Solar Energy Conversion Devices and Plants: Examples lecture 1

1. Determine the DHI and DNI today in Lausanne, assuming the transmittance of the atmosphere is 60%.

Note: $P_D(\beta=0°)$=GHI, $D(\beta=0°)$=DHI

$$GHI = DHI + \overbrace{DNI}^{\tau\dot{q}_{solar}} \cdot \cos(\theta) \quad \text{(eq. 1)}$$

$$K_T = \frac{GHI}{\dot{q}_{solar}\cos(\theta)} \quad \text{(eq. 2)}$$

Assuming: $0.35<K_T<0.75 \rightarrow \frac{DHI}{GHI} = 1.557 - 1.84K_T$ (eq. 3)

Include (eq. 2) into (eq. 3) $\rightarrow DHI = \left(1.557 - 1.84\frac{GHI}{\dot{q}_{solar}\cos(\theta)}\right)GHI$ (eq. 4)

Include (eq. 4) into (eq. 1) $\rightarrow GHI - \tau\dot{q}_{solar}\cdot\cos(\theta) = \left(1.557 - 1.84\frac{GHI}{\dot{q}_{solar}\cos(\theta)}\right)GHI$ (eq. 5)

Rearranging (eq. 5):

$$\rightarrow 0 = \tau\dot{q}_{solar}\cdot\cos(\theta) + \left(1.557 - 1 - 1.84\frac{GHI}{\dot{q}_{solar}\cos(\theta)}\right)GHI$$

$$\rightarrow 0 = \frac{1.84}{\dot{q}_{solar}\cos(\theta)}GHI^2 - 0.557GHI - \tau\dot{q}_{solar}\cdot\cos(\theta)$$

Resolving this second order polynomial:

$$GHI = \frac{0.557 + \sqrt{0.557^2 + 4\tau\dot{q}_{solar}\cdot\cos(\theta)\frac{1.84}{\dot{q}_{solar}\cos(\theta)}}}{2\frac{1.84}{\dot{q}_{solar}\cos(\theta)}} = \left(0.151 + \sqrt{0.023 + 0.543\tau}\right)\dot{q}_{solar}\cos(\theta)$$

Assuming: $\dot{q}_{solar} = 1360\,\mathrm{W/m^2}$, $\tau = 0.6$, $\tau = 0.6$, reading altitude from slide 26: $\alpha = 35°$, therefore zenith: $\theta = 90 - \alpha = 55°$

$$GHI = 579\,\mathrm{W/m^2}$$

$$DHI = GHI - \overbrace{DNI}^{\tau\dot{q}_{solar}} \cdot \cos(\theta) = 111\,\mathrm{W/m^2}$$

Fraction of diffuse: $\frac{DHI}{GHI} = 0.19$

Check if our assumption on K_T was correct: $K_T = \frac{GHI}{\dot{q}_{solar}\cos(\theta)} = 0.74$ √

Note, if alternative the third band of K_T is used ($\frac{DHI}{GHI} = 0.177$):

$$GHI = \overbrace{DHI}^{0.177GHI} + \overbrace{DNI}^{\tau\dot{q}_{solar}} \cdot \cos(\theta) \rightarrow GHI = \frac{\tau\dot{q}_{solar}\cdot\cos(\theta)}{1 - 0.177} = 567\,\mathrm{W/m^2}$$