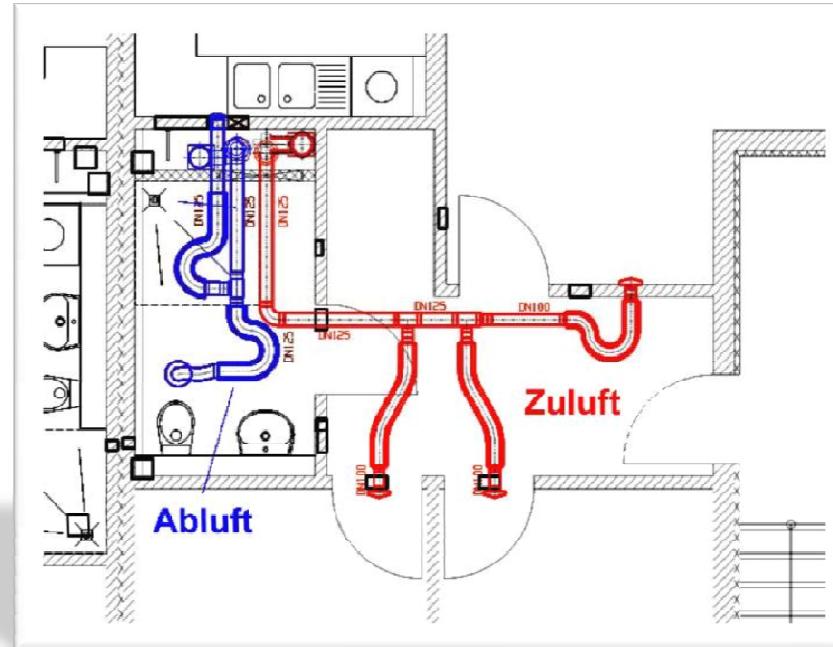
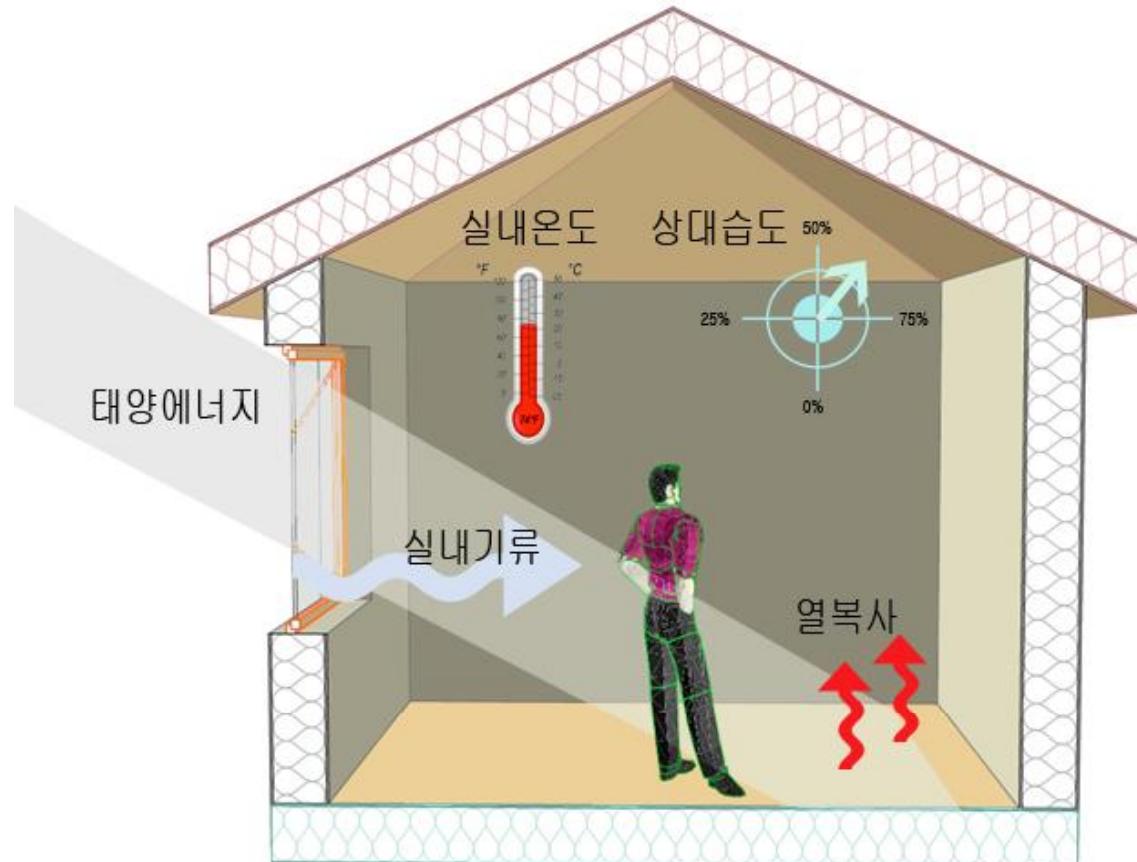


# 패시브하우스의 환기설계



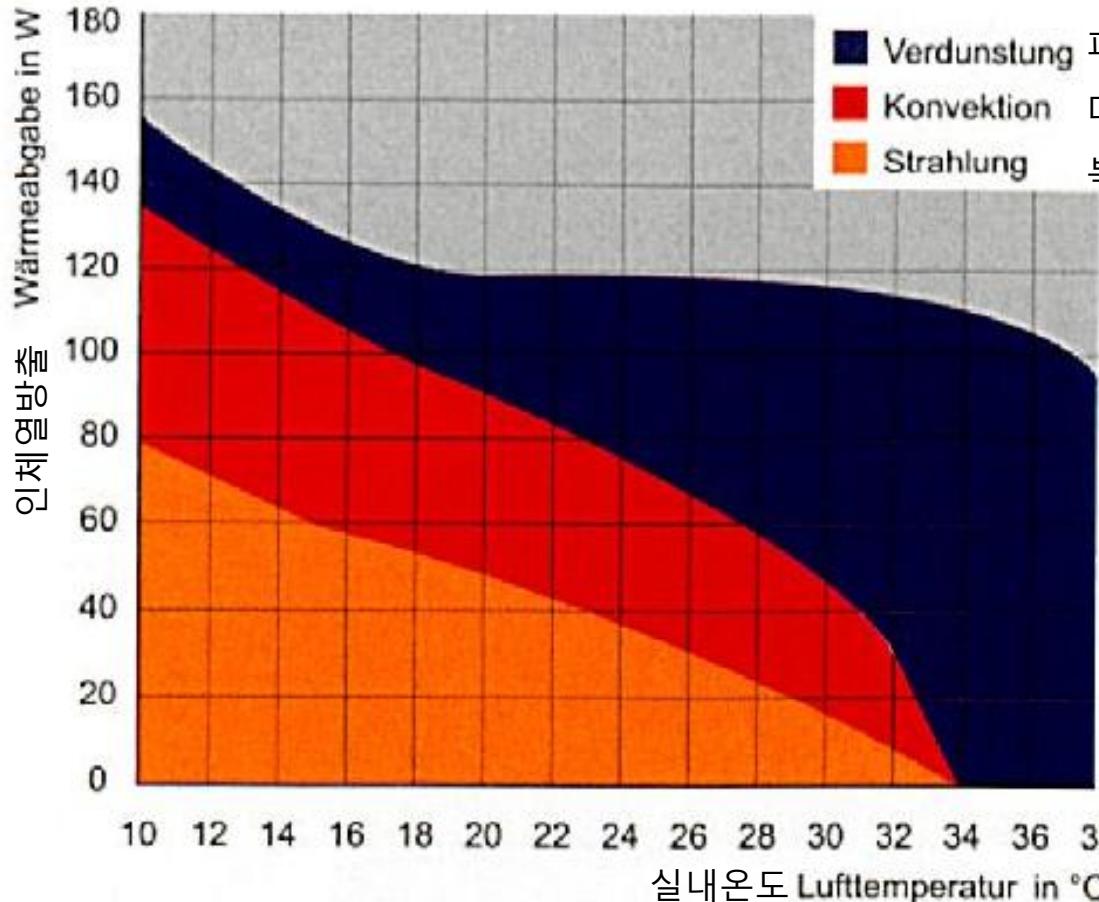


열적 쾌적성에 따른 영향요소들

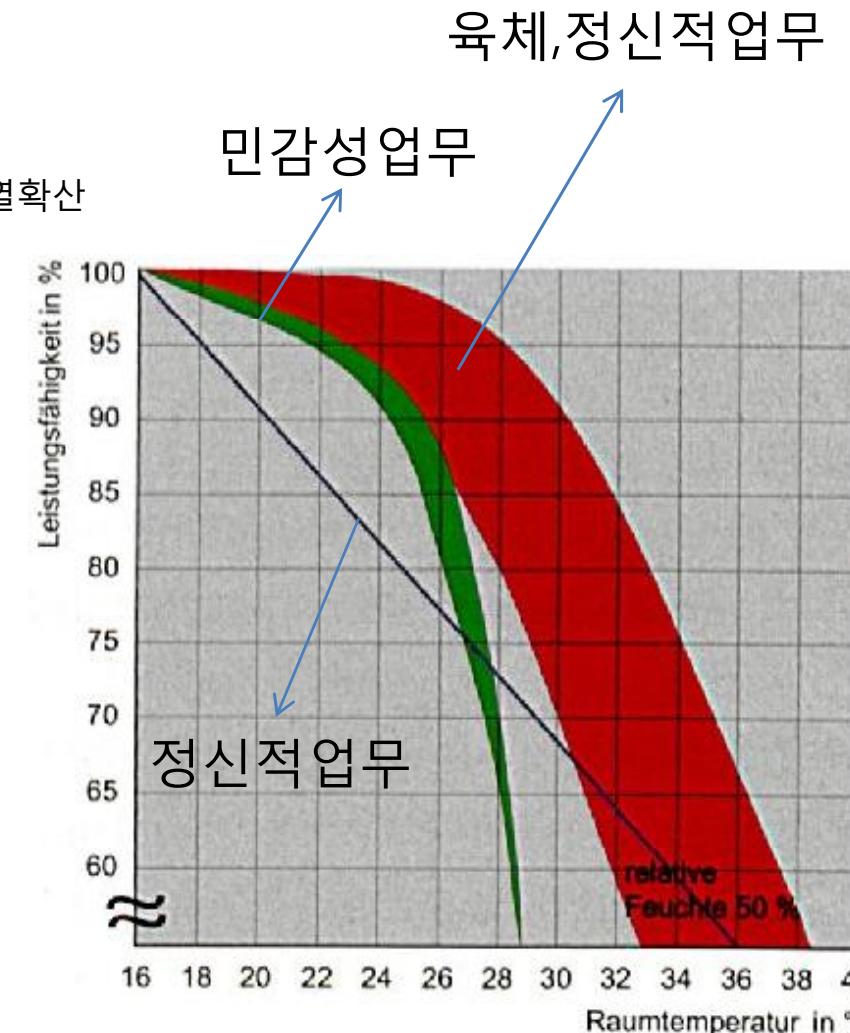
거주쾌적성요소: 물리적 요소와 정신적요소  
의 만족감

- 실내온도
- 실내구조체표면온도
- 상대습도
- 기류
- 활동량
- 착의량
- 개인적 차이 - 공기질, 소음, 거주시간, 거주 인수 등

인체의 열이동 - 복사, 대류, 피부열확산



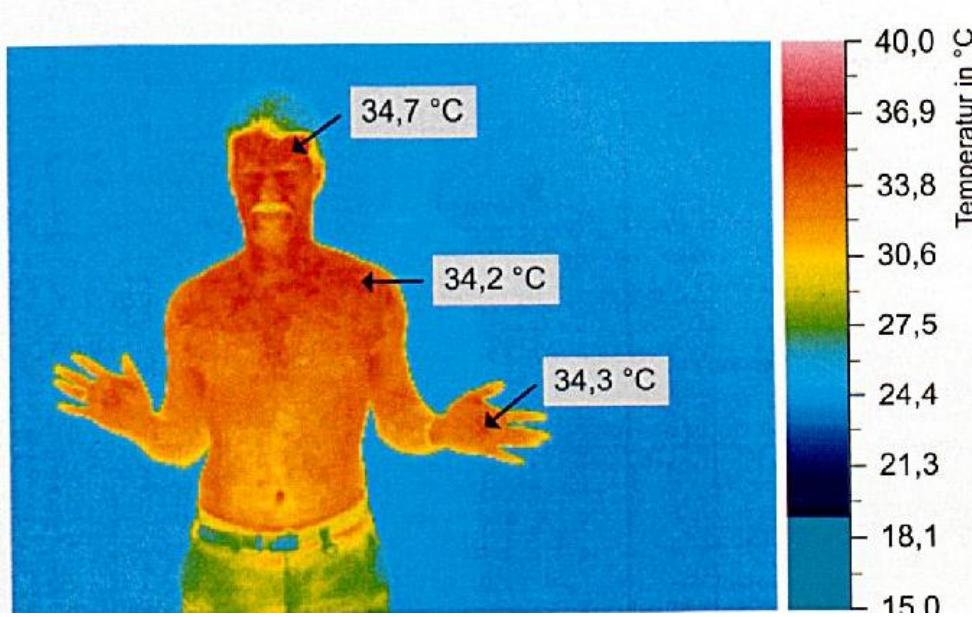
거실에서 온도에 따른 인체의 열방출 방식  
(출처: Arbeitskreis der Dozenten, 1989)



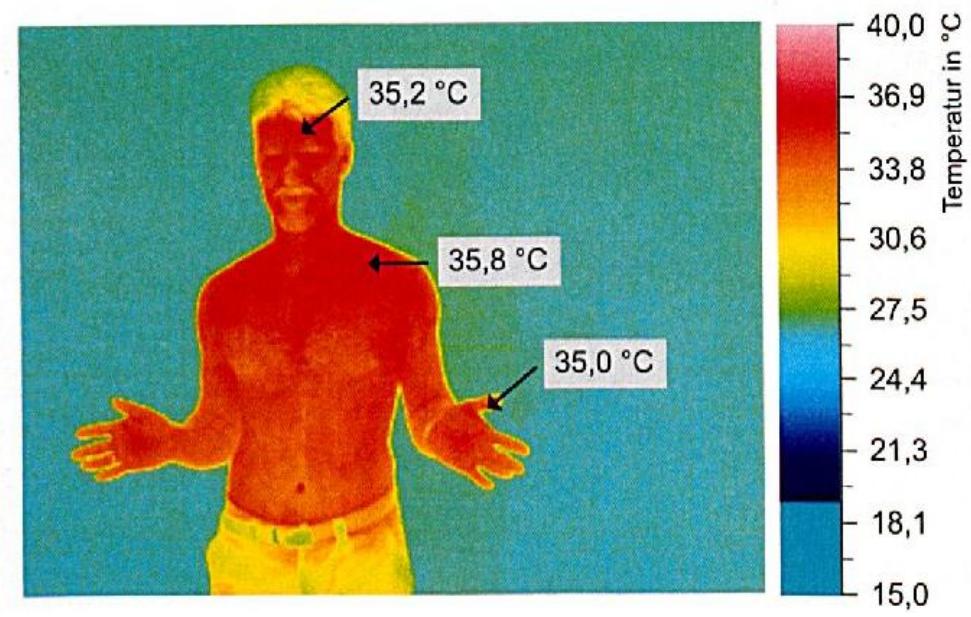
상대습도 50%일 때 실내온도에 따른  
업무효율성(출처: Arbeitskreis der Dozenten, 1989)

01 쾌적성

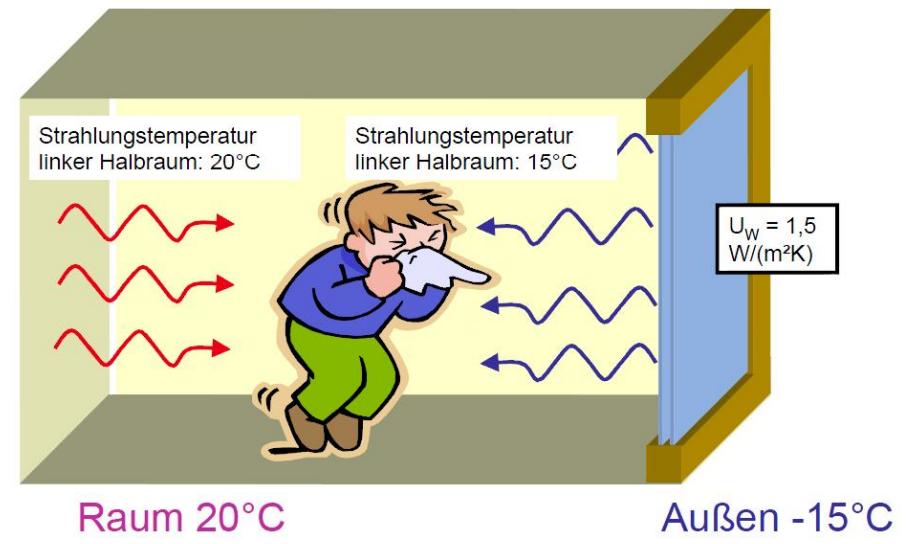
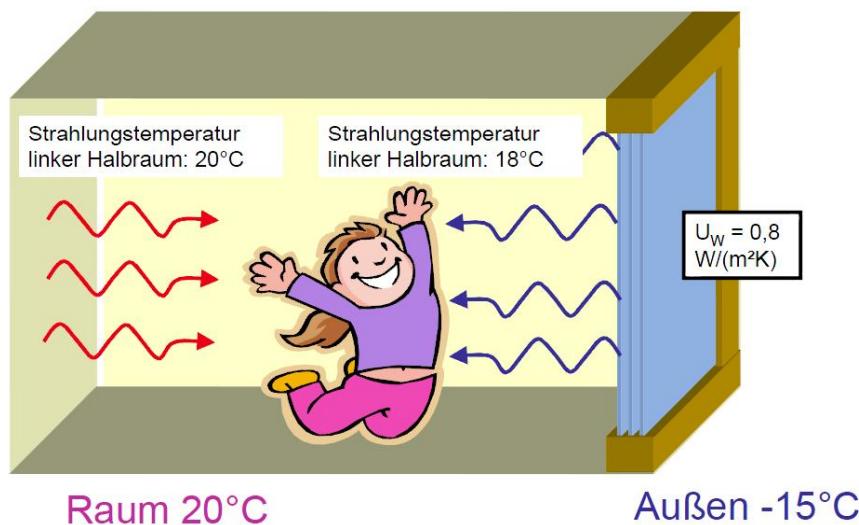
## 패시브하우스의 환기설계

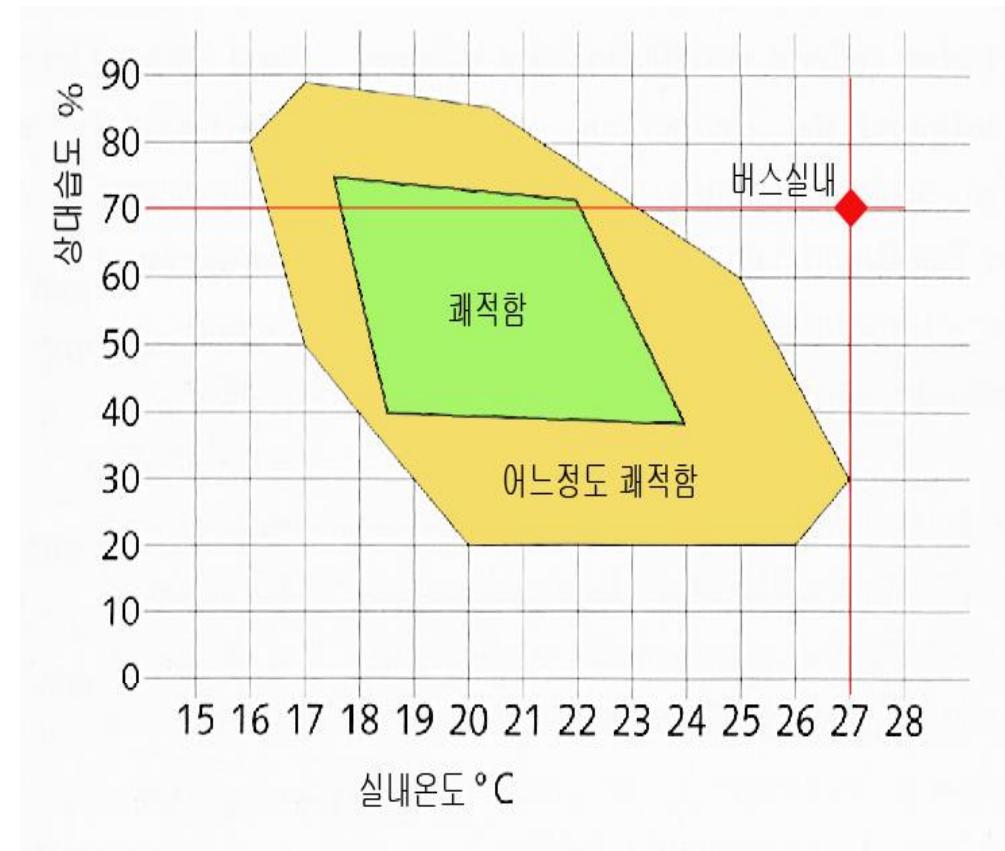


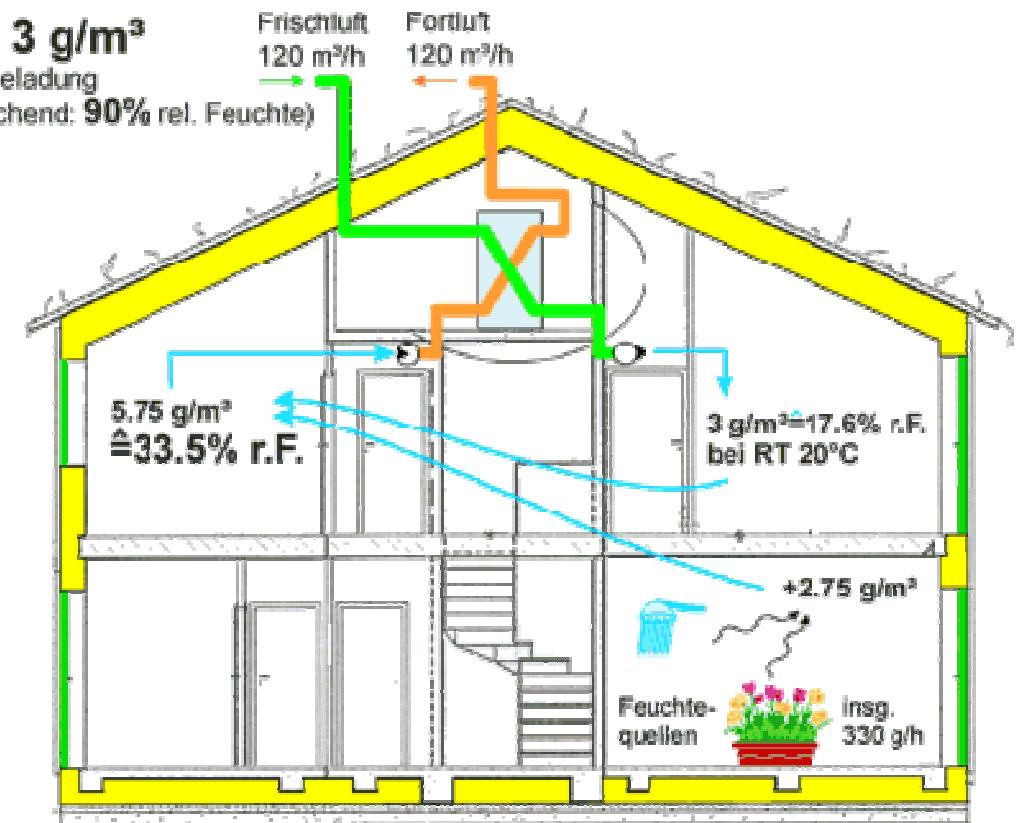
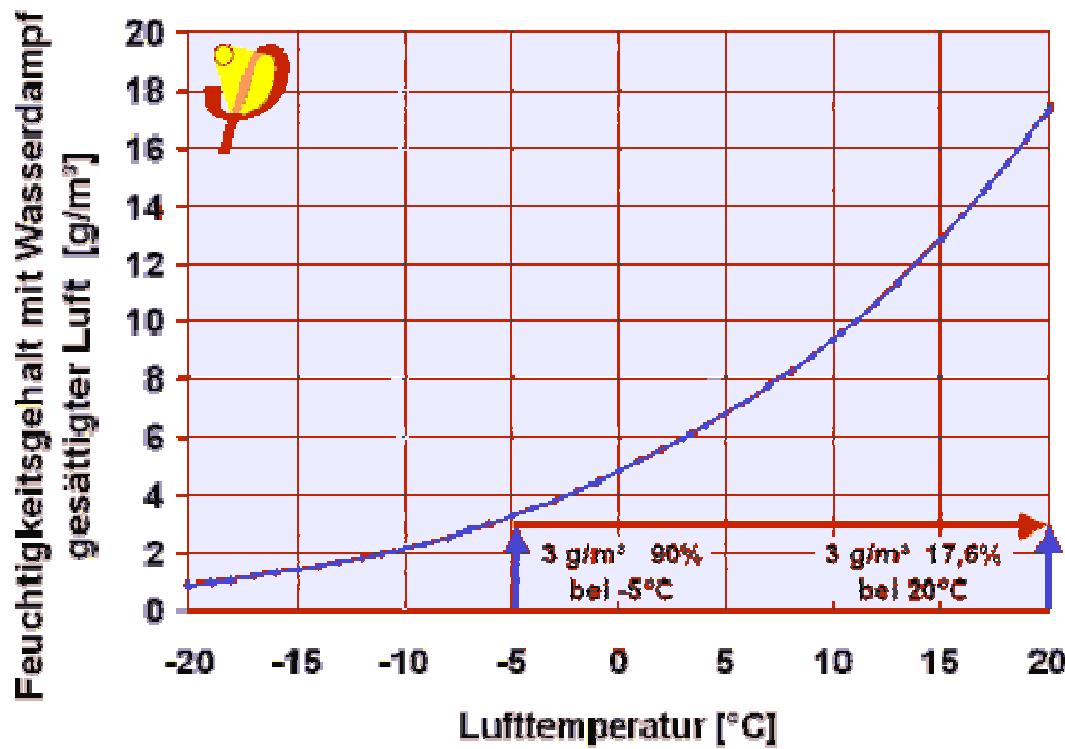
#### 운동하기전에 인체의 발열/실내온도26



## 운동후 인체의 발열/실내온도26

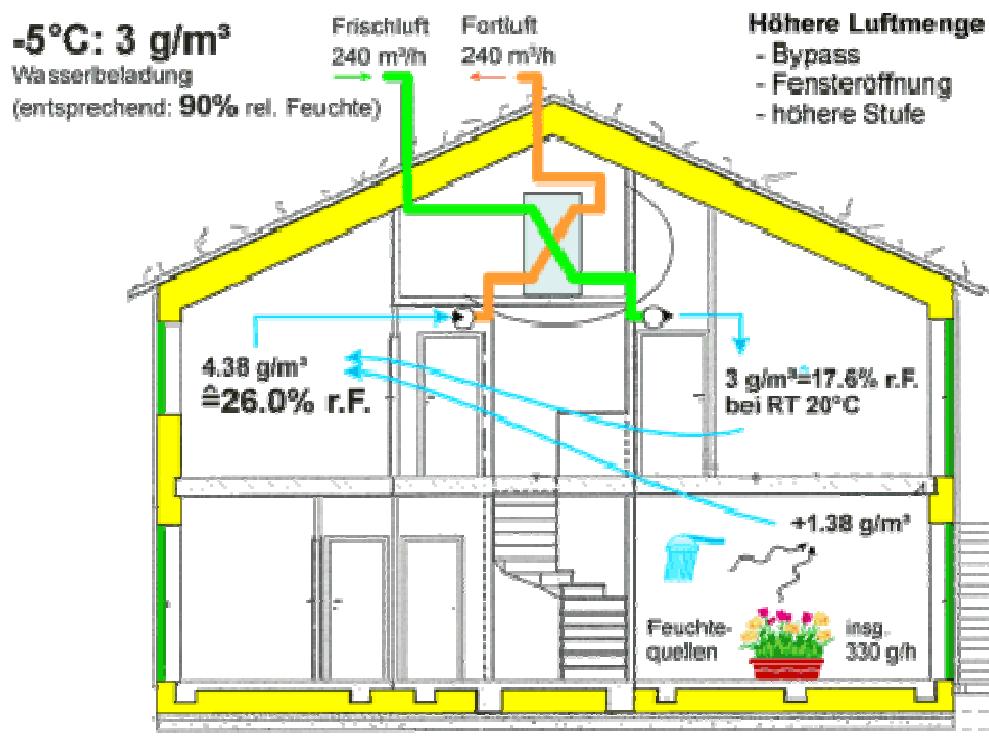






# 01 쾌적성

## 패시브하우스의 환기설계



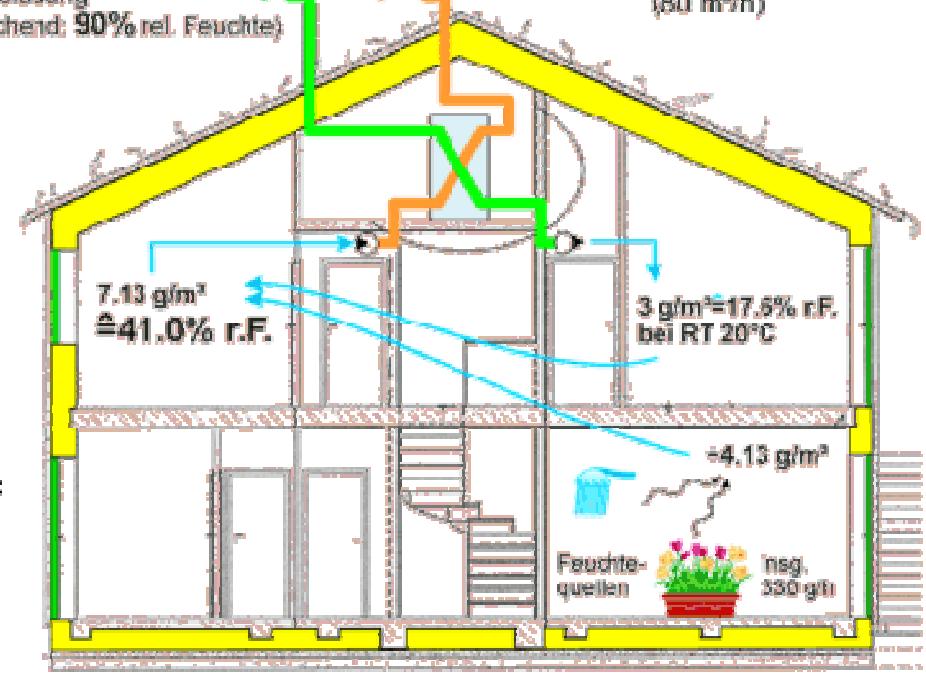
**-5°C: 3 g/m<sup>3</sup>**

Wasserbeladung  
(entsprechend: 90% rel. Feuchte)

Frischluft  
80 m<sup>3</sup>/h

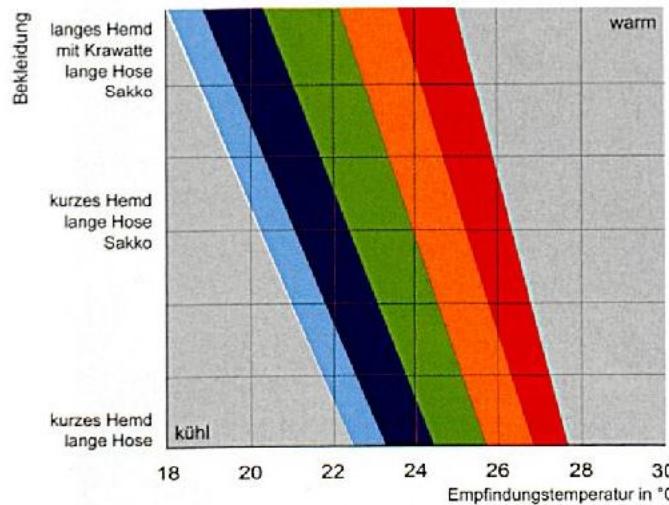
Fortluft  
80 m<sup>3</sup>/h

**niedrigere Luftmenge durch:**  
 - kleinere Stufe  
 (80 m<sup>3</sup>/h)

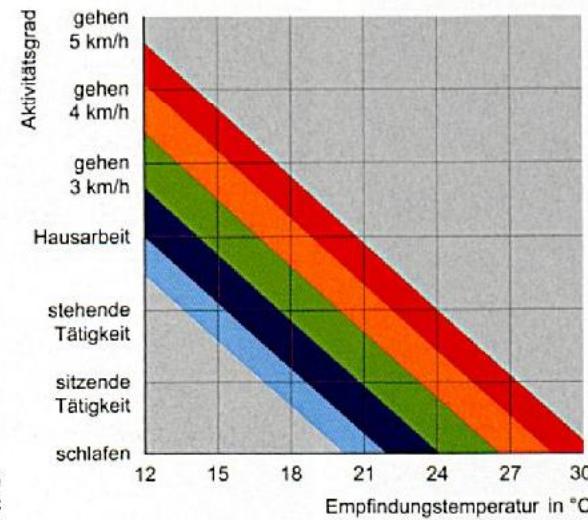


0.5 or 0.8 h<sup>-1</sup>  
 =?

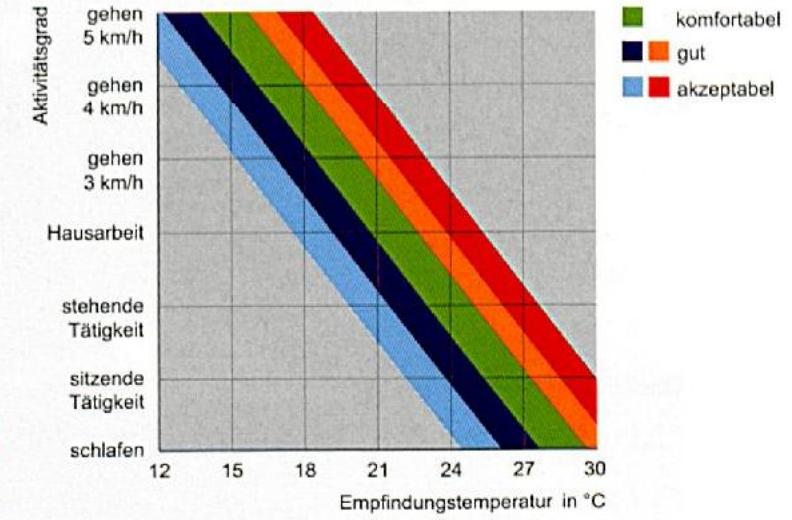
0.25h<sup>-1</sup> / 30%



여름철 착의량에 따른 영향



1Clo 시 활동량에 따른 쾌적성



0.6Clo 시 활동량에 따른 쾌적성  
(여름)

환기는 패시브하우스의 심장이다.

DIN 1946 Chapter6에 따른 환기량, 환기방식

목적:

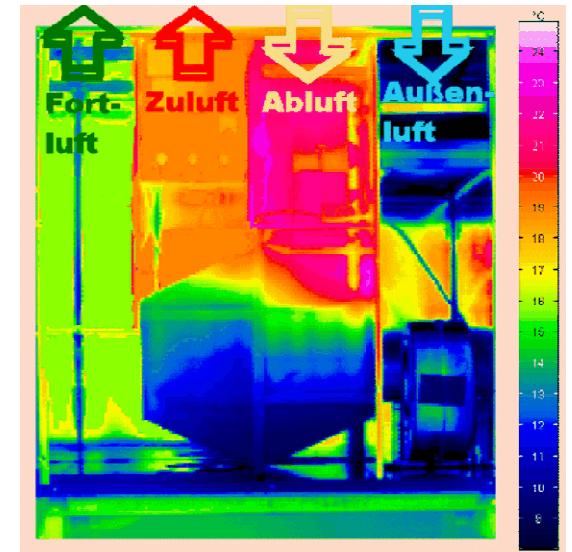
- 건강
- 오염물질 제거
- 쾌적성



• 패시브하우스



배기열회수환기유닛

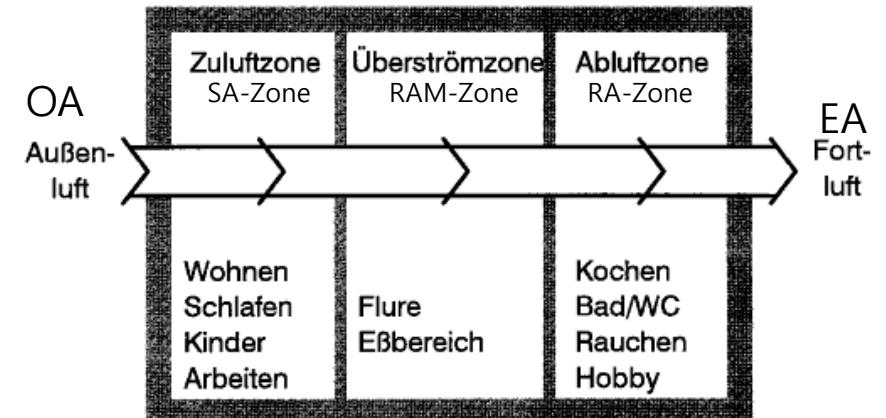


건물의 기밀성 확보: ( $n_{50} \leq 0.6/h$ )

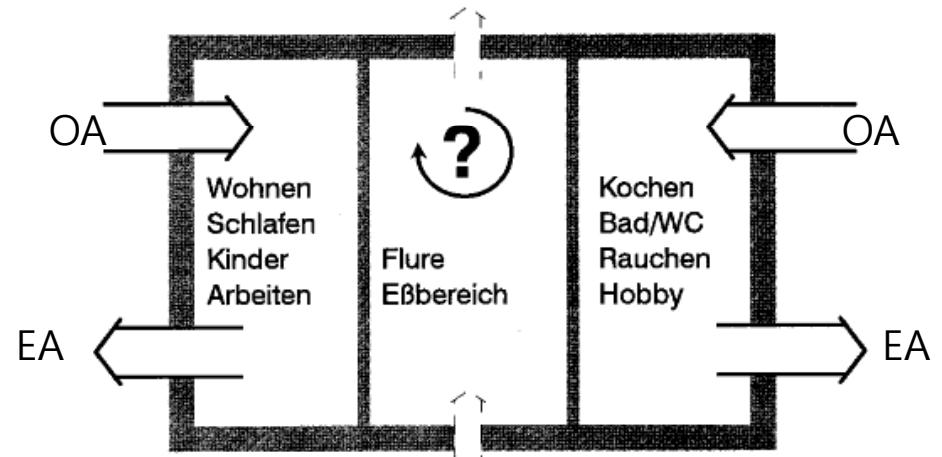
환기유닛 소비전력:  $Q \leq 0.4W/m^3$  환기량

거주공간내 순환형 환기

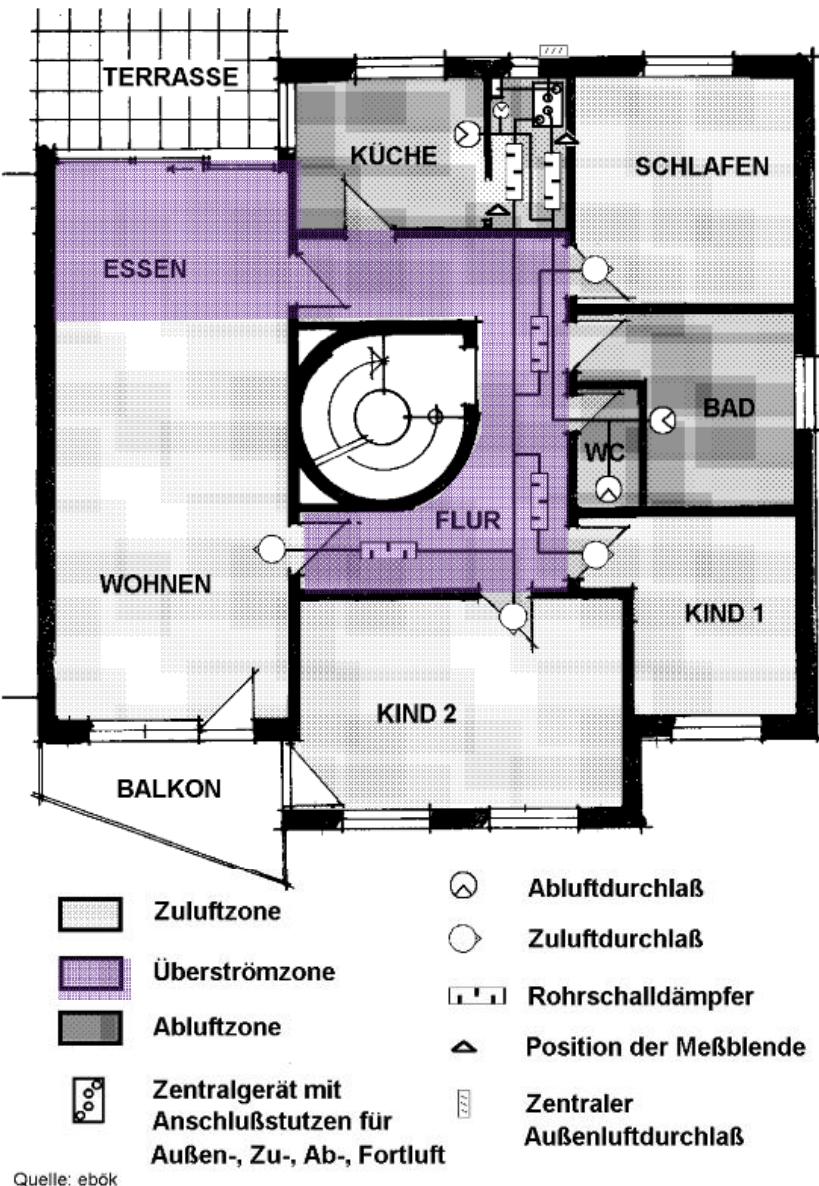
### Querlüftung 순환형 환기



### Einzelraumlüftung 개별형 환기



출처: Borsch-Laaks/IWU



### SA zone

침실이나 거실공간으로 신선한 외기도입이 필요한 존. 거주인원이 없는 경우에도 RAM존에서의 공기질확보를 위해 최소환기량 필요

### RAM zone

복도 또는 식탁공간등으로 SA존에서 RA존으로 이동하는 중간지점으로 자체 환기 가능요소는 없음

### RA zone

높은 잠열부하발생지, 오염발생지로서 부엌, 화장실, 흡연실, 취미실로 공기를 밖으로 배출해야하는 존

Abb. 2: Zonierung und Installationsschema einer Etagenwohnung mit Zu-/Abluftanlage mit Wärmerückgewinnung

## 필요외기 도입량 (E DIN 1946-6기준)

- 결로 방지를 위한 환기량 (최소환기량)

건물의 열손실과 사용자 환경에 따른 환기량이 다름 (곰팡이 및 결로방지최소기준)

- 최소환기량

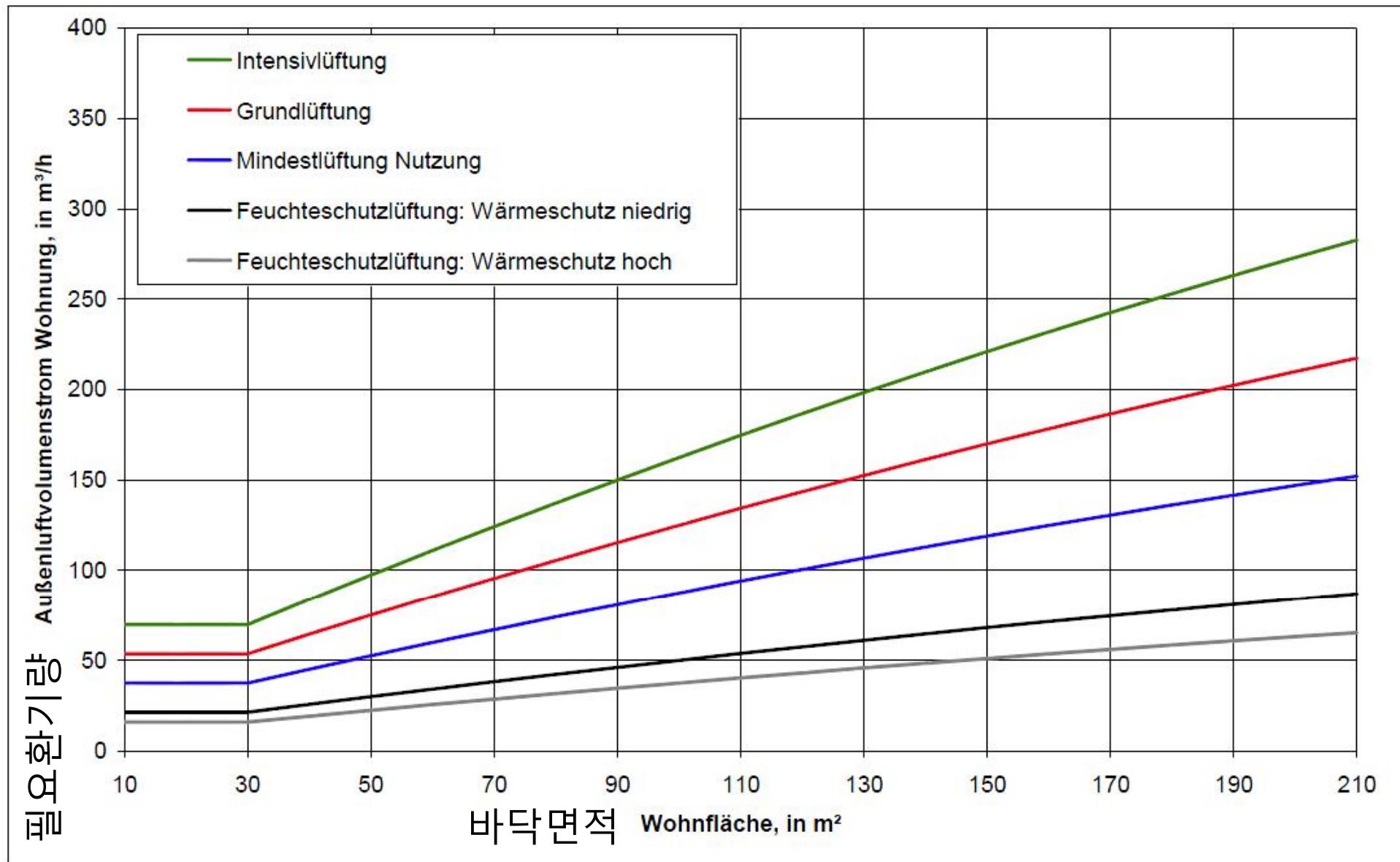
실내공기질 확보를 위한 최소 환기량기준

- 표준환기량

구조체 성능유지와 이용자의 건강한 주거환경을 만족시켜주는 환기량

- 최대환기량

시간에따라 최대부하 발생시 운전되어지는 환기량기준



## 최소환기량 ( DIN 1946기준 )

| 항목      | 1인당 ( $m^3/h$ ) | 면적당 ( $m^3/m^2h$ ) |
|---------|-----------------|--------------------|
| 주거공간    | 30              |                    |
| 개인사무실   | 40              | 4                  |
| 공용사무실   | 60              | 6                  |
| 회의실     | 20              | 10-20              |
| 독서실     | 2               | 12                 |
| 교실/세미나실 | 30              | 15                 |
| 판매시설    | 20              | 3-12               |
| 숙박시설    | 30              | 8                  |

## 최소환기량 (DIN 1946 기준) - 창없는 방

| 항목  | LWR | Min. $m^3/h$ |
|-----|-----|--------------|
| 거실  | 0.8 | 60           |
| 식당  | 1.0 | 60           |
| 침실  | 1.0 | 60           |
| 아이방 | 1.0 | 30           |
| 작업실 | 0.8 | 30           |
| 취미실 | 0.8 | 30           |

# Passive House Planning

## VENTILATION DATA

Building: **Rural Greenhome Standard**

Treated Floor Area  $A_{TFA}$

|       |            |
|-------|------------|
| $m^2$ | <b>117</b> |
| $m$   | <b>2.5</b> |
| $m^2$ | <b>291</b> |

(Areas worksheet)

(Annual Heat Demand worksheet)

(Annual Heat Demand worksheet)

Room Height  $h$

Room Ventilation Volume ( $A_{TFA} \cdot h$ )  $V_V$

체적에 따른 환기량계산:  
 $291 \times 0.3 \times 1.3 = 113.5m^3$

### Ventilation System Design - Standard Operation

Occupancy

|                   |            |        |          |           |
|-------------------|------------|--------|----------|-----------|
| $m^2/P$           | <b>29</b>  |        |          |           |
| $P$               | <b>4.0</b> |        |          |           |
| $m^2/(P \cdot h)$ | <b>30</b>  |        |          |           |
| $m^2/h$           | <b>120</b> |        |          |           |
| Kitchen           | Bathroom   | Shower | WC       | <b>참고</b> |
| <b>1</b>          | <b>1</b>   |        | <b>1</b> | <b>1</b>  |
| $m^3/h$           | 60         | 40     | 20       | 20        |
| $m^3/h$           | <b>140</b> |        |          |           |

Number of Occupants

Supply Air per Person

Supply Air Requirement

Extract Air Rooms

Quantity

Extract Air Requirement per Room

Total Extract Air Requirement

Design Air Flow Rate (Maximum)

|         |            |
|---------|------------|
| $m^3/h$ | <b>140</b> |
|---------|------------|

### Average Air Change Rate Calculation

Daily Operation Duration

Factors Referenced to Maximum

Air Flow Rate

Air Change Rate

Type of Operation

h/d

Maximum

|      |
|------|
| 1.00 |
| 0.77 |
| 0.54 |
| 0.40 |

Standard

|      |
|------|
| 0.77 |
| 0.54 |
| 0.40 |

Basic

|      |
|------|
| 0.54 |
| 0.40 |

Minimum

|      |
|------|
| 0.40 |
| 0.37 |
| 0.26 |

x Residential Building

Average value

0.77

|         |            |
|---------|------------|
| $m^3/h$ | <b>140</b> |
| $m^3/h$ | 108        |
| $m^3/h$ | 75         |
| $m^3/h$ | 56         |

Average Air Flow Rate ( $m^3/h$ )

108

|     |             |
|-----|-------------|
| 1/h | <b>0.48</b> |
| 1/h | 0.37        |
| 1/h | 0.26        |
| 1/h | 0.19        |

Average Air Change Rate (1/h)

0.37

## Infiltration Air Change Rate according to EN 13790

| Wind Protection Coefficients According to EN 13790 |                       |                  |
|--|-----------------------|------------------|
| Coefficient e for Screening Class                  | Several Sides Exposed | One Side Exposed |
| No Screening                                       | 0.10                  | 0.03             |
| Moderate Screening                                 | 0.07                  | 0.02             |
| High Screening                                     | 0.04                  | 0.01             |
| Coefficient f                                      | 15                    | 20               |

Wind Protection Coefficient, e

for Annual Demand: for Heat Load:

|      |      |
|------|------|
| 0.10 | 0.25 |
| 15   | 15   |

Wind Protection Coefficient, f

Net Air Volume for  
Press. Test  $V_{n50}$ Air Change Rate at Press. Test  $n_{50}$ 

1/h 0.60 0.60 251 m³

Air Permeability  $q_{50}$   
0.37 m³/(hm²)

## Type of Ventilation System

 Balanced PH Ventilation Please Check

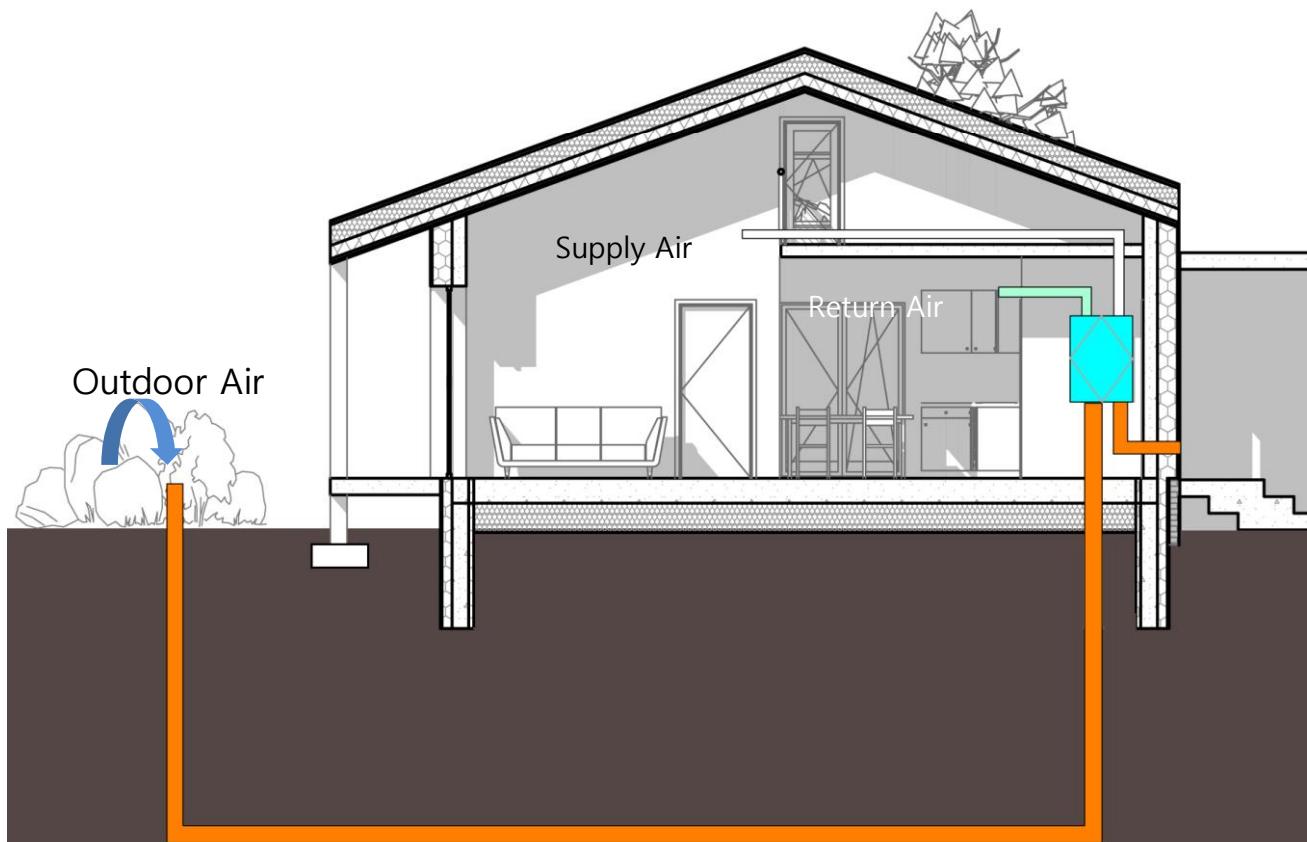
for Annual Demand: for Heat Load:

|                 |
|-----------------|
| 1/h 0.00 0.00   |
| 1/h 0.052 0.129 |

 Pure Extract Air

Excess Extract Air

Infiltration Air Change Rate  $n_{V,Res}$



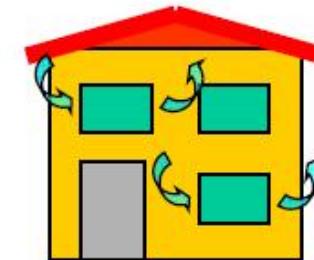
### Secondary Calculation: $\Psi$ -value Supply or Ambient Air Duct

|   |  |                      |
|---|--|----------------------|
| Nominal Width                           | <input type="text" value="150"/>                             | mm                   |
| Insul. Thickness:                       | <input type="text" value="30"/>                              | mm                   |
| Reflective? Please mark with an "x"!    |  |                      |
| <input checked="" type="checkbox"/> Yes |  |                      |
| <input type="checkbox"/> No             |  |                      |
| Thermal Conductivity                    | <input type="text" value="0.035"/>                           | W/(m <sup>2</sup> K) |
| Nominal Air Flow Rate                   | <input type="text" value="108 m&lt;sup&gt;3&lt;/sup&gt;/h"/> |                      |
| $\Delta\vartheta$                       | 15 K   |                      |
| Interior Duct Diameter                  | 0.150 m  |                      |
| Interior Diameter                       | 0.150 m  |                      |
| Exterior Diameter                       | 0.210 m  |                      |
| $\alpha$ -Interior                      | 8.58 W/(m <sup>2</sup> K)                                    |                      |
| $\alpha$ -Surface                       | 3.22 W/(m <sup>2</sup> K)                                    |                      |
| <b><math>\Psi</math>-value</b>          | <b>0.445 W/(mK)</b>  |                      |
| Surface Temperature Difference          | 4.861 K  |                      |

Besserung der  
Beschwerden nach  
1 Jahr Bezug



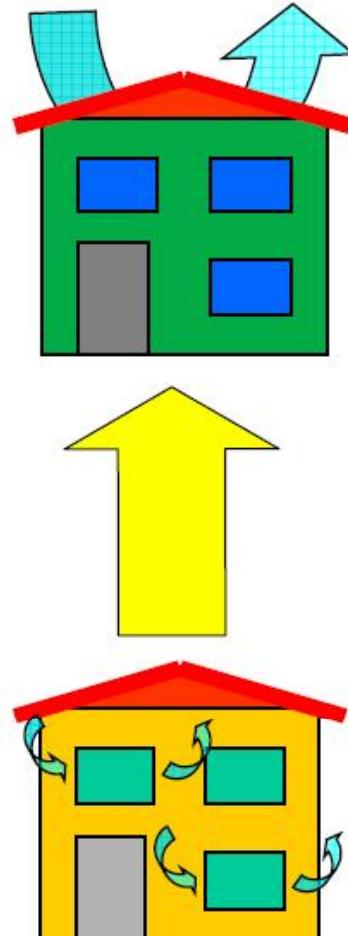
Kontroll. WR-Lüftung



Natürliche Lüftung

|               |      |      |
|---------------|------|------|
| Kopfschmerzen | 27 % | 18 % |
| Unruhe        | 39 % | 22 % |
| Müdigkeit     | 37 % | 23 % |
| Husten        | 36 % | 20 % |
| Halskratzen   | 31 % | 17 % |

출처: 오스트리아 실내공간분석연구소, nach Leech et al. 204



Verbesserung von SBS-Beschwerden wesentlich stärker in mechanisch belüfteten Gebäuden

Keine Verbesserung sonstiger Beschwerden

출처: 오스트리아 실내공간분석연구소, nach Leech et al. 204

## Effective Heat Recovery Efficiency of the Ventilation System with Heat Recovery

Central unit within the thermal envelope.

Central unit outside of the thermal envelope.

Efficiency of Heat Recovery  $\eta_{HR}$

0.74

Transmittance Ambient Air Duct  $\Psi$

W/(mK)

0.445

Length Ambient Air Duct

m

1

Transmittance Exhaust Air Duct  $\Psi$

W/(mK)

0.445

Length Exhaust Air Duct

m

1

Temperature of Mechanical Services Room °C

°C

(Enter only if the central unit is outside of the thermal envelope.)

SSK Recouporator

Calculation see Secondary Calculation

Calculation see Secondary Calculation

Room Temperature (°C)

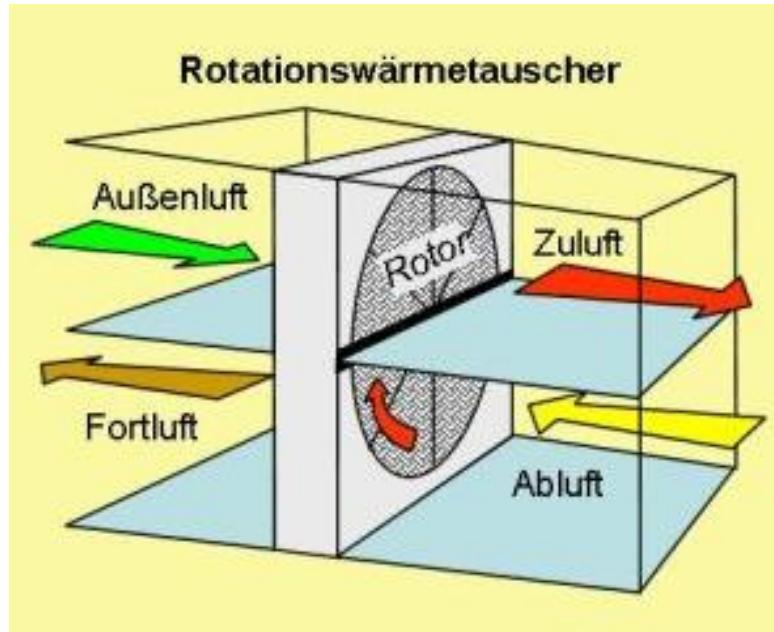
20

Av. Ambient Temp. Heating P. (°C)

4.8

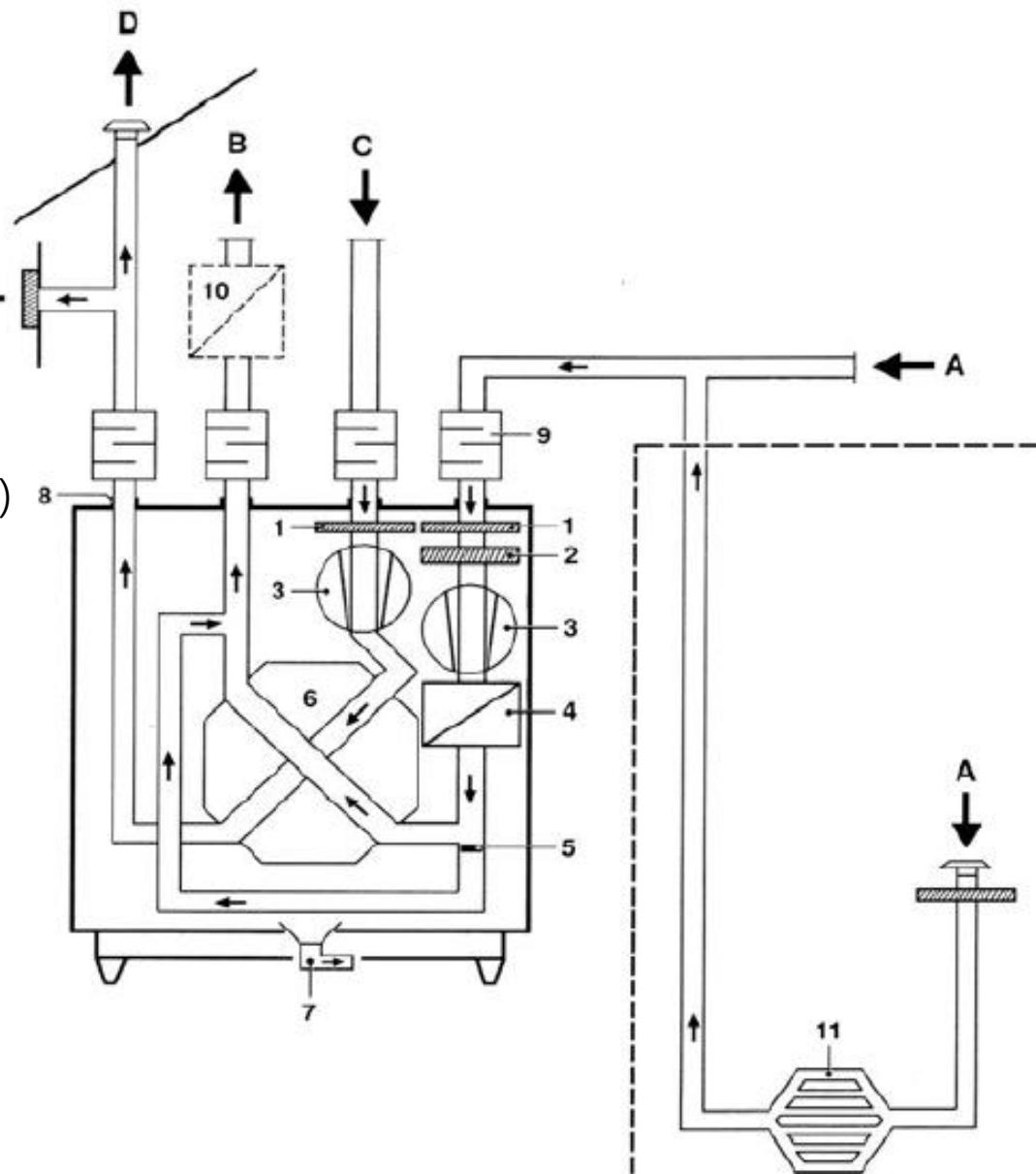
Av. Ground Temp (°C)

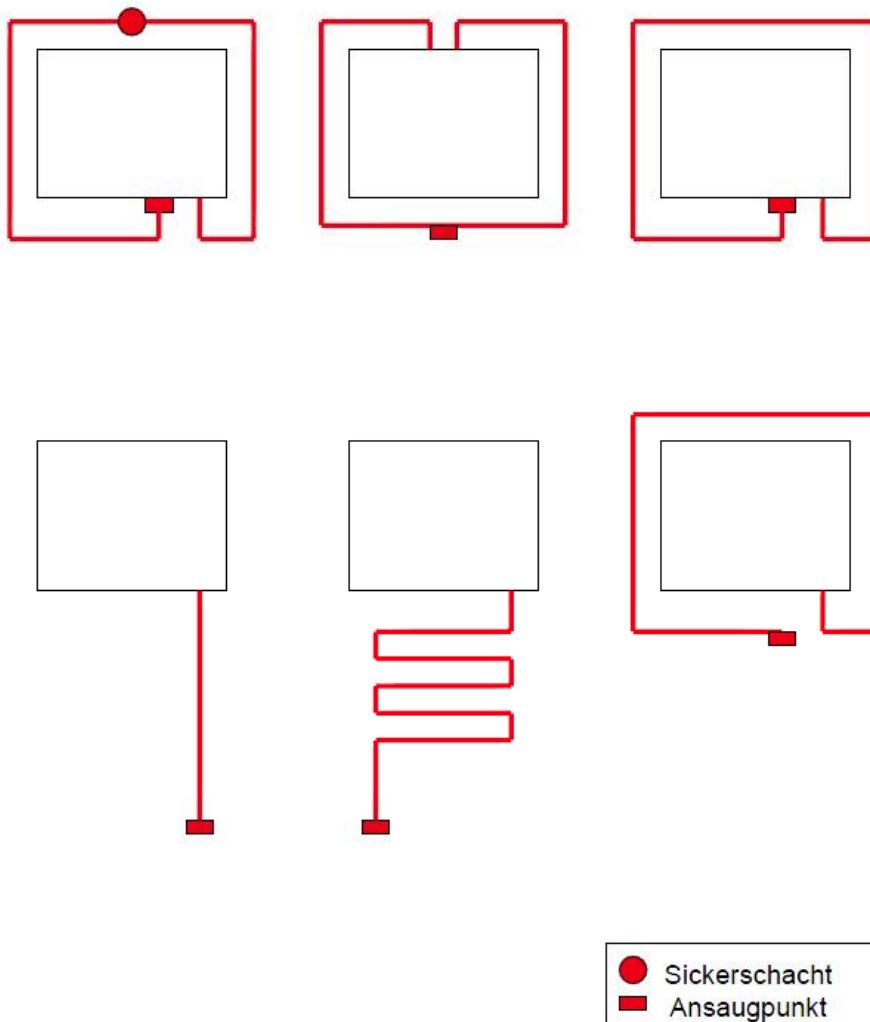
13.2



## 배기열 회수 환기유닛 장치

- 급기온도: 16.5°C 이상
- 공기질: OA-F7 등급 필터, RA- G4 등급필터
- 소비전력: 0.45Wh/m<sup>3</sup> 미만
- 효율: 75% 이상 (EA 와 RA 기준에의한 온도효율)
- 누기율: 3% 미만
- 단열성능: 5W/m<sup>2</sup>K 미만
- 제어시스템: 3단계 제어방식, 필터교환시기 표시등, 밸런싱조절, 바이패스 기능, 동상방지제어, 외기도입시 하이브리드 연결
- 소음성능: 35dB이하

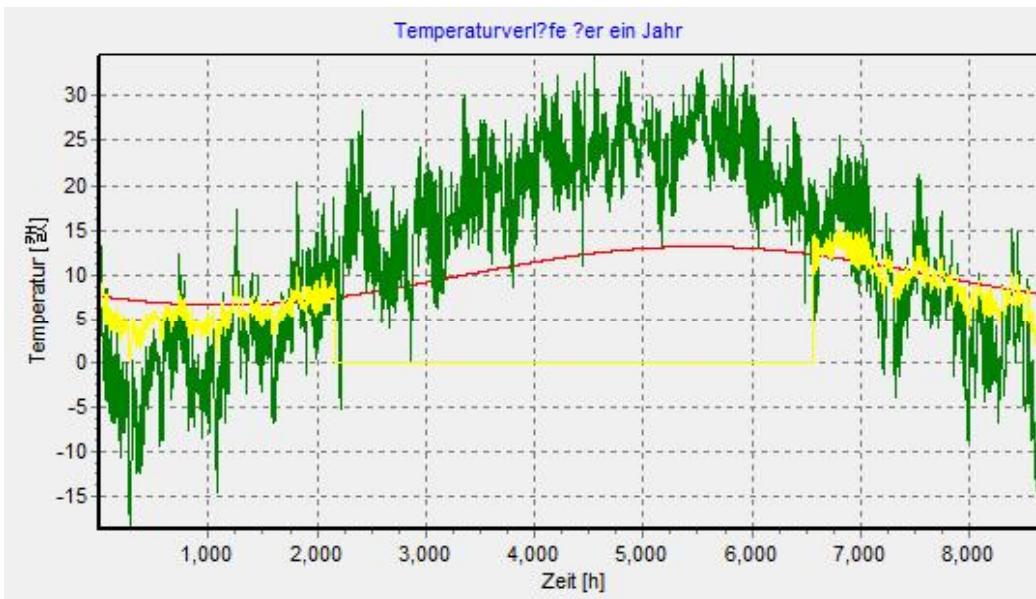




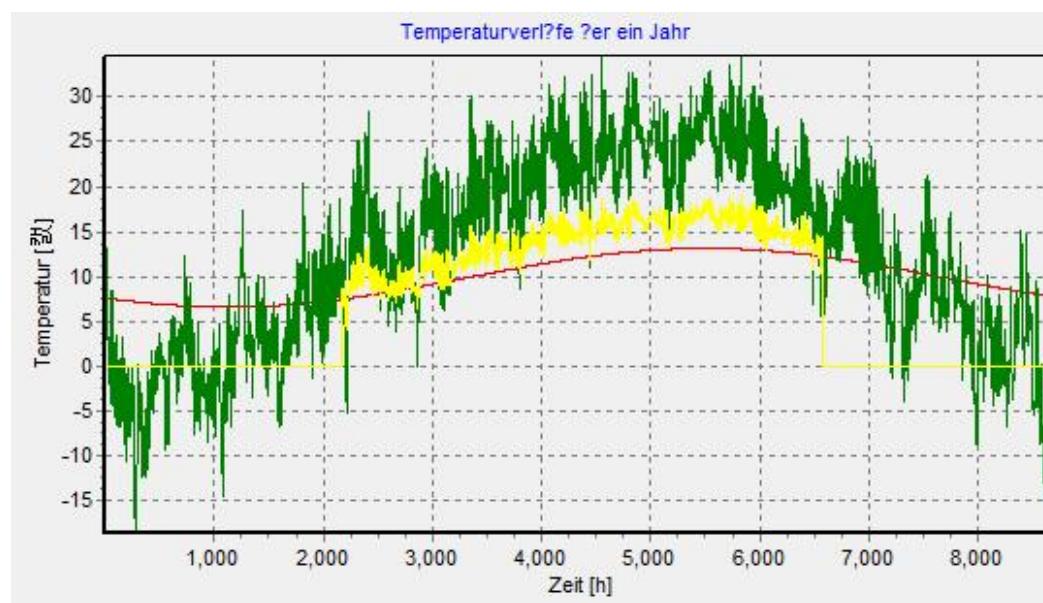
|   | default  | 12 Bodensee m. U.                              | von 01.10 bis 31.03 |
|---|----------|--|---------------------|
| <b>Erdreich</b>   |          |  |                     |
| Bodentyp:   | Sand     |  |                     |
| Dichte [kg/m <sup>3</sup> ]:                                | 1780     |  |                     |
| W?meleitf?igkeit [W/mK]:                                    | 0.93     |  |                     |
| Temperaturleitf?ig. [m <sup>2</sup> s]:                     | 3.758e-7 |  |                     |
| <b>Randbedingung</b>  |          |  |                     |
| Air volumenstrom [m <sup>3</sup> h]:                        | 140      |  |                     |
| Verlegetiefe [m]:   | 2        |  |                     |
| Tiefe Grundwassersp. [m]:                                   | 30       |  |                     |
| <b>L?ftungskanal</b>  |          |  |                     |
| Rohrinnendurchmesser [mm]:                                  | 150      |  |                     |
| Rohrwandst?ke [mm]:   | 10       |  |                     |
| Rohrauhigkeit [mm]:   | 1        |  |                     |
| W?meleitf?igkeit [W/mK]:                                    | 2.3      |  |                     |
| L?nge der Einzelrohre [m]:                                  | 50       |  |                     |
| <b>Ergebnisse</b>   |          |  |                     |
| <b>min. Austrittstemperatur [°H]</b> :                      | 0.01     |  |                     |
| W?mezu / abfuhr [kWh/a]:                                    | 827      | -146   |                     |
| Netto-W?meabgabe [kWh/a]:                                   | 681.1    |  |                     |
| Druckverlust [Pa]:  | 37.4     |  |                     |
| Jahresarbeitszahl [-]:                                      | 16.06    |  |                     |
| W?mebereitstellungsgrad [%]:                                | 21.61    |  |                     |
| <b>Berechnung</b>   |          |  |                     |
| <input type="button" value="Berechnung starten"/>           |          | <input type="button" value="Grafik anzeigen"/> |                     |
| <b>Rohrregister</b>   |          |  |                     |
| Anzahl der Rohre [-]:                                       | 1        |  |                     |
| Durchmesser Verteiler [mm]:                                 | 150      |  |                     |
| Ventilatorwirkungsgrad [%]:                                 | 15       |  |                     |
| Abstand der Rohre [m]:                                      | 1        |  |                     |
| <input type="radio"/> Durchstr?ung nach Tichelmann          |          |  |                     |
| <input checked="" type="radio"/> Durchstr?ung in M?nderform |          |  |                     |

## 10 공기식 지증열교환기 해석

### 패시브하우스의 환기설계



|  |                     |
|--|---------------------|
| 12 Bodensee m. U.                          | von 01.10 bis 31.03 |
| Ergebnisse                                 |                     |
| <b>min. Austrittstemperatur [°H]:</b> 0.22 |                     |
| W?mezu / abfuhr [kWh/a]:                   | 1127 -234           |
| Netto-W?meabgabe [kWh/a]:                  | 892.8               |
| Druckverlust [Pa]:                         | 18.6                |
| Jahresarbeitszahl [-]:                     | 29.72               |
| W?mebereitstellungsgrad [%]:               | 19.30               |



|  |                     |
|--|---------------------|
| 12 Bodensee m. U.                          | von 01.04 bis 31.09 |
| Ergebnisse                                 |                     |
| <b>min. Austrittstemperatur [°H]:</b> 4.06 |                     |
| W?mezu / abfuhr [kWh/a]:                   | 27 -1980            |
| Netto-W?meabgabe [kWh/a]:                  | -1952.4             |
| Druckverlust [Pa]:                         | 18.8                |
| Jahresarbeitszahl [-]:                     | -63.33              |
| W?mebereitstellungsgrad [%]:               | 1600.53             |

Projekt: Rural Greenhome Standard - Projektnr.: RH\_GH\_T001

Auslegung Luftungssystem Teil 3 von 5

**ZULUFT UND ABLUFT-DATENTABELLE:**

**HEINEMAN**  
www.heinemann-gmbh.de

| Raum-bezeichnung | Stock-werk | Grund-fläche               | Raum-volumen                | Abluft komfort             | Zuluft komfort             | Abluft-ventile | Luftmenge pro Abluftventil     | Schlauche pro Abluftventil | Zuluft-ventile | Luftmenge pro Zuluftventil     | Schlauche pro Zuluftventil |
|------------------|------------|----------------------------|-----------------------------|----------------------------|----------------------------|----------------|--------------------------------|----------------------------|----------------|--------------------------------|----------------------------|
| 부엌               | EG         | 12.0 m <sup>2</sup>        | 28.70 m <sup>3</sup>        | 60 m <sup>3</sup> /h       | -                          | 1              | Ventil 1: 60 m <sup>3</sup> /h | Ventil 1: 2                | -              | -                              | -                          |
| 거실               | EG         | 25.2 m <sup>2</sup>        | 60.48 m <sup>3</sup>        | -                          | 60 m <sup>3</sup> /h       | -              | -                              | -                          | 1              | Ventil 1: 60 m <sup>3</sup> /h | Ventil 1: 2                |
| 창고/기계실           | EG         | 5.4 m <sup>2</sup>         | 12.86 m <sup>3</sup>        | 30 m <sup>3</sup> /h       | -                          | 1              | Ventil 1: 30 m <sup>3</sup> /h | Ventil 1: 1                | -              | -                              | -                          |
| 방                | EG         | 14.1 m <sup>2</sup>        | 33.77 m <sup>3</sup>        | -                          | 40 m <sup>3</sup> /h       | -              | -                              | -                          | 1              | Ventil 1: 40 m <sup>3</sup> /h | Ventil 1: 2                |
| 주화장실             | EG         | 5.1 m <sup>2</sup>         | 12.17 m <sup>3</sup>        | 50 m <sup>3</sup> /h       | -                          | 1              | Ventil 1: 50 m <sup>3</sup> /h | Ventil 1: 2                | -              | -                              | -                          |
| 아이방              | EG         | 114.6 m <sup>2</sup>       | 275.06 m <sup>3</sup>       | -                          | 30 m <sup>3</sup> /h       | -              | -                              | -                          | 1              | Ventil 1: 30 m <sup>3</sup> /h | Ventil 1: 1                |
| 안방화장실            | EG         | 1.9 m <sup>2</sup>         | 4.54 m <sup>3</sup>         | 30 m <sup>3</sup> /h       | -                          | 1              | Ventil 1: 30 m <sup>3</sup> /h | Ventil 1: 1                | -              | -                              | -                          |
| 안방               | EG         | 14.6 m <sup>2</sup>        | 35.11 m <sup>3</sup>        | -                          | 40 m <sup>3</sup> /h       | -              | -                              | -                          | 1              | Ventil 1: 40 m <sup>3</sup> /h | Ventil 1: 2                |
| <b>SUMME:</b>    |            | <b>192.9 m<sup>2</sup></b> | <b>462.69 m<sup>3</sup></b> | <b>170 m<sup>3</sup>/h</b> | <b>170 m<sup>3</sup>/h</b> | <b>4</b>       | <b>170 m<sup>3</sup>/h</b>     | <b>6</b>                   | <b>4</b>       | <b>170 m<sup>3</sup>/h</b>     | <b>7</b>                   |

Verhältnis Abluft Komfort / Zuluft Komfort 1.00

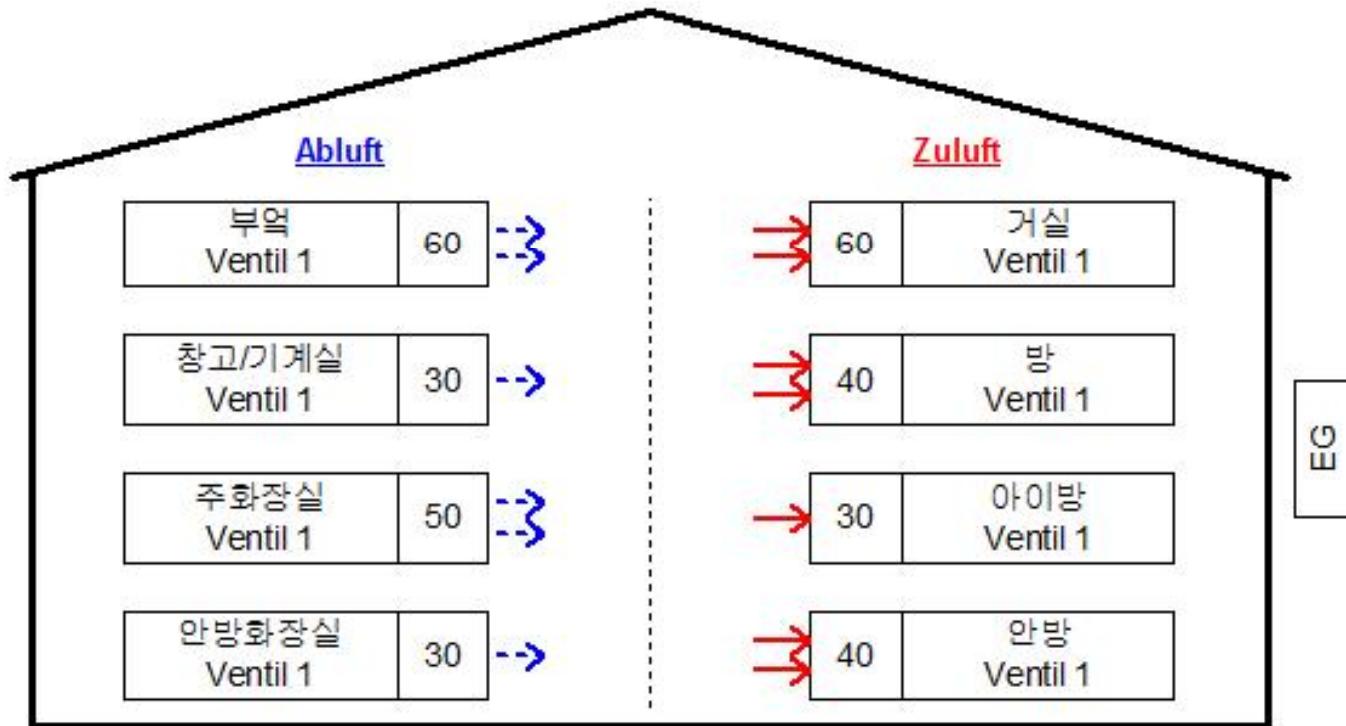
Hinweis: Die Auslegung, erfüllt nicht die Anforderungen nach DIN 1946 Teil 6 - 5/2009!

\* Luftwechselrate DIN: 0.39  
Luftwechselrate Komfort: 0.37

**Diese Tabelle liefert Ihnen folgende Informationen:**

1. Wieviel Ventile müssen für den jeweiligen Raum installiert werden?
2. Handelt es sich um Zu- oder Abluftventile?
3. Wieviel Schläuche sind für das jeweilige Ventil zu verlegen?
4. Welche Luftmenge sollte das jeweilige Ventil in einer mittleren Betriebsstufe des Lüftungsgerätes durchstromen?
5. Welche Luftmenge sollte das Lüftungsgerät in einer mittleren Betriebsstufe fordern?

\*Infiltrationsvolumenstrom wurde bereits abgezogen

**Montagehinweis für ValloFlex:**

Max. Verlegestrecke vom  
Verteilerkasten bis  
Tellerventil ca. 15 m!

**Legende:**

| Luftmenge pro<br>Ventil in m³/h | Raumbezeichnung<br>Ventilnummer |
|---------------------------------|---------------------------------|
| 60                              | 거실 Ventil 1                     |

Anzahl der Pfeile = Anzahl der Schläuche pro Ventilanschlussstein

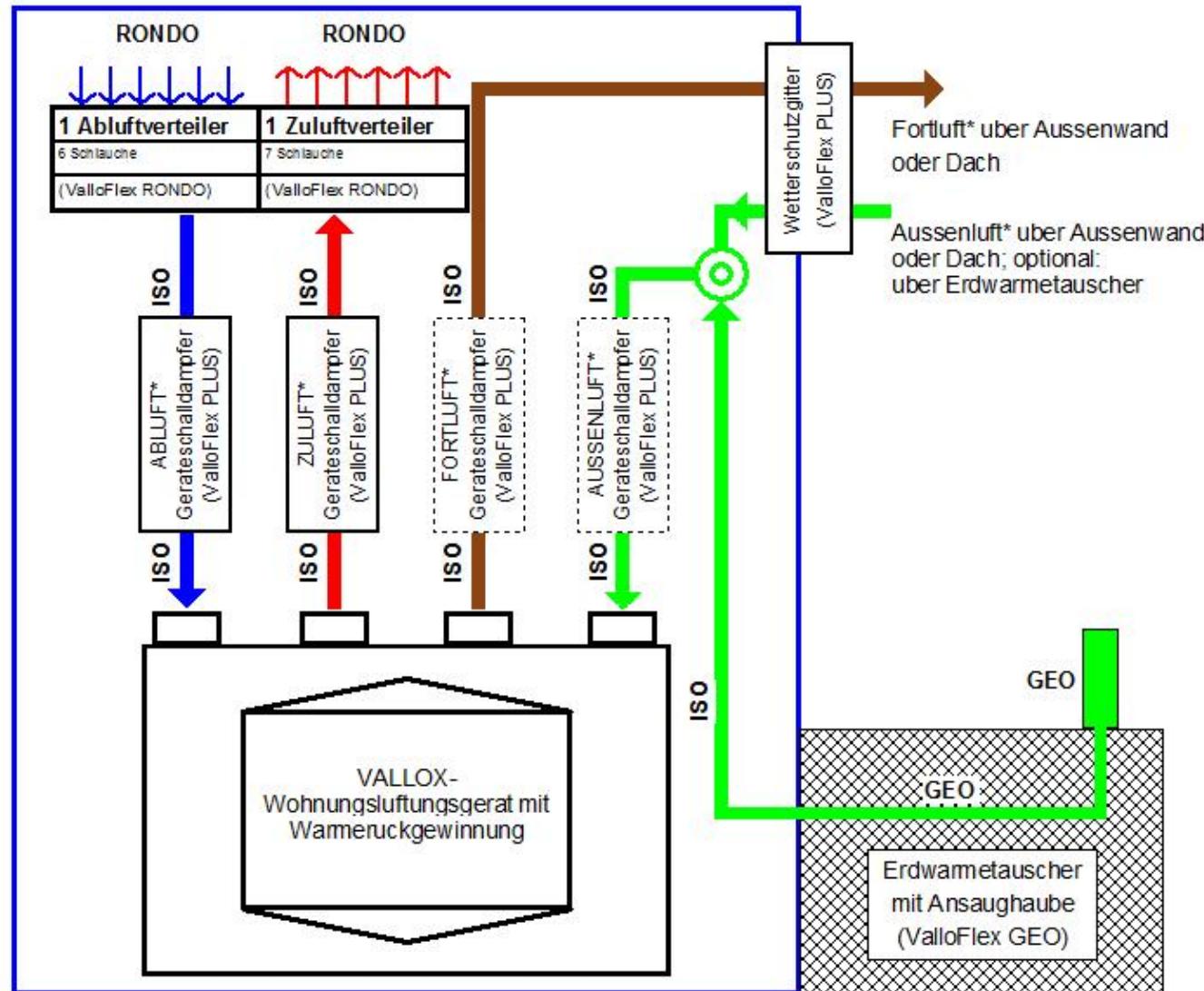
Farbe der Pfeile: rot = Zuluft, blau = Abluft

Projekt: Rural Greenhome Standard - Projektnr.: RH\_GH\_T001

Auslegung Luftungssystem Teil 5 von 5

LUFTFUHRUNG im Technikraum [EG]:

HEINEMANN  
www.heinemann-gmbh.de



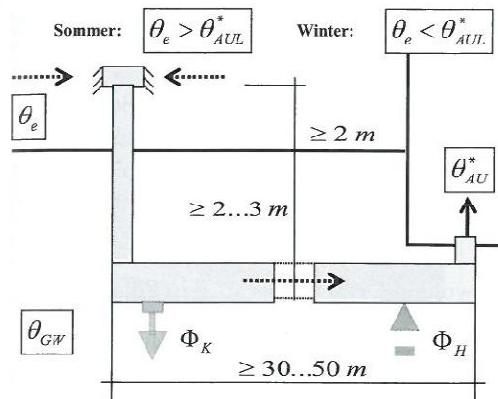
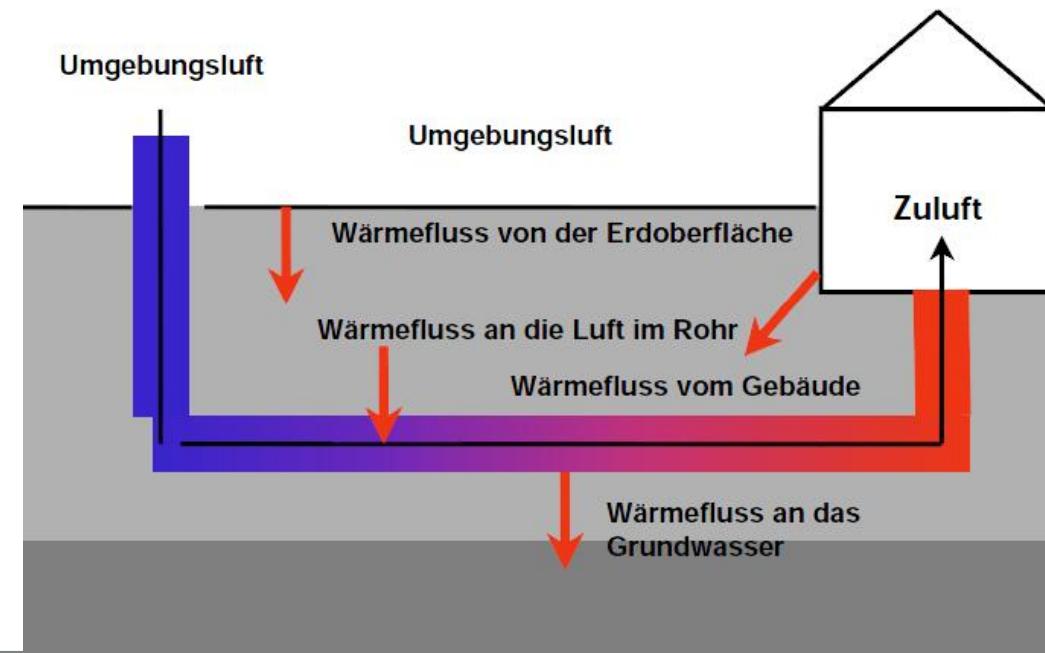


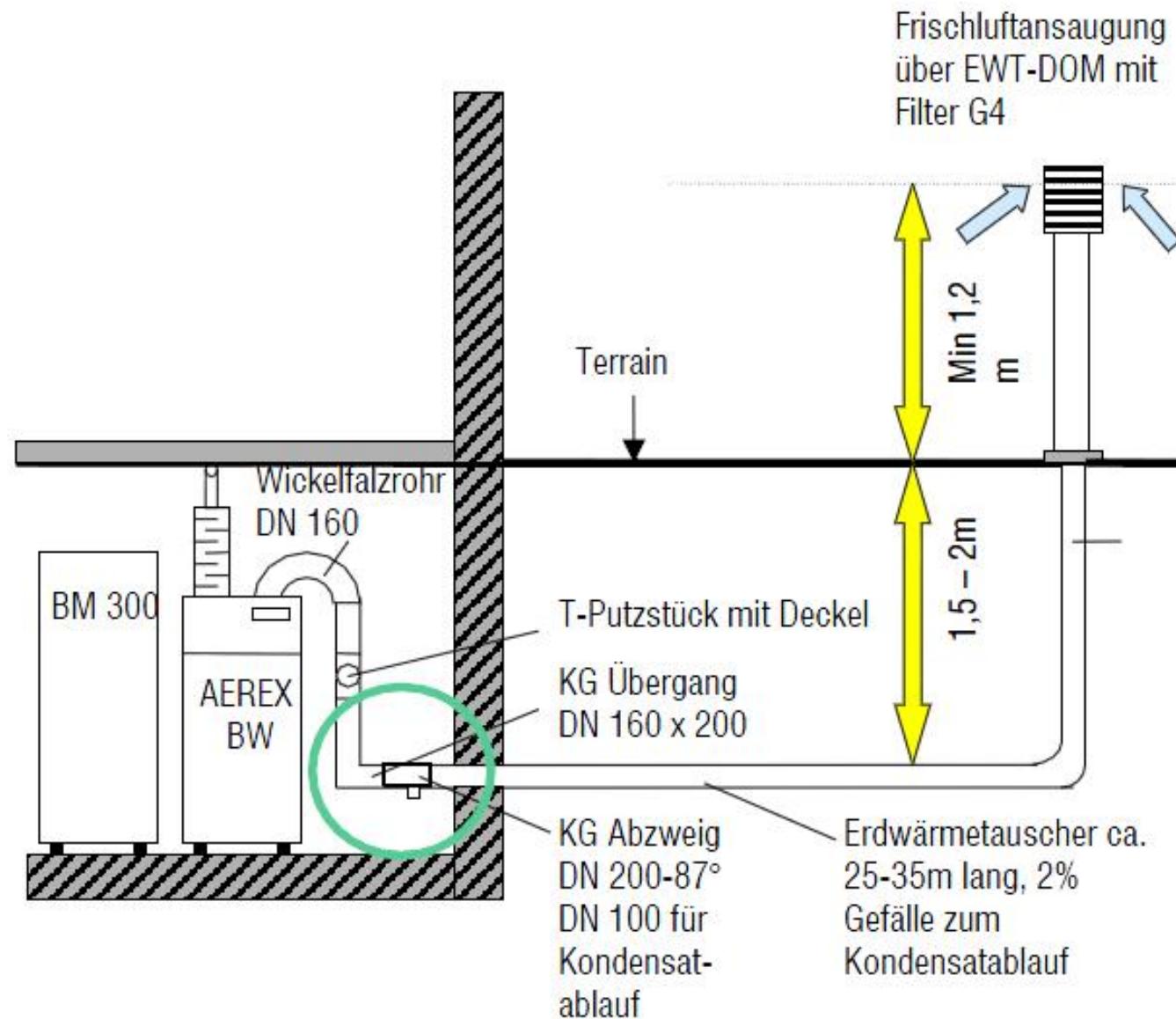
Abb. 2.3-10

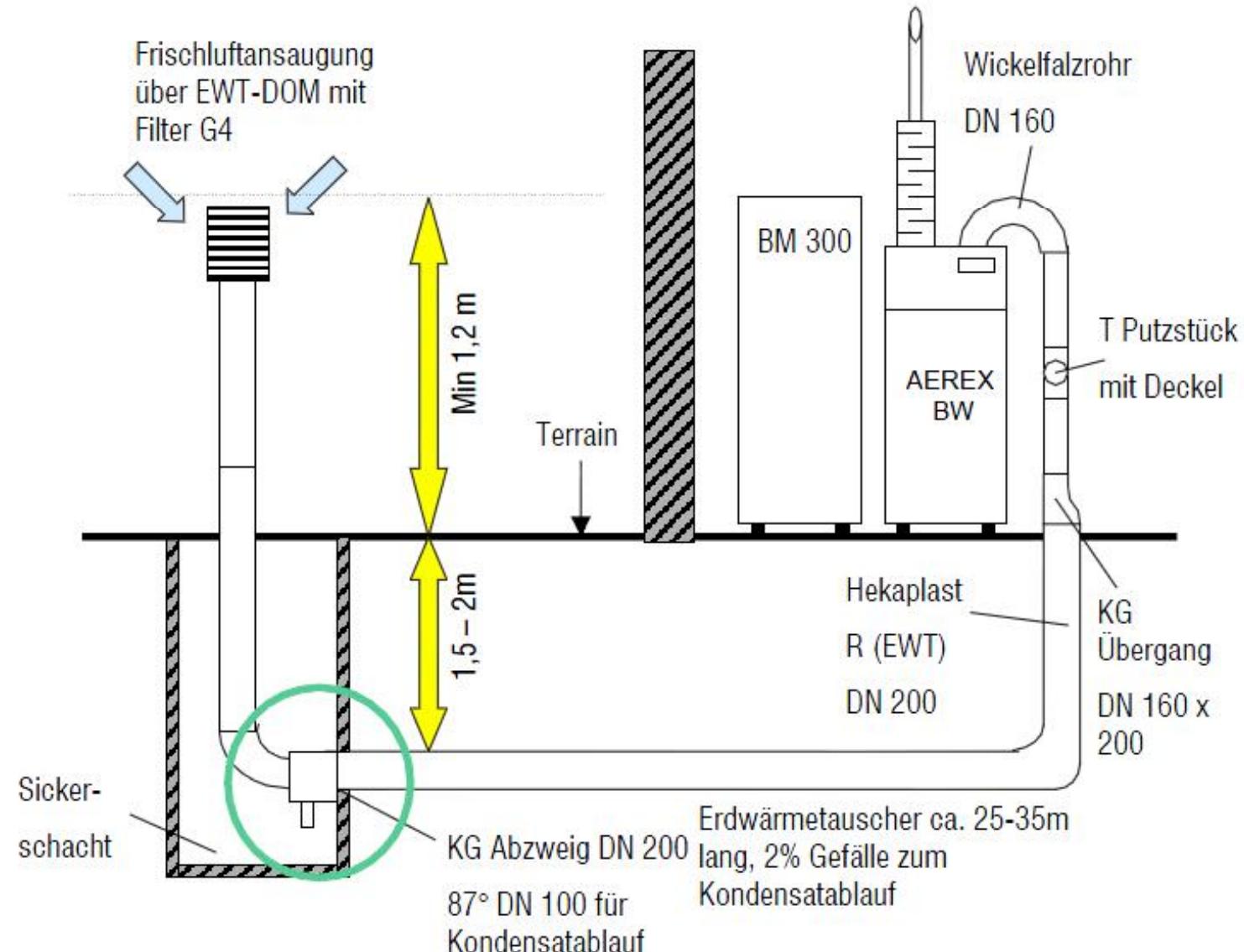
Schematische Darstellung eines Luftbrunnens mit Wärmegewinn  $\Phi_H$  im Winter und Wärmeverlust (Kältegewinn) im Sommer  $\Phi_K$

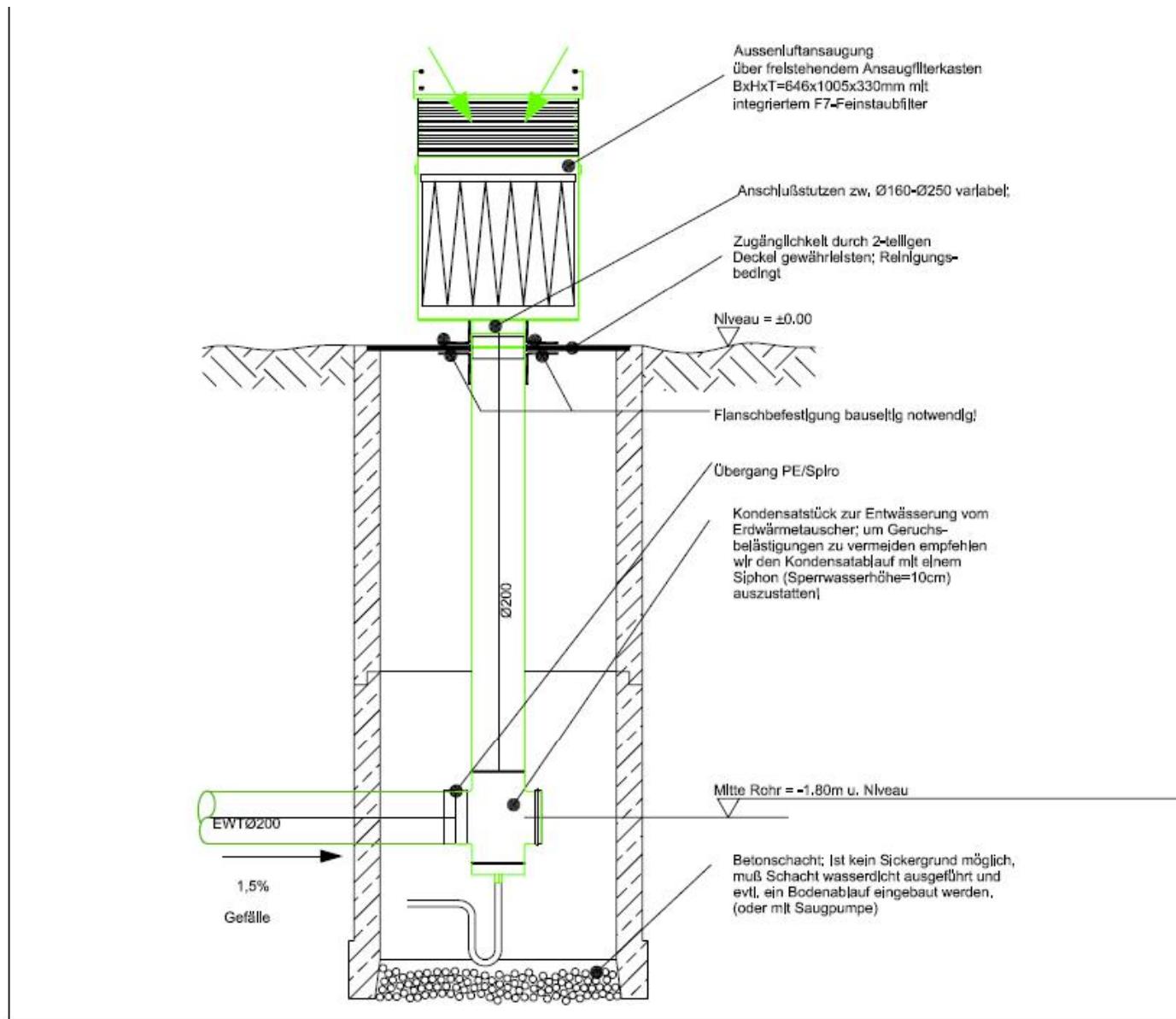


Der Erdreichwärmetauscher soll während der Heizperiode für die Vorerwärmung der Frischluft sorgen. Dabei wird bei einer Normaußentemperatur von -12°C eine Luftaustrittstemperatur von mindestens 0°C angestrebt. Hierfür sind folgende Punkte zu beachten:

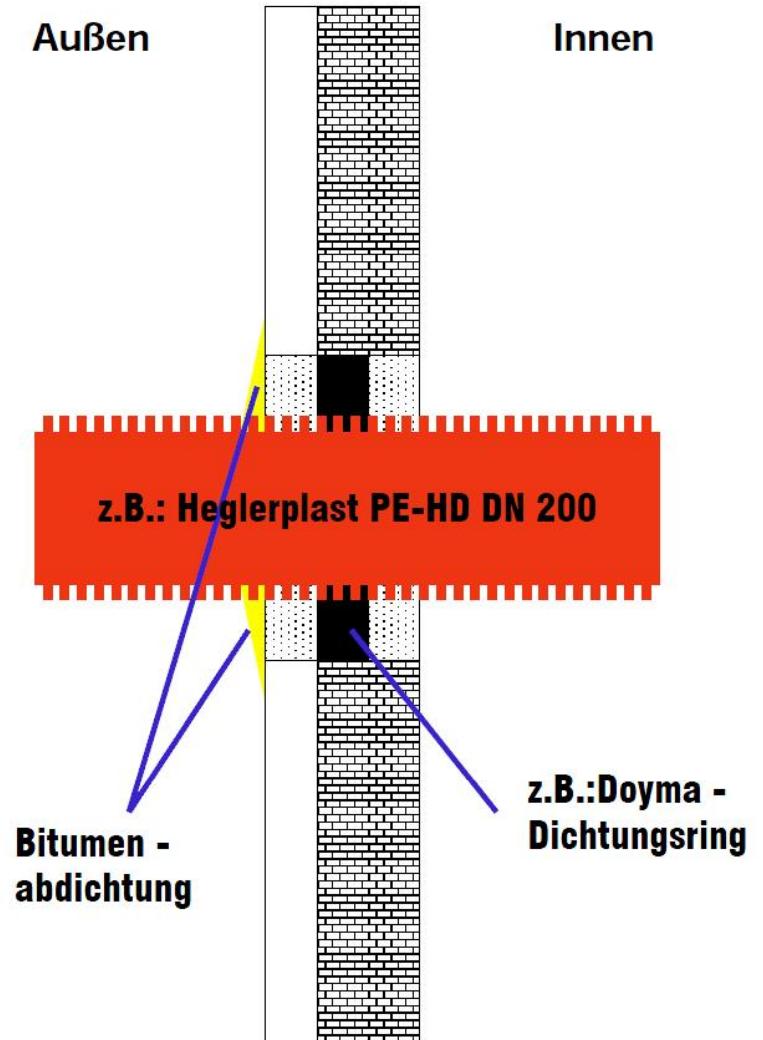
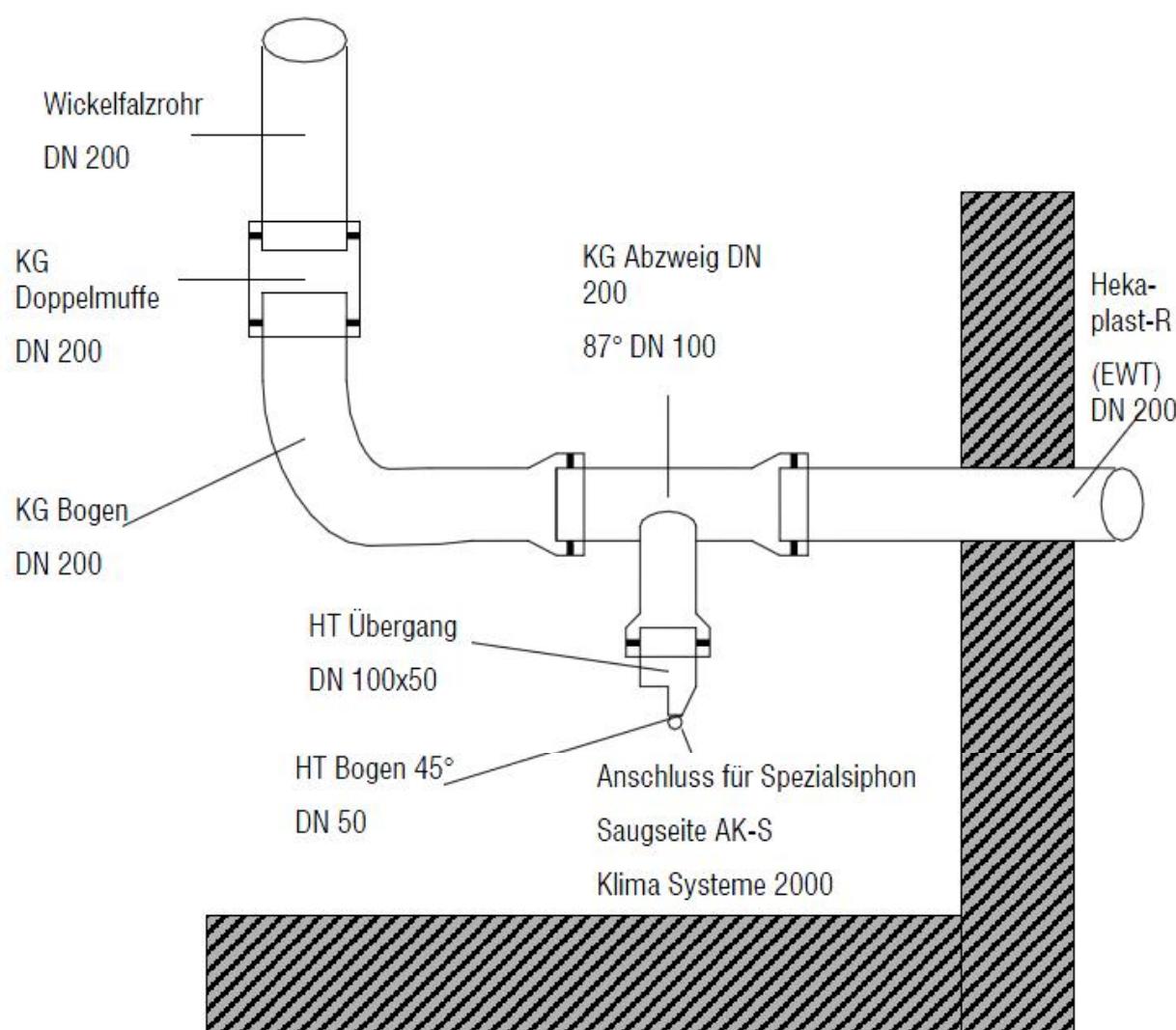
- Verlegetiefe 1,5-2 m unter Terrain
- Länge 25 - 35 m
- Rohrdurchmesser DN 160 (bis 125 m³/h) bzw. DN 200
- 1-2 % Gefälle
- Material PE oder PP (PVC-Rohre sollten auf Grund der Ionenentladung nicht verwendet werden.)

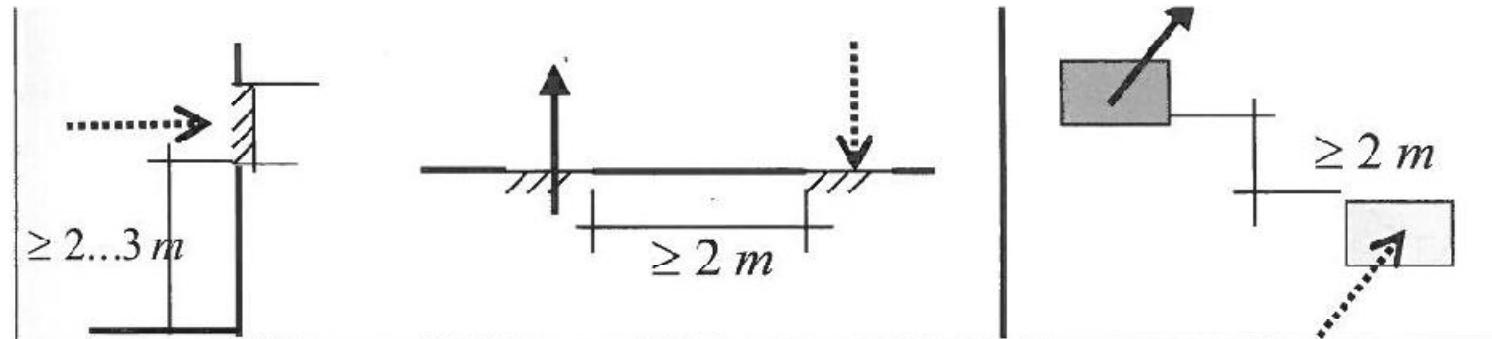




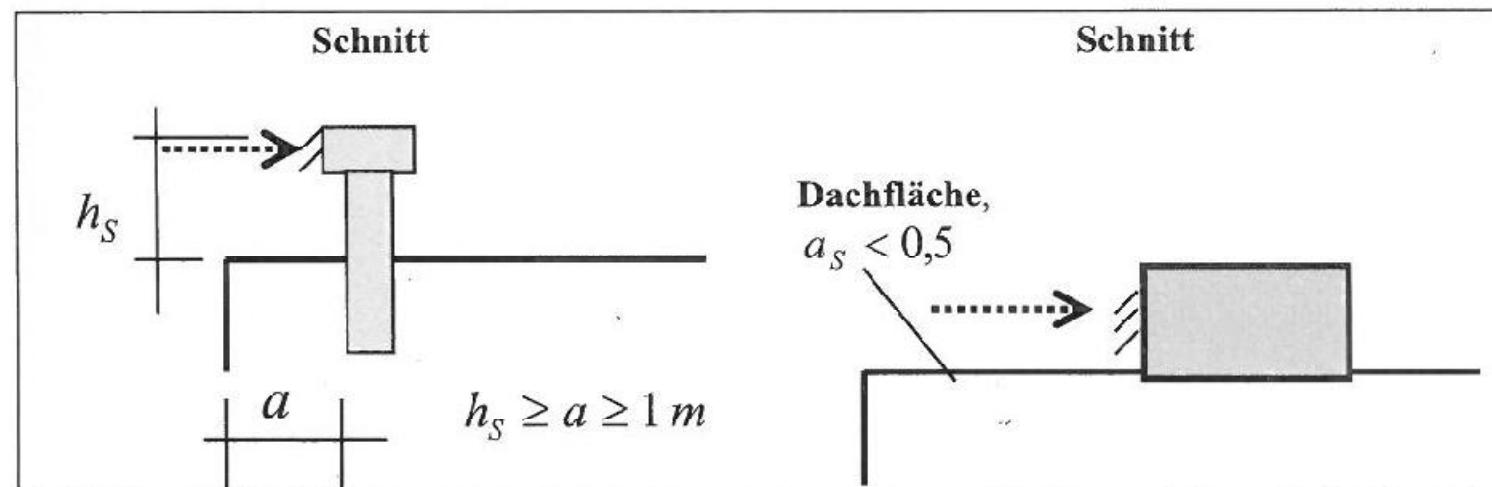


Kriterienkatalog zur Qualitätssicherung in der Ausführung von Passivhäusern in Holzbauweise





**Abb. 2.3-2** Schematische Darstellung der Außenluftansaugung an der Außenwand

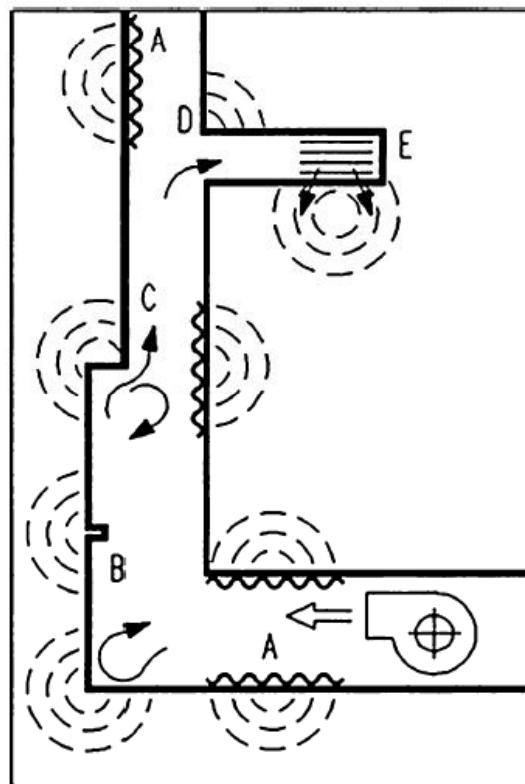
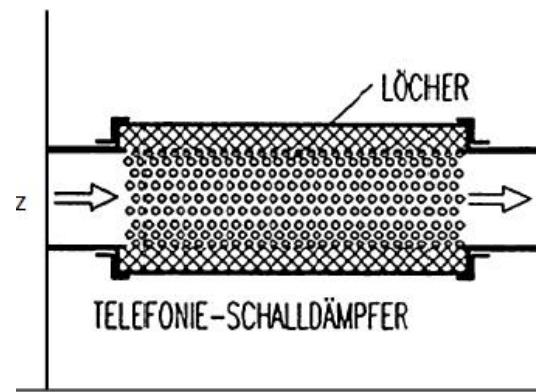


**Abb. 2.3-3** Schematische Darstellung der Außenluftansaugung über Dach

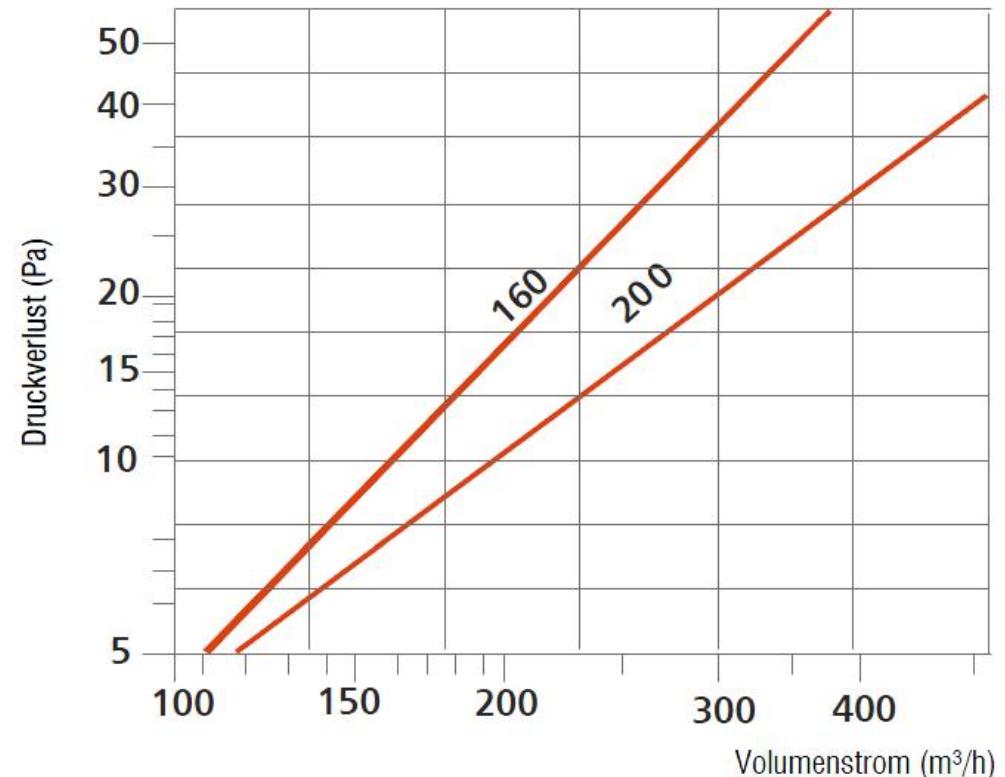
## 12 공기식 지중열교환기 시스템

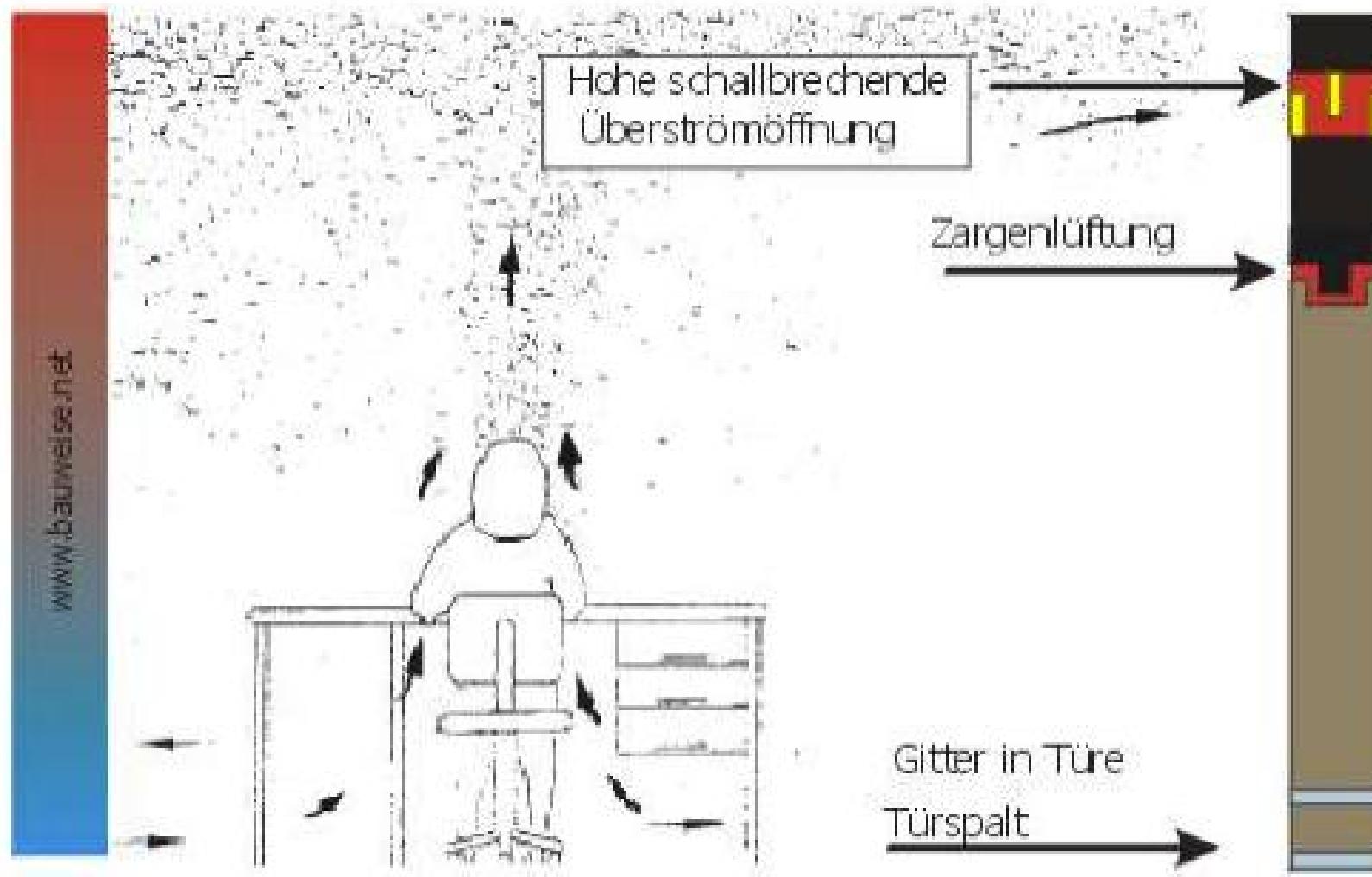
### 패시브하우스의 환기설계





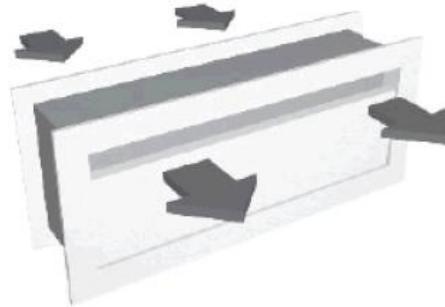
Druckverlustdiagramm







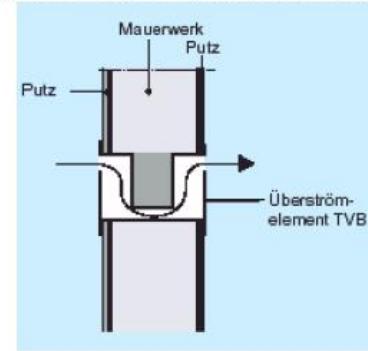
Zwei Bilder aus unserem Gästebad im EG. Hinter der schwarz gefliesten Wand befindet sich die "Speisekammer" mit der Gefriertruhe. Der Eingang zum Bad befindet sich im Bereich des Windfanges (Eingangsbereich). Hier ist eine Zuluft aus den kühlen Windfang ins Bad nicht gewünscht.



Westaflex Überströmelement TVB aus verzinktem Stahlblech,  
weiß lackiert.

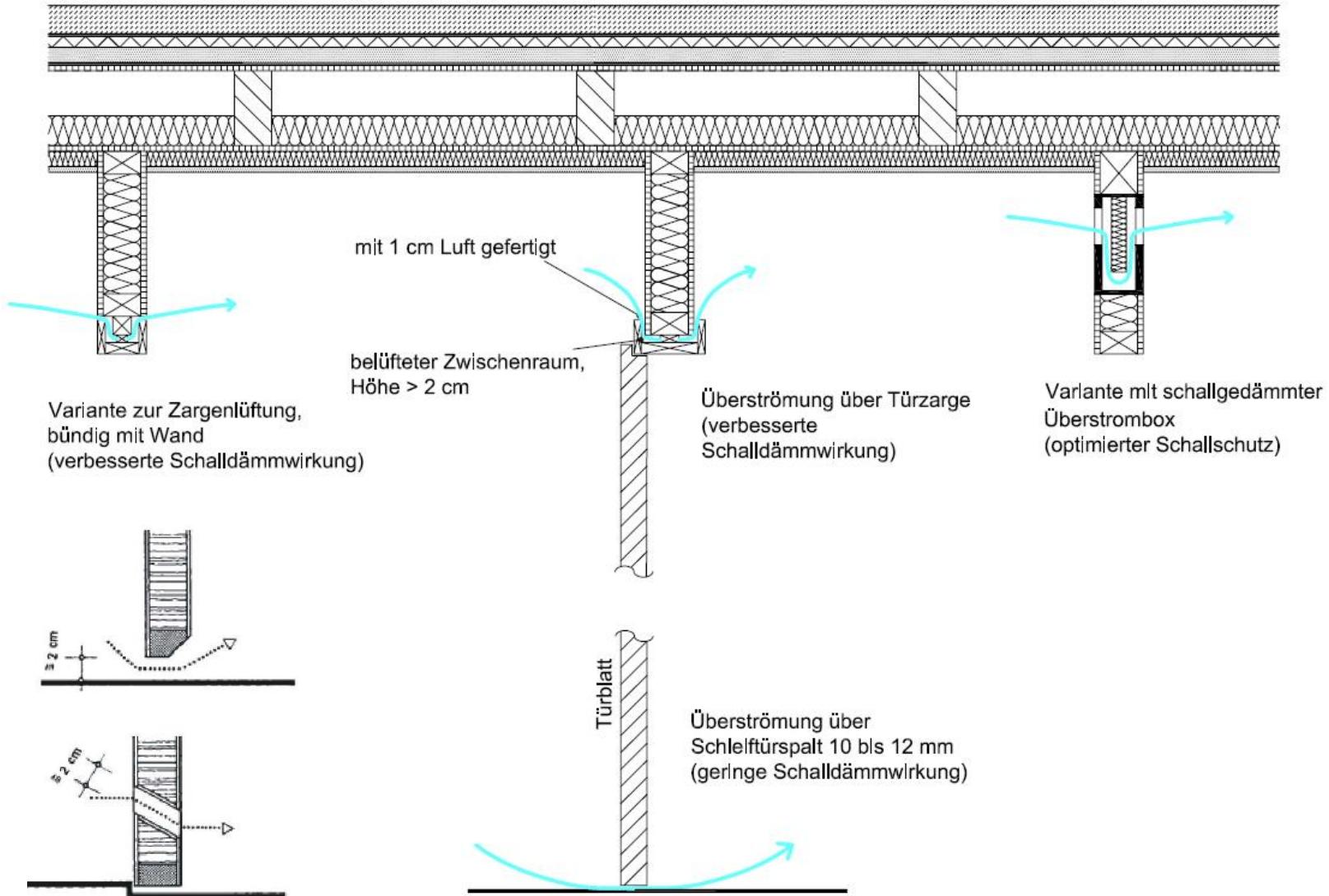


Die warme Luft der Speisekammer soll ins Bad gesaugt werden. Geräusche aus dem Bad (Gästetoilette) sollten nicht in der Küche hörbar sein. Daher setzen wir eine Westaflex-Überströmöffnung zwischen Speis und Bad ein (hohe schallbrechende Überströmöffnung)



Einbauskizze

## DETAILS ÜBERSTRÖMUNG

Schnitt

## 15 냉트연결

패시브하우스의 환기설계



© bauen.com



|  |   |                             |                                    |                    |              |              |   |   |            |                        |
|--|---|-----------------------------|------------------------------------|--------------------|--------------|--------------|---|---|------------|------------------------|
| <b>Ventilation System:</b>                                 | <b>Effective Air Volume, <math>V_V</math></b> | $A_{TFA}$<br>m <sup>2</sup> | <b>Clear Room Height</b>           | $m$                | $m^3$        |              |   |   |            |                        |
|  | $\eta_{eff}$<br><b>72%</b>                    | <b>116.5</b>                | *                                  | <b>2.50</b>        | =            | <b>291.4</b> |  |   |            |                        |
| <b>Effective Heat Recovery Efficiency of Heat Recovery</b> | $\eta_{eHR}$                                  | $n_{V,system}$<br>1/h       | $\Phi_{HR}$                        | $n_{V,Res}$<br>1/h |              |              |   |   |            |                        |
| <b>Efficiency of Subsoil Heat Exchanger</b>                | $\eta_{eHX}$<br><b>18%</b>                    | <b>0.370</b>                | (1 - <b>0.77</b> ) + <b>0.052</b>  | =                  | <b>0.135</b> |              |   |   |            |                        |
| <b>Ventilation Heat Losses <math>Q_V</math></b>            | $V_V$<br>m <sup>3</sup>                       | $n_V$<br>1/h                | $C_{Air}$<br>Wh/(m <sup>3</sup> K) | $G_t$<br>kWh/a     |              |              |   |   |            |                        |
|  | <b>291</b>                                    | *                           | <b>0.135</b>                       | *                  | <b>0.33</b>  | *            | <b>74.7</b>   | = | <b>973</b> | <b>8.3</b>             |
|  |   |                             |                                    |                    |              |              |   |   |            | kWh/(m <sup>3</sup> a) |
|  |   |                             |                                    |                    |              |              |   |   |            | Reduction Factor       |
|  |   |                             |                                    |                    |              |              |   |   |            | $Q_T$                  |
|  |   |                             |                                    |                    |              |              |   |   |            | $Q_V$                  |
|  |   |                             |                                    |                    |              |              |   |   |            | Night/Weekend          |