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Heat requirement of greenhouses including latent heat flux

Unlike buildings, the heat demand of greenhouses is affected also by the evaporation of the respective crop. Due to condensation of water vapour inside the covering material, latent heat is converted into sensible heat and transported outwards through the covering material. The portion of latent heat can increase to more than 50 % of the internal heat transfer and is therefore a significant heat flux, which must be considered in calculations of heat demand. The heat transfer coefficients (U-values), as they are given in literature, are only valid for dry conditions without condensation. In this work, a simplified methodological approach was chosen using heat transfer resistances to consider the latent heat flux and thus, to calculate U-values for greenhouse conditions including condensation.

Keywords
Greenhouse, heat demand, heat transfer coefficient, U-value, latent heat flux, energy balance, thermal screen, black out system

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Optimal climate conditions enable higher yield in greenhouses than in open field production. The production during winter months allows an extension of the cropping period. However, the construction of greenhouses requires high investment costs. Especially for heating and – eventually artificial lighting - high energy costs may arise. With increasing prices of energy, the energy costs as a portion of production costs is increasing. To check the economy of a crop or crop sequence, programs are needed, by which the energy demand of a greenhouse crop can be calculated with low effort. Numerous models are available to calculate the energy consumption. As a rule of thumb, the more complex a model is, the more input parameters are required. If for specific applications these parameters can only roughly be estimated or if default values are used, the accuracy of a more complex model may not be better than the accuracy of a simplified model. Therefore, for this task, a compromise must be found that allows a sufficient accuracy, and requires only a minimum number of parameters. Such a model approach is used in the Hortex Program [1].

The basic equation for the heat requirement Φ of a greenhouse is:

$$\Phi = U_{cs} \times A_s \times (\theta_i - \theta_e) - sol \times A_g \times \tau \times \eta \quad [W] \quad (Eq. 1)$$

The overall heat transfer coefficient U_{cs} contains various parameters of the heat transfer as cladding material, wind speed, cloud cover, heating system and evapotranspiration of the crop with the resulting latent heat flux. The second part of Equation 1 describes the solar energy gain of the greenhouse during day time. τ is the transmittance of the greenhouse roof for global radiation and h describes the portion of global solar radiation which is converted into sensible heat. The value of h can range from about 1.0 (dry greenhouse without plants) and close to 0.0 (for example, a greenhouse with tomato or cucumber crop). To calculate the heat demand with Equation 1 only a few parameters are required. These parameters need to be determined for the specific application (**Table 1** and **2**).

The heat demand coefficient U_{cs} consists of the heat transfer coefficient U and a coefficient for air exchange U_L:

$$U_{cs} = U + U_L \quad [W\ m^{-2}\ K^{-1}] \quad (Eq. 2)$$

The heat flux by air exchange through leakages can be calculated using the following equation:

$$\Phi_L = z \times V_g\ \rho_a\ (c_{pa}\ (\theta_i - \theta_e\ ) + r_0\ (x_i - x_e\ )) \quad [W] \quad (Eq. 3)$$

or using the enthalpy he of the air:

$$\Phi_L = z \times V_g \times \rho_a \times (he_i - he_e) \quad [W] \quad (Eq. 4)$$

The heat transfer coefficient for air exchange UL is then:

$$U_L = \Phi_L \times A_s^{-1} \times (\theta_i - \theta_e)^{-1} \quad [W\ m^{-2}\ K^{-1}] \quad (Eq. 5)$$

Table 1

List of abbreviations

Symbol ***Symbol***	**Beschreibung** ***Description***	**Dimension** ***Dimension***
A	Fläche *Area*	m^2
c	Wärmekapazität *Heat capacity*	J kg^{-1} K^{-1}
co	Kondensatmenge *Quantity of condensation*	g m^{-2} h^{-1}
h	Wärmeübergangskoeffizient *Heat transfer coefficient*	W m^{-2} K^{-1}
he	Enthalpie der Luft *Enthalpy of the air*	kJ kg^{-1}
R	Wärmewiderstand *Resistance of heat transfer*	m^2 K W^{-1}
r0	Verdampfungswärme *Enthalpy of evaporation of water*	J kg^{-1}
sol	Solarstrahlung *Solar radiation*	W m^{-2}
U	Wärmedurchgangskoeffizient *Heat transfer coefficient*	W m^{-2} K^{-1}
V	Volumen *Volume (of air)*	m^3
x	Wassergehalt der Luft *Water content of the air*	kg kg^{-1}
z	Luftwechselzahl *Air exchange rate*	h^{-1}
η	Faktor für die Umwandlung von Solarstrahlung in sensible Wärme *Portion of solar radiation converted to sensible heat*	-
θ	Temperatur *Temperature*	°C
ρ	Dichte *Density*	kg m^{-3}
τ	Durchlässigkeit *Transmittance*	-
Φ	Wärmestrom *Energy flux*	W

The determination of the air exchange rate due to leaks in a greenhouse is possible with a tracer gas. However, the effort is relatively high. When planning new greenhouses only a rough estimate is possible. Modern greenhouses are expected to be relatively air tight, so that errors in the estimation of the air exchange rate are normally negligible. The heat transfer through the covering material is of greater importance, and thus the heat transfer coefficient U. In literature U-values of covering materials are often measured in laboratories [2], and therefore these values are not valid for greenhouse applications.

An important difference to laboratory measurements is the latent heat flux by evapotranspiration of the crop and condensation on the cladding material. The latent heat flux Φ_{icd} takes place on the inside surface of the cladding material parallel to the heat transfer by convection Φ_{icv} and long wave thermal radiation Φ_{ir}:

$$\Phi_i = \Phi_{icv} + \Phi_{ir} + \Phi_{icd} \qquad [\mathrm{W}] \qquad \text{(Eq. 6)}$$

According to these heat fluxes, heat transfer coefficients can be determined:

$$h_i = h_{icv} + h_{ir} + h_{icd} \qquad [\mathrm{W\ m^{-2}\ K^{-1}}] \qquad \text{(Eq. 7)}$$

The convective heat transfer Φ_{icv} depends on the air flow conditions at the cladding material (laminar or turbulent), the heating system (air or pipe heating) and, for free convection, on the greenhouse height and the temperature difference between the air and the roof temperature. The heat transfer by long-wave thermal radiation Φ_{ir} depends on the heating system and the temperature difference of the radiation-exchanging-surfaces. The convective and radiative heat flux can be calculated quite accurately [3, 4]. The latent heat flux Φ_{icd} or the heat transfer coefficient h_{icd} are more difficult to estimate, because the transpiration of a crop is a function of the leaf area index (LAI) and the opening of the stomata, which can change. This causes problems when using heat consumption coefficients (U_{cs}) created by measurements of the heat consumption of greenhouses. Normally the portion of latent heat flux it is not specified for these measurements. Quite often information about the crop during the heat consumption measurement is missing. For these reasons, a transfer of measured U_{cs}-values to other greenhouses with other crops is difficult and may lead to larger errors.

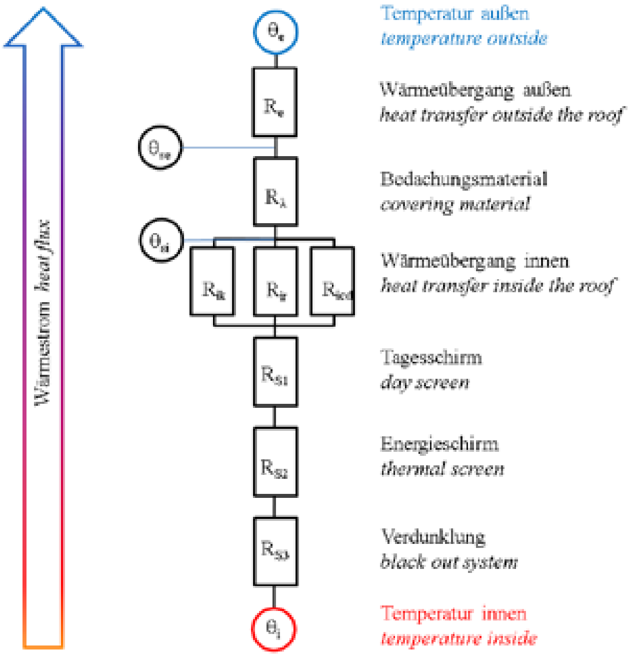
The objective of this work is the development of a methodology to simplify the estimation and consideration of the latent heat flux in heated greenhouses. Based on heat transfer coefficients from literature (laboratory test), U-values for different cladding materials and specific greenhouse conditions, including condensation, shall be determined.

Methods

A resistance model (**Figure 1**) is used as a methodological approach to calculate the heat transfer coefficient. Such an approach is already included in the standard DIN 4701 [5, 6]. Currently BS EN 12831 [8] is available for the calculation of the design heat requirement of greenhouses. Thus the heat transfer of complex cladding systems can be calculated (without latent heat flux). The resistances are obtained as reciprocals of the heat transfer coefficients. The final U-value results from the series connection of resistors as the reciprocal of the sum of the individual resistances:

$$U = (R_i + R_\lambda + R_e)^{-1} \qquad [\mathrm{W\ m^{-2}\ K^{-1}}] \qquad \text{(Eq. 8)}$$

Fig. 1



Model of heat resistors for heat transfer through the covering material from inside to outside

Based on U-values from laboratory measurements [2] the thermal resistance R_λ can be calculated for different materials:

$$R_\lambda = U^{-1} - R_i - R_e \qquad [m^2\ K\ W^{-1}] \qquad \text{(Eq. 9)}$$

Heat transfer coefficients inside and outside the cladding material of $h_i = 9$ and $h_e = 25$ W m^{-2} K^{-1} according to $R_i = 0.111$ and $R_e = 0.04$ m^2 K W^{-1} were used for these calculations. Thus the material-specific resistances R_λ are calculated (**Table 4**). The negative heat transfer resistance R_λ for PE film is due to the permeability of the film for long-wave thermal radiation.

In the next step, greenhouse-specific heat transfer coefficients (U-values) can be determined. The heat transfer coefficient outside he is a function of wind speed (forced convection) and of long wave radiation to the sky or to the clouds. For single glazing a dependency of the external heat transfer coefficient on the wind speed can be determined [3]. For double or multiple glazing under clear sky conditions, the long-wave radiation heat flux outside of the roof may be larger than the heat flux from inside to outside. Then the outside roof temperature drops below the outside air temperature and heat is transferred to the roof by convection. In such cases the specification of a heat transfer coefficient makes little sense, as the values may even be negative. These problems can usually be neglected, since with multiple glazing the outer thermal resistance R_e is very small compared with the thermal resistance R_i of the cladding material.

Table 2

List of indices

Indizes/*Indices*	**Beschreibung/*Description***
a	Luft/*Air*
cd	Kondensation/*Condensation*
cs	Verbrauch/*Consumption*
cv	Konvektion/*Convection*
e	Außen, extern/*External*
g	Gewächshaus/*Greenhouse*
i	Innen/*Inside*
L	Undichtigkeit/*Leakage*
p	Druck/*Pressure*
r	Strahlung/*Radiation*
s	Oberflache/*Surface*
S	Schirm/*Screen*
λ	Leitung/*Conduction*

The thermal resistance R_i inside the cladding material is important for this approach. Heat is transmitted by parallel heat fluxes (Equation 6). The transfer of heat by condensation (latent heat) is an additional heat flux. The heat transfer coefficients are added according to Equation 7.

Depending on the portion of latent heat, specific heat transfer coefficients hi can be estimated. For the calculations below, values of $h_i = 12$ and $h_i = 15$ W m^{-2} K^{-1} are used. These values are corresponding with a portion of latent heat on the inner heat transfer of 25 to 40 %. This range is valid for pot plants [8]. For vegetable crops with a larger leaf area (e.g. tomatoes and cucumbers) a higher proportion of latent heat (about 50–60 %) can be expected.

Results

Heat transfer coefficients (U-values)

In **Table 4**, the calculated U-values for various materials are shown. It is apparent that the differences in the U-values between dry ($h_i = 9$) and humid conditions ($h_i = 12$ and $h_i = 15$ W m^{-2} K^{-1}) are smaller with better thermal insulation. When using thermal screens, each screen creates an additional resistance R_S (**Table 3**), which is added to the total thermal resistance:

$$U = (R_i + R_\lambda + R_e + R_{S1} + R_{S2} + R_{S3})^{-1} \quad [W\ m^{-2}\ K^{-1}] \qquad \text{(Eq. 10)}$$

The values in **Table 4** are valid due to the assumptions of heat transfer coefficients inside and outside the roof. This approach can also be used to determine the U-values for other conditions (e.g. different heating systems).

Table 3

Heat resistance R_λ of screens [8]

Schirm/*Screen*	**R_λ ($m^2\ K\ W^{-1}$)**
Tagesschirm/*Day screen*	0.08
Energieschirm/*Thermal screen*	0.14
Verdunklung/*Black out system*	0.36

Surface temperatures on the inside of the roof

The inner surface temperature θ_{si} of the roof is important for the condensation behaviour and for the estimation of the amount of condensate:

$$\theta_{si} = (R_\lambda + R_e) \times U \times (\theta_i - \theta_e) + \theta_e \qquad [°C] \qquad \text{(Eq. 11)}$$

Assuming for the design case with θ_i = 20 °C and θ_e = -14 °C one gets:

$$\theta_{si} = (R_\lambda + 0.04) \times U \times 34.0 - 14.0 \qquad [°C] \qquad \text{(Eq. 12)}$$

and for higher outside air temperatures of e.g. θ_e = 5,0 °C:

$$\theta_{si} = (R_\lambda + R_e) \times U \times 15.0 + 5.0 \qquad [°C] \qquad \text{(Eq. 13)}$$

The calculated surface temperatures are given in **Table 5**. The inner roof surface temperatures are increasing with better thermal insulation that means with smaller U-values.

Quantity of condensation

The amount of condensate co can be calculated according to the proportion of latent heat with the following equation:

$$co = h_{icd} \times (\theta_i - \theta_{si}) / r_0 \times 3600 \qquad [g\ m^{-2}\ h^{-1}] \qquad \text{(Eq. 14)}$$

For thermal screens it has been assumed that the condensation occurs only at the surface of the roofing material and not at the thermal screen. Using inside heat transfer coefficients of h_i = 12.0 and h_i = 15.0 W m^{-2} K^{-1}, heat transfer coefficients for condensation results in h_{icd} = 3.0 and h_{icd} = 6.0 W m^{-2} K^{-1} respectively. The calculated rates of condensate are given in **Table 5** for the design conditions θ_i = 20 and θ_e = -14 °C and for 'normal' operating conditions θ_i = 20 and θ_e = 5 °C respectively. The quantity of condensate depends crucially on the inner surface temperature of the roof.

With increasing inner surface temperature of the roof, better thermal insulation, lower U-values or rising outside air temperature, the rate of condensate is reduced. This means that the greenhouse air is less dehumidified. The humidity is increased. At the same time, the crop will evaporate less water at higher humidity. The reduced transpiration may limit the uptake of nutrients (e.g. Calcium) and may lead to deficiency symptoms. A high humidity also increases the risk of fungal infections.

Conclusions

Using the described methodology, the heat transfer coefficient can be calculated quite accurately. A comparison with the literature [8] shows a good agreement between the calculated U-values and the results of heat consumption measurements. Thus, the objective of this work is achieved. The error of this approach is smaller for double or multiple glazing than for single glazing. This can be explained with the resistance model. The thermal resistance of single glazing is very small ($R_\lambda \approx 0.0\ m^2\ K\ W^{-1}$). The inner and outer heat transfer resistance determine the total resistance and thus the U-value. As these resistors are subject to various influences, there is a relatively large range of the U-value for single glazing. For double and triple glazing the thermal resistance R_λ is the largest resistance and significantly determines the U-value. Changes of the inner and outer heat transfer coefficients will have only little effect.

The temperature of the inner surface of the roof is crucial to condensation conditions. A better insulation, lower U-values and higher outside air temperatures are resulting in a higher inside–roof-surface temperature. The leaves are exchanging long wave radiation with a warmer roof surface. Therefore the leaves are transmitting less long-wave thermal radiation to the roof. The leaf temperature may be somewhat higher. The influence of the inner roof surface temperature on the amount of condensate is important. With double or triple glazing condensation occurs only at higher air humidity. Compared to single glazing the rate of condensation is significantly reduced. It is interesting how thermal screens are influencing air humidity. On the one hand thermal screens hinder the transport of water vapour to the roof. On the other hand, the inside-roof-surface-temperature decreases with closed screens, so the difference between the water content of the air in the crop area and the saturation water content at the surface of the roof is increased significantly. This approach does not consider a specific permeability of the screen material for water vapour. It is assumed that heat and water vapour are transmitted by the screen material in an analogous manner.

Any effort to save heating energy can be expected generally to go along with increased humidity. In the described approach is not considered that any additional energy for dehumidification is used. A negative impact of high humidity can be mitigated by several measures. The choice of the irrigation system is important. After the irrigation process there should not remain a moist surface that evaporates excess water. The distance of pot plants must be sufficient. Within a closed plant canopy humidity is increased [9] with an increasing risk of fungal infections. Larger temperature gradients are causing moisture gradients. In areas with lower temperatures the relative humidity is increased. This may cause condensation on the leaves or fruits. A more uniform distribution of temperature and humidity can be achieved in conjunction with fans by selection and proper arrangement of the heating system, so that higher humidity up to 90 % RH may have no negative impact.

Table 4

Heat transfer coefficients (U-values) for a dry greenhouse ($h_i = 9\ W\ m^{-2}\ K^{-1}$) [2] and two versions with condensation ($h_i = 12$ and $h_i = 15\ W\ m^{-2}\ K^{-1}$); ($h_e = 25\ W\ m^{-2}\ K^{-1}$)

Re = 0.04 $m^2\ K\ W^{-1}$		**$h_i = 9$ $W\ m^{-2}\ K^{-1}$**	**$h_i = 12$ $W\ m^{-2}\ K^{-1}$**	**$h_i = 15$ $W\ m^{-2}\ K^{-1}$**
R_i	**$m^2\ K\ W^{-1}$**	**0.11111**	**0.083333**	**0.0666667**
	U-Wert/*U-value*	**R_λ/R_λ**	**U-Wert/*U-value***	**U-Wert/*U-value***
Folien/*Film material*	**$W\ m^{-2}\ K^{-1}$**	**$m^2\ K\ W^{-1}$**	**$W\ m^{-2}\ K^{-1}$**	**$W\ m^{-2}\ K^{-1}$**
PE-Folie UV-stabilisiert, einfach *PE, UV-stabilized, single*	7.0	-0.01	8.7	10.1
PE-Folie UV-stabilisiert, doppelt *PE, UV-stabilized, double*	3.4	0.14	3.8	4.0
EVA-Folie, koextrudiert, einfach *EVA, coextruded, single*	6.2	0.01	7.5	8.5
PVC-Folie, einfach *PVC, single*	6.1	0.01	7.3	8.4
PE-Luftpolsterfolie *PE „Bubble Wrap“*	5.4	0.03	6.3	7.1
ETFE-Folie, “no drop”, einfach *ETFE-film, no drop, single*	6	0.02	7.2	8.2
ETFE-Folie, “no drop”, doppelt *ETFE-film, no drop, double*	3	0.18	3.3	3.5
Starre Materialien/*Rigid material*	**U-Wert/*U-value***	**R_λ/R_λ**	**U-Wert/*U-value***	**U-Wert/*U-value***
Floatglas, einfach *Float glass, single layer*	6	0.02	7.2	8.2
Floatglas, Isolierglas *Float glass, double layer*	3	0.18	3.3	3.5
PMMA-Stegdoppelplatte, 16 mm, Alltop *PMMA „Alltop“ 16 mm*	2.5	0.25	2.7	2.8
PMMA-Stegvierfachplatte, 32 mm *PMMA 32 mm, fourfold*	1.6	0.47	1.7	1.7
PVC- oder glasfaserverstärkte Platten *PVC or fibre glass corrugated*	6.8	0.00	8.4	9.7
Polycarbonat-Stegdoppelplatten 6 mm *PC 6 mm double*	3.6	0.13	4.0	4.3
Polycarbonat-Stegdoppelplatten 10 mm *PC 10 mm double*	3.2	0.16	3.5	3.7
Polycarbonatplatten, 16 mm, X-Struktur *PC 16 mm, x-structure*	1.8	0.40	1.9	2.0
Polycarbonat-Fünffachplatten 32 mm *PC 32 mm fivefold*	1.4	0.56	1.5	1.5
Materialkombinationen/*Combinations*	**U-Wert/*U-value***	**R_λ/R_λ**	**U-Wert/*U-value***	**U-Wert/*U-value***
GFC (eisenarmes Glas + ETFE-Folie) *GFC (low iron AR glass + ETFE-film)*	3.1	0.17	3.4	3.6
FGFC (ETFE-Folie + Glass + ETFE) *FGFC (ETFE-film + glass + ETFE-film)*	1.8	0.40	1.9	2.0
Einfachglas + Tagesschirm *Single glass + day screen*	3.98	0.08	4.48	4.84
Einfachglas + Tages- + Energieschirm *Single glass + day + thermal screen*	2.56	0.22	2.75	2.88
Einfachglas + 2 Schirme + Verdunklung *Single glass + 2 screens + black out*	1.33	0.58	1.38	1.42
Isolierglas + Tagesschirm *Double glass + day screen*	2.43	0.08	2.61	2.73
Isolierglas + Tages- + Energieschirm *Double glass + day + thermal screen*	1.81	0.22	1.91	1.97
Isolierglas + 2 Schirme + Verdunklung *Double glass + 2 screens + black out*	1.10	0.58	1.13	1.15

Table 5

Temperature inside the cover and amount of condensation at heat transfer coefficients inside of $h_i = 9$, $h_i = 12$, $h_i = 15$ W m^{-2} K^{-1}; $h_e = 25$ W m^{-2} K^{-1}; $\theta_i = 20$ °C

	Dachinnenflächentemperatur ***Temperature inside the cover***			**Kondensatmenge** ***Amount of condensation***			
h_e = 25 W/(m^2 K)	**$h_i = 9$**	**$h_i = 12$**	**$h_i = 15$**	**$h_i = 12$**	**$h_i = 15$**	**$h_i = 12$**	**$h_i = 15$**
R_e = 0.04 m^2 K W^{-1}				**θ_e = -14 °C**		**θ_e = 5 °C**	
	θ_{si}	θ_{si}	θ_{si}	**co_i**	**co_i**	**co_i**	**co_i**
Folien/*Film material*	**°C**	**°C**	**°C**	**g m^{-2} h^{-1}**	**g m^{-2} h^{-1}**	**g m^{-2} h^{-1}**	**g m^{-2} h^{-1}**
PE-Folie UV-stabilisiert, einfach *PE, UV-stabilized, single*	-6.4	-4.6	-3.0	118	220	52	97
PE-Folie UV-stabilisiert, doppelt *PE, UV-stabilized, double*	7.2	9.4	10.9	51	87	22	38
EVA-Folie, koextrudiert, einfach *EVA, coextruded, single*	-3.4	-1.2	0.6	101	185	45	82
PVC-Folie, einfach *PVC, single*	-3.0	-0.8	1.0	99	181	44	80
PE-Luftpolsterfolie *PE „Bubble Wrap“*	-0.4	2.0	3.9	86	154	38	68
ETFE-Folie, “no drop”, einfach *ETFE-film, no drop, single*	-2.6	-0.4	1.5	98	177	43	78
ETFE-Folie, “no drop”, doppelt *ETFE-film, no drop, double*	8.7	10.7	12.2	44	75	20	33
Starre Materialien/*Rigid material*	**°C**	**°C**	**°C**	**g m^{-2} h^{-1}**	**g m^{-2} h^{-1}**	**g m^{-2} h^{-1}**	**g m^{-2} h^{-1}**
Floatglas, einfach *Float glass, single layer*	-2.6	-0.4	1.5	98	177	43	78
Floatglas, Isolierglas *Float glass, double layer*	8.7	10.7	12.2	44	75	20	33
PMMA-Stegdoppelplatte, 16 mm, Alltop *PMMA „Alltop“ 16 mm, double*	10.6	12.4	13.6	36	61	16	27
PMMA-Stegvierfachplatte, 32 mm *PMMA 32 mm, fourfold*	14.0	15.3	16.1	23	37	10	16
PVC- oder glasfaserverstärkte Platten *PVC or fibre glass corrugated*	-5.7	-3.7	-2.1	114	211	50	93
Polycarbonat-Stegdoppelplatten 6 mm *PC 6 mm double*	6.4	8.7	10.3	54	93	24	41
Polycarbonat-Stegdoppelplatten 10 mm *PC 10 mm double*	7.9	10.1	11.5	48	81	21	36
Polycarbonatplatten, 16 mm, X-Struktur *PC 16 mm, x-structure*	13.2	14.6	15.6	26	42	11	19
Polycarbonat-Fünffachplatten 32 mm *PC 32 mm fivefold*	14.7	15.9	16.6	20	32	9	14
Materialkombinationen/*combinations*	**°C**	**°C**	**°C**	**g m^{-2} h^{-1}**	**g m^{-2} h^{-1}**	**g m^{-2} h^{-1}**	**g m^{-2} h^{-1}**
GFC (eisenarmes Glas + ETFE-Folie) *GFC (low iron AR glass + ETFE-film)*	8.3	10.4	11.9	46	78	20	34
FGFC (ETFE-Folie + Glass + ETFE) *FGFC (ETFE-film + glass + ETFE)*	13.2	14.6	15.6	26	42	11	19
Einfachglas + Tagesschirm *Single glass + day screen*	-5.9	-4.9	-4.1	61	105	27	46
Einfachglas + Tages- + Energieschirm *Single glass + day + thermal screen*	-8.8	-8.4	-8.1	37	63	16	28
Einfachglas + 2 Schirme + Verdunklung *Single glass + 2 screens + black out*	-11.3	-11.2	-11.1	19	31	8	14
Isolierglas + Tagesschirm *Double glass + day screen*	4.2	5.5	6.4	35	59	16	26
Isolierglas + Tages- + Energieschirm *Double glass + day + thermal screen*	-0.4	0.3	0.8	26	43	11	19
Isolierglas + 2 Schirme + Verdunklung *Double glass + 2 screens + black out*	-5.8	-5.5	-5.4	15	25	7	11

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