Energy efficiency in buildings and new technologies

Czech-Austrian Winter/Summer School

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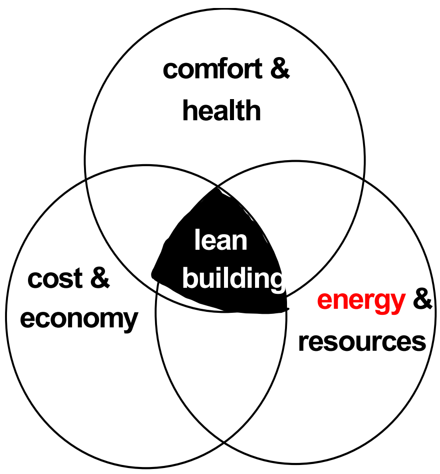
Whole life optimised building =>



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Gebäudebestand in Österreich

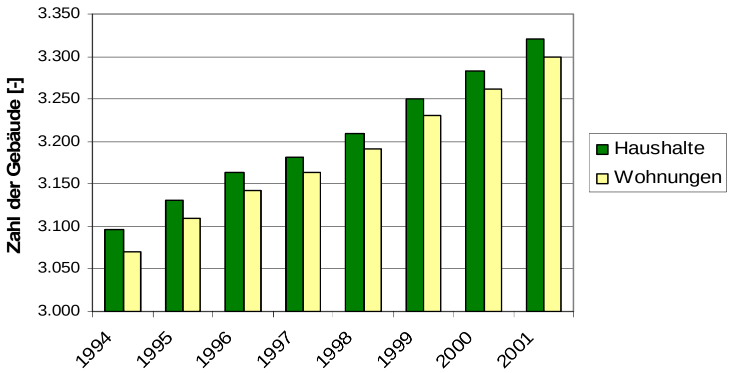

Abbildung: Entwicklung des Gebäudebestandes in Österreich, Quelle: www.statistik.austria.at, 15.03.2005

Quelle: Statistik Austria, (2004)

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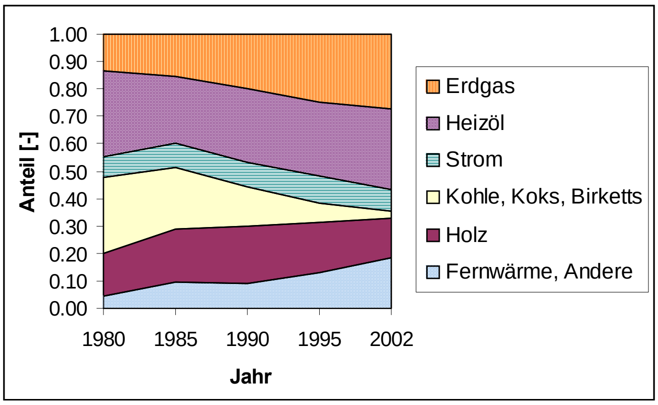
Energy carriers in Austrian households



Quelle: Statistik Austria, (2005)

Heating values and specific CO_2-emissions of fossil fuels

Energy carrier	Lower heating value	CO_2-emissions (related to lower heating value)
Hard coal	8,14 kWh/kg	0,350 kg/kWh
Lignite	2,68 kWh/kg	0,410 kg/kWh
Ignite briquetts	5,35 kWh/kg	0,380 kg/kWh
Coke	7,50 kWh/kg	0,420 kg/kWh
Heavy duty oil	10,61 kWh/l	0,290 kg/kWh
Oil „extra light“	10,08 kWh/l	0,270 kg/kWh
Natural gas	10,00 kWh/m3	0,200 kg/kWh

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Energy balance of a building over its lifetime

Construction

Maintenance

Energy consumption

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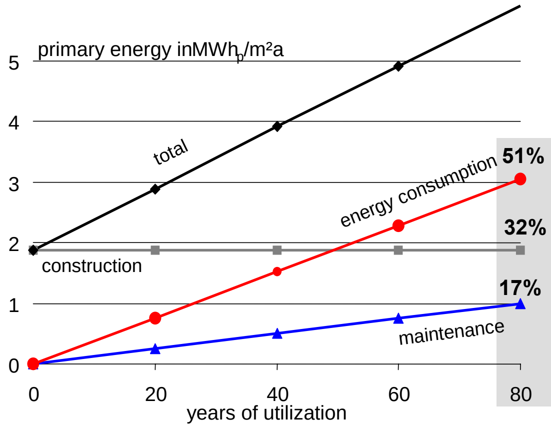
Life Cycle Energy

embodied energy 1,9 MWh/m²



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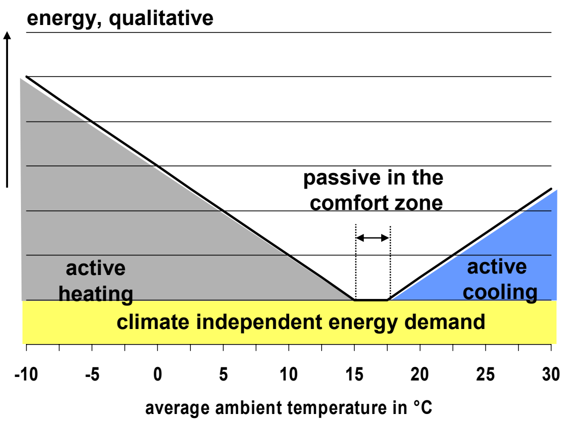
Current Buildings

Energy for:
- **heating**
- **cooling**
- **ventilation**
- **lighting**
- **utilization**



Example: Mid European climate

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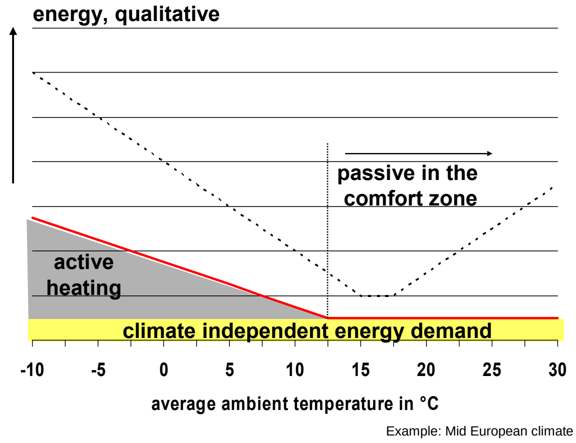
Lean Buildings

Energy for:
- heating
- cooling
- ventilation
- lighting
- utilization



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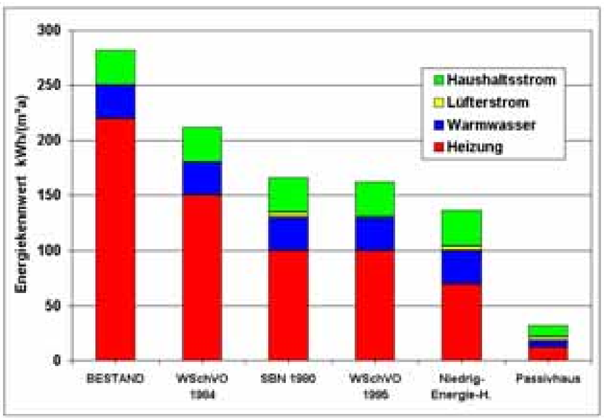
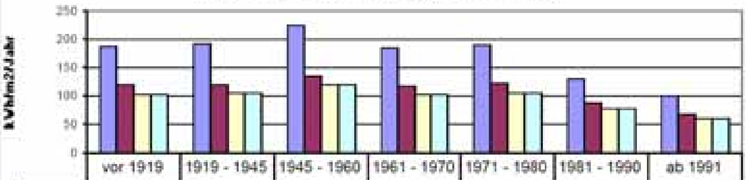
Energy demand of buildings



Specific space heating energy demand of single (SFH) and multi family buildings (MFH-K : small, MFH-G big) in decpendenc of year of errection in Austria

Raumheizungskennzahlen nach Baualtersklassen und Haustypen (nutzenergiebezogen)



	vor 1919	1919 - 1945	1945 - 1960	1961 - 1970	1971 - 1980	1981 - 1990	ab 1991
EFH	188	193	226	186	191	130	99
MFH-K	121	121	136	118	122	88	67
MFH-G	103	106	120	103	104	78	60
NWG	103	106	120	103	104	78	60

Quelle: Jungmeier, et al. (1996)

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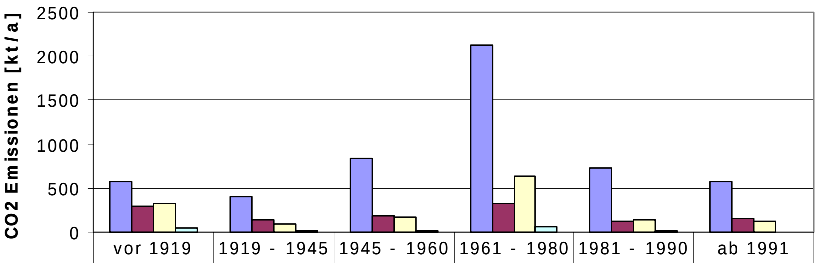
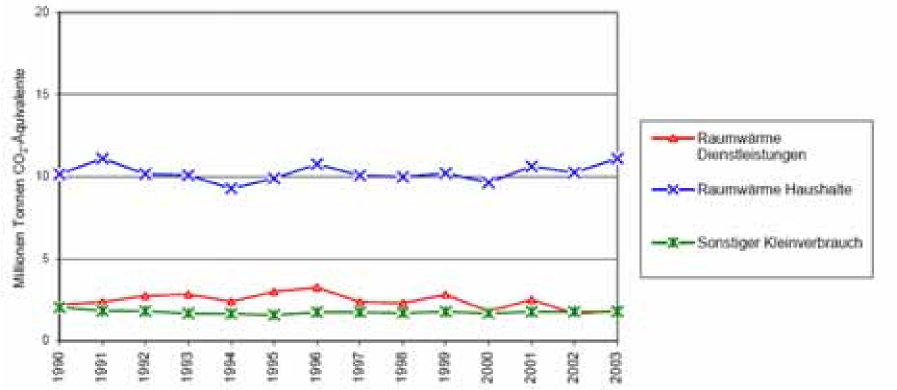
CO_2-emissions from space heating of appartements in Austria



	vor 1919	1919 - 1945	1945 - 1960	1961 - 1980	1981 - 1990	ab 1991
EFH	580	408	841	2 134	732	575
MFH-K	293	144	179	333	128	148
MFH-G	321	94	177	636	140	118
NWG	49	11	22	55	16	7

Quelle: eigene Berechnung

CO_2-equivalent emissions from the residential sector (Raumwärme Haushalte) and other small



Quelle: BMLFUW (2005)

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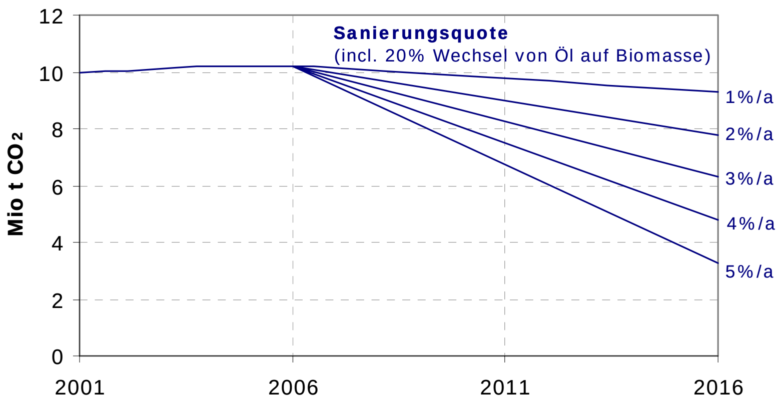
Trendscenario of thermal renovation and fuel switch of all Austrian dwellings (basic data from Statistik Austria, 2001)



Quelle: eigene Berechnung

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Steps of integrated building design für low energy demand

Boundary conditions
(Size, orientation, number of persons, climatic indoor conditions, Costs (errection and operation), etc.)

↓

Energetical optimization of the building itself
(measures at the building)

↓

Simple and efficient heating, ventilation, cooling system

↓

Ecologically benign heat and cold production
(renewable energy carriers)

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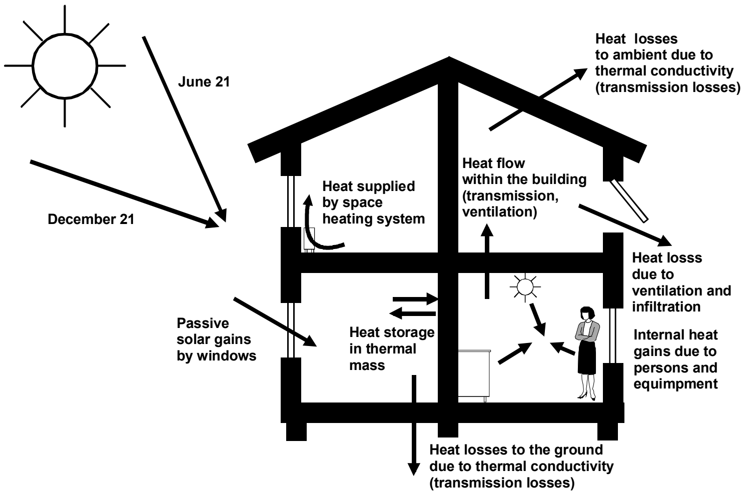
Energetical System Building

Building behaviour
- Active thermal mass
- Passive solar energy use

User behaviour
- Ventilation
- Internal Heat gains
- Indoor air set temperature
- Shading

Control
- Indoor air temperature controlled (centralized, decentralized)
- Outdoor air temperature dependend (centralized)
- Analog - digital
- Irradiation controlled
- Positioning of sensors

Energetical System Building



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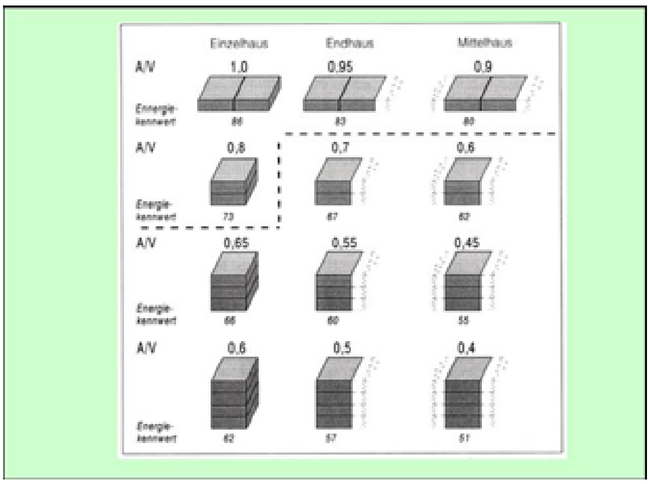
Building Shape: Ratio of A/V for differetn shapes



Quelle: Feist, W., 1998, Das Niedrigenergiehaus

Heat transfer coefficient for transmission heat losses

$$U = \frac{\dot{Q}}{A \cdot \Delta T} (= k) \qquad [W/(m^2K)]$$

mit A... Heat transfer surface $[m^2]$

$\dot{Q}$... Transferred heat $[W]$

ΔT... Forcing temperature difference $[K]$

$\dot{q} = \frac{\dot{Q}}{A} = U \cdot \Delta T$ .... specific heat flow $[W/m^2]$

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Heat conduction through a wall

$$\frac{1}{U} = \frac{1}{\alpha_i} + \sum_n \frac{s_n}{\lambda_n} + \frac{1}{\alpha_a}$$

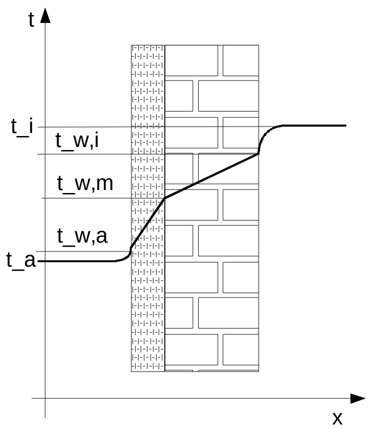
$$R = R_i + \sum_n R_n + R_a$$

mit α… heat transfer coeffcient [W/(m² K)]

λ_n… thermal conductivity [W/(m K)]

s_n… thickness of layer [m]

R… thermal resistance [(m² K)/W]



Maximum U-values (W/m²K) for Austrian provinces (2003)

Stand: 9/2003	B	K	N	O[1]	S[2]	St	T	V	W[3]
gültig seit	‘02	‘97	‘96	‘99	‘02	‘97	‘98	‘96	‘01
Außenwand	0,38	0,40	0,40	0,50	0,35	MFH: 0,50 EFH: 0,40	0,35	0,35	0,50
Wände gegen unbeheizte Gebäudeteile und Feuermauern	0,50	0,70	0,70	0,70	0,50	0,70	0,50	0,50	0,50
Wände gegen getrennte Wohn- und Betriebseinheiten	0,90	1,60	1,60	1,60	0,90	1,60	0,90	1,60	0,90
Decken gegen Außenluft, Dachböden, Durchfahrten	0,20	0,25	0,22	0,25	0,20	0,20	0,20	0,25	0,25
Decken gegen unbeheizte Gebäudeteile	0,35	0,40	0,40	0,45	0,40	0,40	0,40	0,40	0,45
Decken gegen getrennte Wohn- und Betriebseinheiten	0,70	0,90	0,90	0,90	0,90	0,90	0,70	0,90	0,90
Fenster	1,70	1,80	1,80	1,90	1,70	1.90	1,70	1,80	1,90
Außentüren	1,70	1,80	1,80	1,90	1,70	1,70 / 1,90	1,70	1,90	1,90
Erdberührte Wände	0,35	0,50	0,50	0,50	0,40	0,50	0,40	0,50	0,50
Erdberührte Fußböden	0,35	0,50	0,50	0,50	0,28 5	0,50	0,40	0,50	0,45

Abkürzungen:
MFH .... Mehrfam. Haus
EFH/ZFH ... Ein- u. Zweifam. Haus
GT .... Glastüre

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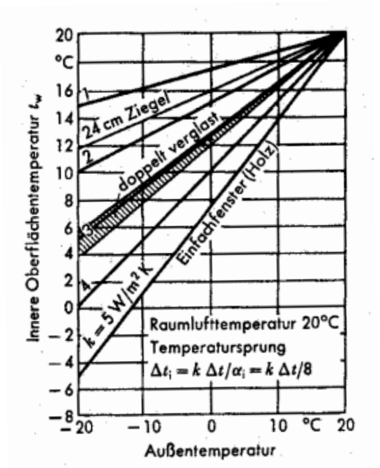
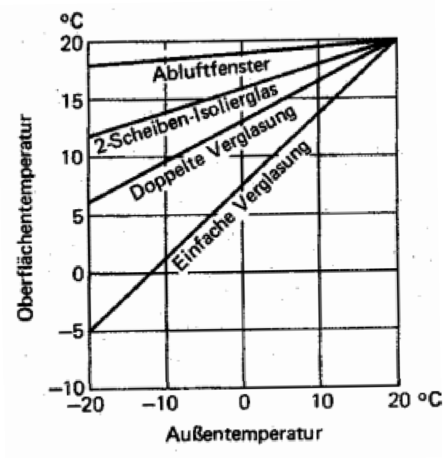
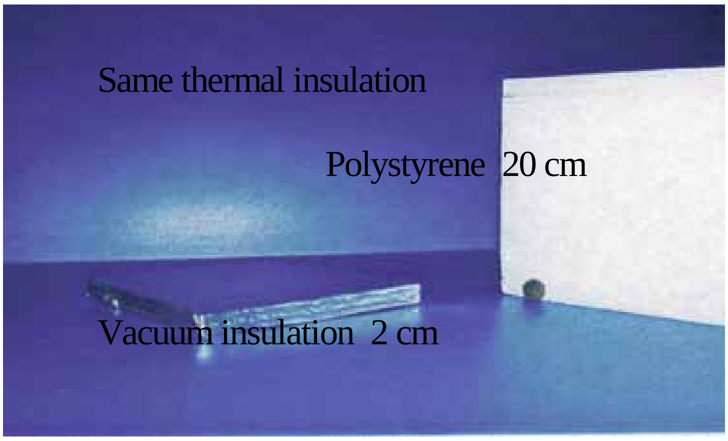
Room air temperature – temperature of surrounding surfaces ⇔ thermal comfort



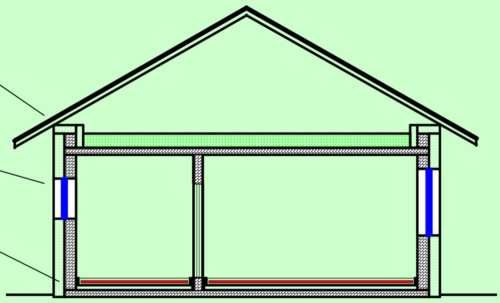




Avoiding thermal bridges

Problematic zones:

- **Connection of roof**
- **Windows**
- **Floor e.g. cellar ceiling**
- **Balkonies**



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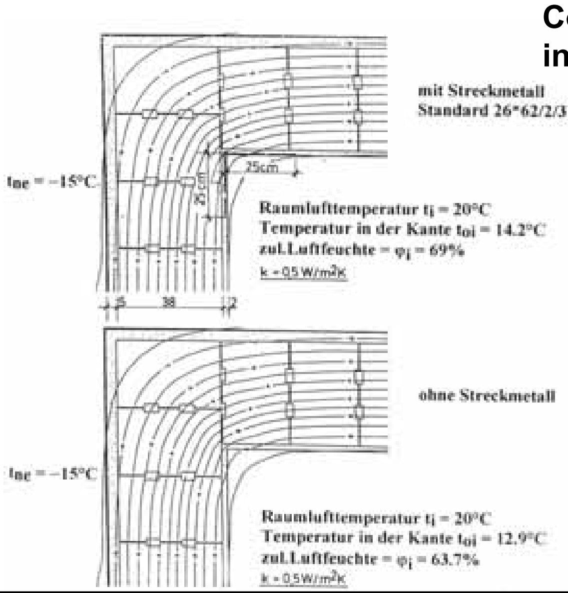
Course of temperature in an edge



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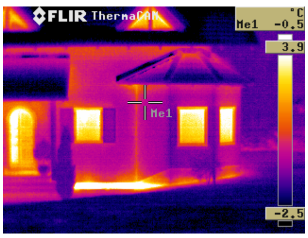
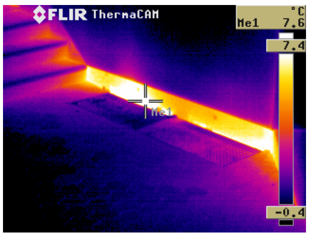
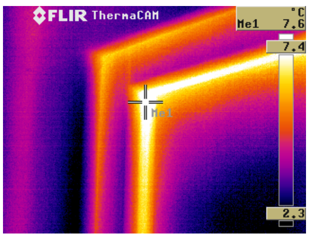
Thermal bridges, Thermographie



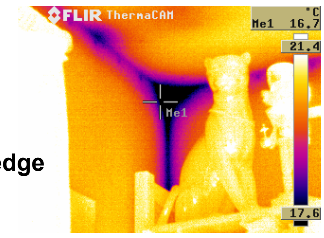




Ground floor to cellar,

Window

interior edge



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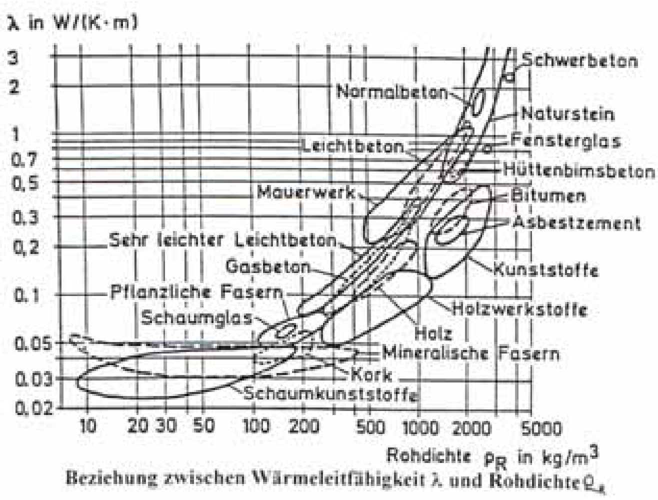
Material: Thermal conductivity λ and density ρ



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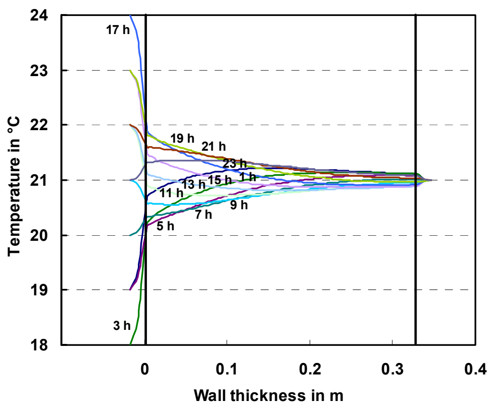
Principal of active thermal mass

$$\dot{q} = -\lambda \frac{\partial T}{\partial x} \qquad \frac{\partial \dot{q}}{\partial x} = -\lambda \frac{\partial^2 T}{\partial x^2} = \rho_{Sp}\, c_p \frac{\partial T}{dt}$$



Needs room air temperature shifts

Stored and released heat : 0.076 kWh/(m² d).

Significant temperature change up to a depth of ca. 10 cm (concrete wall)

It is not useful to make this wall thicker

Thermal mass means AREA not DEPTH

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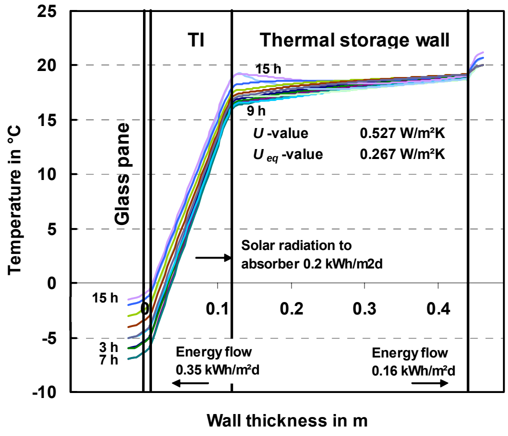
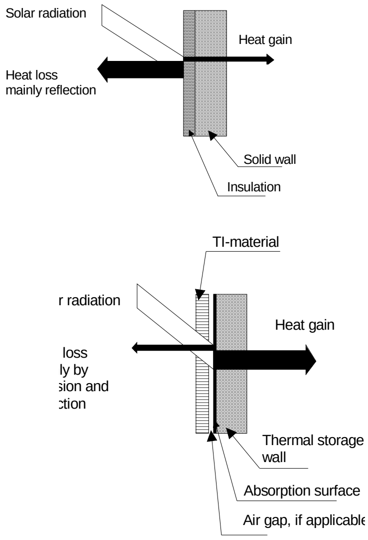
Transparent Insulation





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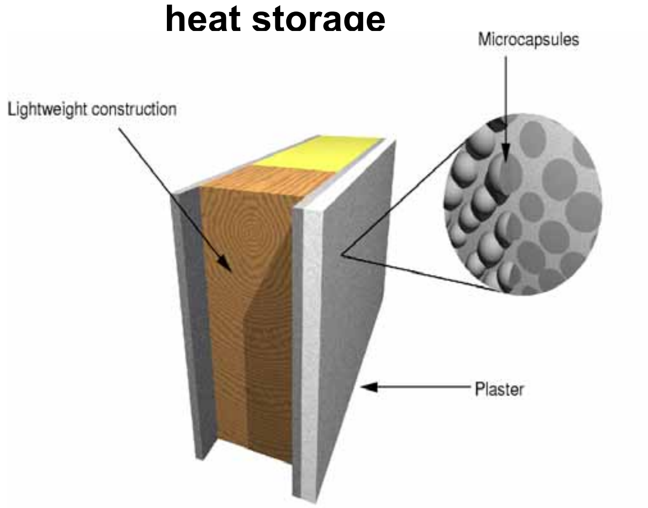
Micro-encapsulated phase change material, heat storage



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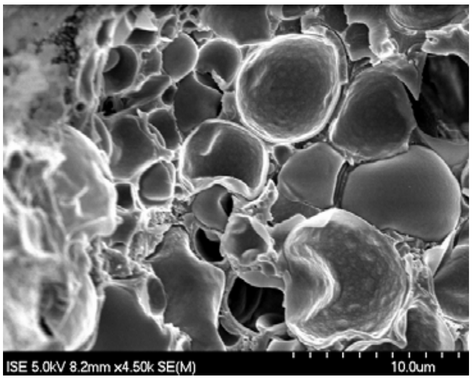
Micro encapsulated phase change materials

- Organic phase change materials
- PMMA-capsule (BASF), ~20 µm
- Integration into plaster, gipsum, concrete
- Increase of the thermal mass in a small temperature range
- Reduction of temperature peaks in summer time
- No active air conditioning



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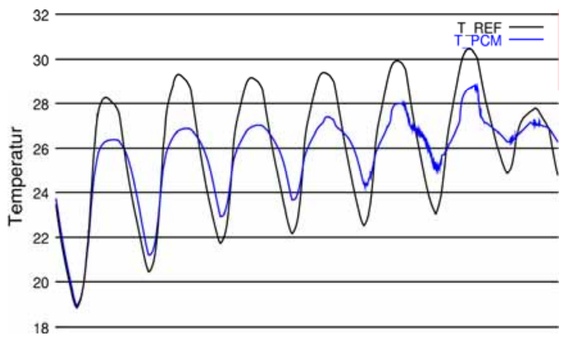
Application of PCMs on inner walls

Temperature behaviour of a test and a reference cell in comparison



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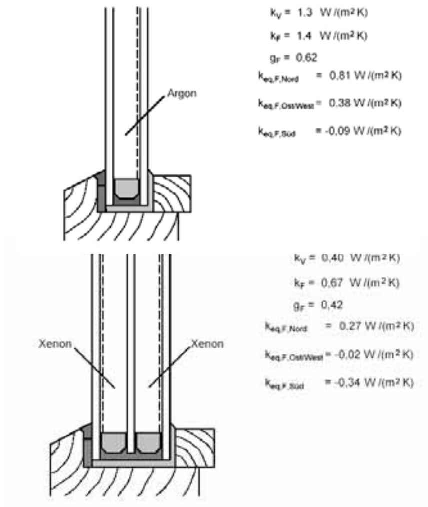
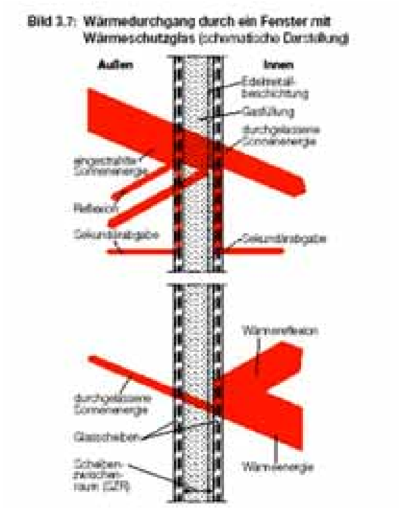
Energy transmitttance through windows





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Energy transmittance (g) and heat transfer coefficient (U) for different glazings

	Diffuse *g*-value	*U*-value glazing in W/(m² K)
Insulating glazing (4 + 16 + 4 mm, air)	0.65	3.00
Thermal insulation double-glazing (4 + 14 + 4 mm, argon)	0.60	1.30
Thermal insulation double-glazing (4 + 14 + 4 mm, xenon)	0.58	0.90
Thermal insulation triple-glazing with argon filling	0.44	0.80
Thermal insulation triple-glazing with krypton filling	0.44	0.70
Thermal insulation triple-glazing with xenon filling	0.42	0.40
10 cm plastic capillaries, one cover pane	0.67	0.90
10 cm plastic honeycombs, one cover pane	0.71	0.90
10 cm glass capillaries, two panes	0.65	0.97
2.4 cm granular aerogel, two panes filled with air	0.50	0.90
2 cm evacuated (100 mbar) aerogel plate, two panes	0.60	0.50

The diffuse *g*-values were measured for a poor in iron 4 mm front pane, whereas for the *U-values* an average sample temperature of 10 °C has been assumed.

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$$U_{eq} = U_W - S_F\, g$$

S_F = 0,95 north, 1,65 east/west, 2,4 south

Diffuse g-value ($g_{diffuse}$), U-value of the window (U_w) and equivalent U-values (U_{eq}) corresponding to different glazing types (see /3-5/)

	$g_{diffuse}$	U_w	U_{eq} (south)	U_{eq} (east/west)	U_{eq} (north)
			in W/(m^2 K)		
Simple glazing	0.87	5.8	3.7	4.4	5.0
Double-glazing (air 4 + 12 + 4 mm)	0.78	2.9	1.0	1.6	2.2
Double-glazing with thermal insulation and argon filling (6 + 15 + 6 mm)	0.60	1.5	0.1	0.5	0.9
Triple-glazing with thermal insulation and krypton filling (4 + 8 + 4 + 8 + 4 mm)	0.48	0.9	-0.3	0.1	0.4
Triple-glazing with thermal insulation and xenon filling (4 + 16 + 4 + 16 + 4 mm)	0.46	0.6	-0.5	-0.2	0.2

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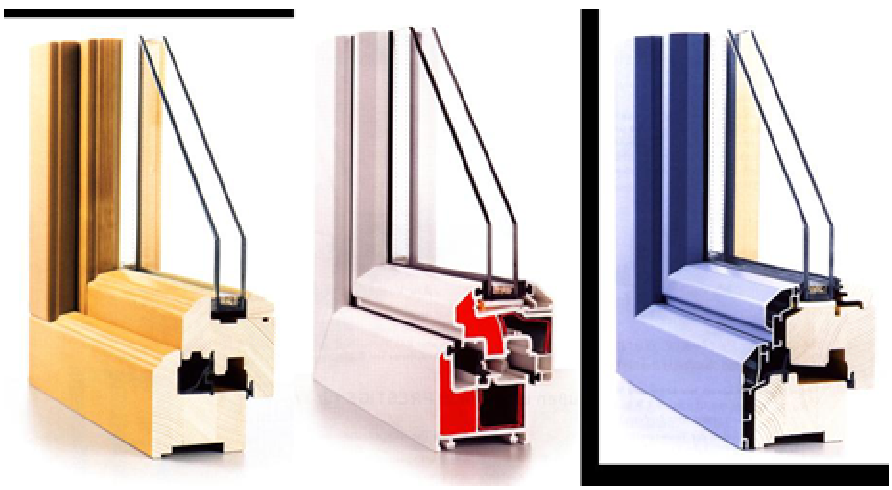
2-panes windows



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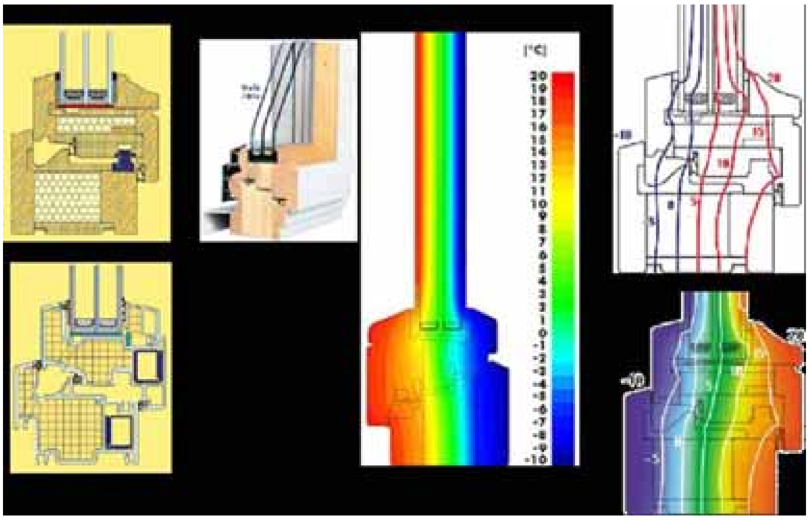
3-pane low U windows



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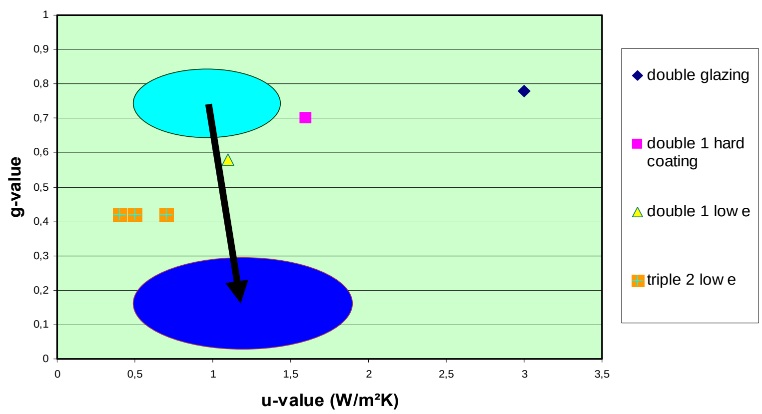
Potential for future glazings



Switchable glazings

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Factors influencing the solar transmittance of windows

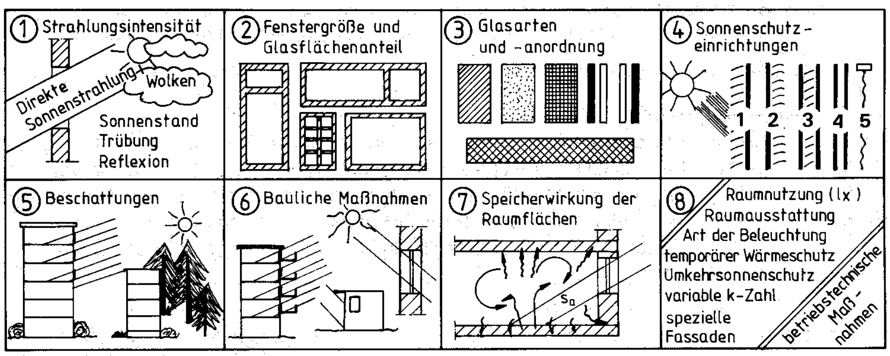
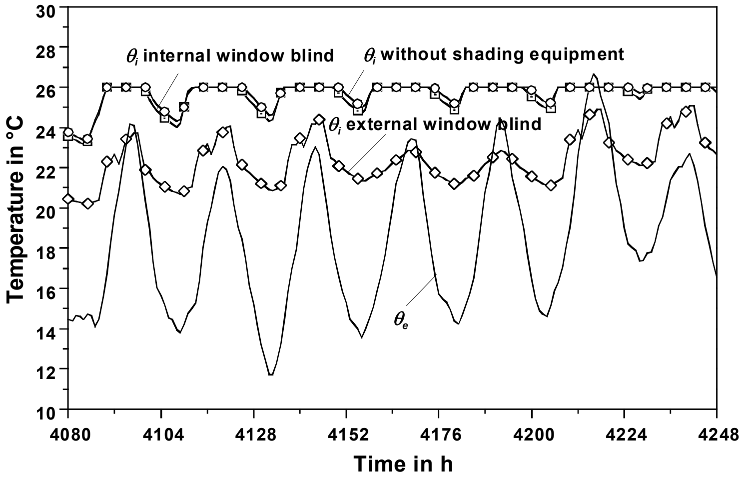


Abb. 7.24 Einflußgrößen auf Sonnenwärme durch Fenster

Shading by internal and external window blinds (θ_e ambient temperature, θ_i room temperature)



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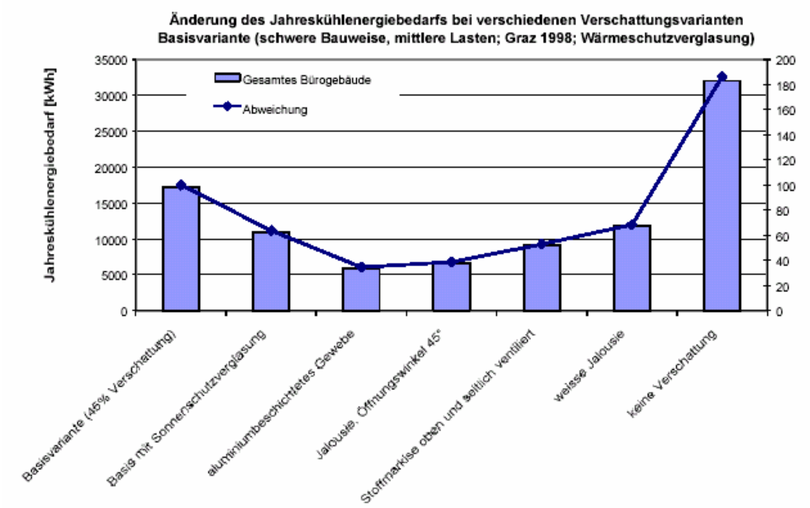
Cooling energy demand for different shading strategies in an office building



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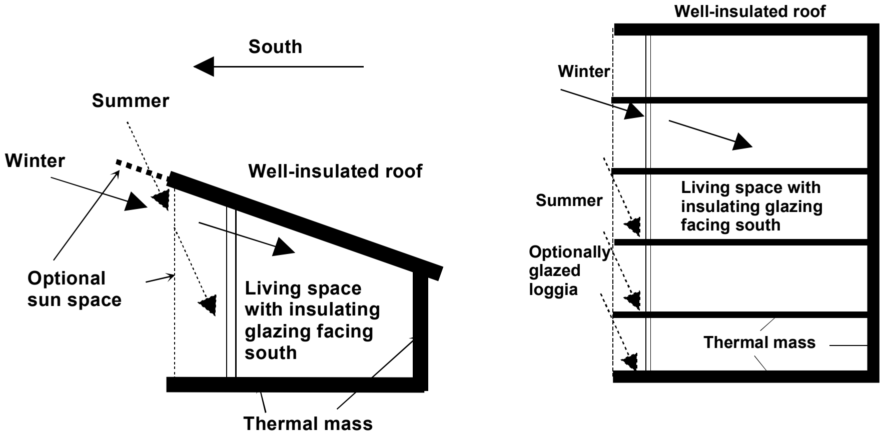
Shading of transparent building surfaces by roof overhangs (left: one family home, right: multiple families home)



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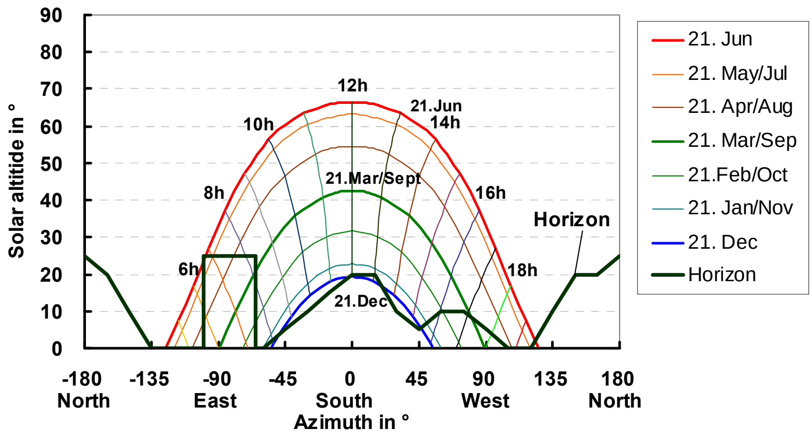
Solar position plot



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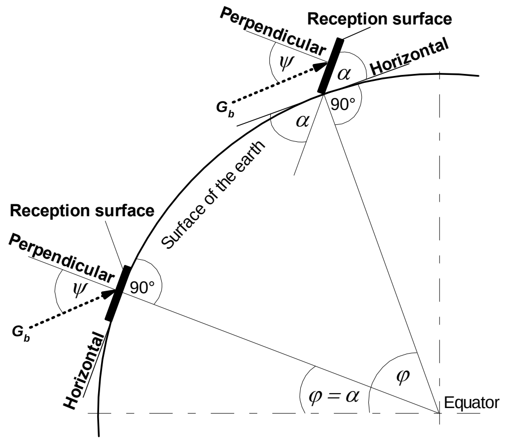
Geometrical interrelationship of solar radiation incident on tilted surfaces



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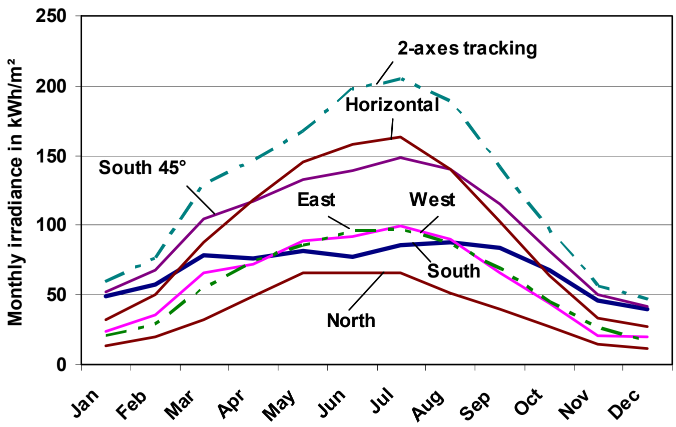
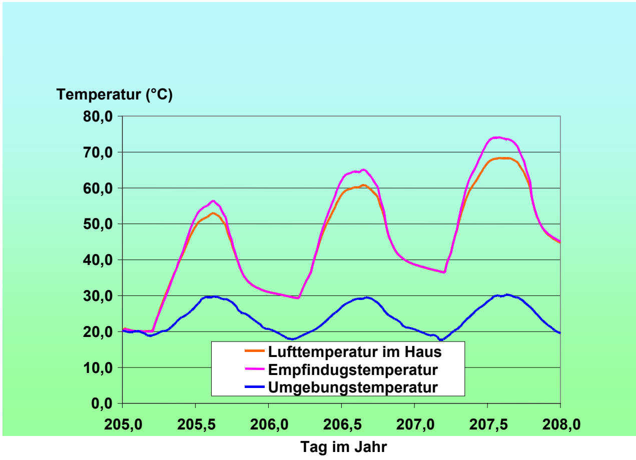
Global radiation incident on surfaces with various alignments in Central Europe (climate Graz/Austria, 47° latitude)



Summer Overheating in an office building (simulated)



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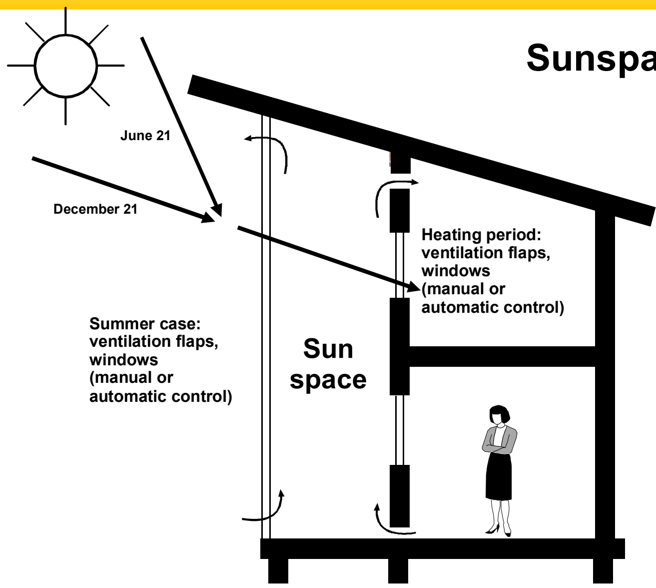
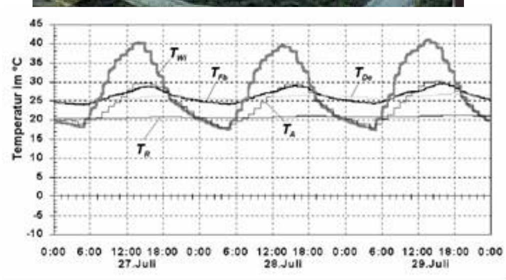
Sunspaces



Sunspace



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Low-energy lean multi family building

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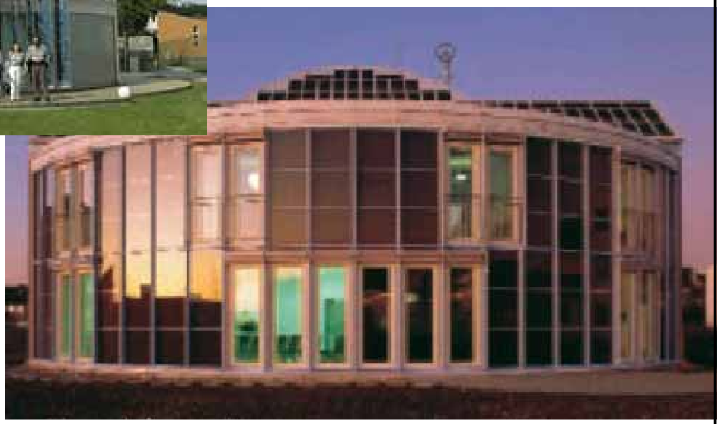
Solar houses



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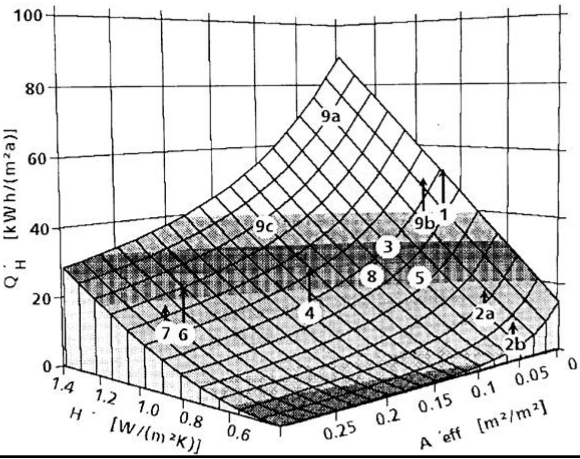
„Passive row houses“

„Solarhouses“ – „Passivhouses“

Gebäudekennfeld für ein Gebäude mittelschwerer Bauart und einigen realisierten Gebäuden: 7: Solarhaus Freiburg, 2: Passivhaus Kranichstein (a: Endhaus, b: Mittelhaus), Q´H: spezifischer Heizenergiebedarf (Voss, 1997)



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Biomass

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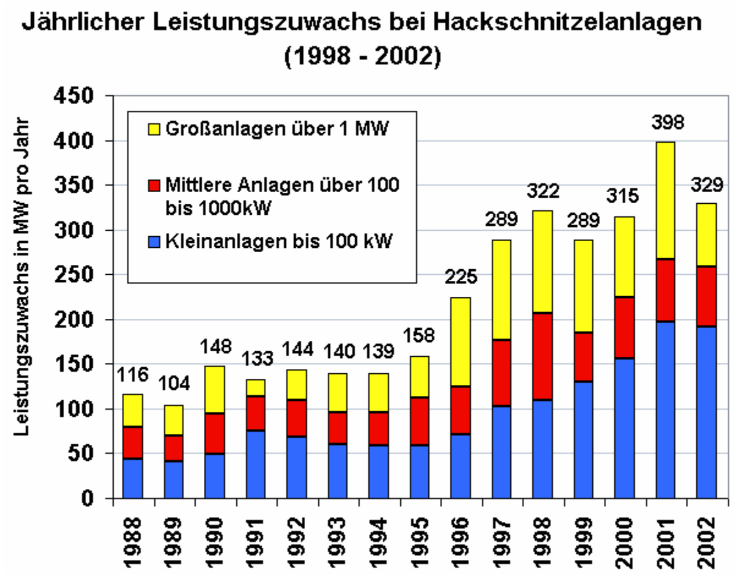

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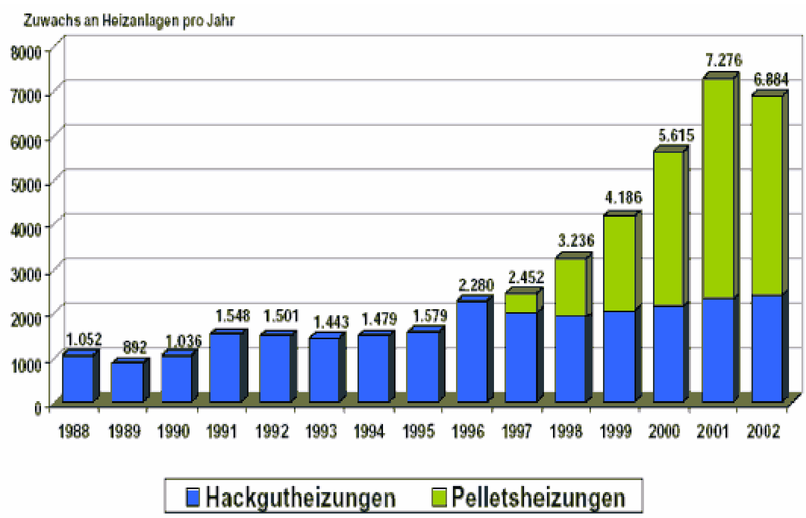
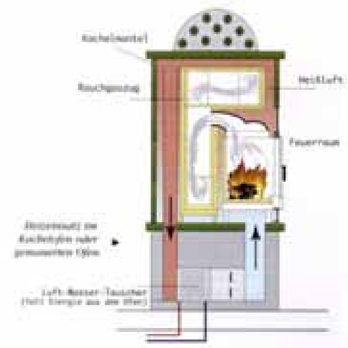
Yearly increase of biomass heating systems in Austria



„Kachelofen“



- Positioning that several rooms can be heated, with water HX inside a coupling to a water heating system can be done
- Efficiency about 60-70 %
- High startup emissions (cold burning chamber)

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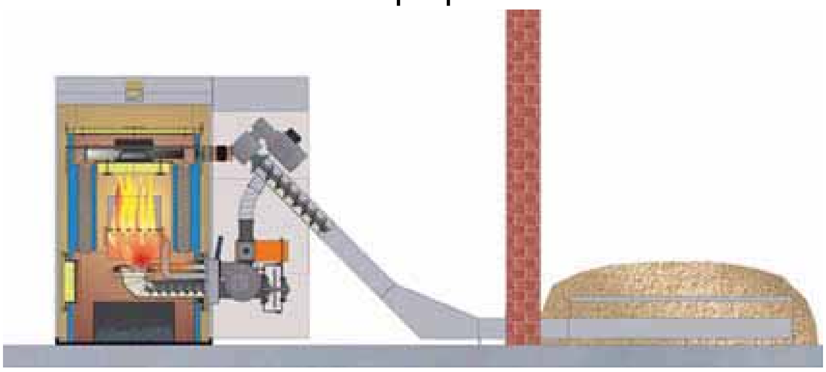
“Kaminofen”

- Positioning that several rooms can be heated, with water HX inside a coupling to a water heating system can be done
- Efficiency about 60-70 %
- High startup emissions (cold burning chamber)

Log wood burner with downward flame

- Logs and ash is transported autmomatically downwards
- Logs are dries before burned
- Burning chamber is NOT cooled

Automatic wood chips/pellets burner



- Similar maintenance a soil or gas burners
- Similar emissions as oil burner
- Slightly higher investment than oil burner
- Biomass store has to be reached yb the blowing tube of the truck

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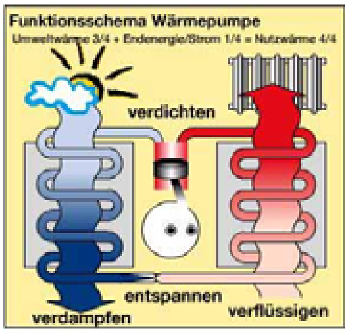
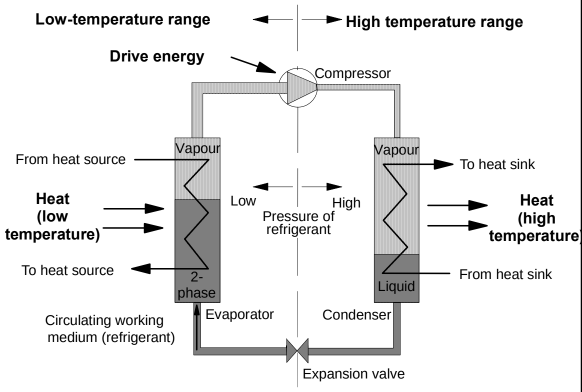
Heat pumps





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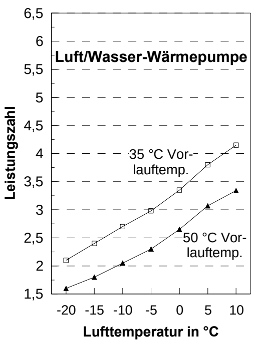
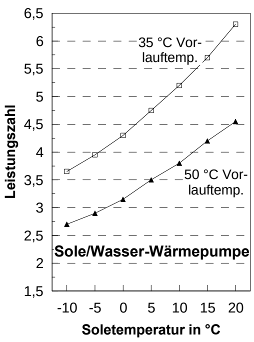
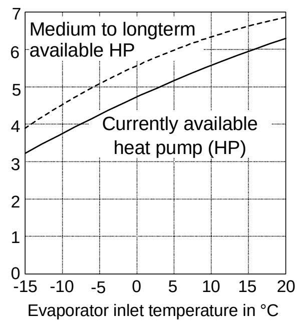
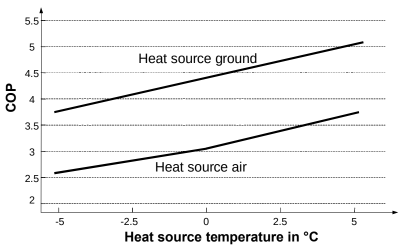
Heat pump COP and boundary conditions









Quelle: Kaltschmitt, Streicher, Wiese, 2006

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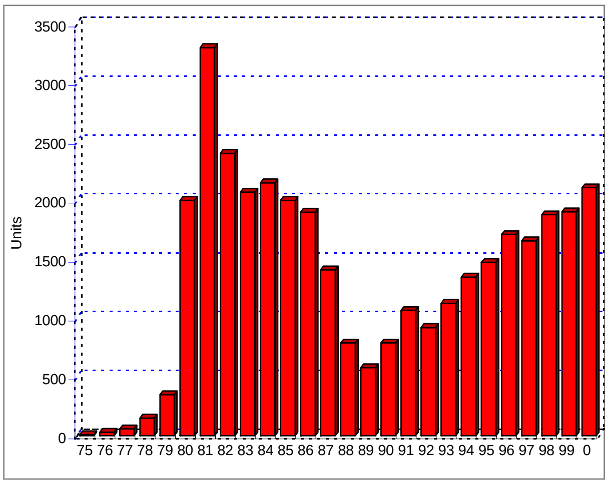
Space heating heat pumps in Austria



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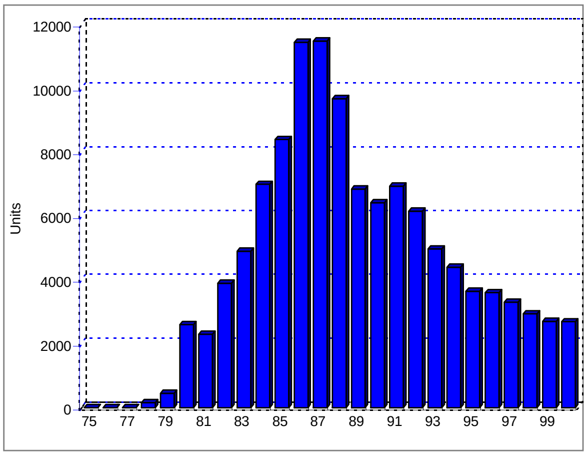
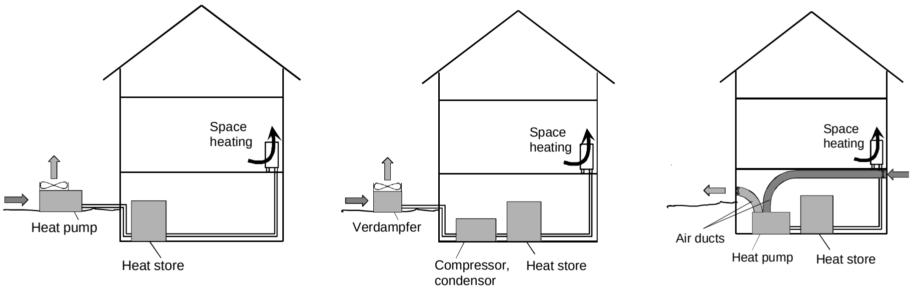
Domestic hot water heat pumps in Austria



Ambient air as heat source



Quelle: Kaltschmitt, Streicher, Wiese, 2006

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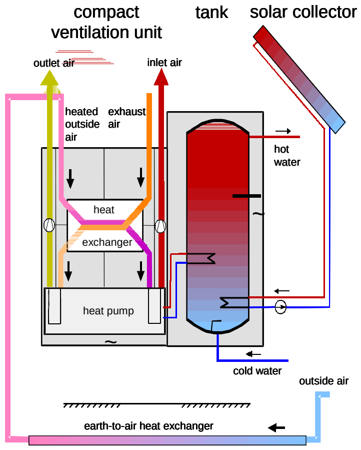
Compact heating and domestic hot water unit

- air-to-air heat recovery
- exhaust air heat pump
- storage
- solar collector
- earth-to-air heat exchanger



Source: Fraunhofer-Institut für Solare Energiesysteme ISE, 2000

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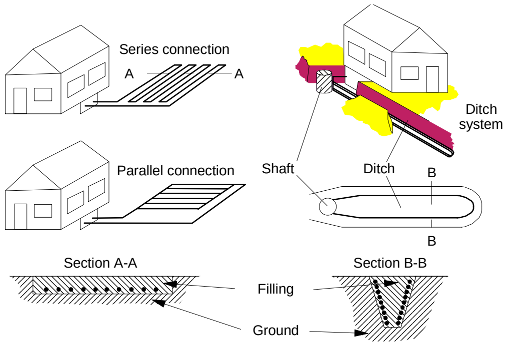

Ground as heat source

Type of soil	Withdrawn heat capacity
Dry, sandy soil	10 – 15 W/m^2
Humid, sandy soil	15 – 20 W/m^2
Dry loamy soil	20 – 25 W/m^2
Humid loamy soil	25 – 30 W/m^2
Water saturated sand/gravel	30 – 40 W/m^2

Quelle: Kaltschmitt, Streicher, Wiese, 2006, VDI 4640

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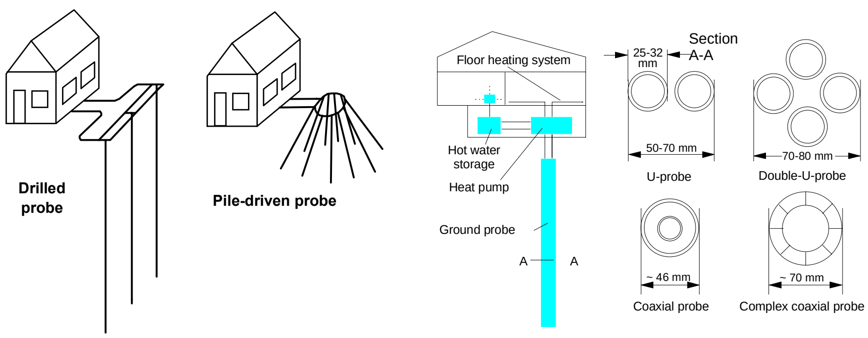
Ground as heat source



Quelle: Kaltschmitt, Streicher, Wiese, 2006

	1 800 h/a	2 400 h/a
General guidelines		
Bad subsoil (dry lose rocks)	25 W/m	20 W/m
Solid rock subsoil, water-saturated lose rock	60 W/m	50 W/m
Solid rock with high heat conductivity	84 W/m	70 W/m
Individual soils		
Gravel, sand, dry	< 25 W/m	< 20 W/m
Gravel, sand, carrying water	65 – 80 W/m	55 – 65 W/m
Gravel, sand, strong groundwater flow, for small systems.	80 – 100 W/m	80 – 100 W/m
Clay, loam, moist	35 – 50 W/m	30 – 40 W/m
Limestone (solid)	55 – 70 W/m	45 – 60 W/m
Sandstone	65 – 80 W/m	55 – 65 W/m
Acidic magmatites (e. g. granite)	65 – 85 W/m	55 – 70 W/m
Alkaline magmatites (e. g. basalt)	40 – 65 W/m	35 – 55 W/m
Gneiss	70 – 85 W/m	60 – 70 W/m

The requirement for using the table: only heat withdrawal (heating incl. hot water) takes place; length of the individual ground probes between 40 and 100 m; smallest space between two ground probes would be a minimum of 5 m for ground probe lengths of 40 to 50 m or at least 6 m for ground probes with lengths of over 50 to 100 m. Suitable ground probes are double-U probes with an individual tube diameter of 25 or 32 mm or coaxial probes with at least a diameter of 60 mm. The values given above can fluctuate considerably, depending on rock formations such as crevasses, foliation and weathering.

Quelle: Kaltschmitt, Streicher, Wiese, 2006, VDI 4640

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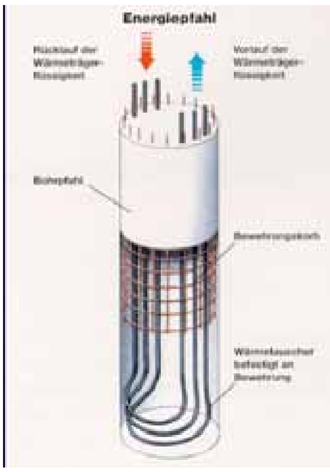
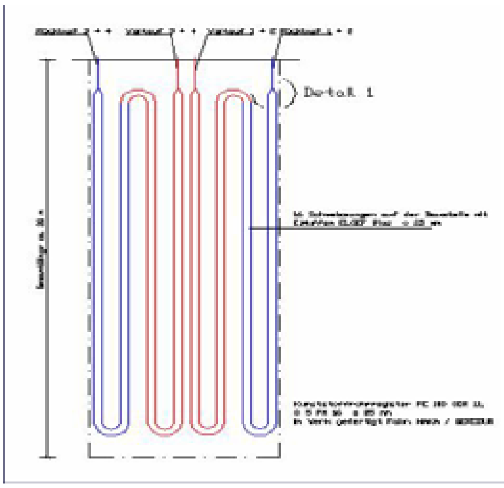
Energy poles





Quelle: Sauerwein, Bilfinger Berger,

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Vorgefertigter Bewehrungskorb

Energy poles

Verteilerstation Energiepfähle

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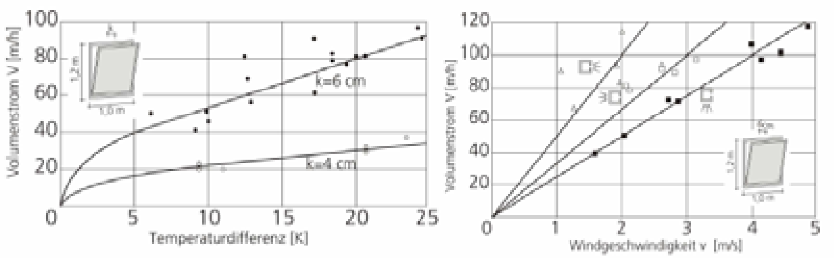
Natural ventilation

Quelle: Bohne, Skript techn. Gebäudeausrüstung, UNI-Hannover

Natural ventilation

Luftaustausch bei natürlicher Lüftung durch Temperaturdifferenz und Windgeschwindigkeit



Quelle: Bohne, Skript techn.
Gebäudeausrüstung, UNI-Hannover

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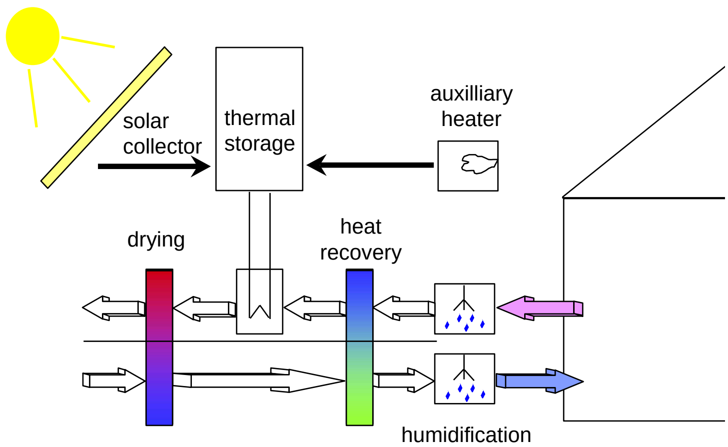
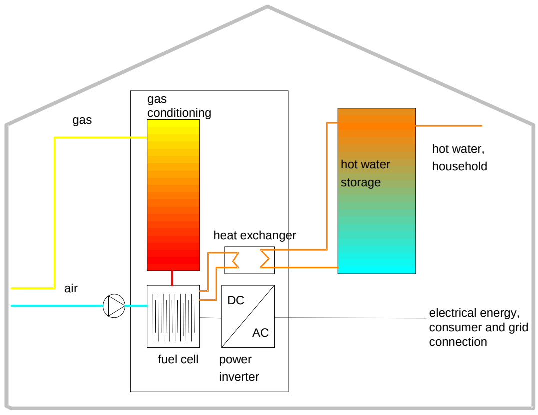
Solar dessicant cooling



Domestic fuel cell system



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New control strategies

Higher efficiency

Total energy supply concepts

Integration into the grids

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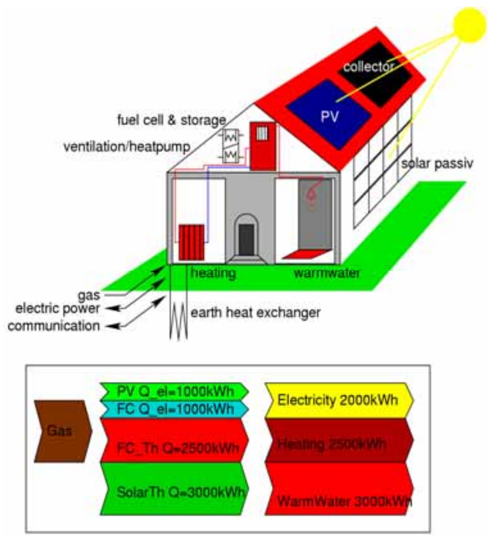
Concept of the domestic supply with fuel cells



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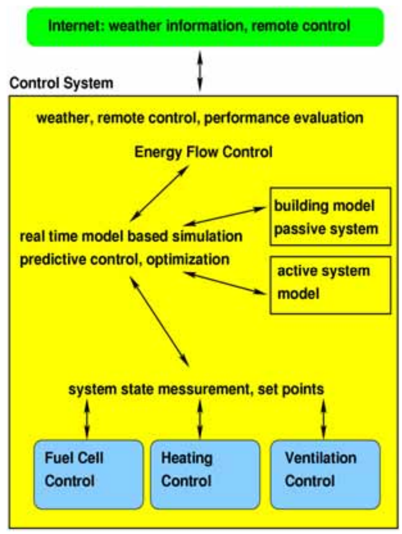
Control strategy



Summary

New materials enable new systems

New systems enable new energy concepts for buildings

New control stategies enable an optimized energy supply

Always under consideration of comfort and health, cost and economy and available resources