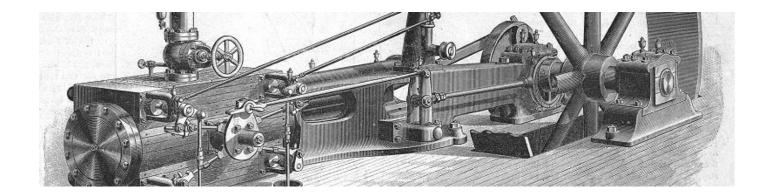
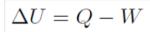
Thermodynamics



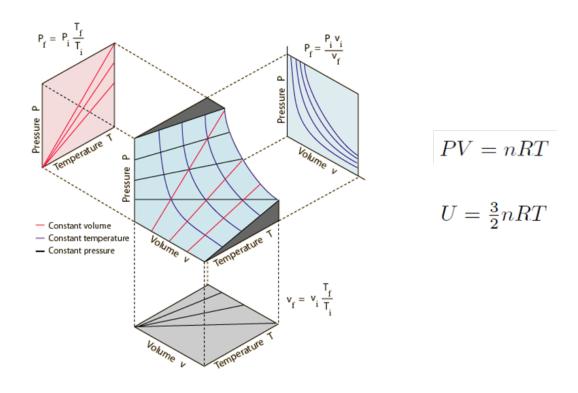
The first law: a heat engine balances internal energy, heat and work



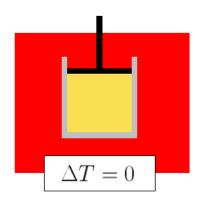




The ideal gas provides the simplest system to consider in thermodynamics

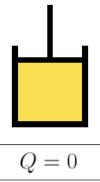


Work done by an ideal gas within isothermal and adiabatic process can be calculated



$$W_{\rm isoth} = nRT \ln(V/V_0)$$

$$PV = \text{const.}$$

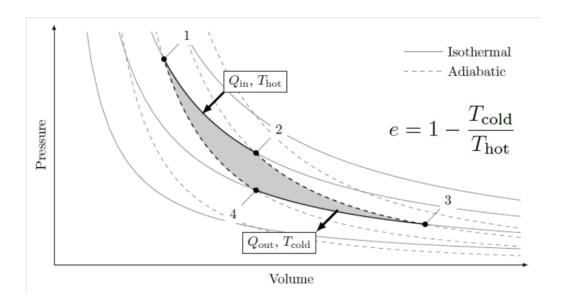


$$W_{\rm adiab} = -\frac{3}{2}nR\Delta T$$

$$PV^{\gamma} = \text{const.}$$

 $\gamma = 5/3$

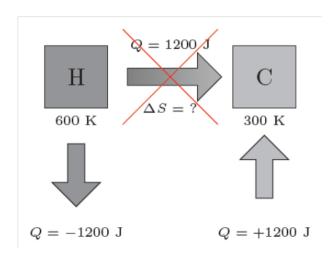
The Carnot heat engine is reversible and is therefore the upper bound on efficiency



Another perspective on entropy: energy irreversibly lost to mechanical work



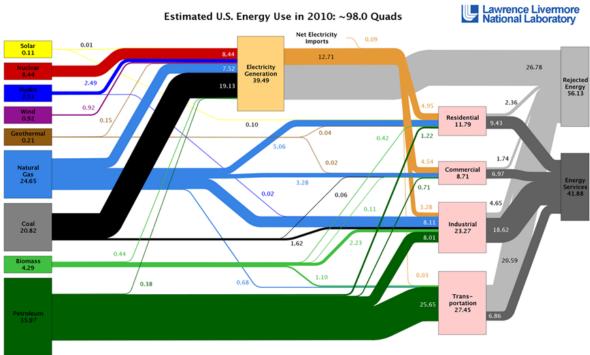
Any decrease in system entropy must come from a larger increase somewhere else



$$\Delta S = Q/T$$

$$\Delta S \ge 0$$

Practical questions about the most efficient use of global energy is challenging



Source LLNL 2011. Data is based on DOE/EIA-0384(2010), October 2011. If this information or a reproduction of it is used, credit must be given to the Lawrence Livermore National Laboratory and the Department of Energy, under whose suspices the work was performed. Distributed electricity represents only retail electricity sales and does not include self-eneration. EIA reports flows for hydro, wind, solar and geothermal in 8TU-equivalent values by assuming a typical fossif fleel plant "heat rate" (see EIA report for explanation of change to geothermal in 2010). The efficiency of electricity production is calculated as the total retail electricity delevered divided by the primary entry input into electricity generation. Gnu use efficiency is estimated as 80% of the production is calculated as the total retail electricity delevered divided by the primary entry input into electricity generation. Gnu use efficiency is estimated as 80% of the production is calculated as the total retail electricity delevered divided by the primary entry input into electricity generation. Gnu use efficiency is estimated as 80% of the production is calculated as the total retail electricity delevered divided by the primary entry input into electricity generation. Gnu use efficiency is estimated as 80% of the production is calculated as the total retail electricity delevered divided by the primary entry input into electricity generation. Gnu use efficiency is estimated as 80% of the primary entry en

Nearly all electricity generated in the US comes ultimately from steam engines

