User Friendly Heating Systems for Low Energy and Passive Multi Family Buildings

Coordinator:
Ao. Univ.-Prof. Wolfgang Streicher
Institut für Wärmetechnik
Technische Universität Graz

Project partners

- **Institut für Wärmetechnik , TU Graz**
  Wolfgang Streicher, Richard Heimrath, Thomas Mach, Karin Schweyer
- **Arbeitsgemeinschaft ERNEUERBARE ENERGIE – AEE INTEC**
  Alexander Thür, Dagmar Jähnig, Irene Bergmann
- **Interuniversitäres Forschungszentrum für Technik, Arbeit und Kultur (IFZ)**
  Harald Rohracher, Jürgen Suschek-Berger
- **Energieinstitut Vorarlberg**
  Helmut Krapmeier

Partner Industry

- Drexel und Weiss, Energieeffiziente Haustechniksysteme GmbH
- Hexatherm Energietechnik GesmbH
- KWB Kraft & Wärme aus Biomasse GmbH
- Vaillant Ges.m.b.H.

Financed by:

Austrian Federal Ministry of Transportation, Innovation and Technology (BMVIT) in the research program frame of « Building of Tomorrow ».

Starting point

- **Low-Energy and Passive houses are becoming a kind of „Standard" in Austria and Germany.
(more and more also in multi family buildings)**
- **There is only one HVAC system, that is preferred for such buildings by now**
  - Air heating system with exhaust air heat recovery,
  - Exhaust air heat pump for air inlet and domestic hot water (DHW),
  - Ground coupled ground-air heat exchanger (optional)
  - Solar thermal collector for DHW (recommended)

Definitions

Passivehouse

Remainig space heat demand 15 kWh/m²a
Total end use energy demand 42 kWh/m²a
Total primary energy demand 120 kWh/m²a
(at 20°C room temperature, related to net area)

New definition 2003
Primary energy demand without electricity for domestic use (other than HVAC auxiliary) 40 kWh/m²a

Low energy buildings

No common definition,
space heat demand between 45 – 65 kWh/m²a.

Project goals

Pros and cons of different space heating systems for multi family buildings insulated with passive-house-level (air-air-water or ground coupled heat pump, biomass, fossil, centralized/decentralised, with or without exhaust air heat recovery taking)

- **Qualitative criteria (comfort, social acceptance, user friendliness', failure safeness**
- **End-use and primary energy demand (life cycle)**
- **$CO_{2\text{-equivalent}}$ emissions (life cycle)**
- **Heat delivery costs (VDI 2067)**
- **Fulfilling of user requirements (ventilation, temperature, internal gains)**
- **Reaction after increased ventilation or longer temperature setback in winter**

Methodology

Analysis of measurement of CEPHEUS projects and questionnaire data of 52 apartments (Gnigl, Kuchl, Egg, Gneis-Moos, Hörbranz)

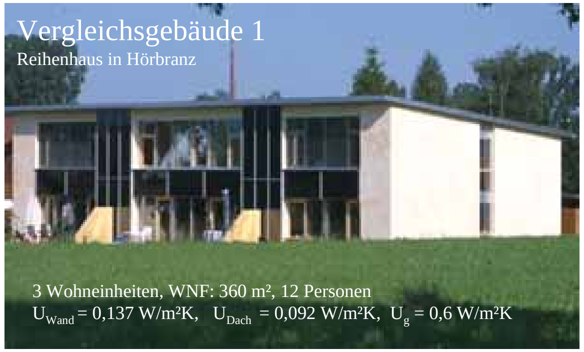
- User profiles (temperature, ventilation, occupancy, internal loads)
- Comfort needs
- Acceptance of different space heating concepts

Simulation of two measured buildings (Egg, Hörbranz)

- Calibration of the simulation tool and definition of reference buildings
- Analysis of sensitivities of input data (climate, user behavior, measurement accuracy etc.).

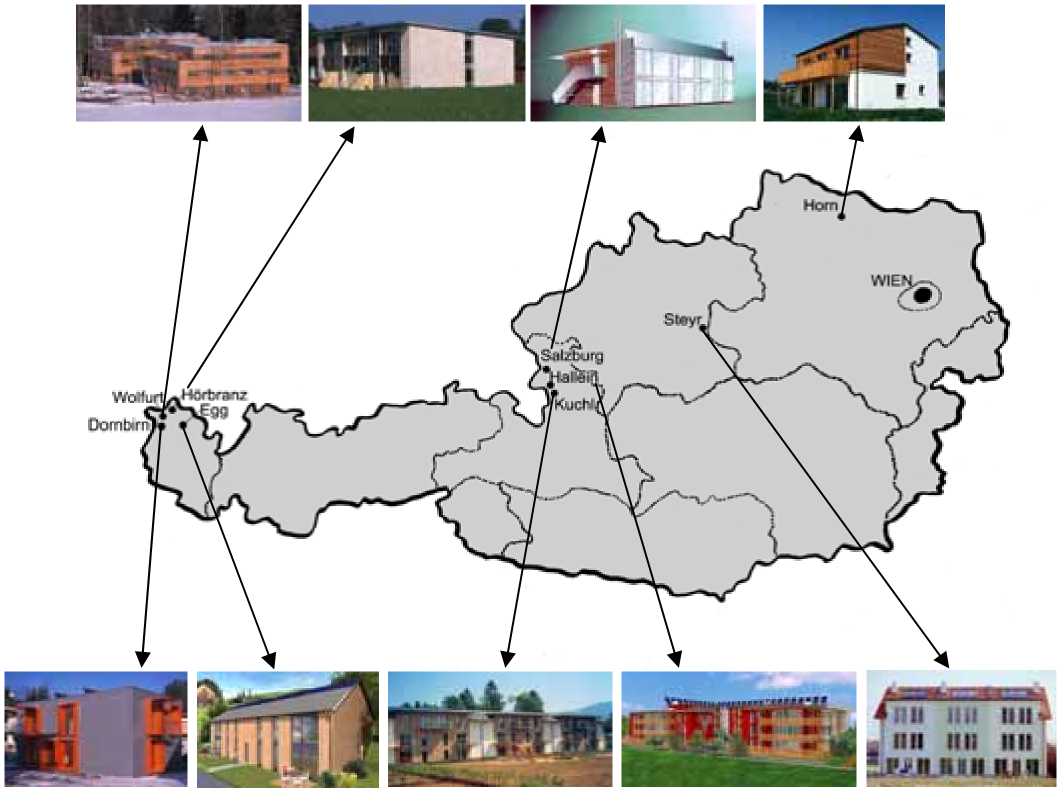
Methodology

Definition of two reference buildings (one was the 3 apartment building Hörbranz and the other a new defined 12 apartment building



Selection of four heating systems and simulation of different scenarios (standard, high/low heat load, response to special user behavior)

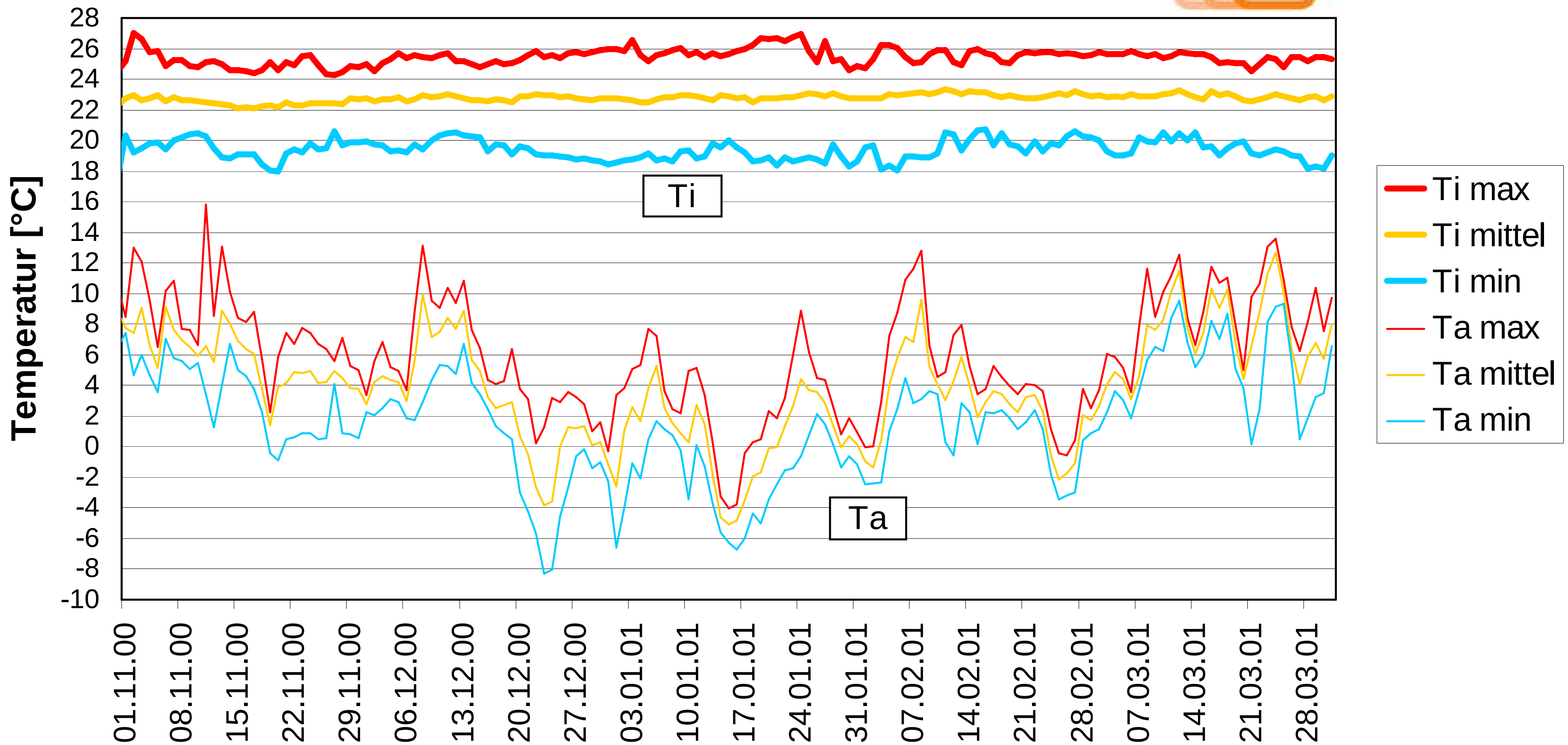
Projekt CEPHEUS



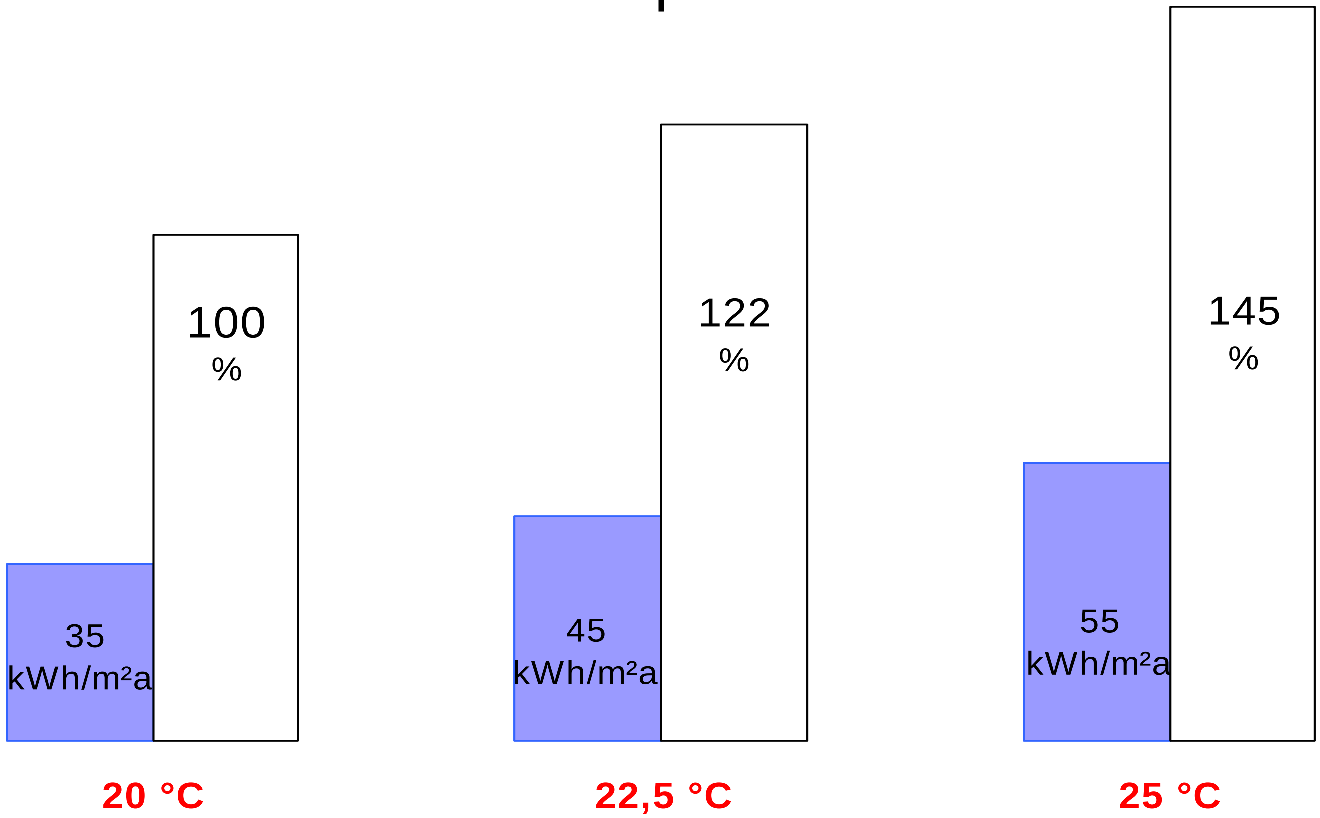
Austria:
9 Projects,
84 Apartements,
4 Provinces

CEPHEUS Hüllkurven

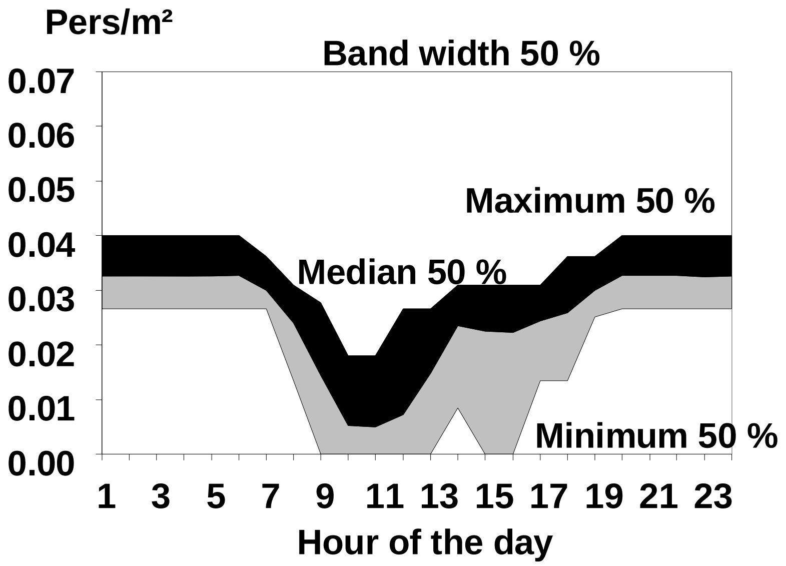
Taussen und Tinnen, Tageswerte



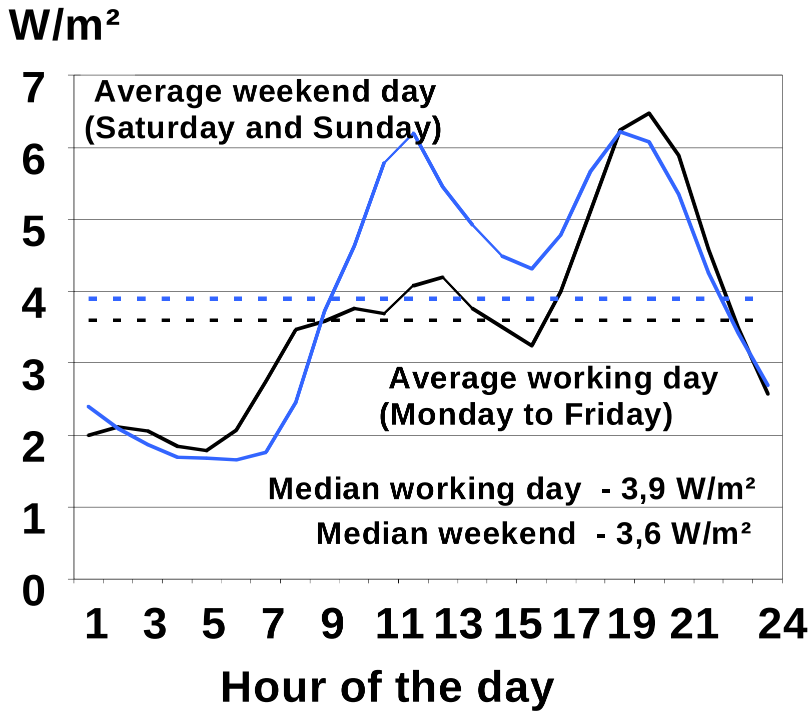
Dependency of space heating energy demand on room air temperature



Occupancy



Electricity demand other than HVAC-system



Extreme user scenarios

	High heat load	Standard heat load	Low heat load
Raum air setr temperature	25°C	22,5°C	20°C
Air exchange rate	0,8 h^{-1}	0,4 h^{-1}	0,2 h^{-1}
Internal load	2 Persons per flat, 3 kWh/d el. demand	4 Persons per flat, 7 kWh/d el. demand	6 Persons per flat, 15 kWh/d el. demand
DHW demand	50 l/(d Pers 60°C)	50 l/(d Pers 45°C)	30 l/(d Pers 45°C)

Influence of user behavior on the space heat demand

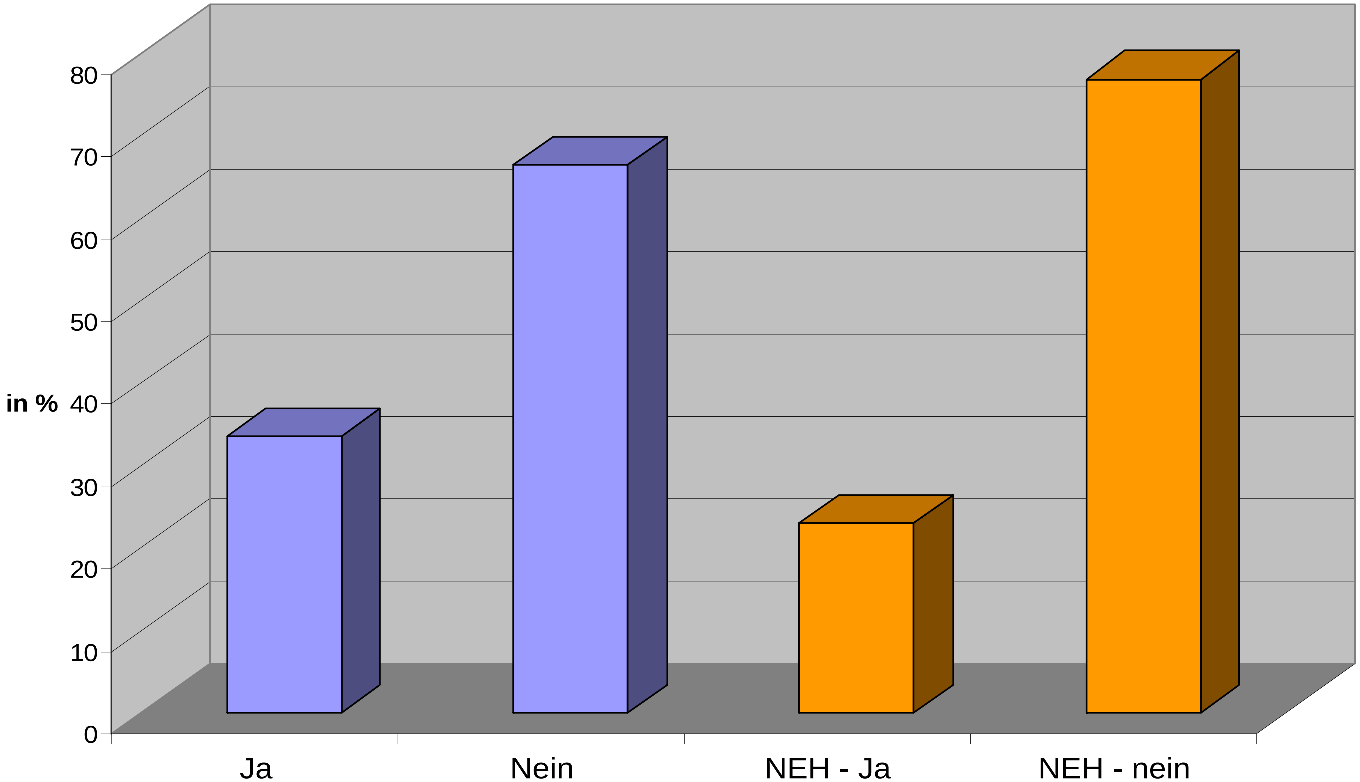
	Variation of user behaviour				Space heat demand		
	Electr. demand	People in apart m.	Room tem-perature	Air exchange rate	Space heat demand	Difference to base case	
	kWh/ (d app)		°C	[1/h]	kWh/(m² a)	kWh/ (m² a)	%
3 Ap base.	7	4	22,5	0.4	44.5	Base case	
3 Ap 20°C	7	4	20	0.4	34.9	-9.6	-22
3 Ap 25°C	7	4	25	0.4	54.8	+10.3	+23
3 Ap ex 1	3.5	2	25	0.8	100.7	+56.2	+126
3 Ap ex 2	15	6	20	0.2	11.6	-32.9	-74

Ap. : apartement

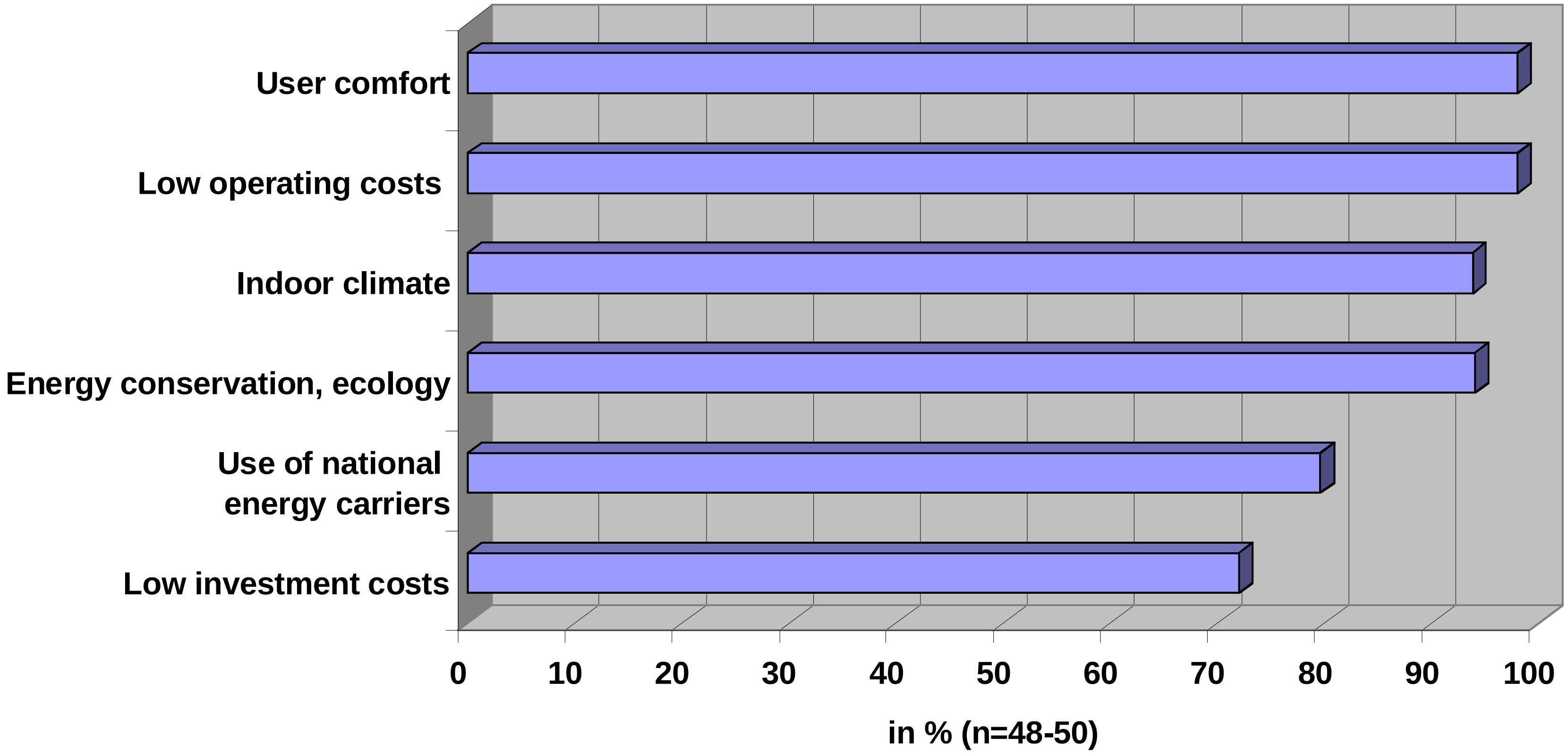
Knowledge of users in MFH

Quelle: Könighofer et al., 2001, n=467

Do you know which heating system is installed in your house ?

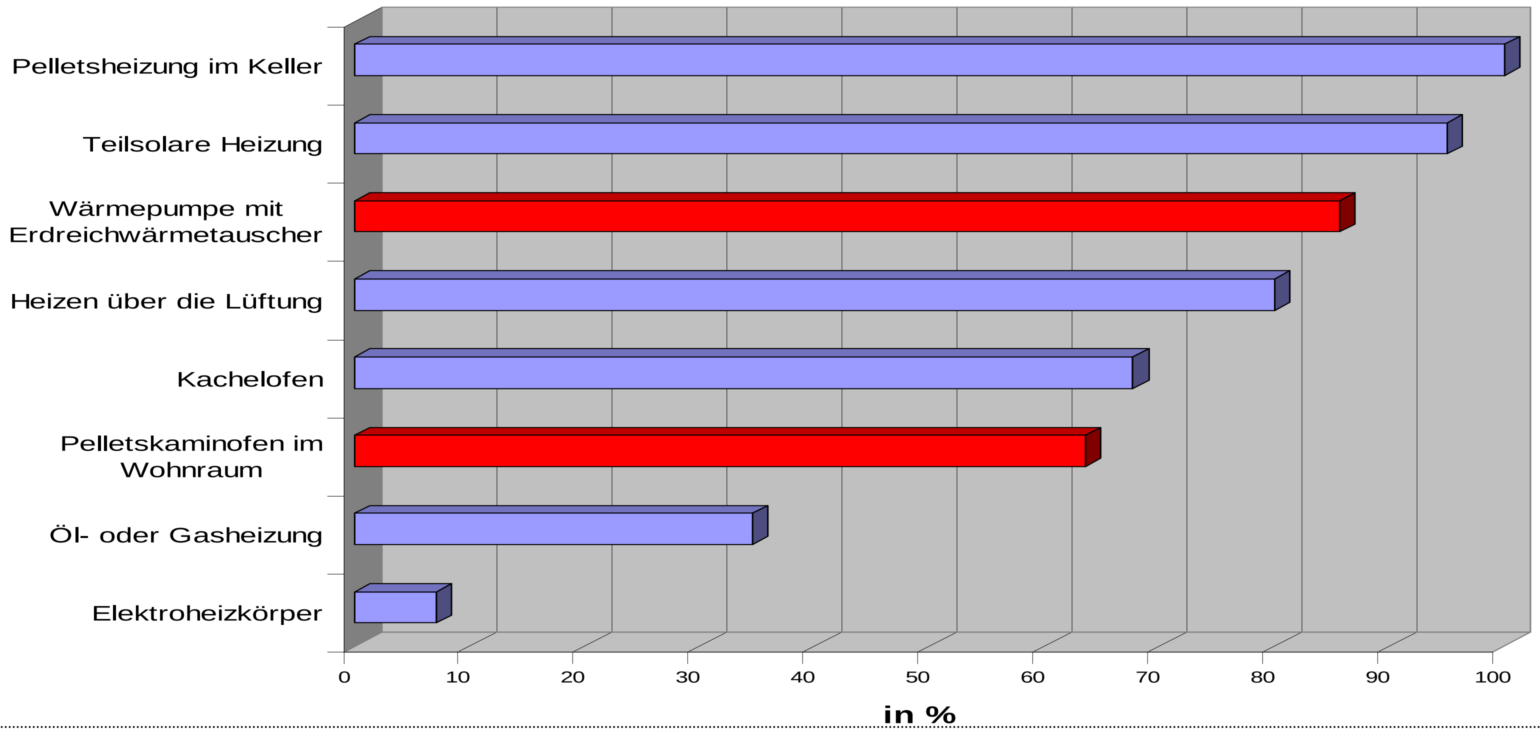


Importance of issues for the heating systems
(questionnaire to residents in multi family low-energy and passive houses)



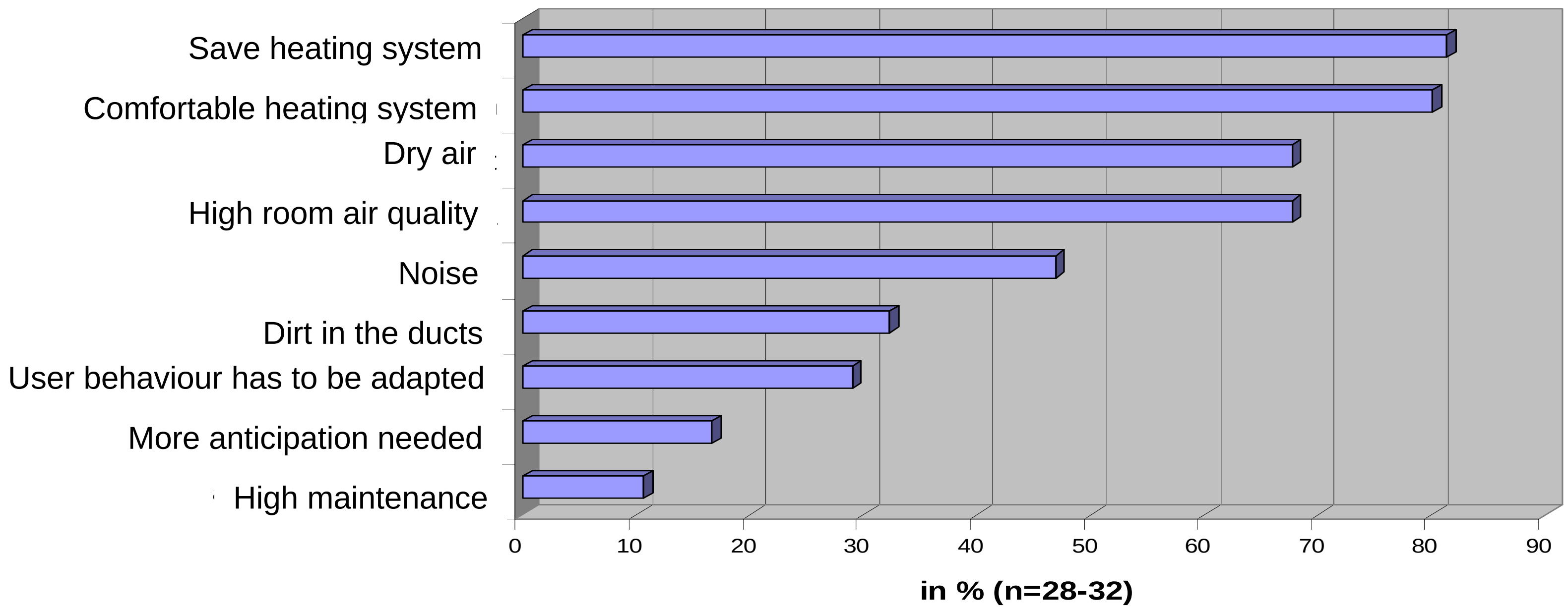
What kind if heating system do people want to have

Quelle: Streicher et. al. 2001, n=53



What is your impression of forced ventilation?

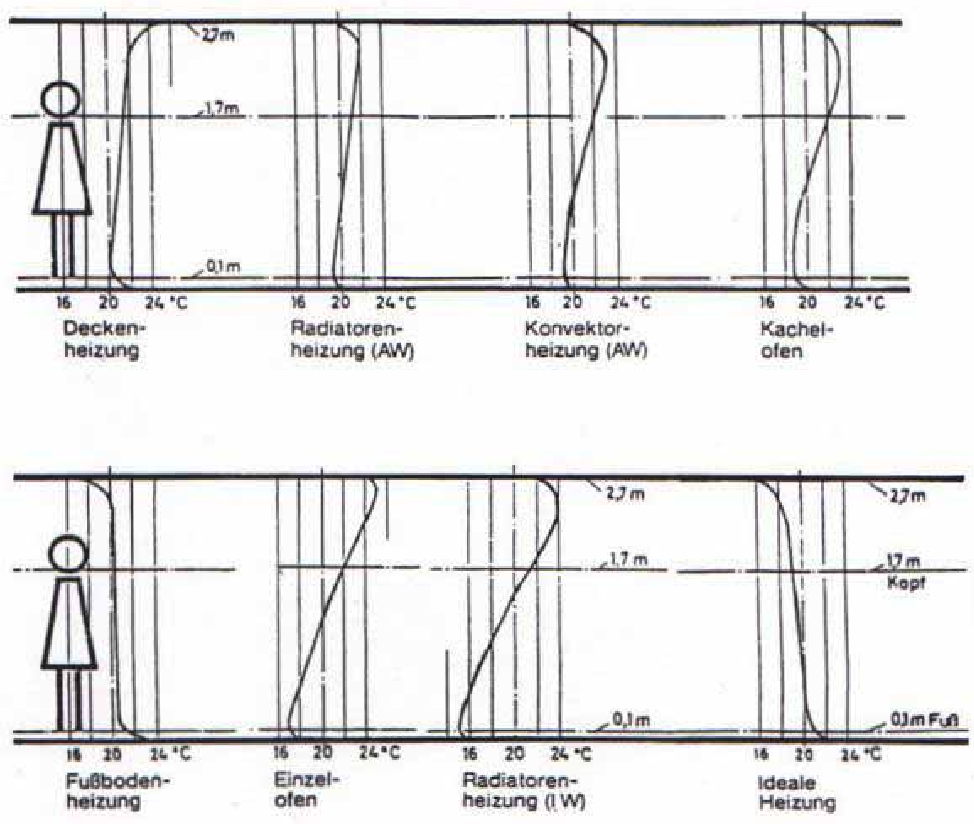
Quelle: Streicher et al. 2001, n=53

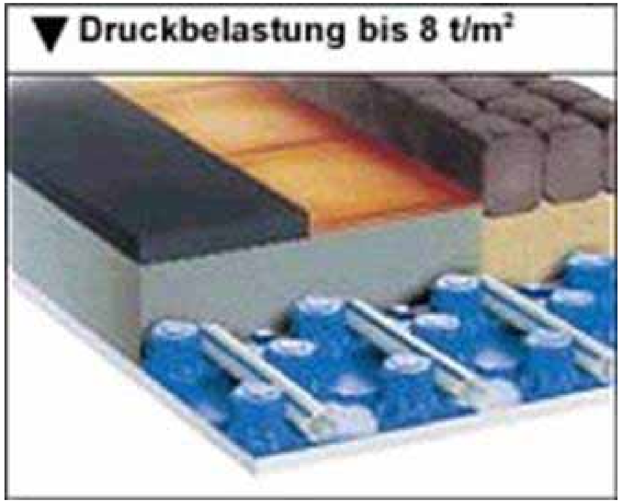


Heat delivery systems

	Air heating	Water based systems			
Space heating		Wall	Floor	Roof	Radiator
Space heating capacity (at T_{max})	10 $W/m^2_{living.ar.}$ add. to ventilation	200 $W/m^2_{Heatar.}$	80 $W/m^2_{Heatal.}$	40 $W/m^2_{Heatar.}$	1300 $W/m^2_{Heata.}$
T_{max} heating system	60 °C	50 °C	40 °C	35 °C	90 °C
Spec. heat delivery at 40°C forward temperature	5 $W/m^2_{living\ ar.}$. at n = 0,5 add. to ventilation	130 $_{Heatar}$	80 W/m^2_{Heatar}	40 $W/m^2_{Heatar.}$	530 W/m^2_{Heatar}
Heating without ventilation possible	No	Yes	Yes	Yes	Yes
Window ventilation possible	Yes	Yes	Yes	Yes	Yes
Heating during window ventilation	No	Yes	Yes	Yes	Yes
Noise	(No)	No	No	No	No
Space cooling					
Cooling summer (Air-ground hx,)	Yes	No	No	No	No
Night cooling summer (closed window)	Yes	No	No	No	No
Max. cooling capacity	3 $W/m^2_{linig\ ar.}$ at n = 0,5 add. to ventilation	50 $W/m^2_{cool\ ar.}$	20 $W/m^2_{cool\ ar.}$	80 $W/m^2_{cool\ ar.}$	negligible

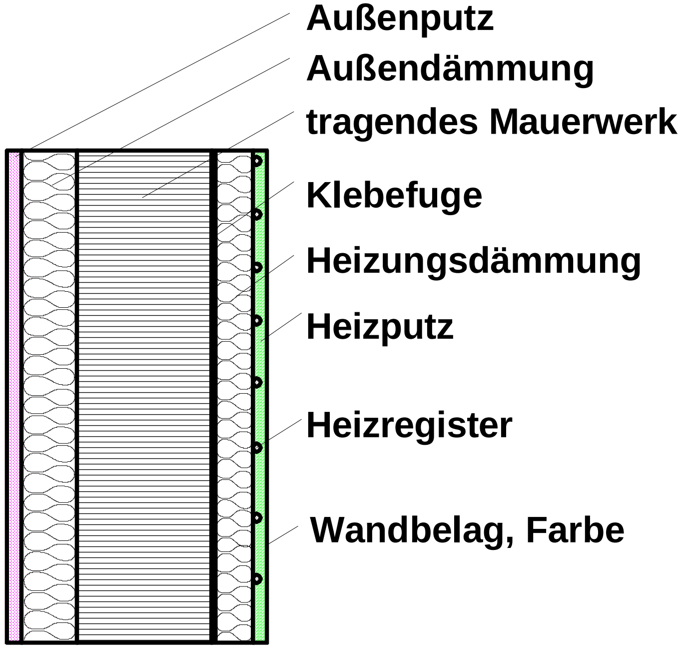
Temperature distribution for different heat delivery systems




Druckbelastung bis 8 t/m²

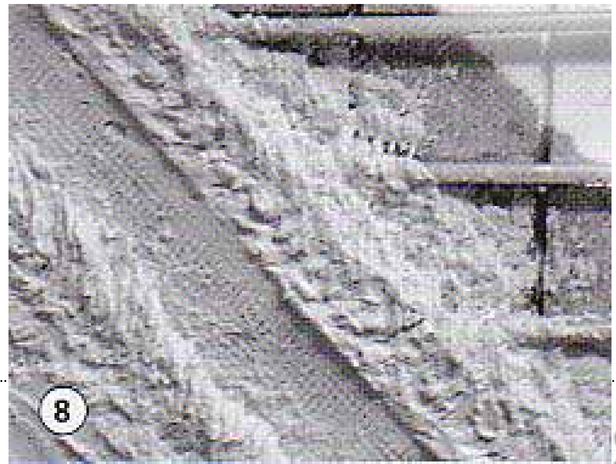
Wall Heating

Aufbau einer Wandheizung



Dry mounting

Wet mounting



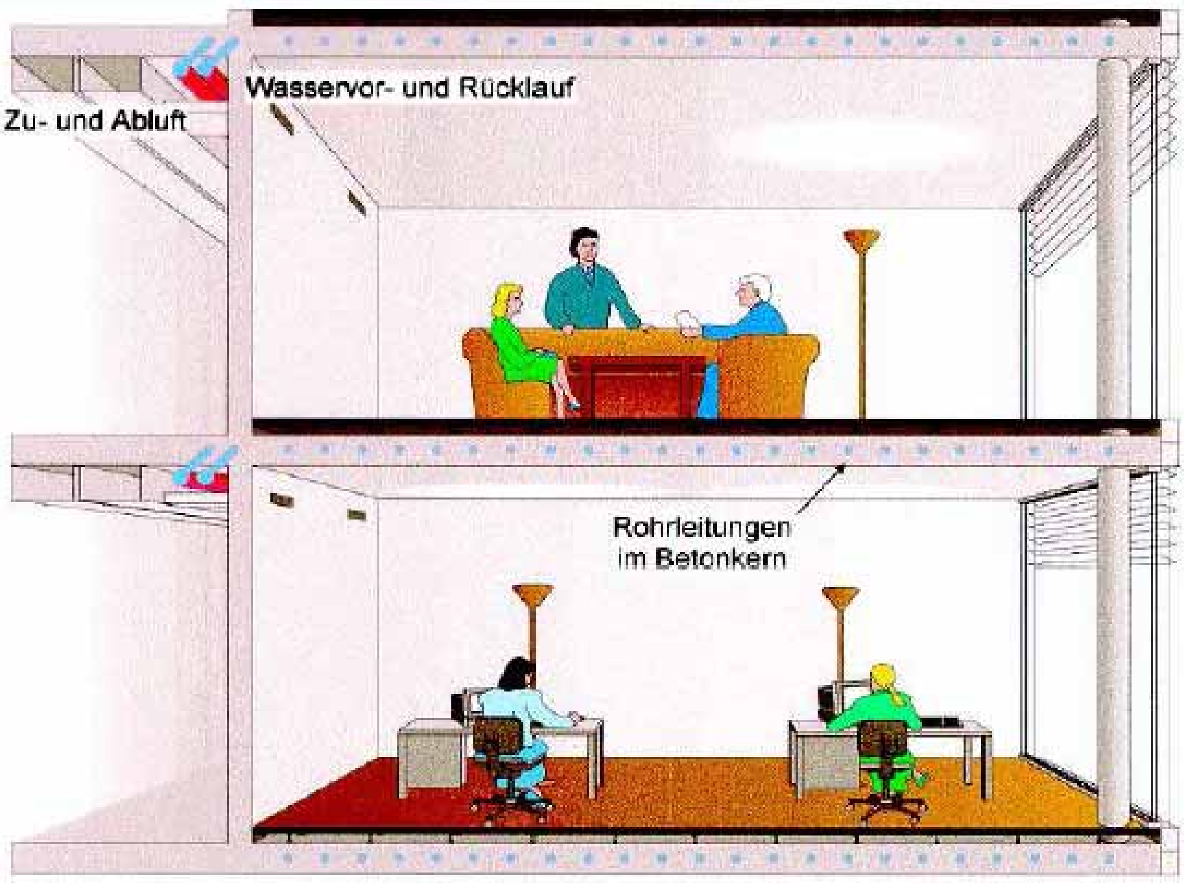
Ceiling heating

Abgehängte Decke

Dry mounting

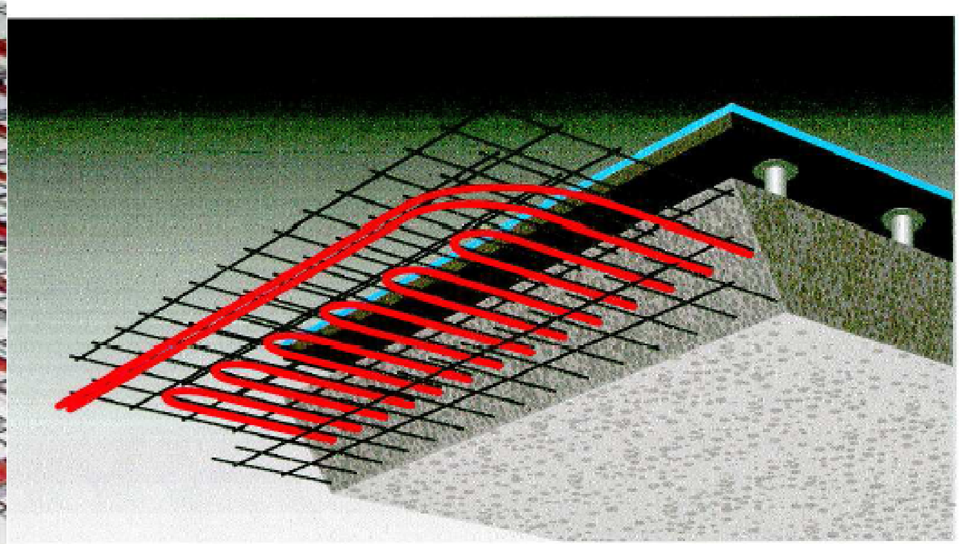
Wet mounting

Acivated layers



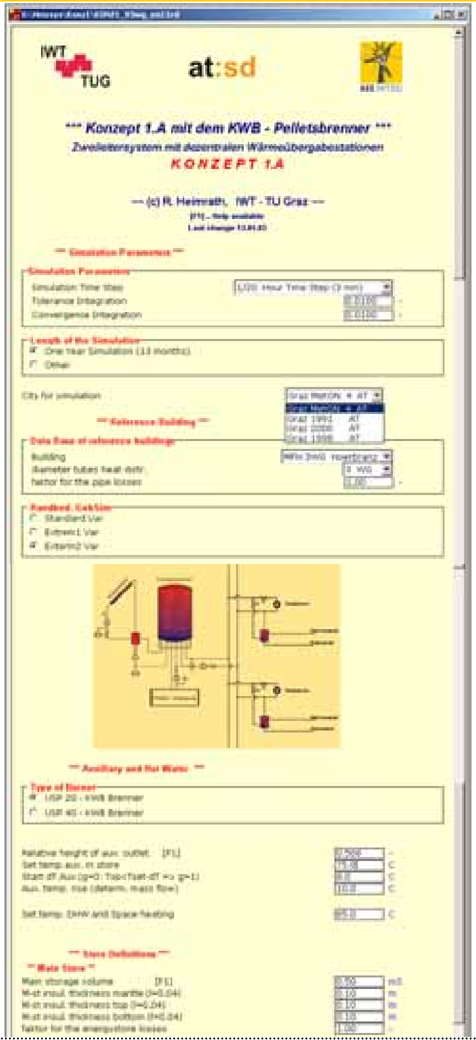
Activated concrete layers

Bewehrungsaufbau mit Rohrregister



Other aspects for space heating systems

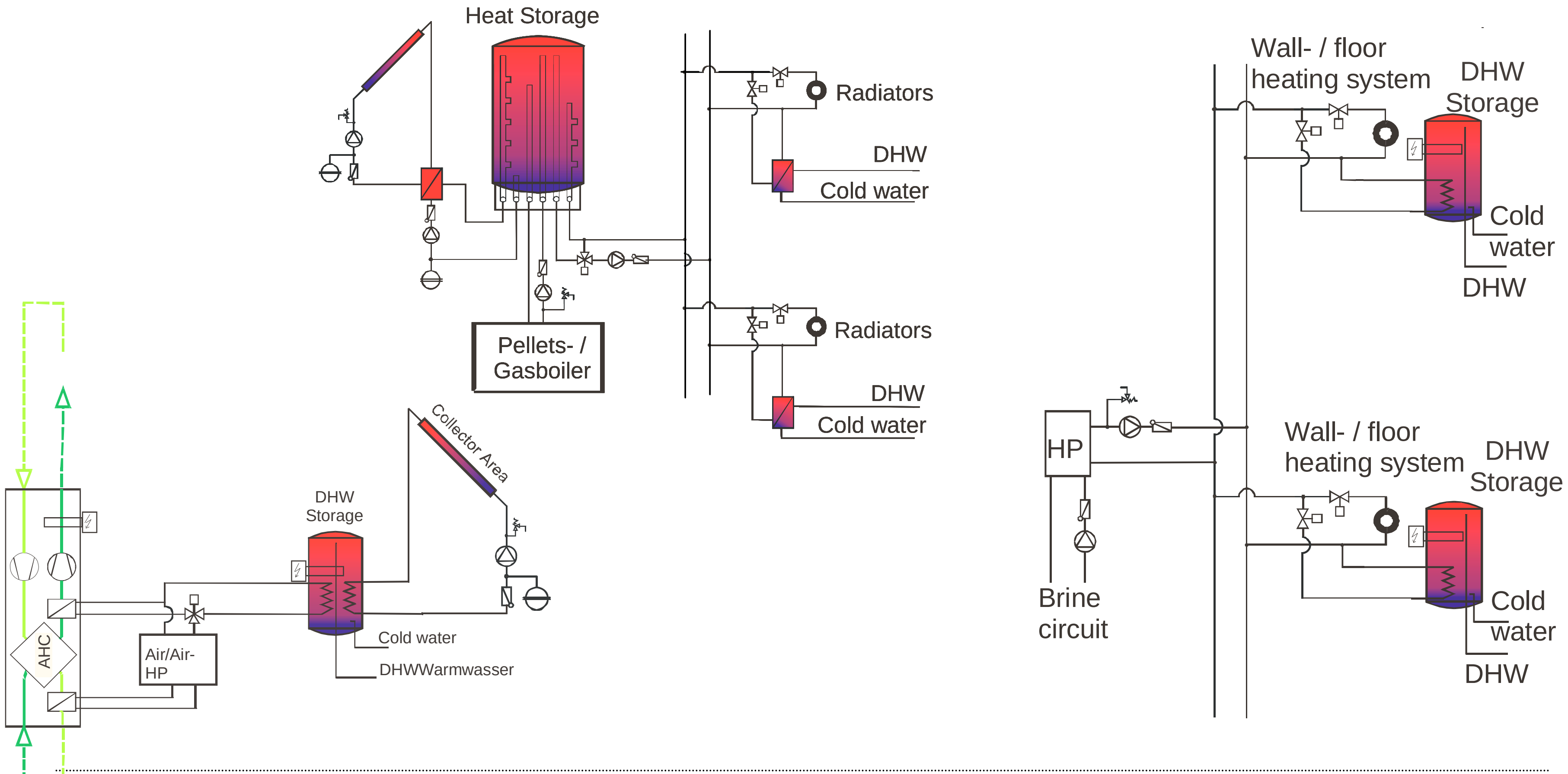
- Forced ventilation can be seen positive (always fresh air available) or negative (I am forced to ...)
- Are boilers available in the needed capacity range.
- Space demand of the systems
- Possibility to perform cooling in summer
- Failure safety at installation and operation
- Planners and installers systems knowledge available



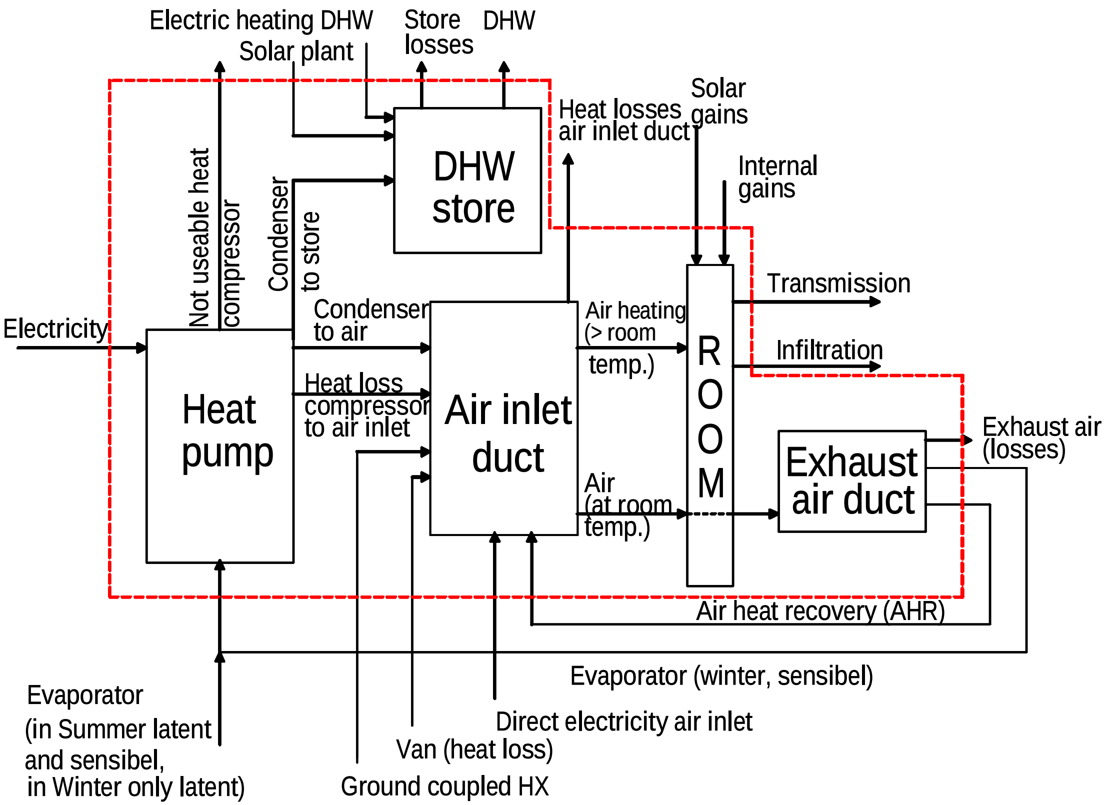
Simulation of 4 selected space heating systems in TRNSYS

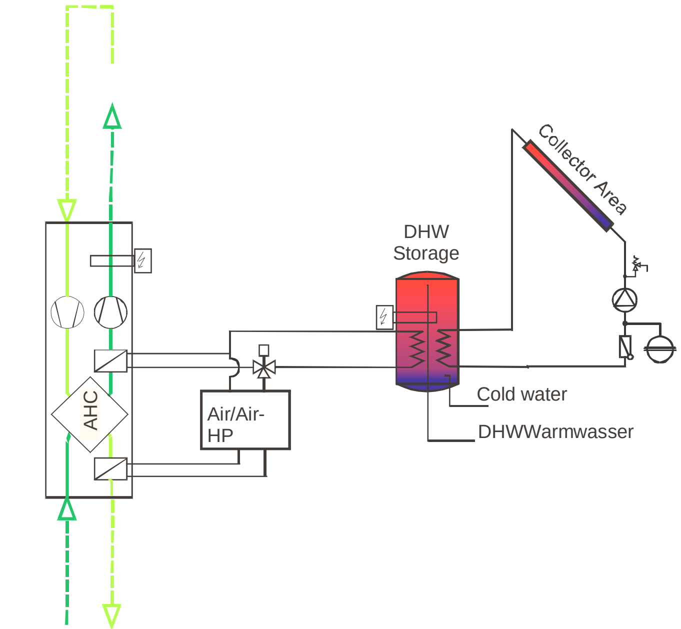
- In both reference buildings
- With/without solar thermal plant
- User behavior (standrad and two extremes)
- Reaction to special user behavior (leave windows open in winter, heating up after temperature setback in winter over 14 days)

Detailed simulation of 4 heating systems with TRNSYS



Evaluated energy flow for Air-Air-Water Heat Pump system

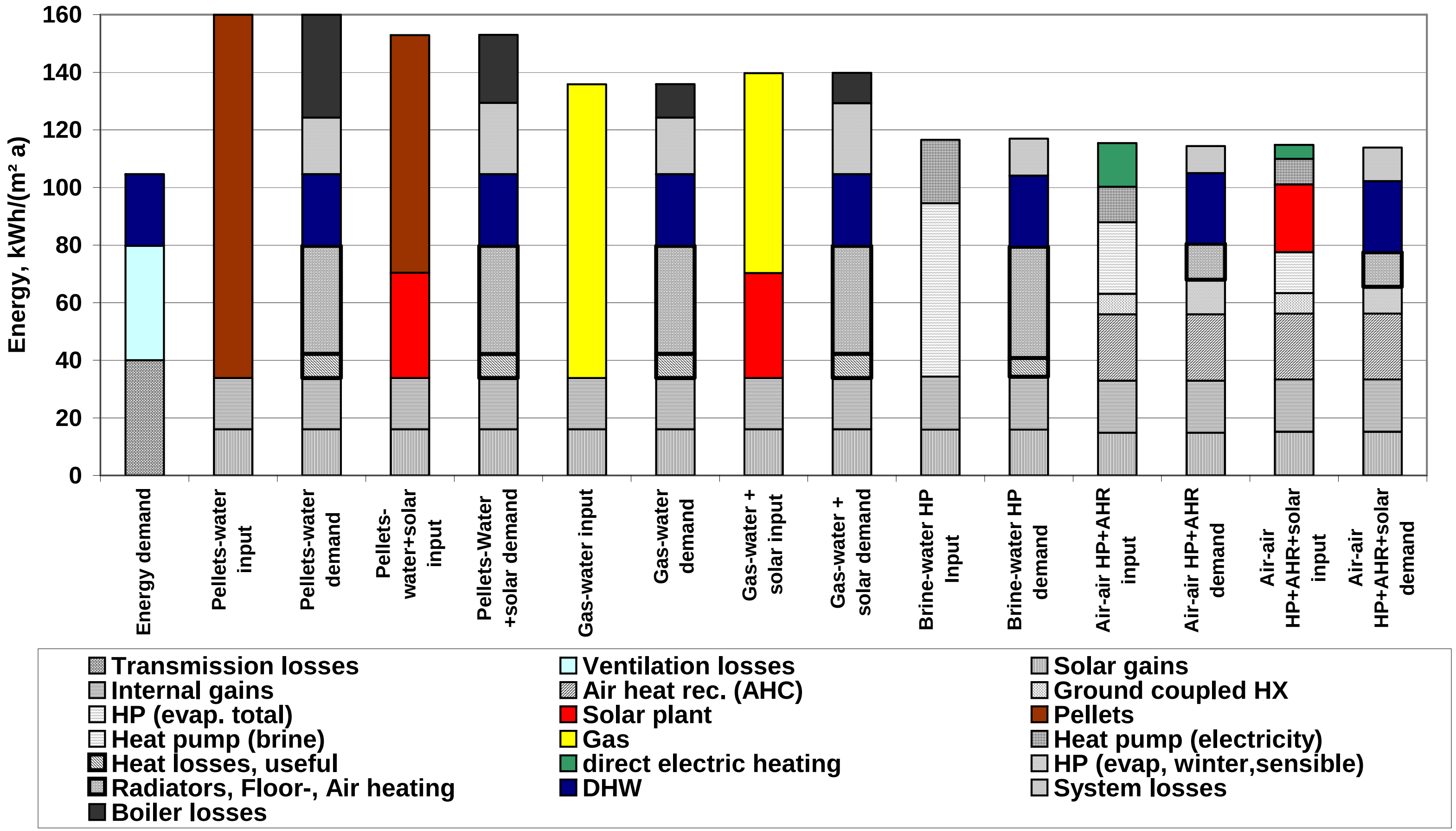




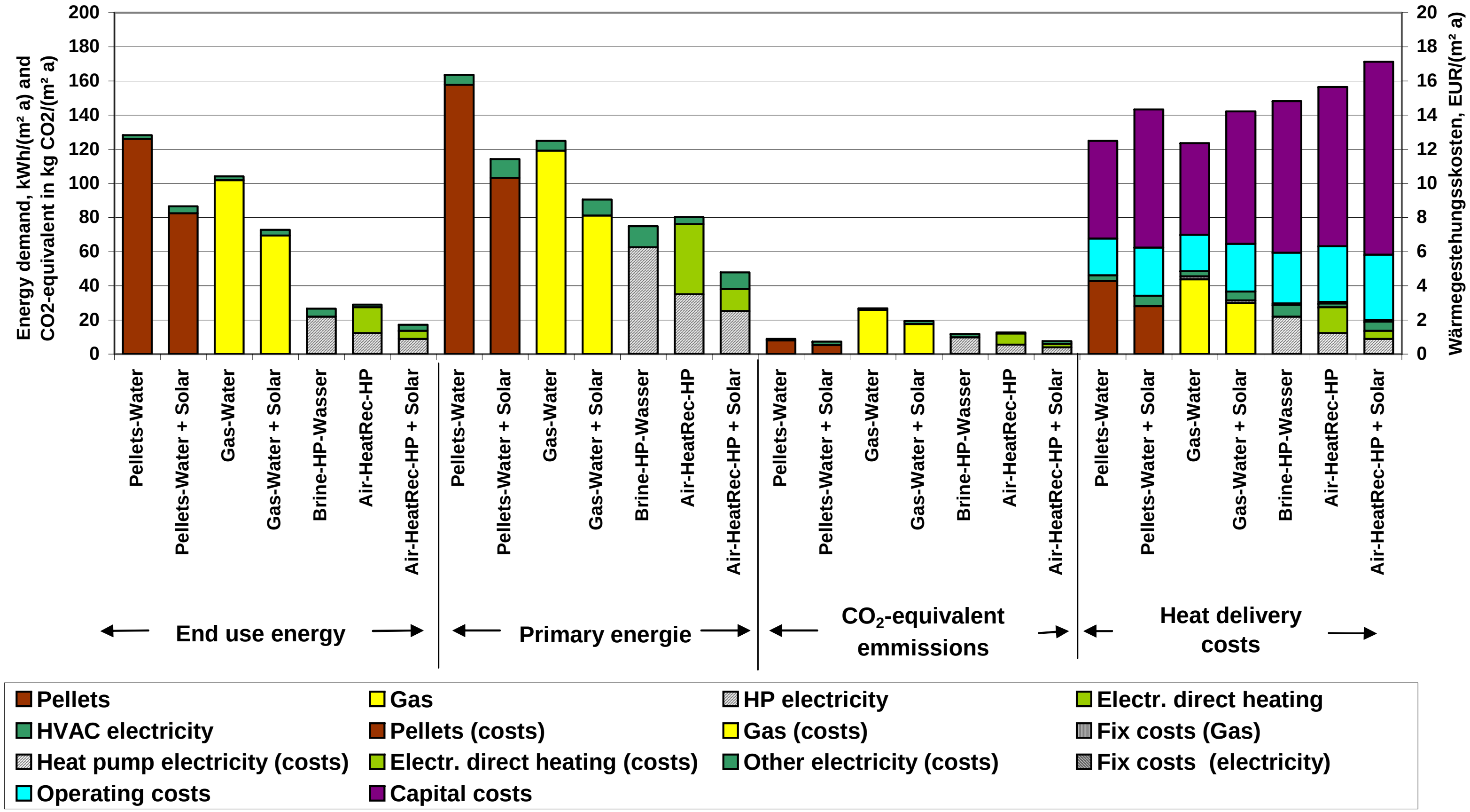
Comparison of the 4 systems by

- End-use energy demand
- Primary energy demand
- $CO_{2\text{-equivalent}}$ emissions
  (Gemis and other literature)
- Heat delivery costs (VDI 2067, operating energy demand from simulation, costs from literature and offers)
- Satisfaction of user demand (ventilation, temperature, internal gains)
- Reaction to special user behavior (leave windows open in winter, heating up after temperature setback in winter over 14 days)

Energy balance - comparison of all systems (base case, 3 flats)



End-use and Primary Energie Demand, CO2-equivalent Emmissions and Heat Delivery Costs
Comparison of all Systems (Base Case, 3 Flats)



Reaction to special user behavior

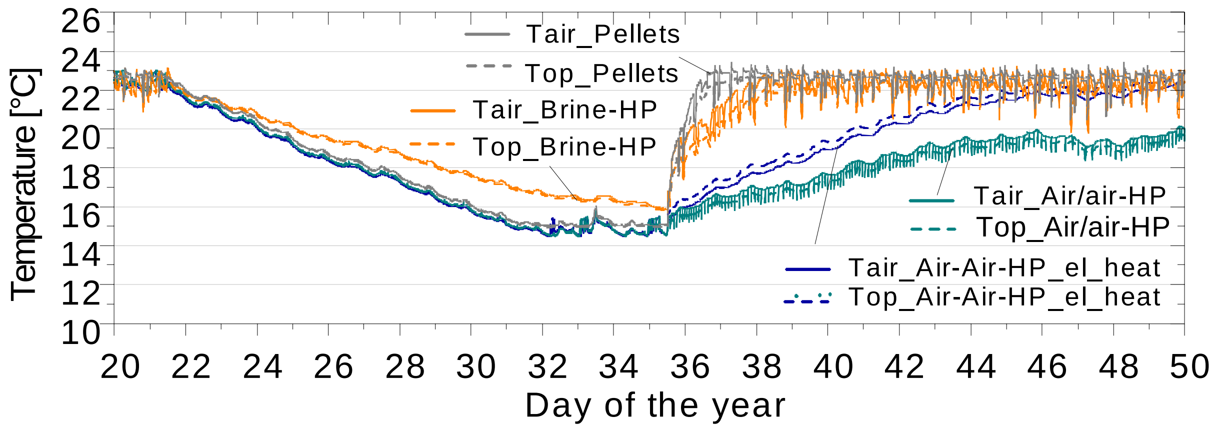
Cold winter period:

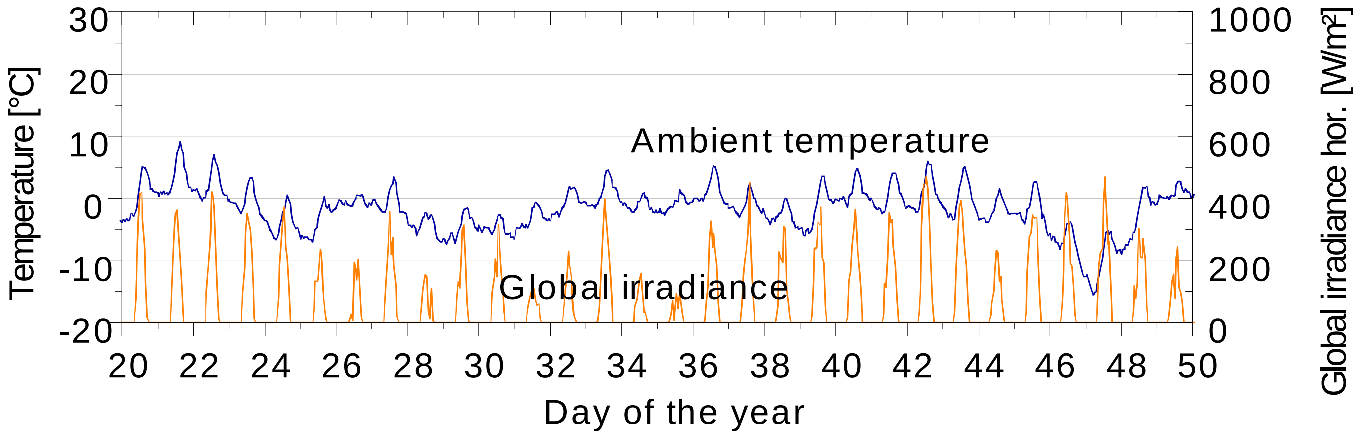
- 4 hours of high ventilation through windows
- Reheating to 22°C after 14 days temperature setback to 15°C

Statistics on

- Room air temperature,
- Room air humidity
- Heat load

14 days temperature setback





Summary of quantitative and qualitative criteria (3 Ap.)

		PwoS	PwS	GwoS	GwS	GHP	AirwoS	Air wS
Standard scenario								
Space heat demand	kWh/m²a	45,9	45,9	45,9	45,9	45,1	48,6	48,1
DHW energy demand	kWh/m²a	24,9	24,9	24,9	24,9	24,9	24,9	24,9
End use energy demand								
Pellets/Gas	kWh/m²a	126	82,5	102	69,4			
Electricity heating system	kWh/m²a					22,0	27,5	13,7
Auxiliary electricity for HVAC	kWh/m²a	2,2	4,1	2,1	3,4	4,6	1,5	3,6
Primary energy demand	kWh/m²a	163	114	125	91	75	80	45
$CO_{2\text{-equivalent}}$-Emissions	kg/m²a	8,9	7,3	26,8	19,4	11,9	12,7	7,6
Heat delivery costs VDI 2067	EUR/m²a	12,5	14,3	12,4	14,2	14,8	15,6	17,1
Variation of room temp. at heating	°C	±0,3	±0,3	±0,3	±0,3	±0,5	±0,4	±0,4
Temp. recovery after 4 h winter vent.	h	3	3	3	3	6	18	18
Temp recov. 14 winter days temp 15°C	d	1	1	1	1	3	9	9
Extreme scenario high heat load								
Space heat demand	kWh/m²a	101	101	101	101	101	101	101
Heat demand not covered	kWh/m²a	5,1	4,6	5,1	5,0	8,2	17,7	19,8
Heat delivery costs VDI 2067	EUR/m²a	15,5	17,3	15,4	17,2	17,4	19,2	21,3
Extreme scenario low heat load								
Space heta load	kWh/m²a	13,8	13,8	13,8	13,8	15,2	15,2	15,2
Heat delivery costs VDI 2067	EUR/m²a	10,7	12,8	10,5	12,5	13,8	14,8	16,3

Conclusion

- All systems analyzed are suitable for the reference buildings
- The air-air-water heat pump system has the lowest energy demand when coupled to a solar plant (otherwise similar to brine water heat pump) but the highest costs (it includes as only system the mechanical ventilation system)
- The lowest CO_2-equivalent emissions has the pellets systems closely followed by the air-air-water heat pump system coupled to a solar plant
- The cheapest system is the centralized gas burner system closely followed by the pellets system
- The air-air-water heat pump system may has problems for extreme user behavior and reheating in cold winter periods due to its limited heating capacity (air exchange rate 0.5 h^{-1}, max 50°C inlet temperature => 13.5 W/m^2). A small (el.?) furnace can help significantly