

- **Dual Carbon Constraints** Fossil fuels are finite and burning them contributes to climate change and pollution.
- **Conservation of Energy** During an interaction, energy can change from one form to another but the total amount of energy remains constant.
- **Second Law of Thermodynamics** It asserts that energy has quality as well as quantity, and actual processes occur in the direction of decreasing quality of energy.

克劳修斯表述

克劳修斯表述是以**热量传递的不可逆性**（即热量总是自发地从高温热源流向低温热源）作为出发点。

虽然可以借助**制冷机**使热量从低温热源流向高温热源，但这个过程是借助外界对制冷机**做功**实现的，即这过程除了有热量的传递，还有功转化为热的其他影响。

1850年克劳修斯将这一规律总结为：

“不可能把热量从低温物体传递到高温物体而不产生其他影响。”^[3]

开尔文表述

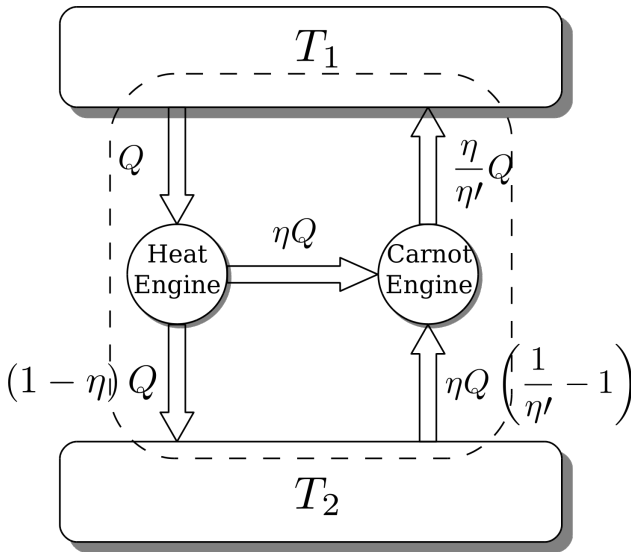
参见：**永动机#第二类永动机**

开尔文表述是以**第二类永动机不可能实现**这一规律作为出发点。

第二类永动机是指可以将从单一热源吸热全部转化为**功**，但大量事实证明这个过程是不可能实现的。功能够自发地、无条件地全部转化为热；但热转化为功是有条件的，而且转化效率有所限制。也就是说功自发转化为热这一过程只能单向进行而不可逆。

1851年**开尔文勋爵**把这一普遍规律总结为：

“不可能从单一热源吸收能量，使之完全变为有用功而不产生其他影响。”



2. 对于不可逆循环，对循环过程进行微分，与在相同热源的可逆循环进行比较，利用卡诺定理，得到 $\oint \frac{\delta Q}{T} < 0$ 。^[19]

综上，可以得到对于一切在给定热源下的工作循环，系统流入的热量 Q 与环境温度 T 存在： $\oint \frac{\delta Q}{T} \leq 0$ 。当且仅当工作循环为可逆循环时 $\oint \frac{\delta Q}{T} = 0$ 。^[11]

熵

主条目：**熵**

熵的热力学定义

熵作为状态参量最早由克劳修斯于1854年首次引入，1865年他把这一状态参量命名为Entropie（德语）（来源于希腊语τροπή, umkehren, 转变）。^{[11]p.184[2]p.274}

其引入过程如下：

考察可逆循环过程中的克劳修斯不等式 $\oint \frac{\delta Q}{T} = 0$ ，可以得到循环中某一过程 L （始、末状态分别为 a 、 b ）中 $\int_L \frac{\delta Q}{T}$ ，只与 a 、 b 有关，而与具体路径无关。

则必然存在一**态函数**；其微分量为 $\frac{\delta Q}{T}$ ，定义这个面量为**熵**(S)。

则对于可逆过程 L ， $\Delta S = \int_L \frac{\delta Q}{T}$ ，而不可逆过程的熵变可以通过相应的可逆过程求得。

熵增加原理

考察一系列不可逆过程中熵的变化（如在绝热环境中理想气体的真空自由膨胀，在绝热环境中两物体间热传递等等）经过计算，可以得到，这些过程中系统的熵 $\Delta S > 0$ 。

而现在已有大量的实验证明：

“热力学系统从一个平衡态到另一平衡态的过程中，其熵永不减少；若过程可逆，则熵不变；若不可逆，则熵增加。”

- Thermodynamics deals only with the **change** of the total energy.
- **First Law of Thermodynamics** The law of conservation of energy states that the total energy of an isolated system is constant; energy can be transformed from one form to another, but cannot be created or destroyed. $Q - W = \Delta U$. Or in another form, $Q = \Delta U + W$.
- **Thermal Efficiency** Net work output \div Total Heat Input.
- **Enthalpy** is defined thermodynamic potential, designated by the letter "H", that consists of the internal energy of the system (U) plus the product of pressure (p) and volume (V) of the system. $H = U + pV$ and when the pressure is assumed constant, we have $\delta H = \delta U + p\delta V$.
- **WACC** is just a fancy name for Weighted Average Cost of Capital.
- **LCOE** Levelized Energy Cost is the price at which electricity must be generated from a specific source to break even over the lifetime of the project.
- **Biomass** Renewable; Connected to farming and agriculture; Multiuse; Environmental concerns include land and water use, fertilizer and other nutrient requirements; Naturally diffuse and distributed.
- **Sustainable Bioenergy** The use of water, land and the debate between food and fuel.
- **Hydrothermal** Two main types, dry steam (vapor-dominated) reservoirs and hot water (liquid-dominated).
- **Geothermal Challenges** Characterizing and Predicting; Accessing; Engineering; Sustaining; Monitoring.
- **Solar Technologies** Non-Concentrated, Photovoltaic, Solar Thermal; Concentrated, Concentrated Photovoltaic, Concentrated Solar Power.
- **PV and CSP** Solar photovoltaic (PV) directly converts solar energy into electricity using a PV cell made of a semiconductor material. Concentrating solar power (CSP) devices concentrate energy from the sun's rays to heat a receiver to high temperatures. This heat is transformed first into mechanical energy (by turbines or other engines) and then into electricity solar thermal electricity (STE).
- **CSP Technologies** Parabolic trough, Linear Fresnel Reflector, Power tower and Parabolic Dish/Stirling. generation. *Physical and Chemical* process. Sensible heat, latent heat; Chemical Energy.
- **Thermal Storage** Tested technologies: single tank oil thermocline with filler materials, Two-tank Oil Technology. Commercial: Two-tank Molten Salt, Saturated Steam. Under development: High-temperature Concrete Regenerator Type Storage, Combined sensible & Latent heat, Cascade Latent Heat Storage. Under research: Fluidized Bed Sand Storage, Conventional Heat Transfer Fluid, Formulate New Molten salts Compositions.

- **Nuclear Sustainability** On the other hand, NPPs are cheap to operate: the existing operating NPPs, for which the initial capital investments are largely depreciated, are among the lowest cost generators. Not surprisingly, interest has grown in extending NPP operating lifetimes from their initial licensed lifetimes of 30-40 years, and actual license extensions of up to 60 years are already a reality.
- Nuclear energy comes from uranium, a nonrenewable resource that must be mined.
- 13 percent of the world's electricity comes from nuclear power plants that emit little to no greenhouse gases. Nuclear power facilities can produce energy at a 91 percent efficiency rate 24/7, while maintaining the method with the lowest emissions. More than 70 percent of America's emission-free power comes from nuclear energy sources.
- The building of new nuclear facilities creates between 1,400 and 3,500 jobs for construction workers, and after the facility is built maintains 400 to 700 permanent positions paying roughly 36 to 44 percent more than the average salary of the surrounding area. American nuclear energy facilities are the highest regulated plants in the world, subject to more scrutinous observations and regulations.
- The average exposure for each worker in the U.S. nuclear energy industry is 290 mrem, which is only one-third of the 900 mrem per year occupational exposure of airline pilots and cabin crews who regularly fly the high-altitude New York -Tokyo route.
- Recent increases in international fossil fuel market prices have eliminated the margins for natural gas and coal, leaving nuclear power as the least-cost electricity generation option for base-load electricity generation.
- Moreover, in most countries, the cost of containing, storing, and disposing of nuclear waste is included in the price of the electricity generated.
- Significant health impacts from NPPs thus arise only from major accidents that release radiation. Caused by serious design flaws coupled with major operator errors.
- **Probability of Occurrence** over N number of years:

$$P = 1 - (1 - p)^N$$
- **Gringorten Formula** $T = \frac{n+0.12}{i-0.44}$
- To find the power generated (in Watts) by a wind turbine:

$$P = \frac{1}{2} \rho A v^3 C_p$$
air density, swept area, wind speed and the power coefficient.
- Nuclear power can be a cost-effective electricity supply technology, especially at current fossil fuel price levels; surpasses other options in internalizing its externalities; is a cost-effective way to reduce carbon emissions from an electricity generation (any internalization of greenhouse gas emissions further improves its competitiveness); manages its waste safely; has an incomparable industrial safety record with a philosophy of continual improvement; and is not a principal contributor to proliferation risks, and that halting or reversing the expansion of nuclear power would not appreciably reduce such a risk.
- Vertical wind speed power law profile: $v_2 = v_1 * \left(\frac{z_2}{z_1}\right)^\alpha$.