Renewable Energy MSc Lecture Notes

By

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Course Contains:

- **Renewable Energy Overview**
- **Basic of Renewable Energy Supply**
- **Solar Thermal Heat Utilization**
- **Photovoltaic Power Generation**
- **Wind Power Generation**
- **Hydroelectric Power Generation**

Solar Thermal Heat Utilization

(Lecture 3)

Contents:

Principles- *Absorption, emission, reflection and transmission*

- ***Absorption***
- Solar thermal utilization is *the conversion of short-wave solar radiation into heat* (photo thermal conversion process).
- A body's capacity to absorb radiation is called absorbing capacity or **absorption** $\boldsymbol{\alpha}$
- An ideal **black body** absorbs radiation at every wavelength and therefore has an absorption coefficient equal to **one**.

Principles- *Absorption, emission, reflection and transmission*

- **Emission ε** represents the power radiated by a body.
- The relationship between **absorption α and emission ε** is defined by **Kirchhoff's law .**
- **Radiation and the absorption coefficient is constant** at a given temperature, and in terms of its amount, equal to the specific radiation of the black body at this temperature.
- The **reflection** coefficient ρ describes the ratio of the reflected to the incident radiation.
- The **transmission** coefficient τ defines the ratio of the radiation transmit-ted through a given material.

$$\alpha + \rho + \tau = 1$$

Principles- Optical features of absorbers

- Absorbers have to *absorb radiation and partially convert it into heat.*
- The absorber → for opaque for radiation (*τ= 0)*
- *Therefore:* α + ρ =1

An ideal absorber:

no reflection any **short-wave radiation**

Completely absorbs solar radiation within this wave range (*α = 1).*

Given an ideal absorber, it reflects all of the radiation and does not absorb at all.

Absorption (*α) and reflection coefficient (ρ) of an ideal (ideal) and a standard real* absorber *(real)*

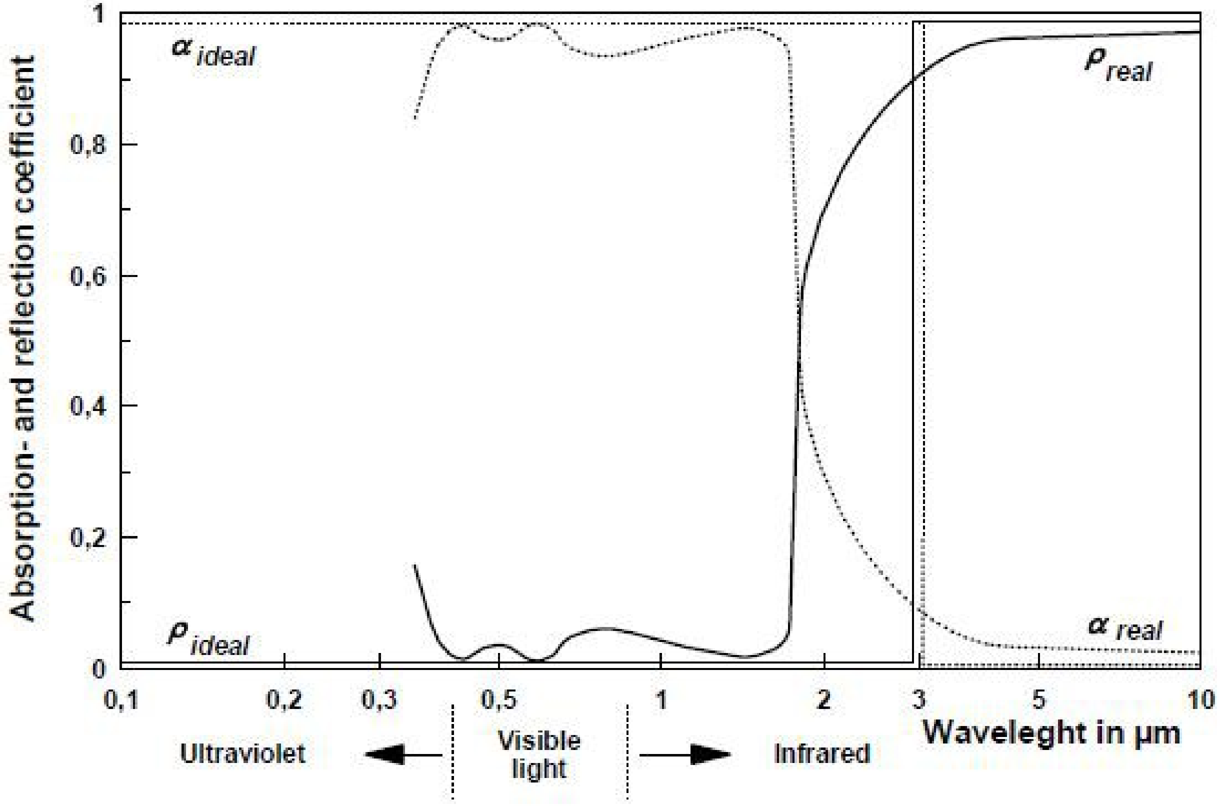


Table 4.1 Optical features of absorbers (according to /4-1/)

		Solar irradiance			Infrared-radiation			α_S/ε_I
		α_S (ε_S)	τ_S	ρ_S	α_I (ε_I)	τ_I	ρ_I	
Selective	Black nickel	0.88	0	0.12	0.07	0	0.93	12.57
Absorber	Black chromium	0.87	0	0.13	0.09	0	0.91	9.67
	Aluminium grid	0.70	0	0.30	0.07	0	0.93	10.00
	Titanium-oxide- nitride	0.95	0	0.05	0.05	0	0.95	19.00
Non-selective absorber		0.97	0	0.03	0.97	0	0.03	1.00

- **Absorption coefficient for various different materials, the transmission and reflection coefficients for the solar irradiance and the infrared range of the solar radiation spectrum.**
- **Compared to the non-selective absorber, selective absorber surfaces show high degrees of α_s/ε_I**
- **α_S is the absorption coefficient in the spectrum of solar irradiance, ε_I is the emission coefficient in the infrared radiation spectrum.**
- **Titanium oxide shows a particularly high α_s/ε_I-ratio.**

Principles- Optical features of covers

Table 4.2 Optical features of covers (according to /4-1/)

	Solar spectrum			Infrared radiation		
	$\alpha_S\ (\varepsilon_S)$	τ_S	ρ_S	$\alpha_I\ (\varepsilon_I)$	τ_I	ρ_I
Sheet glass	0.02	0.97	0.01	0.94	0	0.06
Infrared reflecting glass (In_2O_3)	0.10	0.85	0.05	0.15	0	0.85
Infrared reflecting glass (ZnO_2)	0.20	0.79	0.01	0.16	0	0.84

- Glass fulfils the required optical features within the luminous spectrum very well.
- Infrared light emitted by the collector , however, cannot pass through, but is mainly absorbed.
- If the degree of absorption is high, the temperature of the glass cover rises and the radiation losses to the environment are correspondingly high
- These losses can be reduced by vacuum-coating of layers that reflect infrared light.

Principles- Energy balance

General energy balance: describes the general energy balance of a medium that absorbs radiation and converts it into heat:

$$\dot{G}_{G,abs} = \dot{Q}_{conv,abs} + \dot{Q}_{rad,abs} + \dot{Q}_{refl,abs} + \dot{Q}_{cond,,abs} + \dot{Q}_{useful}$$

Global Radiation

Convection Losses Abs,

Long-wave Radiation

Reflection Losses

Thermal Cond. Losses

Principles-Efficiency and solar fractional savings

The efficiency η of the conversion of solar radiation energy into useable heat in the collector results from the ratio of the useful thermal flow transported by the heat transfer medium Q_{useful} to the global radiation incident on the collector

$$\eta = \dot{Q}_{useful} / \dot{G}_g$$

In many cases the solar fractional saving F_s is significant. It is defined in different ways by the relevant literature. In this context, it is the ratio between the utilisable emitted energy through conversion of solar radiation by the solar installation ex-storage to the actual demand for heating, domestic warm water or process heat that is to be covered partly or entirely by solar energy

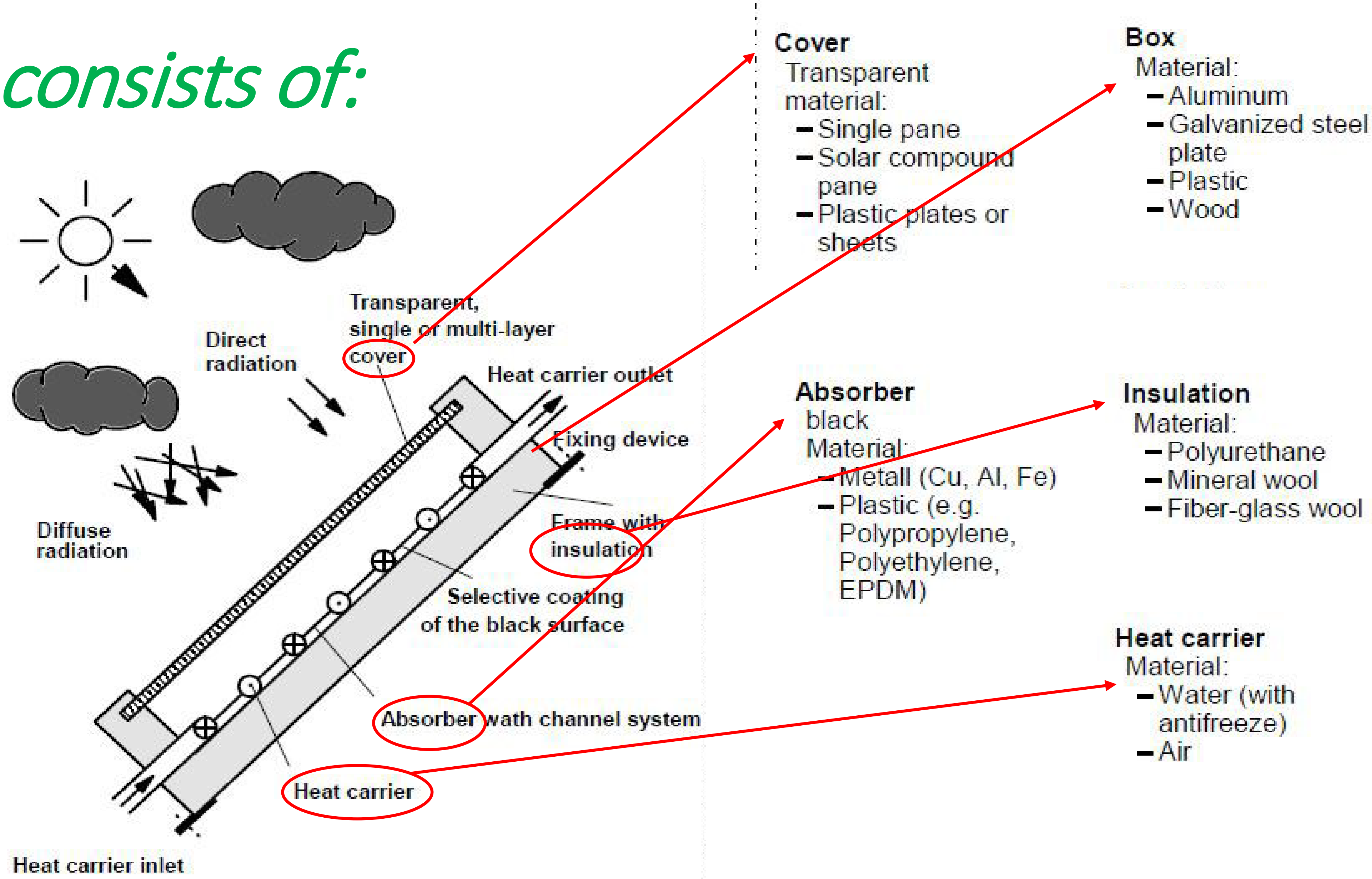
$$F_s = 1 - \frac{\dot{Q}_{aux}}{\dot{Q}_{demand}}$$

Technical description

- Main components: ***Collector***
- Essential component: ***liquid or gaseous heat transfer medium and pipes to transport the heat transfer medium***
- *Heat storage with none, one or several heat exchangers plus, for certain designs,*
- *Pumps with a drive to maintain the heat carrier cycle*
- *Sensors and control instruments*

Collector consists of:

- Absorber
- Transparent
- Cover
- Frame insulation
- heat insulation
- heat carrier inlet and outlet



Technical description- *Collector* Installation

- Collectors are mainly installed on pitched roofs; in this respect the integration into the roofing or the on-roof installation, on top of the tiles, are common technical solutions.
- Integration into **the roof is less visible and cheaper than the on-roof** installation. It is preferably used for new buildings or larger collector arrays on already existing roofs. Additionally, ***roofing costs are saved for the parts of the roof where the collectors are installed***.
- Installation of collectors on flat areas (e.g. on flat roofs, in gardens) facilitates optimal adjustment and incline when compared to the installation on pitched roofs.
  - Mainly standardized frames are used to integrate the collector.
  - Frames need to be arranged so that shading is avoided.

Technical description

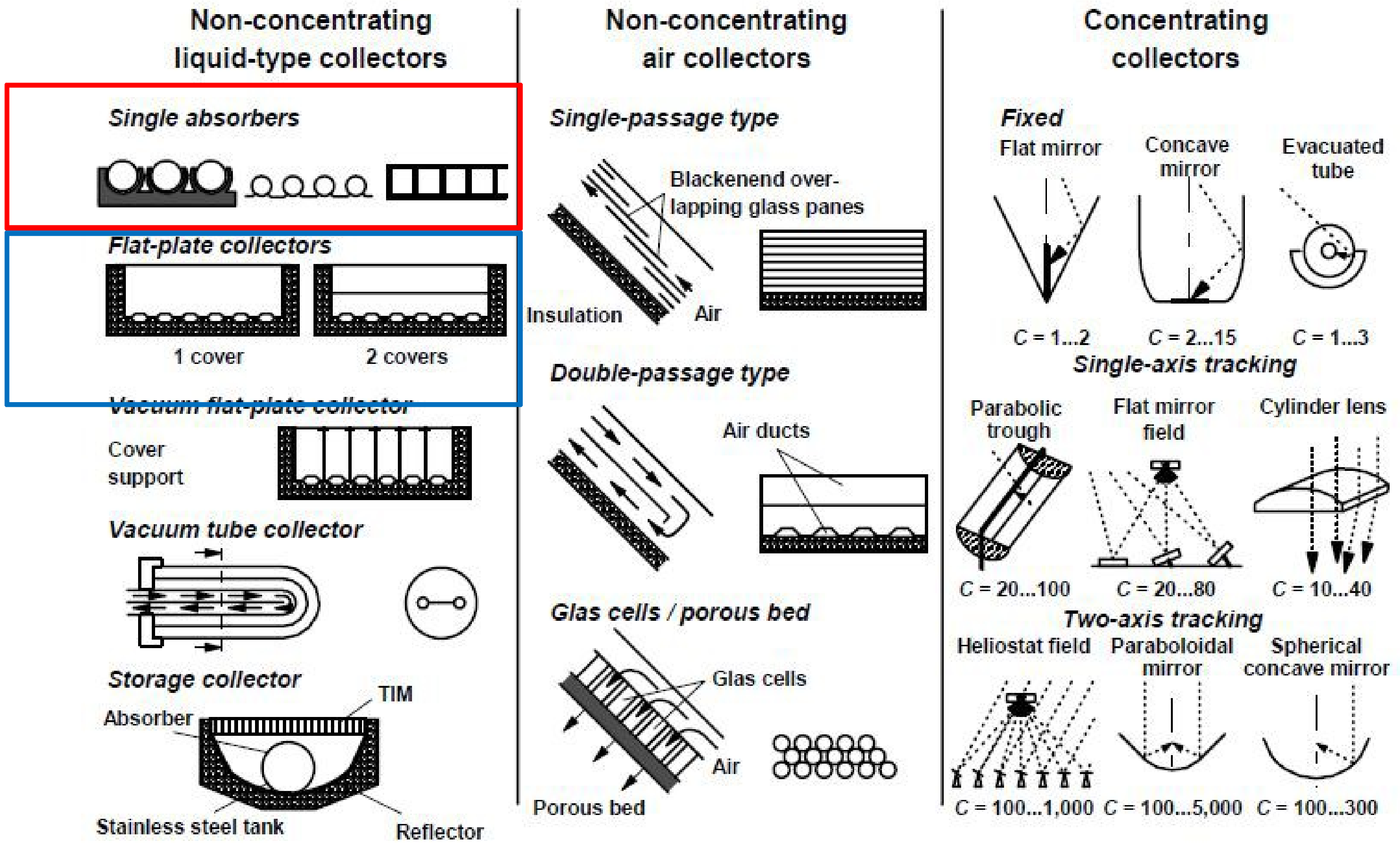
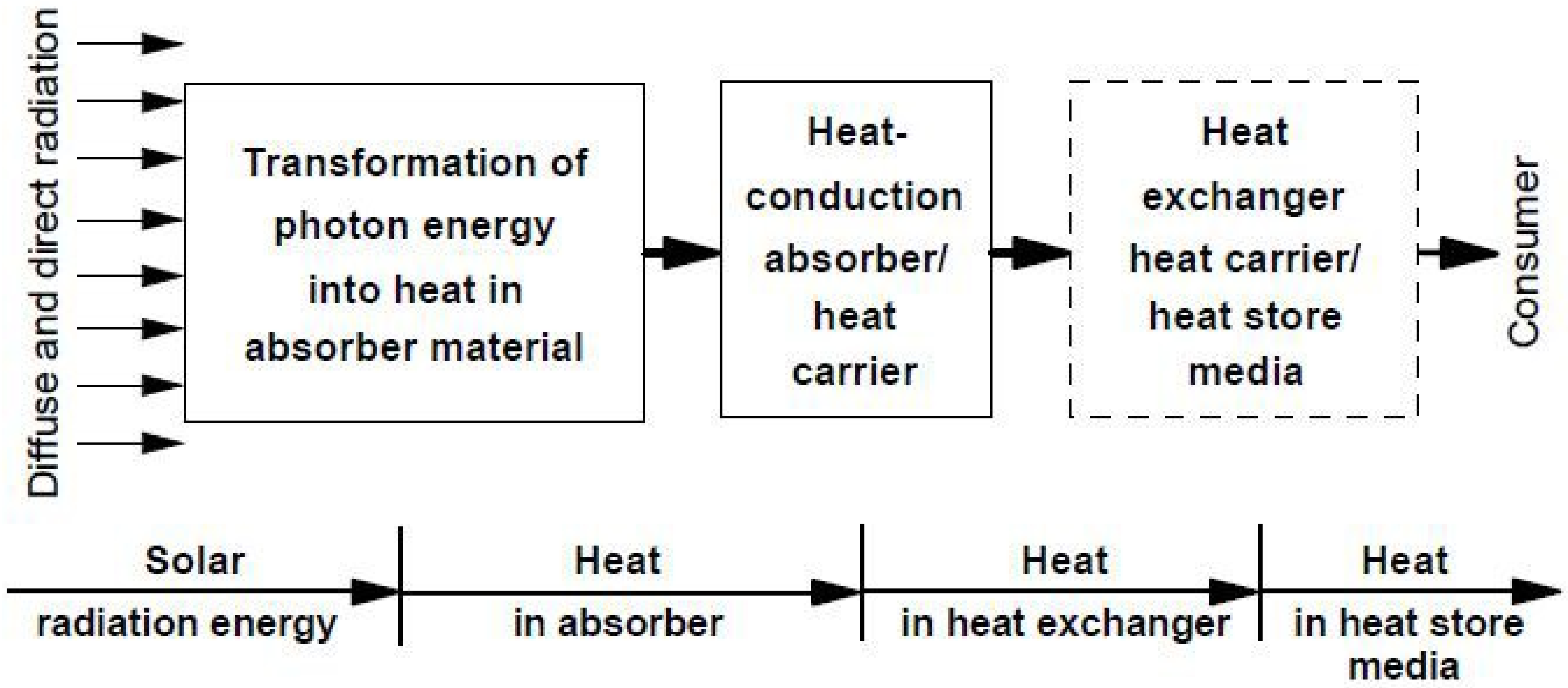


Fig. 4.4 Overview of different collector types (*C* concentration ratio; defined as the ratio of the optically active collector area to the absorber area exposed to radiation; TIM transparent insulation material; see e.g. /4-2/ and various other sources)

Technical description-Energy conversion chain



Energy conversion chain of solar thermal heat utilisation

Technical description-System design concepts

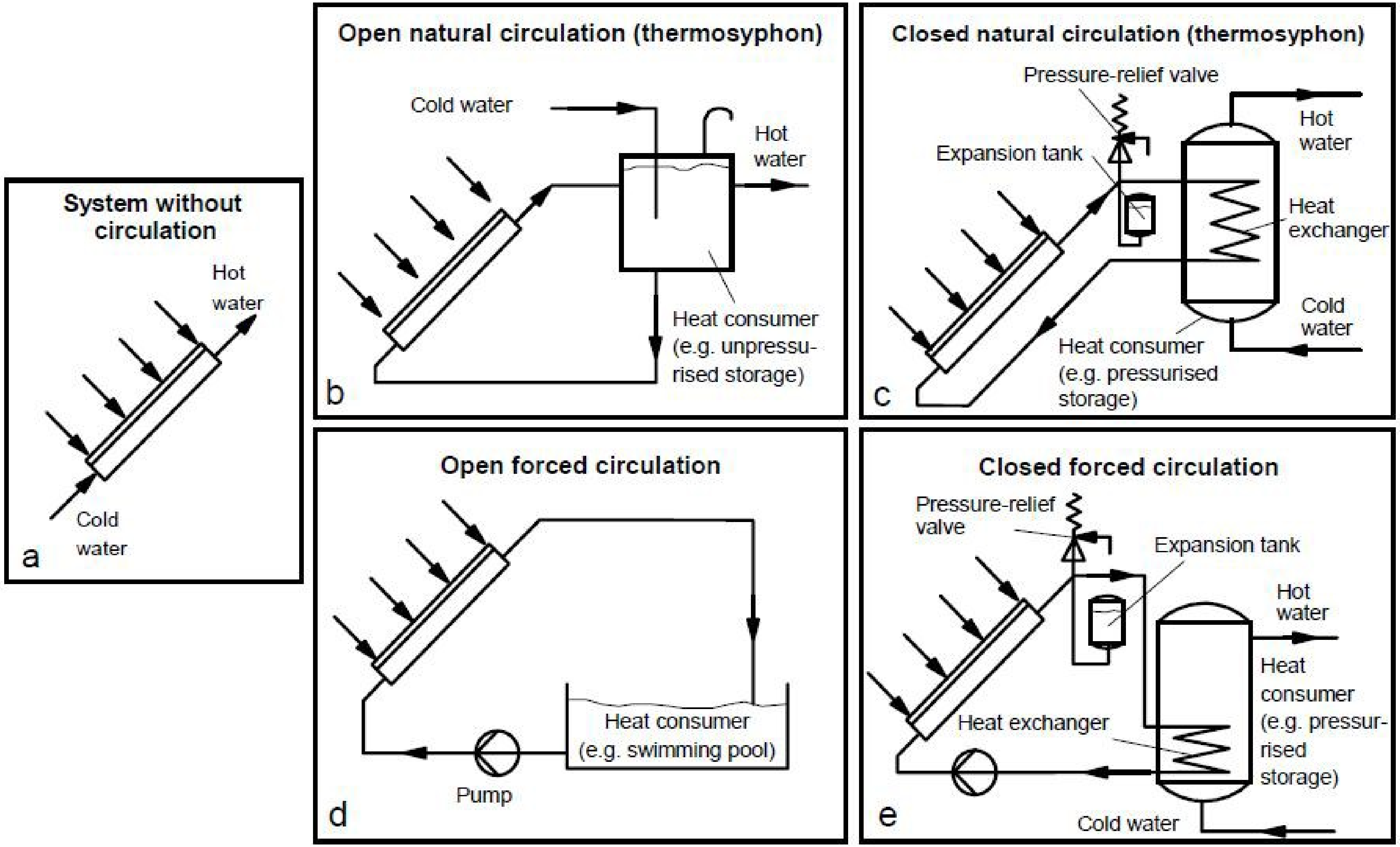


Fig. 4.11 Basic concepts of active solar thermal systems

Technical description-Applications:

- Solar heating of open air
- Swimming pools
- Small systems
- Solar-supported district heating systems