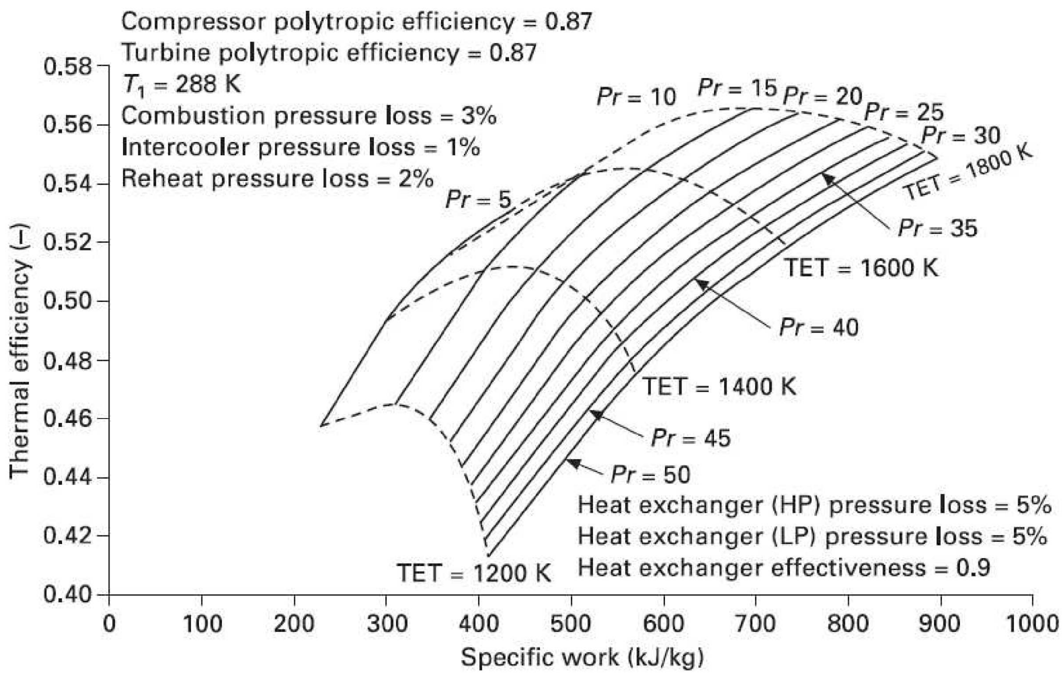
Performance map of Intercooled, Reheat and Regenerative Cycle



Combined Cycle Power Plant

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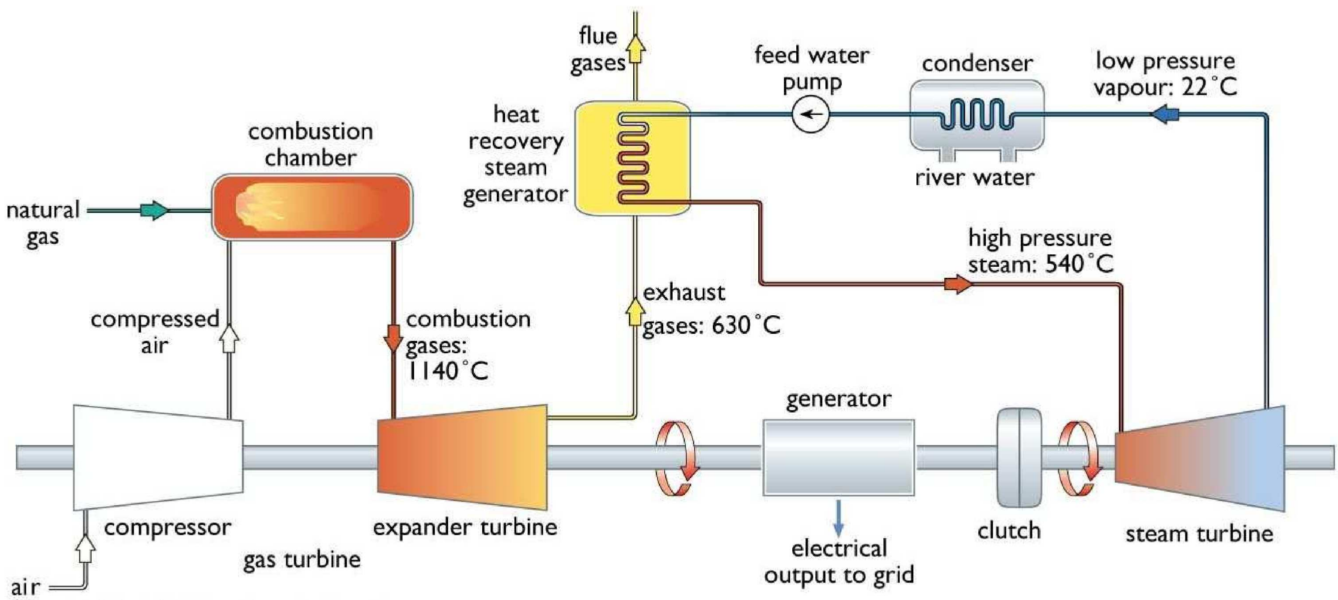

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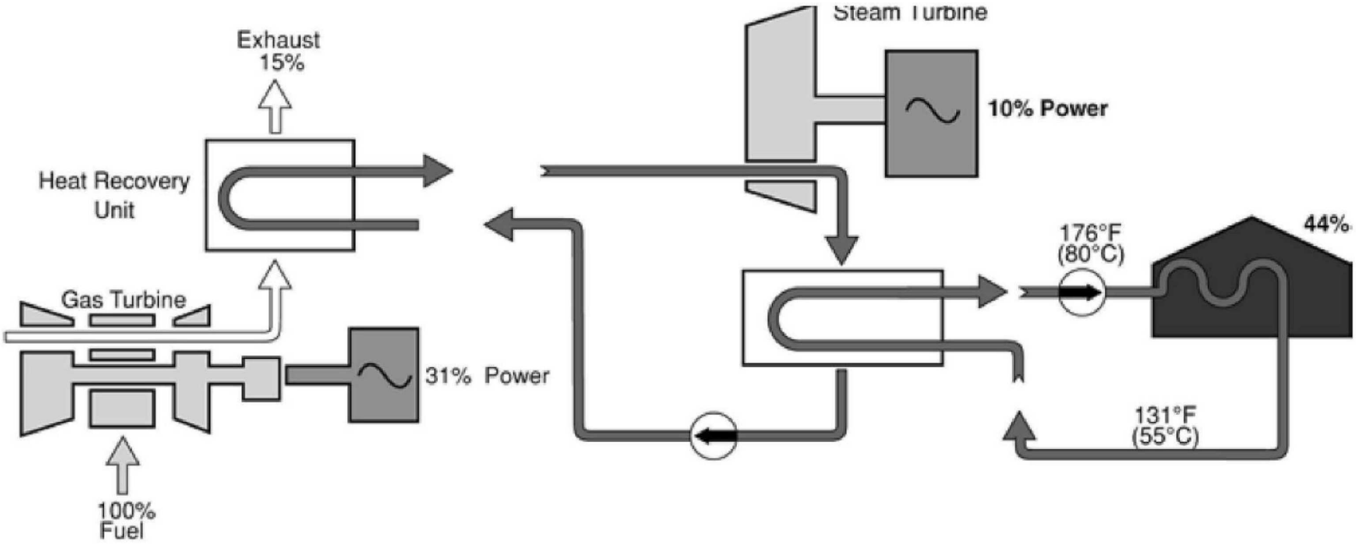
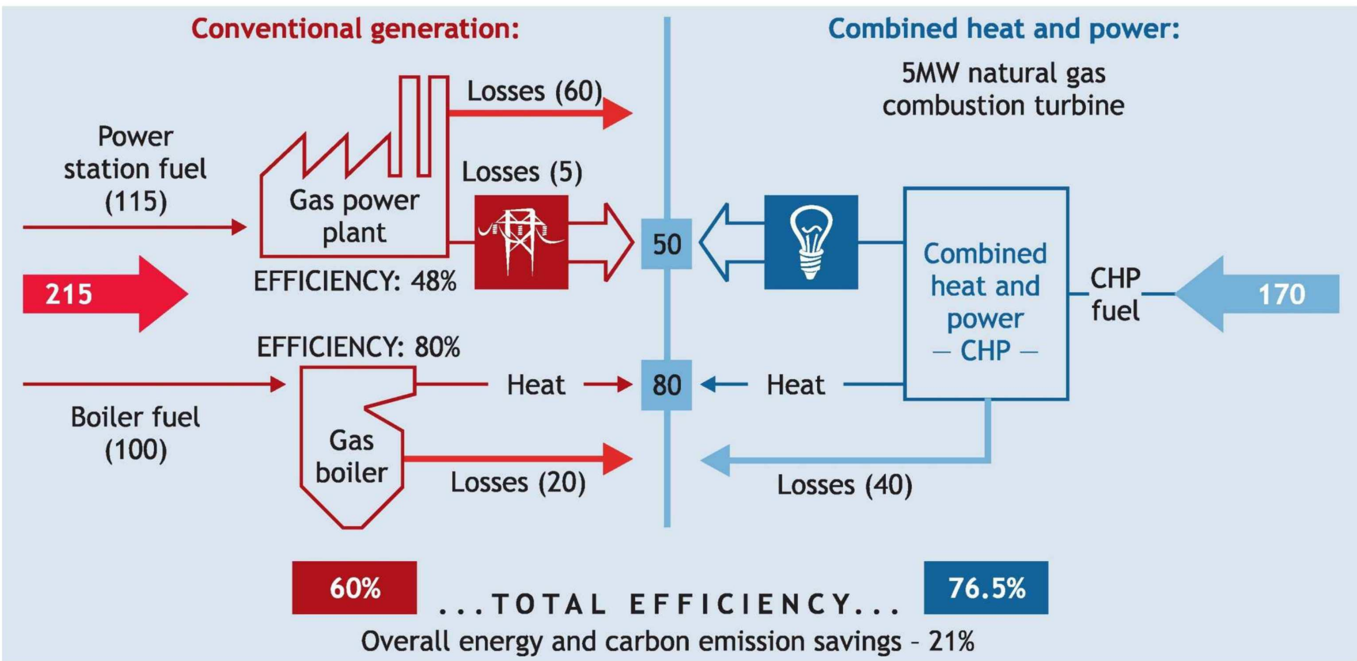
Combined Heating-Cooling-Power (CHP)



CHP Performance Example



Thanks a lot!