**Answer to Marathon problem 9: problem 86 page 279**

**Computation of total energy from the sun/hectare hour**

The total sunlight energy flux falling on a hectare = (1 kW/m2)\*10,000 m2 = 10,000 kW=1\*107 W/hectare

Since 1 W= 1 J/second, the cumulative energy falling on a hectare of agricultural land in an hour (=3600 s) is computed as follows:

**Total energy from sun = Energy Flux J \* 3600 s = 1\*107 J \* 3600 ~~s~~ =3.6\*1010 J**

**h\*hectare hectare s h hectare ~~s~~ h h hectare**

**Computation of energy upconverted to sugar/hectare hour**

We are given that 20 kg of sucrose (C12H22O11, MW=342 g/mol) is created per hour per hectare via the up-conversion reaction below:

12CO2 (g)+ 11 H2O(l)🡪 sucrose + 12O2 ΔH/mol sucrose= 5640 kJ/mol

To compute the efficiency of this chemical up-conversion in utilizing the available sunlight energy, we first convert the enthalpy per mole of sucrose to its equivalent energy/g of sucrose:

5640 kJ \* 1 mol sucrose = 16.49 kJ

Mol sucrose 342 g sucrose g sucrose

Since a total of 20 kg sucrose= 20,000 g sucrose is created in 1 hour per hectare, the energy required to do this is found so:

**Energy used to make 20 kg sucrose = 20,000 ~~g~~ sucrose \* 16.49 kJ = 3.3\*105 kJ = 3.3\*108 J**

**h \*hectare h hectare ~~g~~ sucrose h hectare h hectare**

Thus, the efficiency of agricultural energy conversion into sucrose on a hectare of land is finally calculated as below:

**Computation of Efficiency of Solar Upconversion to sucrose**

**% Efficiency = 100 \*(energy used make 20 kg sucrose/h hectare)**

**(Total solar energy from sun/h hectare)**

**Efficiency % = =100\* 3.3\*108 J/h = 0.9166 ~ 0.92%**

**3.6\*1010J/h**

**While a seemingly low %, the `upconversion’ of the sun’s energy by chlorophyll-based photosynthesis rarely breaks 3% efficiency. Mother Nature, in her wisdom, however, compensates for this by essentially covering any sunlit and arable bit of land with photo-converting plants.**