Thermodynamics of Energy Conversion

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EXERCISES 8

1) Calculate how long each reserve lasts if we assume current consumption and if we assume continuing growth.

2009 energy demand is 16 TW

Coal	215 TWy	13 years
Crude oil	240 TWy	15 years
Coal	900 TWy	60 years
Uranium	300 TWy	20 years
total	1645 TWy	108 years

In 2050 the world energy demand is expected to be >25 TW

Coal	215 TWy	10 years
Crude oil	240 TWy	12 years
Coal	900 TWy	30 years
Uranium	300 TWy	15 years
total	1645 TWy	67 years

2) Calculate the weight loss of the sun per second due to the energy emission. The solar constant is 1360 W/m^2 and the distance between sun and earth is 149.6·10^6 km.

$E = m \cdot c2$

$P = 4 \cdot \boldsymbol{\pi} \cdot (149.6 \cdot 10^9 \text{ m})^2 \cdot 1360 \text{ W/m}^2 = 3.8 \cdot 10^{26} \text{ W}$
$dm/t = P \cdot c^{-2} = 3.8 \cdot 10^{26} \text{ W}/(3 \cdot 10^8 \text{ m/s}) = 4 \cdot 10^9 \text{ kg/s}$

3) Estimate the maximum and annual average solar intensity in Lausanne. How much is the average intensity in summer and in winter?

maximum = 1360 W/m^2
average = 160 W/m^2
in winter average = 50 W/m^2
in summer average = 250 W/m^2

4) Calculate the power of a vacuum collector in winter (ΔT = 60K).

I = 500 W/m^2
$P = A \cdot (I_0 \cdot \eta - k \cdot \Delta T)$
$P/A = 50\text{W/m}^2 \cdot 0.72 - 1.4 \cdot 60\text{K} = 276 \text{ W/m}^2$

5) Calculate the power of a concentrating solar power tower per 400x400 m^2 if we assume maximum efficiency and if we assume real established efficiency of 17%.

$$\eta = \left(1 - \frac{\sigma T_H^4}{IC}\right) \cdot \left(1 - \frac{T^0}{T_H}\right)$$

T_H = 1500°C
Emissivity $\boldsymbol{\sigma}$ = 1
Intensity = 1369 W/m^2
T^0 = 370 K
C = 8'000 (50% of surface area)
σ (Stefan-Boltzmann-constant) = $5.67 \cdot 10^{-8}$ W/m^2·K^4

Efficiency = (1 - $5.67 \cdot 10^{-8}$W/m^2·K^4·1773K^4/(1369·160'000)·(1-370/1773) = 0.998·0.79 = 79%
Solar power: P = 8000·680 W/m^2 = 5.44 MW (50% of intensity during the day time).

maximum el. power P_{el} = 0.75· 5.44 MW = 4.1 MW during 12/24 h

power of a real installation 0.17· 5.44 MW = 0.92 MW during 24/24 h