

# Chemical Engineering (Thermodynamics I) (UCH305)



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# **Lecture 17**

## **Second Law of Thermodynamics**

## Outline

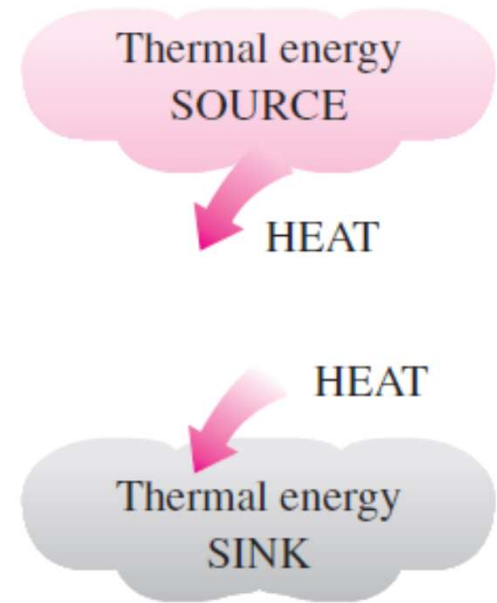
- Thermal energy reservoirs
- Heat engines
- Refrigeration devices
- Heat pump

## Thermal energy reservoirs

- A hypothetical body with a relatively large *thermal energy capacity* that can supply or absorb finite amounts of heat without *undergoing* any change in temperature.
- Thermal energy capacity (W/K) = (mass × specific heat) =  $\left[ C = \dot{m} \times C_p \right]$
- Such a body is called a **thermal energy reservoir**, or just a **reservoir**.
  - Source (Supply the thermal energy), and
  - Sink (Absorb the thermal energy).

- In practice, large bodies of water such as
  - oceans,
  - lakes, and
  - rivers as well as the
  - atmospheric air
  - \* can be modeled accurately as thermal energy reservoirs because of their large thermal energy storage capabilities or thermal masses.
- The *atmosphere*, for example, does not warm up as a result of heat losses from residential buildings.
- Likewise, *mega Joules* of waste energy dumped in large rivers by power plants do not cause any significant change in river water temperature.

- A reservoir that **supplies energy** in the form of *heat* is called a **source**, and one that **absorbs energy** in the form of *heat* is called a **sink** (Fig.)
- Thermal energy reservoirs are often referred to as *heat reservoirs* since they **supply** or **absorb** energy in the form of *heat*.



A source supplies energy in the Form of heat, and a sink absorbs it.

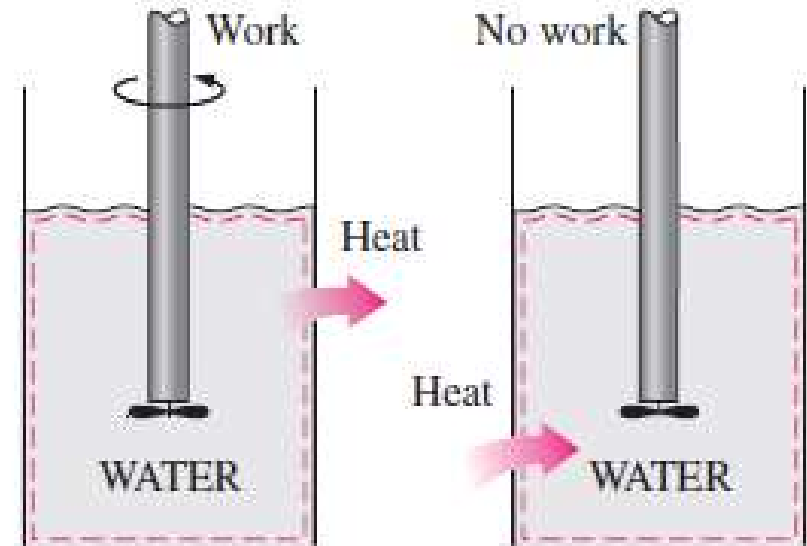
# Conversion of work to energy & energy to work

- Work can easily be converted to other forms of energy, but converting other forms of energy to work is not that easy.

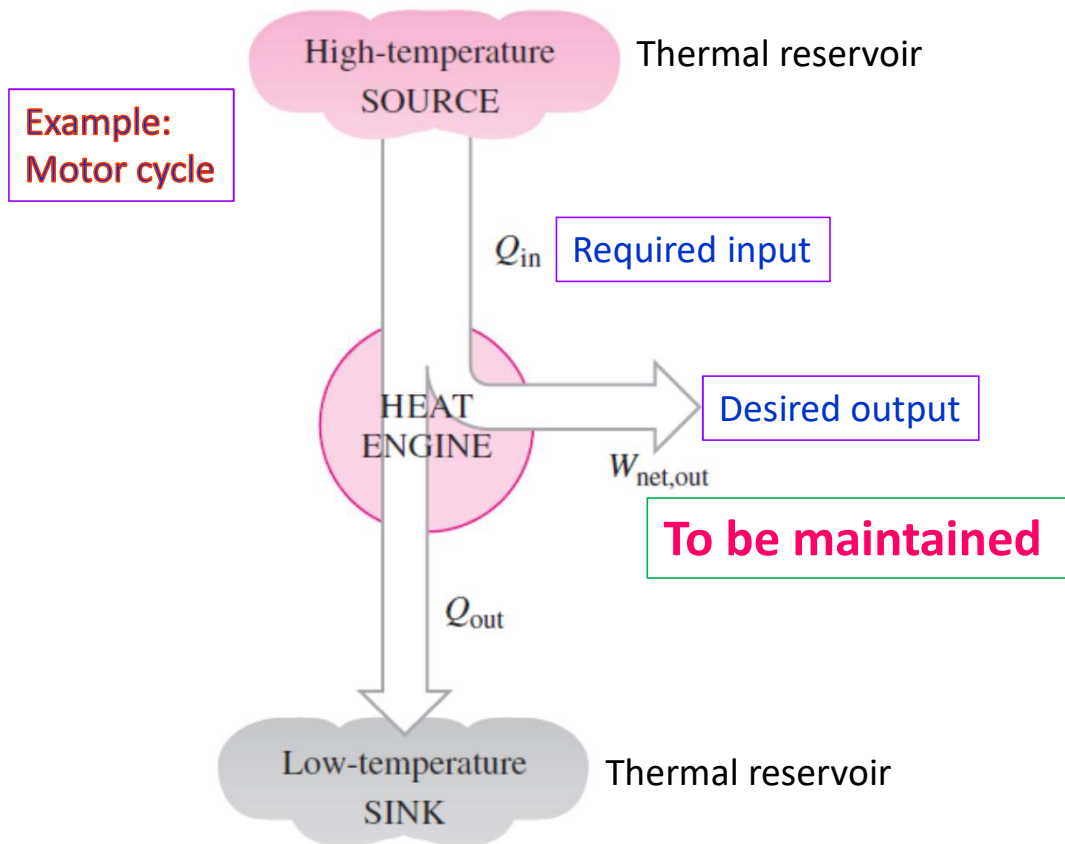
The mechanical work done by the shaft, is first converted to the *internal energy* of the water. This energy may then leave the water as *heat*. Any attempt to reverse this process will fail (transferring heat to the water does not cause the shaft to rotate).

It is concluded that...

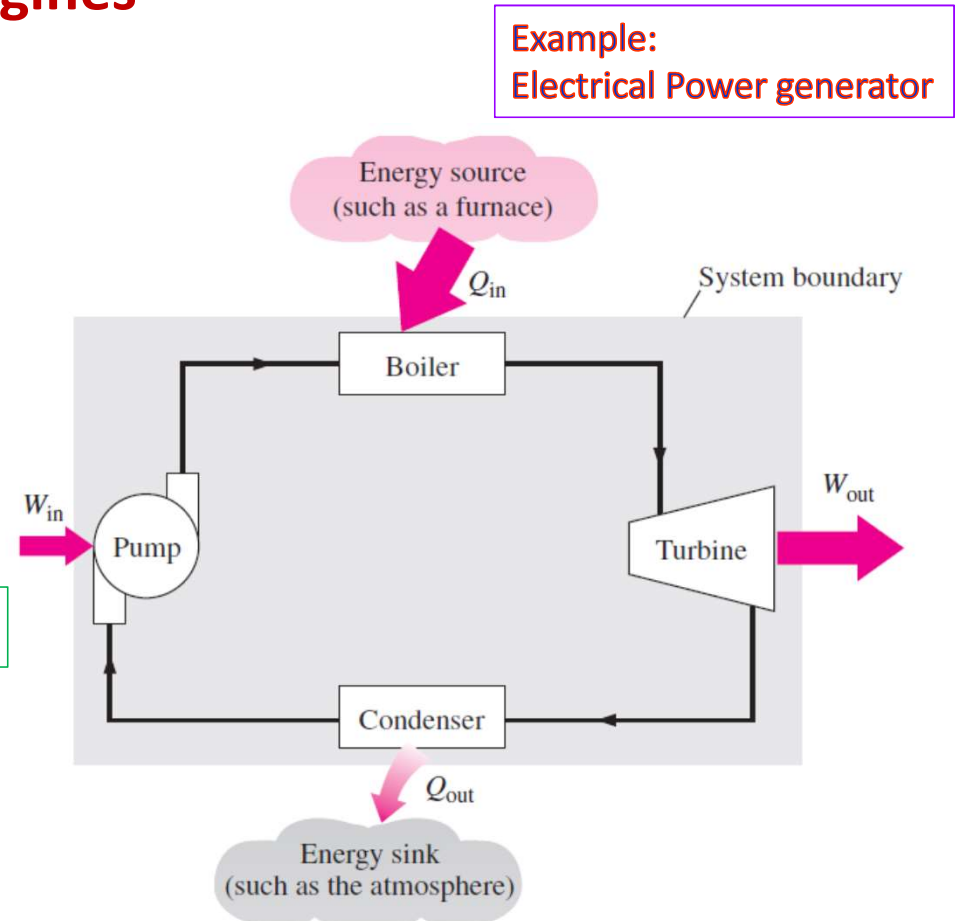
- Work can be converted to heat directly and completely.
- Converting heat to work requires the use of some special devices. These devices are called **heat engines**.



# Heat engines

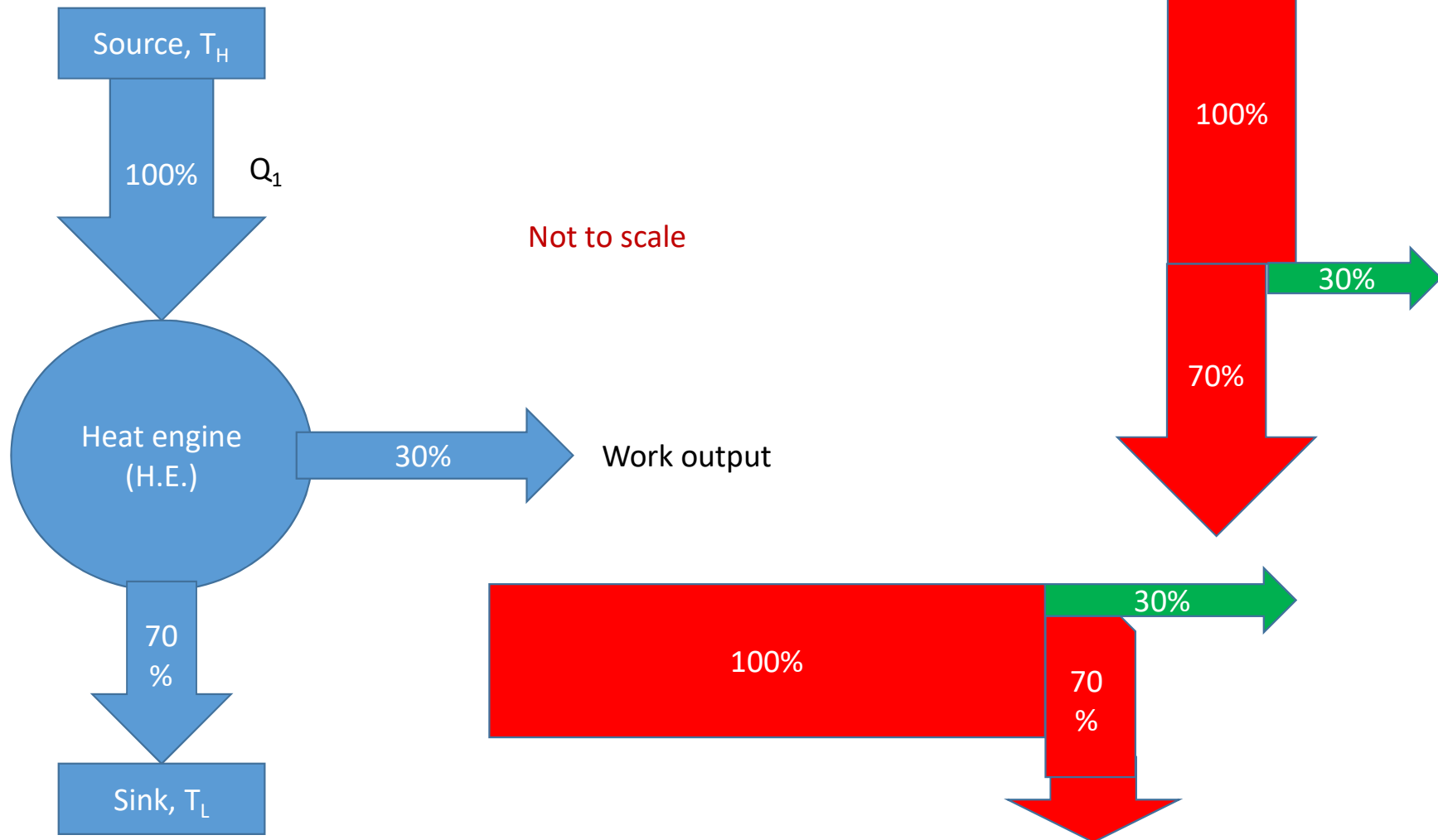


Part of the heat received by a heat engine is converted to work, while the rest is rejected to a sink.

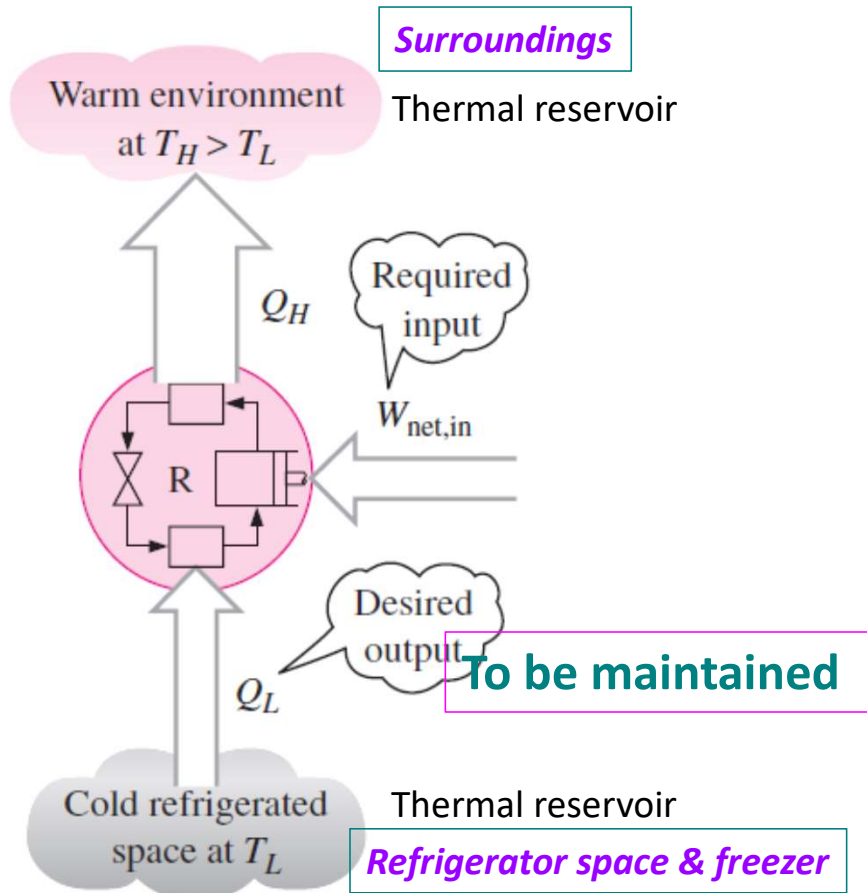


Schematic of a steam power plant

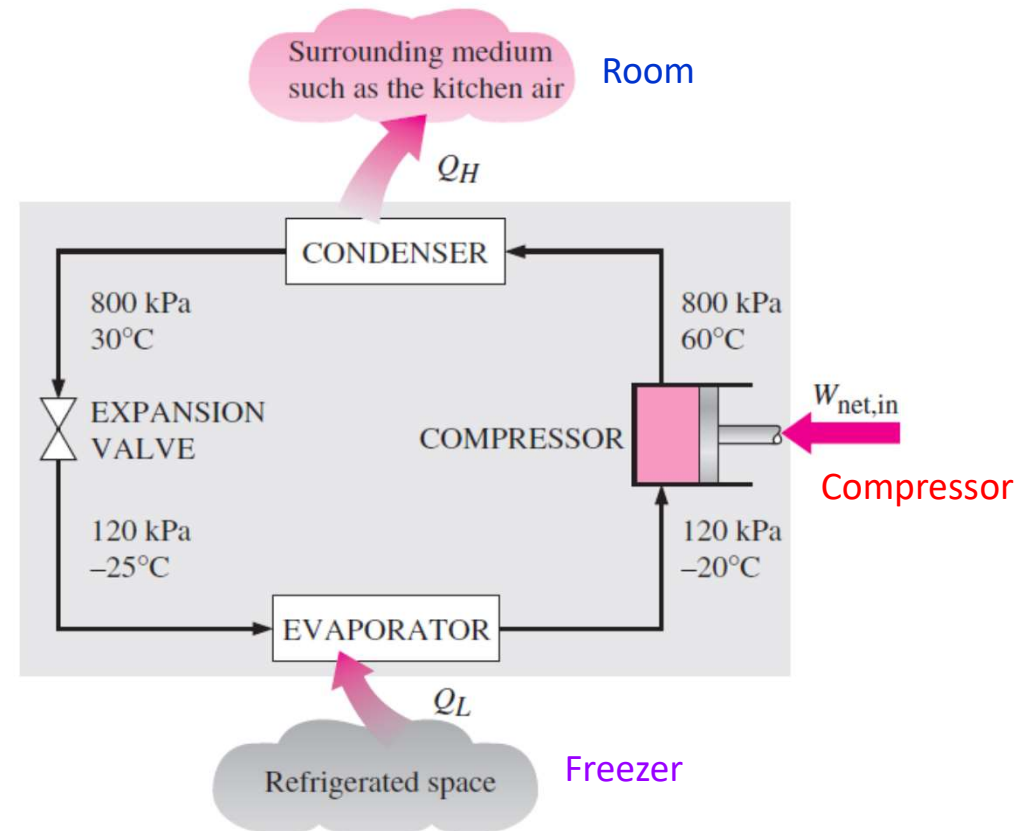
## Sankey diagram – Heat engine



# Refrigerators

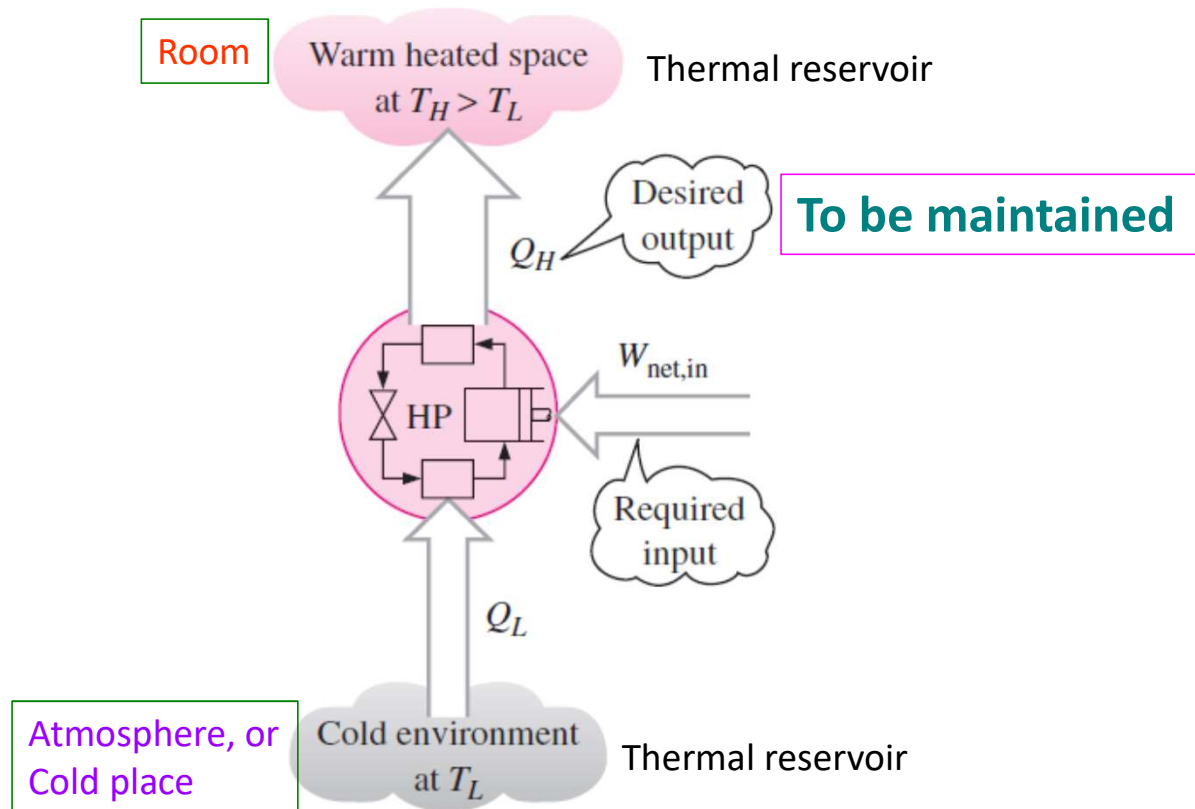


The objective of a refrigerator is to remove  $Q_L$  from the cooled space.



Basic components of a refrigeration system and typical operating conditions.

# Heat Pump



The objective of a heat pump is to supply heat  $Q_H$  into the warmer space.

## The Second Law of Thermodynamics Statements

- There are **two** classical statements of the second law:

1. The Kelvin–Planck statement,

\* which is related to *heat engines*

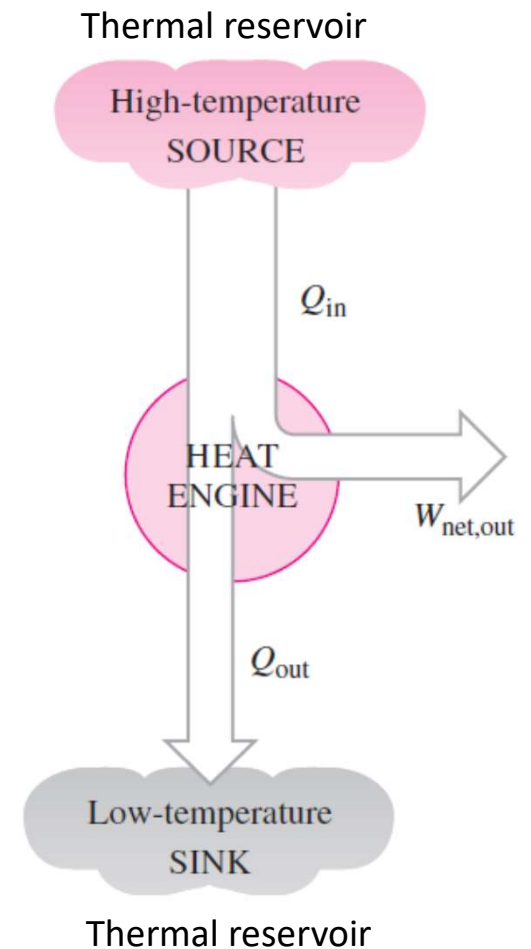
&

2. The Clausius statement,

\* which is related to *refrigerators* or *heat pumps*.

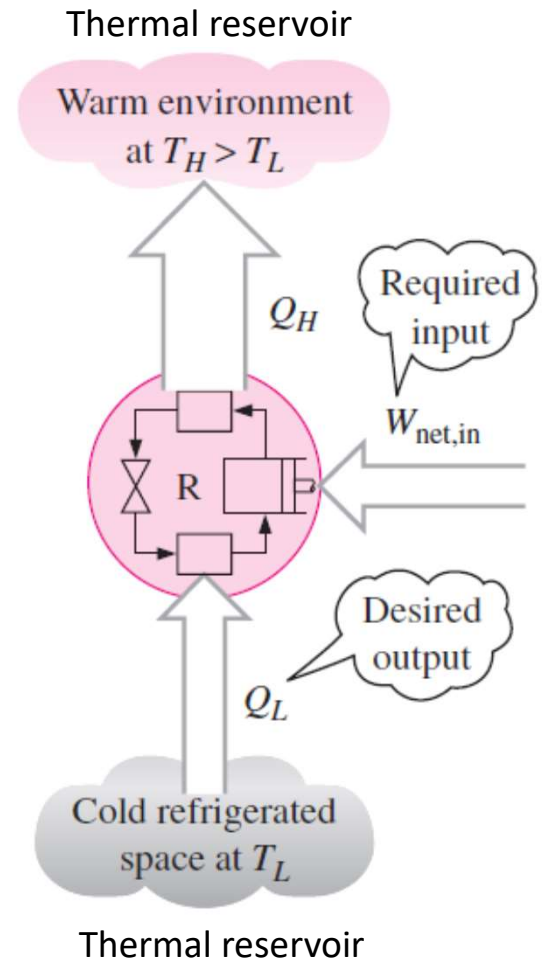
## The Second Law of Thermodynamics: Kelvin–Planck Statement

- *It is impossible for any device that operates on a cycle to receive heat from a single reservoir and produce a net amount of work. (Heat engine)*
- *No heat engine can have a thermal efficiency of 100 percent.*
- *For a power plant to operate, the working fluid must exchange **heat** with the **furnace** as well as the **environment** .*



## The Second Law of Thermodynamics: Clausius Statement

- The Clausius statement is expressed as follows:
  - It is impossible to construct a device that operates in a cycle and produces no effect other than the transfer of heat from a lower-temperature body to a higher-temperature body.



## References

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2. Smith J. M. and Van Ness H. C., *Chemical Engineering Thermodynamics, Tata McGraw-Hill* (2007).
3. Nag, P.K., *Engineering Thermodynamics, Tata McGraw Hill* (2008) 3rd ed.
4. Cengel, Y. A. and Boles, M., *Thermodynamics: An Engineering Approach, Tata McGraw Hill* (2008).

*Special Thanks to Professor D. Gangacharyulu.*

*Thank you for your  
Patience*