Thermodynamics of Energy Conversion and Storage

Prof. Dr. Andreas ZÜTTEL
Assistant: Yasemen Kuddusi

EXERCISES 9

1) How many times does the water exchange in the atmosphere per year?

12900 km^3 in the atmosphere
505000 km^3/year evaporation from sea and 71000 km^3/year from land

576000 km^3/year/12900 km^3 = 44.7/year, almost once per week.

2) Estimate the precipitation in Switzerland per year and the energy potentially in the water.

Outflow: 1300 mm/a,
V = 1.3 $m^3/m^2 \cdot 41 \cdot 10^9$ m^2 = $53.3 \cdot 10^9$ m^3/year = 1690 m^3/s

approx. 1/3 falls on > 1700 m, therefore,
41000 $km^2/3 \cdot 1.3m/a \cdot 9.81m/s^2 \cdot (1700\text{-}200)m$ = $2.6 \cdot 10^{14}$ Ws/a = 74 GWh/a = 8.5 GW

3) Why is the efficiency of water turbines limited to approx. 90%?

The turbine converts kin. energy into kin. energy, however, the fluid transferring the energy has to leave the turbine. Therefore, about 10% of the kin. energy remain in the fluid.

4) Calculate the power of hydro power plant with h = 500 m, and dV/dt = 220 m^3/s.

P = $dm/dt \cdot g \cdot h = dV/dt \cdot r \cdot g \cdot h$ = 220 $m^3/s \cdot 1000$ $kg/m^3 \cdot 9.81$ $m/s^2 \cdot 500$ m
P = $1.079 \cdot 10^9$ $kg \cdot m^2/s^2$ = $1.079 \cdot 10^9$ W = 1.079 GW

5) Calculate the power of river hydro power plant with h = 10 m, and dV/dt = 500 m^3/s.

P = $dm/dt \cdot g \cdot h = dV/dt \cdot r \cdot g \cdot h$ = 500 $m^3/s \cdot 1000$ $kg/m^3 \cdot 9.81$ $m/s^2 \cdot 10$ m
P = $4.905 \cdot 10^7$ $kg \cdot m^2/s^2$ = $4.905 \cdot 10^7$ W = 49 MW