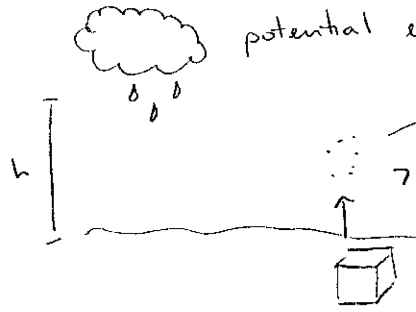
4/3

Hydrological Cycle:

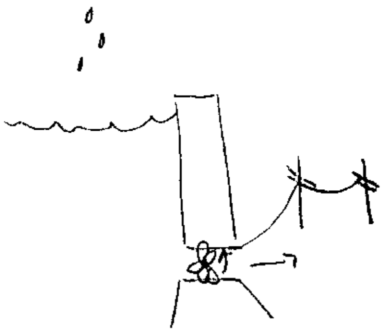


potential energy: $m \cdot g \cdot h$

2×10^4 J/kg energy in evaporated water

78 W/m² evaporation

1 m³ water per 1 m² land



*assume we catch every drop of rain (over-estimate)

$$E = m \cdot g \cdot h$$

$$\frac{E}{m} = \text{energy density} = gh$$

[J/kg]

$$p_e \approx (10 \text{ m/s}) \cdot (100 \text{ m})$$

$$p_e \approx 1000 \text{ J/kg}$$ for water in dams

efficiency: $\varepsilon = \frac{\text{energy out}}{\text{energy in}} = \frac{1 \times 10^3}{2 \times 10^4} = \boxed{.05\%}$

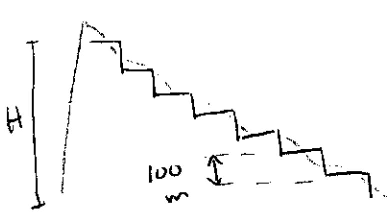
↳ evaporation

∴ Hydro cannot fulfill energy needs.

[efficiency relative to sun: $\varepsilon = \frac{1 \times 10^3}{2 \times 10^4} \times \frac{78}{200} \approx \boxed{0.02\%}$]

max efficiency dams:

avg. land elevation H: 2 km too high; (1000 m); 10 m too low



(terraces)

$$\frac{H}{h} = \frac{\varepsilon_{max}}{\varepsilon} = 10 \Rightarrow \boxed{\varepsilon_{max} \approx 0.5\%}$$

∴ Hydro definitely can't fulfill energy needs.

Biofuels:

How efficient is photosynthesis?

Corn: enough corn to feed me = 100 W

land required to grow corn =

6 acres = 20,000 m² too big

(2000 m² = ½ acre)

100 m² too small

$$\varepsilon_{food} = \frac{100\,W / 2000\,m^2}{200\,W/m^2} = \frac{0.05}{200} \approx \boxed{0.03\%}$$

↳ the sun

about 5 times more non-edible part than edible, so:

$$\varepsilon_{photo} = 5 \times \varepsilon_{food} = \boxed{0.15\%}$$ (our estimate)

↳ uses both edible & non-edible parts of plant

Real answer: ε_{photo} land mean: 0.2%

ε_{food} (premodern): ~0.015%

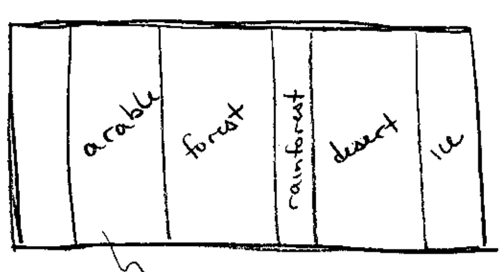
(fertilized): ~0.25%!

(fertilized corn): 0.5%! → corn is the super food! (?) lots of calories (but little nutrients)

land area for agriculture: 30%

∴ Biofuels cannot fuel the world.

avg. land per person = 6 acres ~ area of main quad



↳ about half the Harper quad

avg. 2500 m² per person