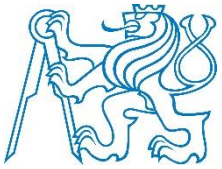
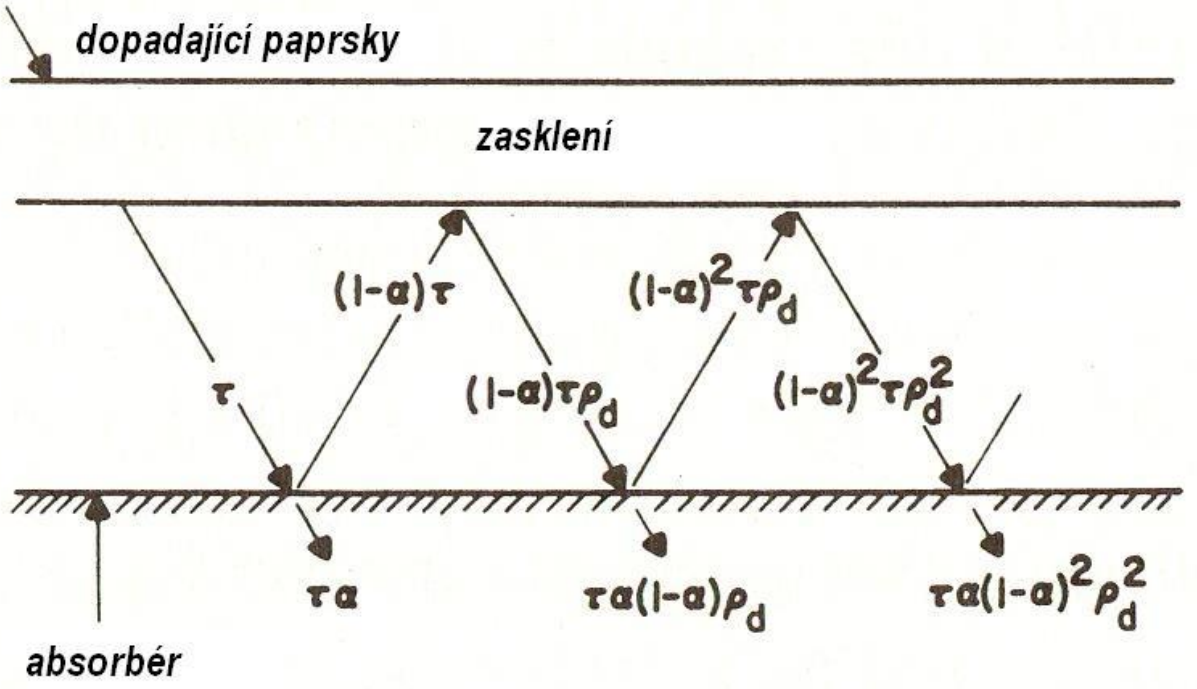


Solar collectors

- optical characteristics
- testing and certification

System glazing - absorber



τ glazing transmittance for solar radiation

α absorber absorptance for solar radiation

ρ_d diffuse reflectance (from absorber)

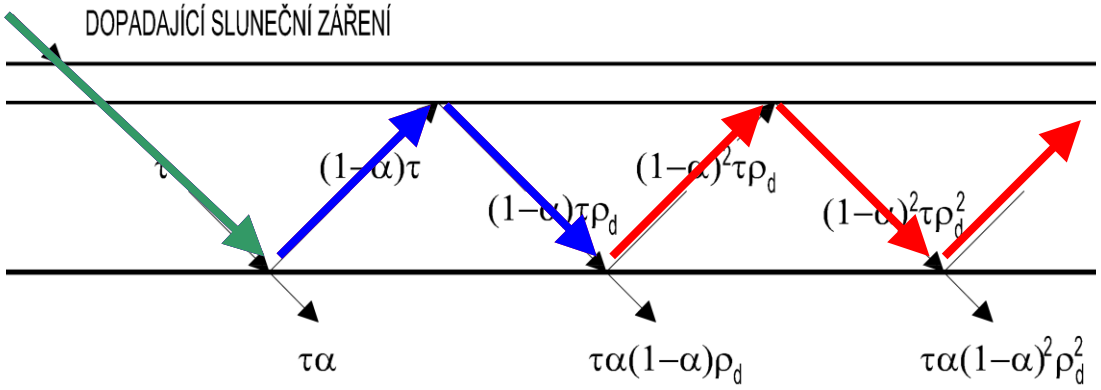
System glazing - absorber

$$(\tau\alpha) = \tau\alpha \sum_{n=0}^{\infty} \left[(1-\alpha)\rho_d \right]^n = \frac{\tau\alpha}{1-(1-\alpha)\rho_d}$$

reflectance for diffuse radiation: integration in the range 0 to 90°

simplification: $\rho_d = \rho(60°)$

System glazing - absorber



$$(\tau\alpha) = \tau \cdot \alpha \cdot \sum_{n=0}^{\infty} \left[(1-\alpha)\cdot \rho_d\right]^n$$

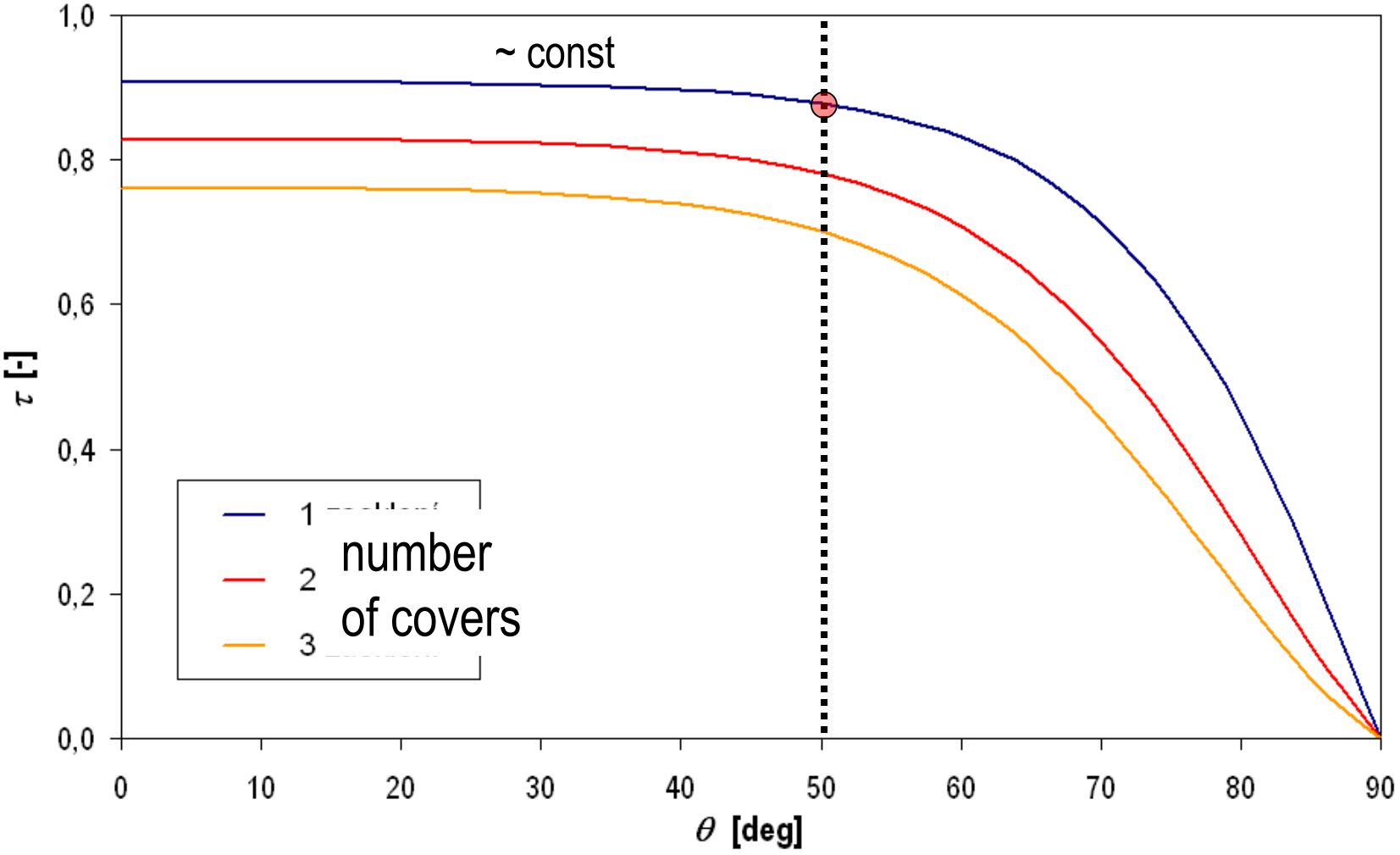
$$(\tau\alpha) = \tau \cdot \alpha + \tau \cdot \alpha \cdot (1-\alpha)\cdot \rho_d$$

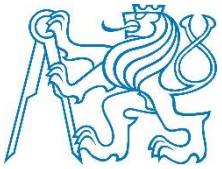
$$(\tau\alpha) = \tau \cdot \alpha$$

example: glass, n = 1,52, K = 10 m^{-1}, ρ_d = 15 %

incidence angle 0°		incidence angle 60°	
$\tau = 0{,}88,\ \alpha = 0{,}90$		$\tau = 0{,}80,\ \alpha = 0{,}80$	
$\tau\alpha$	= 0,792	$\tau\alpha$	= 0,640
$(\tau\alpha)$	= 0,804	$(\tau\alpha)$	= 0,659
$(\tau\alpha)$	= 0,804	$(\tau\alpha)$	= 0,660

Glazing optical properties - transmittance





Incidence angle modifier (K_θ, IAM)

efficiency characteristics apply for normal incidence $\theta = 0°$ x usually $\theta \neq 0°$

$$\eta(\theta) = \eta_0(\theta) - a_1 \cdot \frac{t_m - t_e}{G} - a_2 \cdot \frac{(t_m - t_e)^2}{G}$$

incidence angle modifier (IAM) – influence of incidence angle on collector efficiency, optical characteristic, angle dependent correction

$$K_\theta = \frac{\eta_0(\theta)}{\eta_0(0°)}$$

symetric collectors: $K_\theta(\theta)$

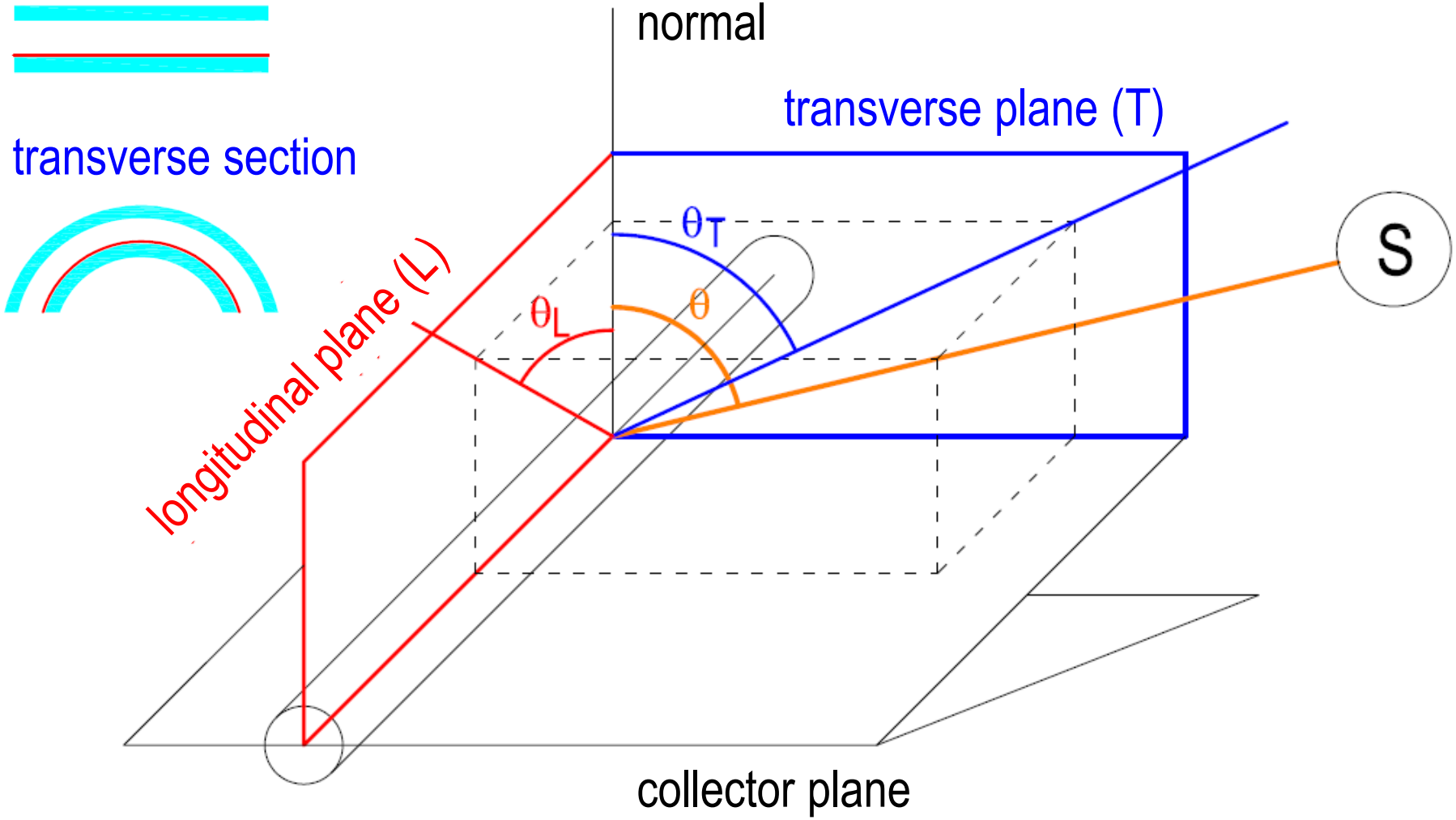
asymetric collectors: $K_\theta(\theta) = K_L(\theta_L) \cdot K_T(\theta_T)$

Optical characteristics of collector

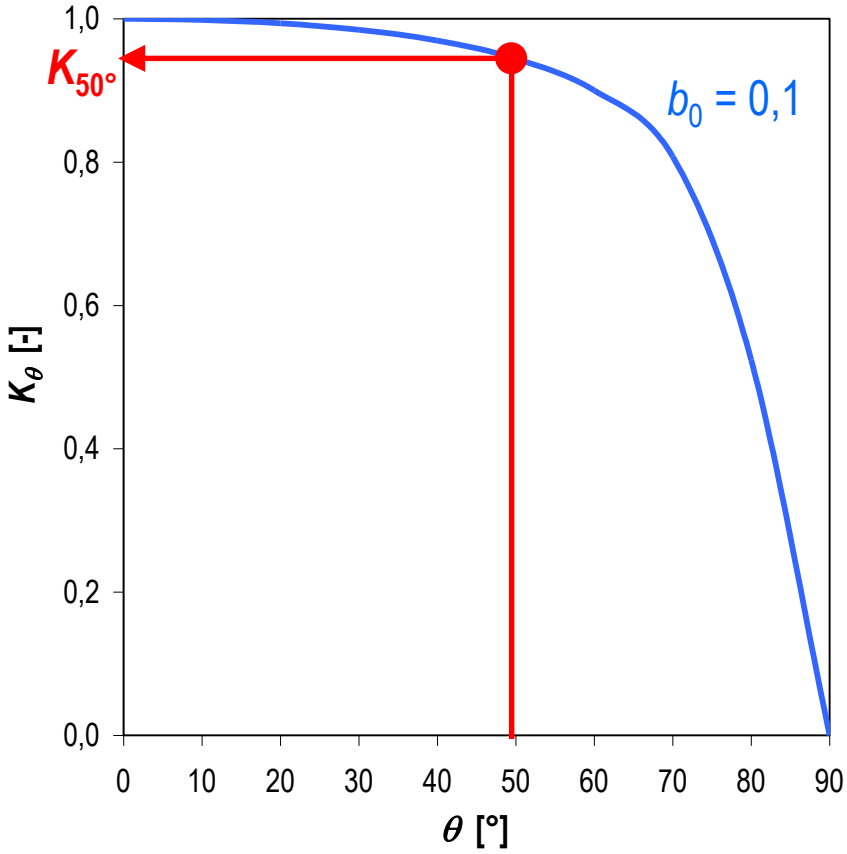
longitudinal section

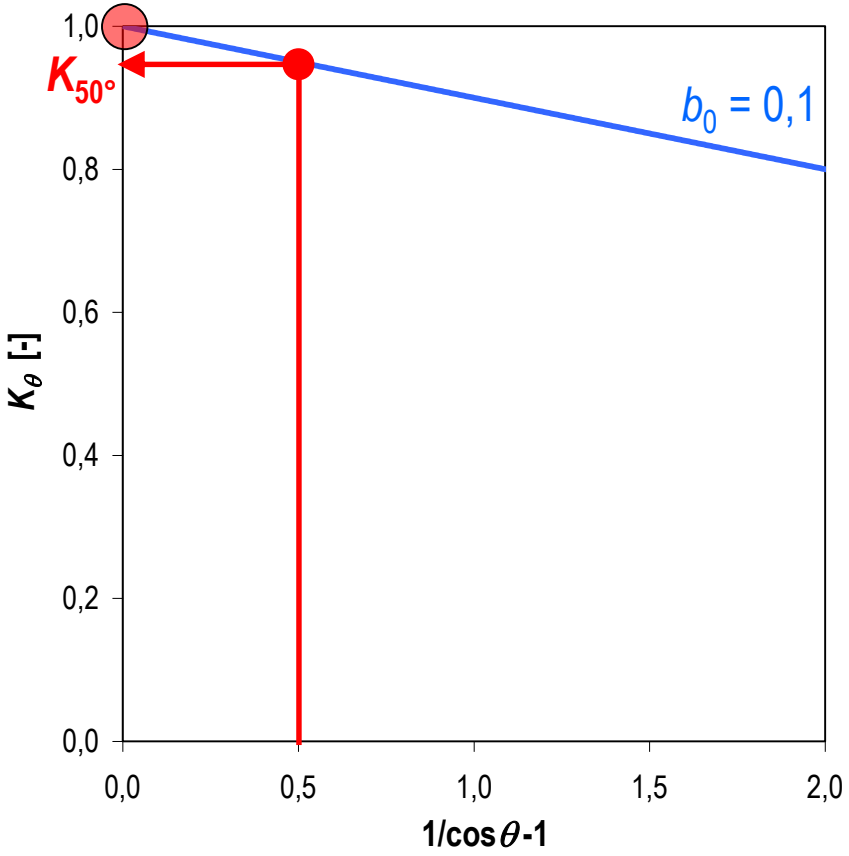
transverse section

$K_\theta = K_{\theta,L}(\theta_L).\ K_{\theta,T}(\theta_T)$



Incidence angle modifier (K_θ, IAM)



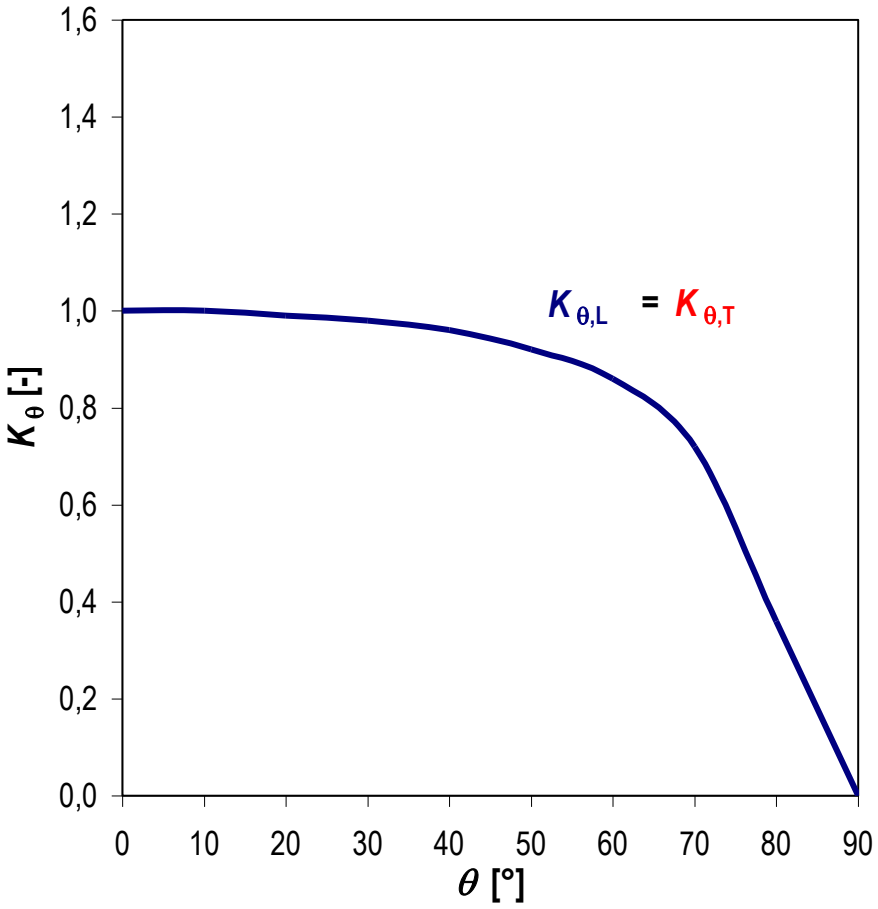


$$K_\theta = 1 - b_0 \cdot \left(\frac{1}{\cos\theta} - 1 \right)$$

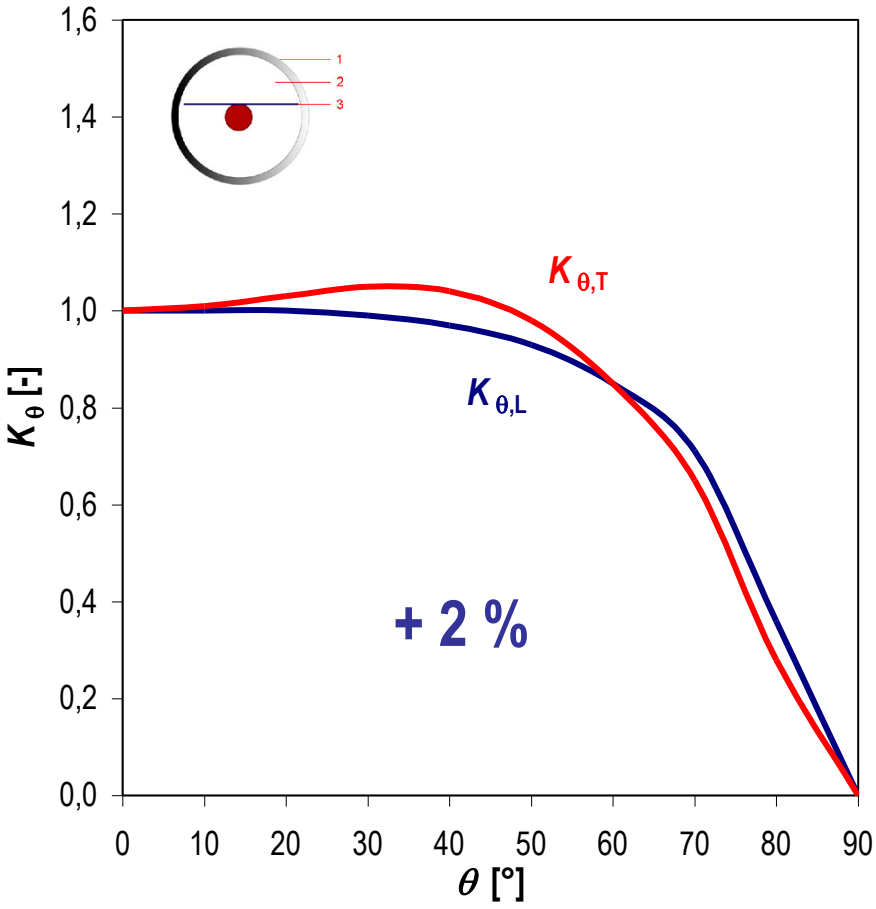
only for flat glazings / absorbers

Incidence angle modifier

flat plate collector

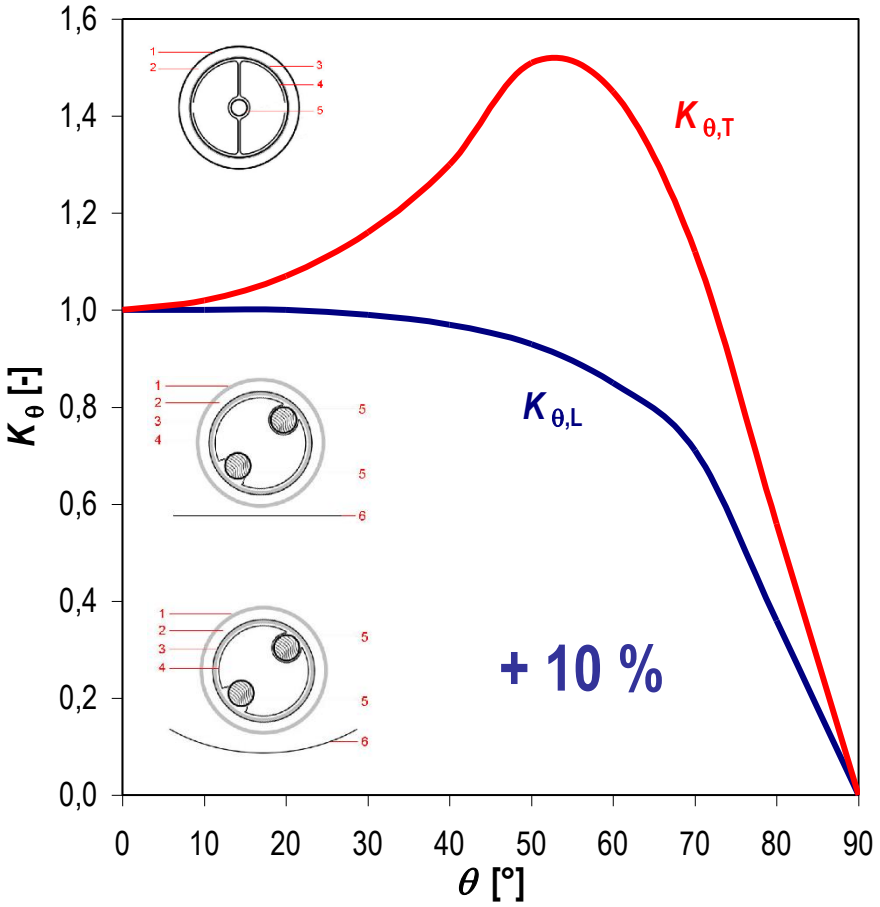


tube collector with flat absorber

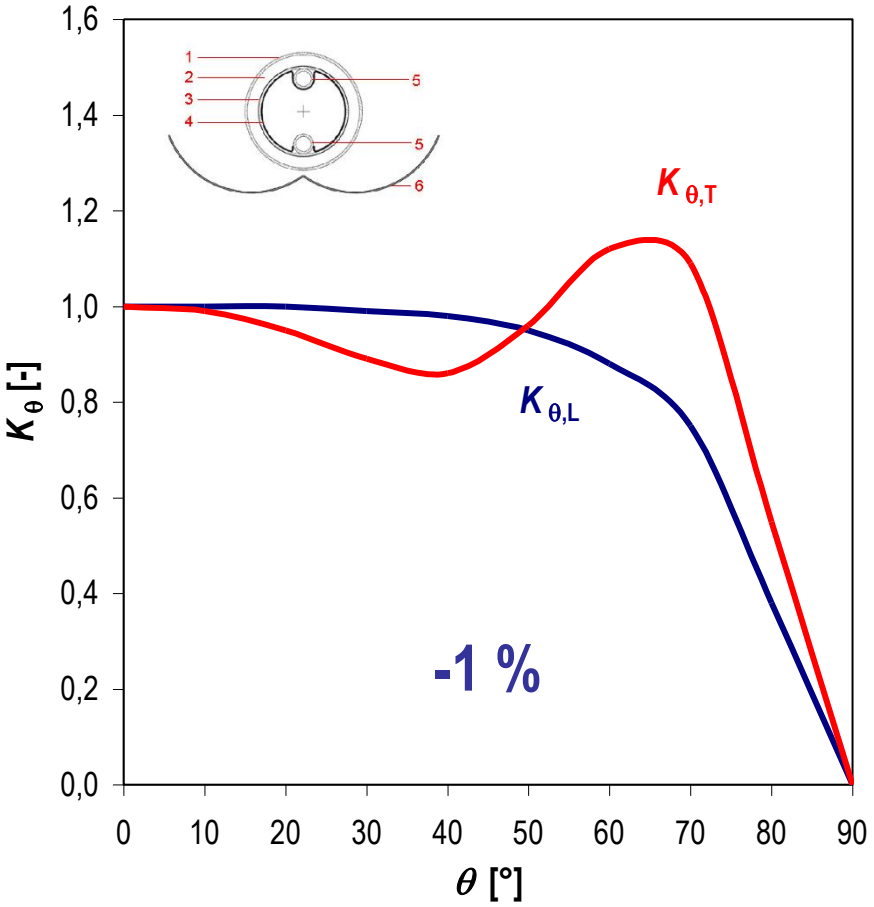


Incidence angle modifier

tube collector with cylindrical absorber (with/without reflector)



tube collector with CPC reflector



Incidence angle modifier

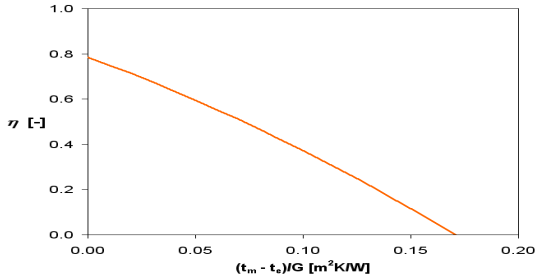
It is important to :

- consider the optical characteristic always as a complex ($K_\theta * \eta_0$)
- high increase of K_θ at 50 – 60° indicate low η_0
- and vice versa ...

Collector heat output at real conditions

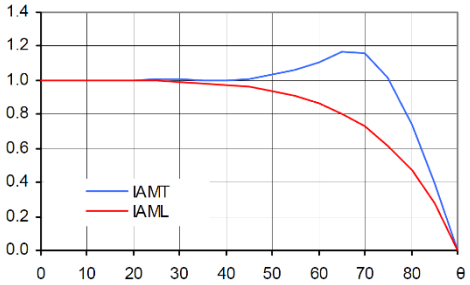
efficiency (heat output) characteristic at normal incidence

$$\eta = \eta_0 - a_1 \cdot \frac{t_m - t_e}{G} - a_2 \cdot \frac{(t_m - t_e)^2}{G}$$



IAM characteristics for other incidence angles (direct, diffuse)

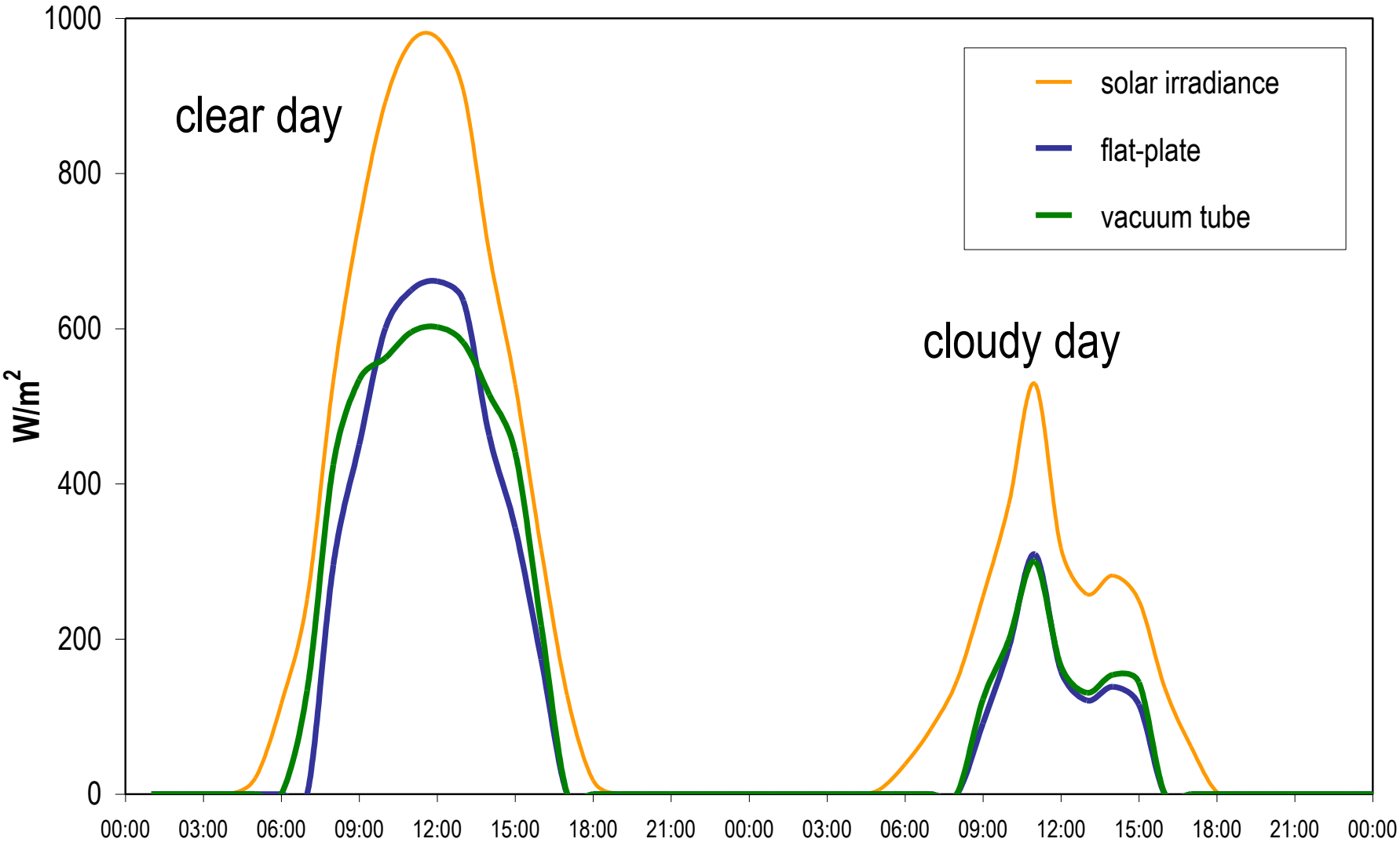
$$K_{\theta,b} = \frac{\eta_0(\theta)}{\eta_0(0°)} \qquad K_{\theta,d} = \int_0^{\pi/2} K(\theta) \sin 2\theta d\theta$$



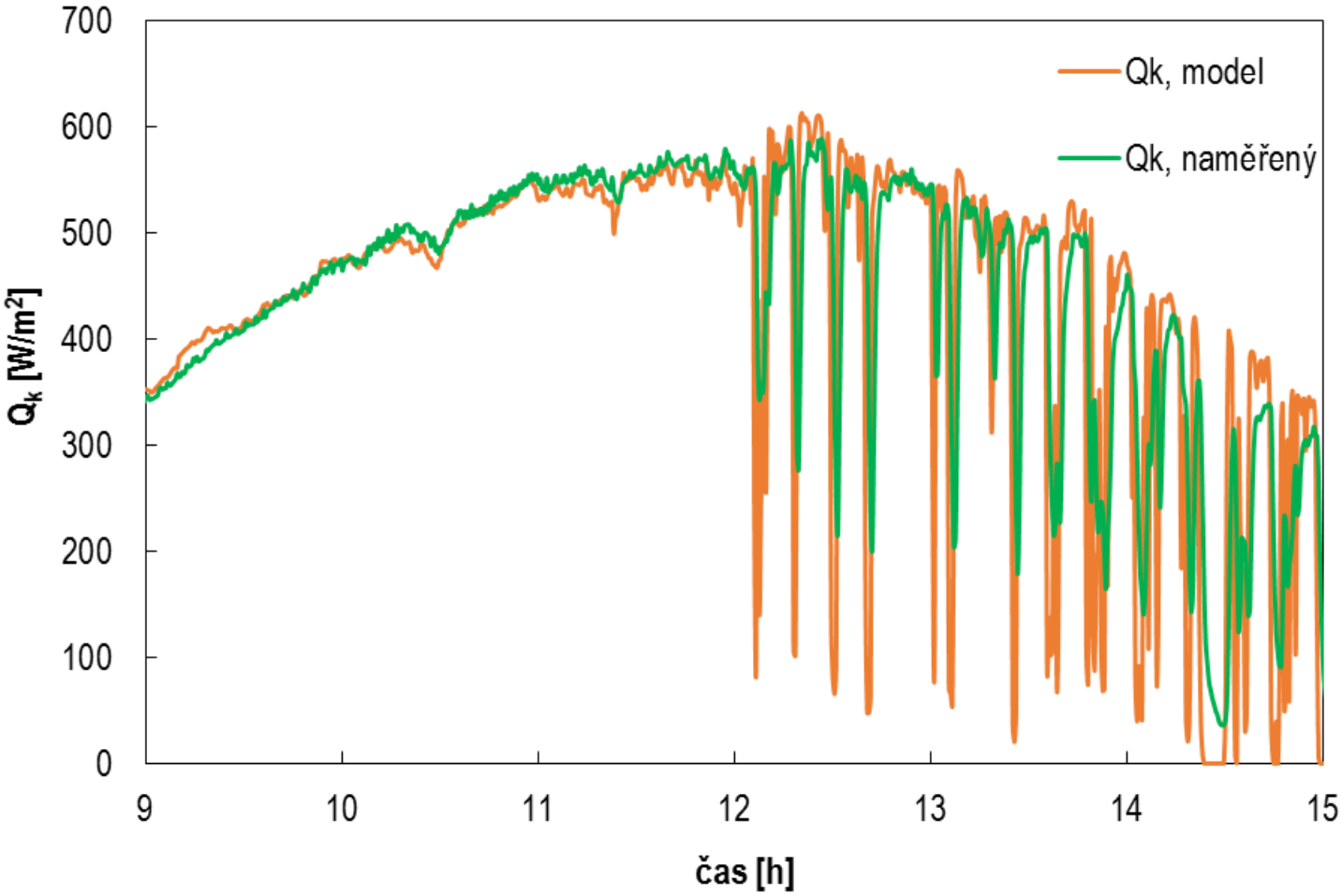
heat output for real conditions (direct and diffuse radiation)

$$\dot{Q}_k = A_a[\eta_0(K_{\theta,b}G_{b,T} + K_{\theta,d}G_{d,T}) - a_1(t_m - t_e) - a_2(t_m - t_e)^2]$$

Collector heat output at real conditions

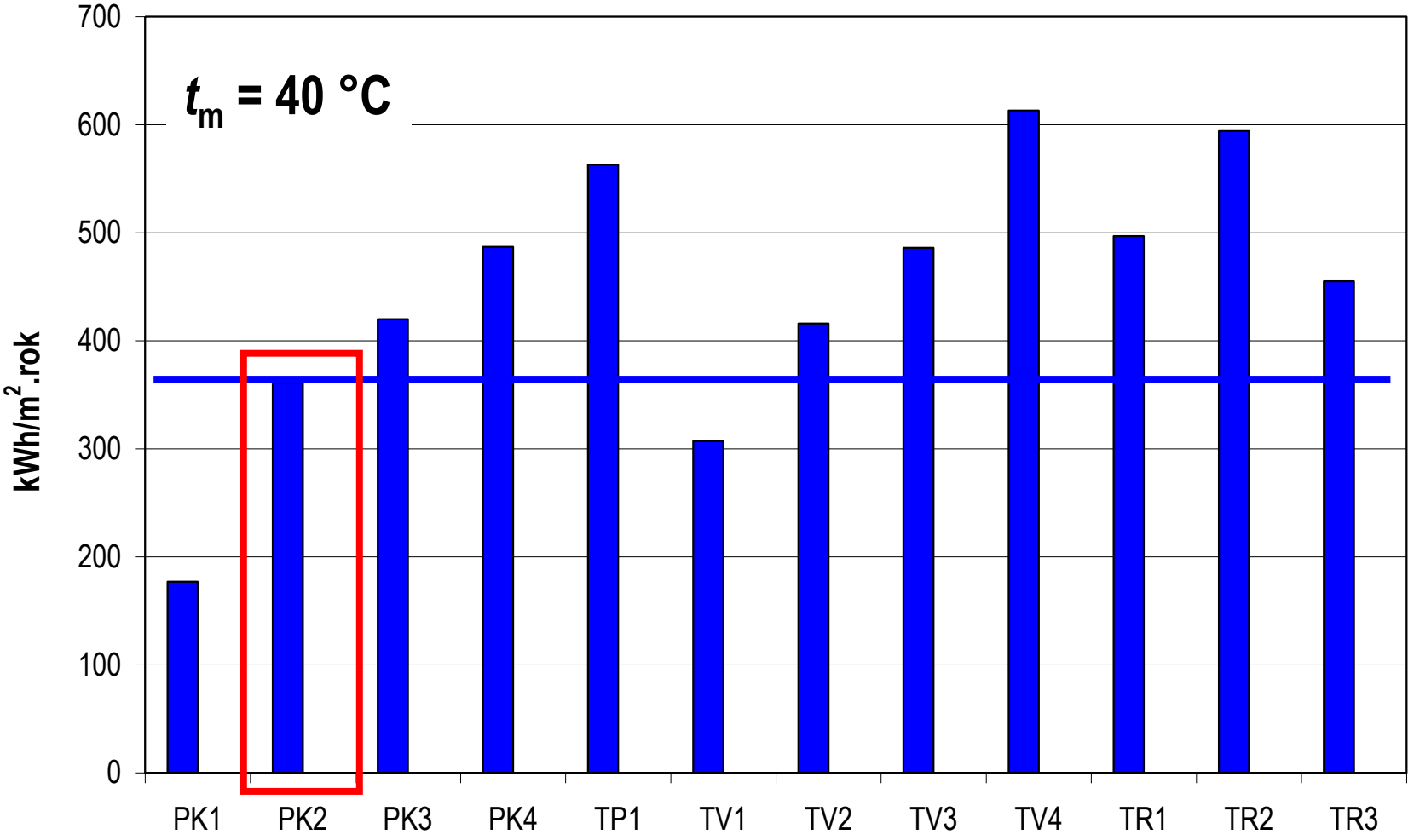


Collector heat output at real conditions



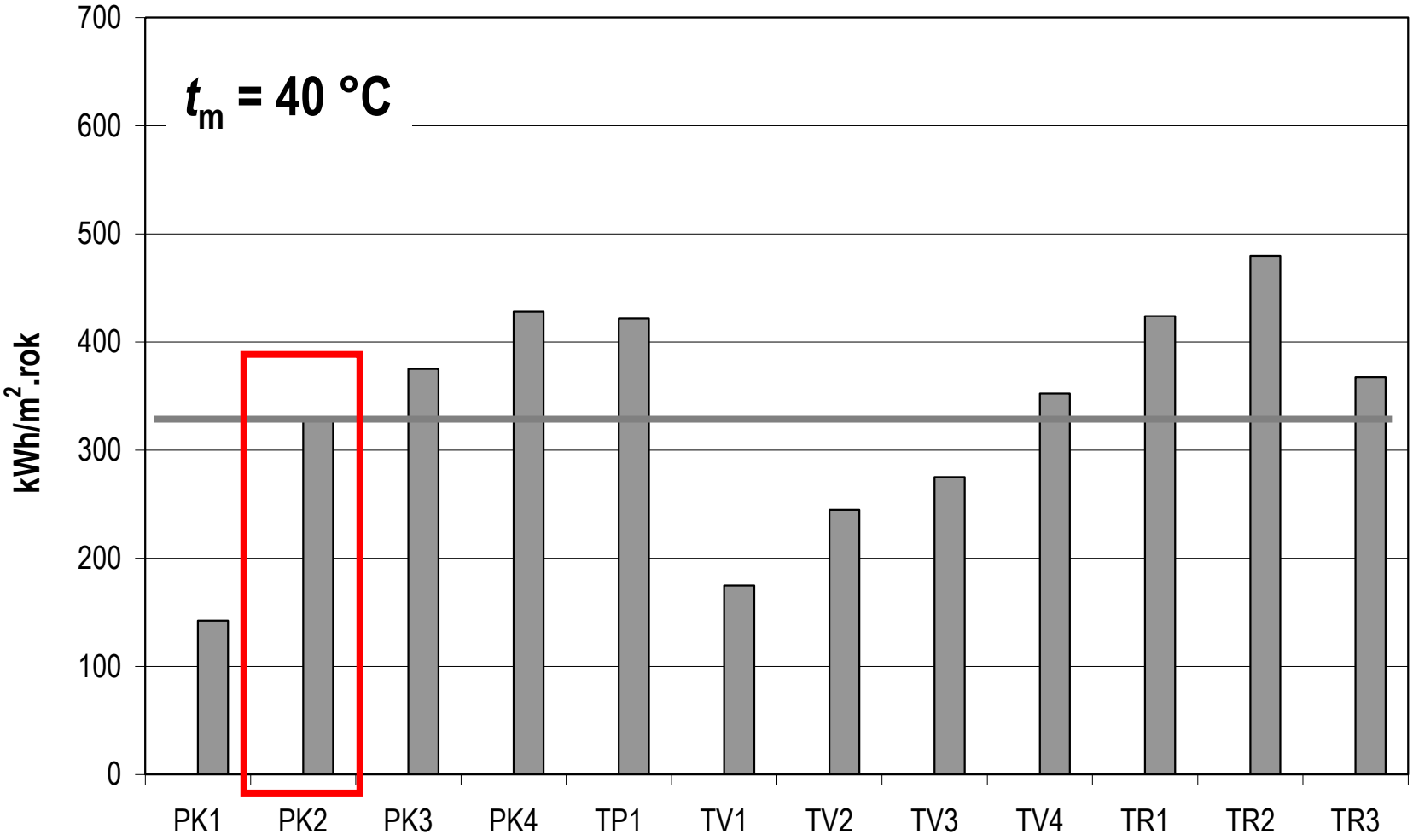
Collector performance – net annual gain

related to aperture area A_a

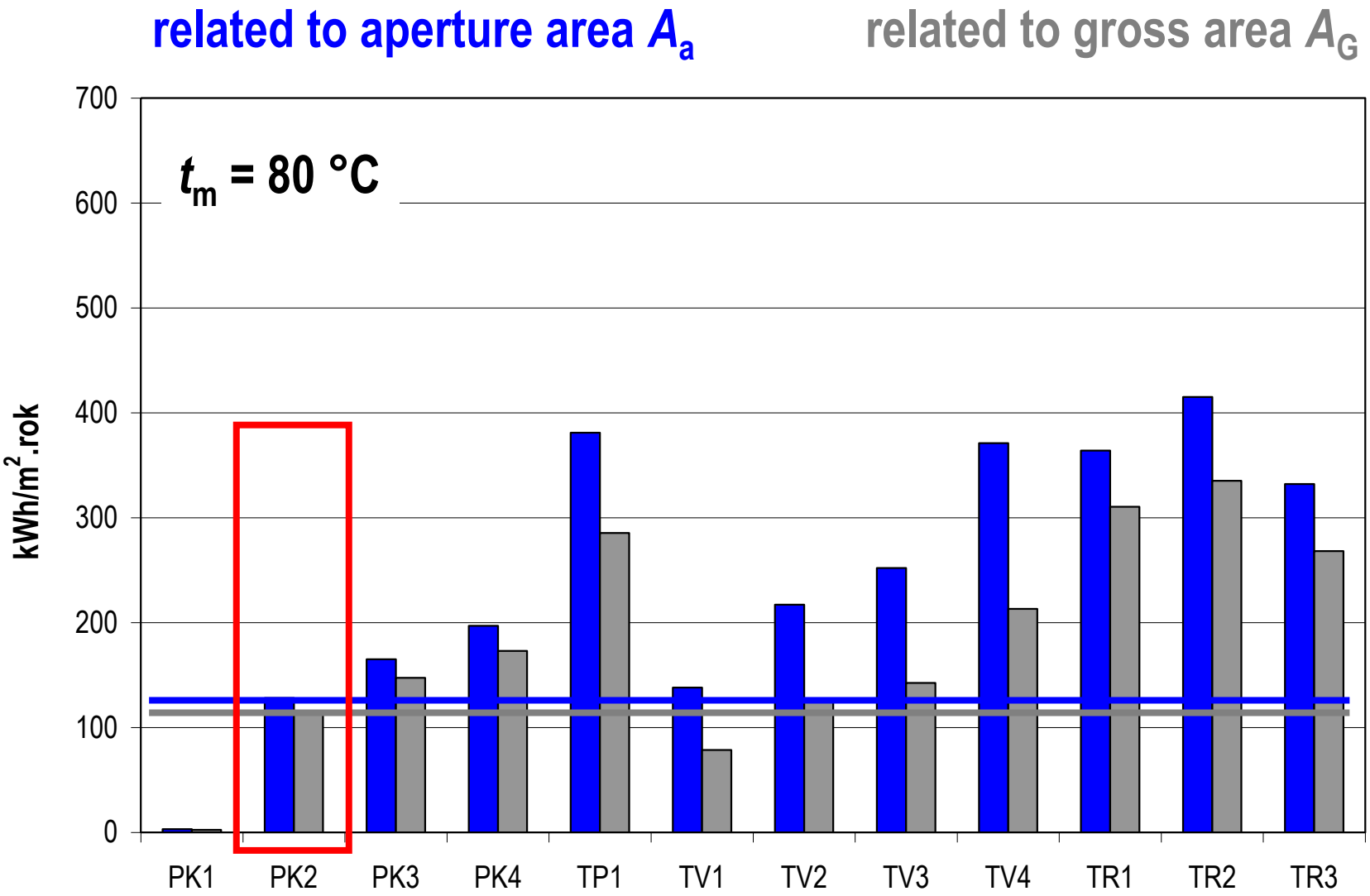


Collector performance – net annual gain

related to gross area A_G



Collector performance – net annual gain

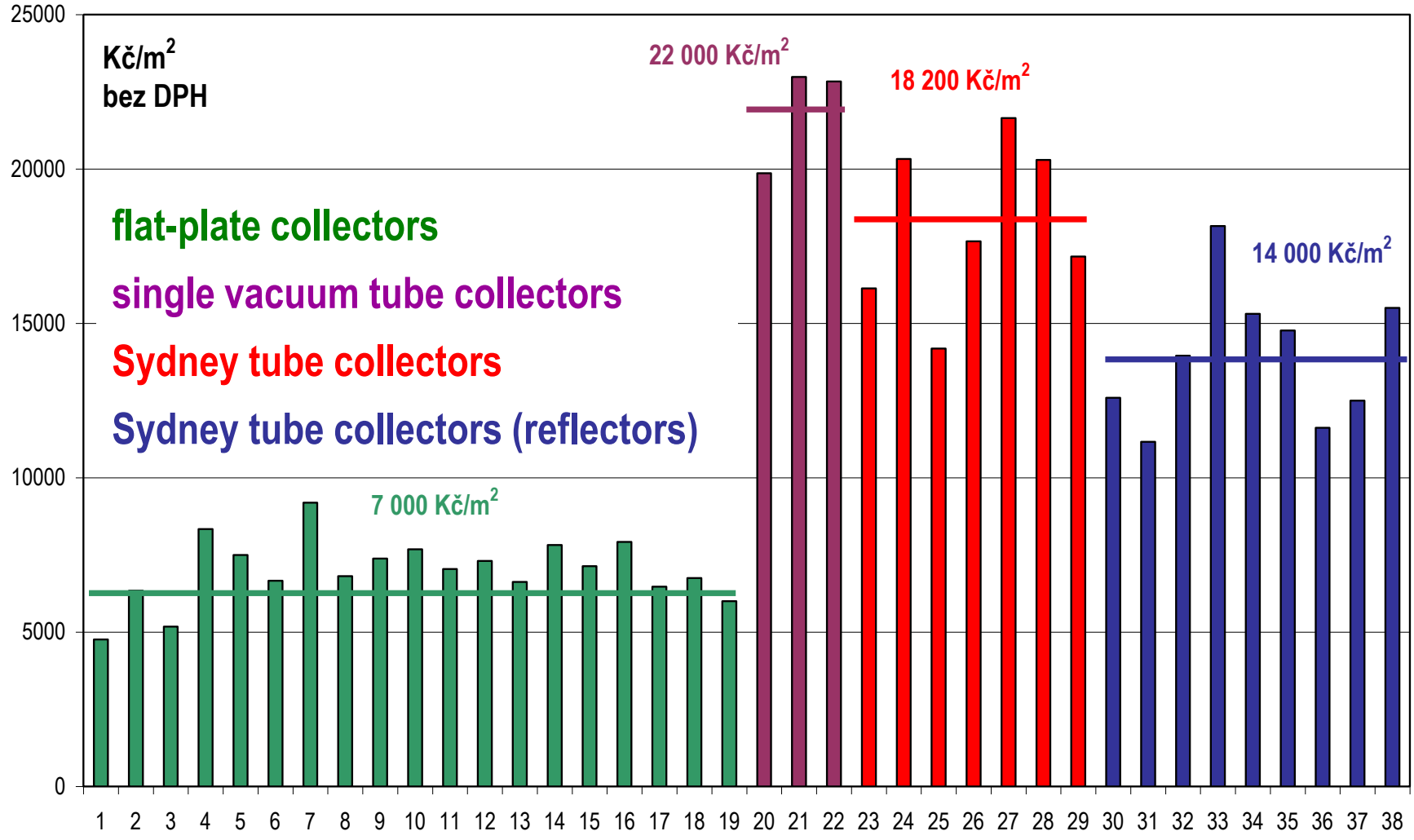


It can't be generalized ...

To evaluate suitability of solar collector ...

- information on type of collector is not sufficient („flat-plate is best for hot water", „vacuum tube is the best", „Sydney tube works under clouds")
- efficiency curve indicates but it is not sufficient for detailed comparison, need for optical characteristic (especially for tube collectors!!!)
- need for information on operation and climate conditions the collector will work in ...
- what is the aim of evaluation or comparison – relating the output to aperture or gross area

... and the price matters



Testing of solar collectors (EN)

- **report on tests in accordance to EN 12975**
  - **heat output and efficiency**
  - internal pressure
  - high temperature resistance
  - exposure
  - external thermal shock
  - internal thermal shock
  - rain penetration (glazed)
  - mechanical load
  - impact resistance

NO other certificates are needed to approve the properties !

Solar Keymark

Certification quality mark (CEN)

- solar collectors, factory made solar systems
- voluntary **certification** by third party, complex conformity with EN
- it is not a CE mark ! (conformity with EU directive), **not applicable** for usual colectors
- documented production inspection (ISO 9000)
- inspector selects **ANY** collector to be tested from the store or production line
- continuous checks in defined periods
- information: **collector passed ALL tests according to EN 12975-2**

no info, if collector is highly efficient or not, only stability of presented efficiency characteristic for all products under tested designation

Blue angel

Ekologic mark

- for products generally, most known mark in Germany
- for solar collectors: definition of materials, which could be used
- minimum heat gain **525 kWh/m^2.a** determined by simulation (!)

determined in specified solar system model for hot water preparation

storage: volume, insulation thickness, thermal conductivity

pipes: length, diameter, insulation thickness, thermal conductivity

heat demand: amount, temperature and daily profile of hot water

climatic conditions: Wurzburg

requirement: collector area set to cover **40 %** of the demand

Simulation model of solar system