Thermodynamics of Energy Conversion and Storage

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EXERCISES 12

1) Compare the heat released by the radioactive decays with the heat capacity and the heat flow for 1 km^3 of rock 3000 m below the surface.

Heat produced approx. $2 \cdot 10^{-12}$ W/kg , density is approx. 2500 kg/m^3
P = $5 \cdot 10^{-9}$ W/m^3

Heat capacity is approx. 1 kJ·kg^{-1}·K^{-1}, density is approx. 2500 kg·m^{-3}, ΔT = 100 K
Q = 250'000 kJ·m^{-3} = 69 kWh·m^{-3}

Heat conductivity approx. λ = 2 W·m^{-1}·K^{-1}
$P = \lambda \cdot V \cdot A^{-1} \cdot \Delta T = 2\ W \cdot m^{-1} \cdot K^{-1} \cdot 1\ km^3 \cdot (1\ km^2)^{-1} \cdot 100K = 200\ W$

2) Calculate the volume necessary in order to cover the energy demand of a person with geothermal heat.

Energy demand per capita is approx. 5 kW
V = 5000 W/$5 \cdot 10^{-9}$ W/m^3 = 10^{12} m^3 = 1000 km^3
Therefore, the location for geothermal heat extraction has to be selected carefully.

3) Calculate the primary energy use per capita in Iceland and compare with Switzerland. .

260 PJ/year
300’000 people in Iceland
$260 \cdot 10^{15}$ Ws/year
27.4 kW/capita in Iceland, 5 kW/capita in Switzerland

4) Calculate the kinetic energy in the system moon-earth and compare with the global energy demand.

m_{moon} = $7.34767309 \cdot 10^{22}$ kg, distance(earth-moon) = 384400 km, the moon goes around the earth in 27.3 days.
$W = 1/2 \cdot m \cdot v^2 = 0.5 \cdot 7.34767309 \cdot 10^{22}\ kg \cdot (384.4 \cdot 10^6\ m \cdot 4 \cdot \pi)^2 = 8.572 \cdot 10^{41}\ J = 2.38 \cdot 10^{35}\ kWh$
Global energy demand: 18 TW·365d/a·24h/d = $1.576 \cdot 10^{14}$ kWh·a^{-1}
The kinetic energy of the moon covers the world energy demand for approx. 10^{21} years.

5) How much is the amount of biomass production increased, if the light intensity and the CO_2 concentration is optimized.

18·24·365 TWh/year/100 kWh/m^2/year = $1.6 \cdot 10^{12}$ m^2 = $1.6 \cdot 10^6$ km^2

We are approximately now at around 0.04 vol% CO_2. Then if you optimize the lux as well as the concentration you reach a plato as shown on Slide 51.