Herrick Laboratories PURDUE UNIVERSITY

2014 Purdue Conferences
Compressor Engineering
Refrigeration and Air Conditioning
High Performance Buildings

Energy Conservation Potential by Optimization of Air Flow Rate of Mechanical Ventilation

HLK STUTTGART

Dipl.-Ing. Bing Gu

Dipl.-Ing. Joerg Schmid

Prof. Dr.-Ing. Michael Schmidt

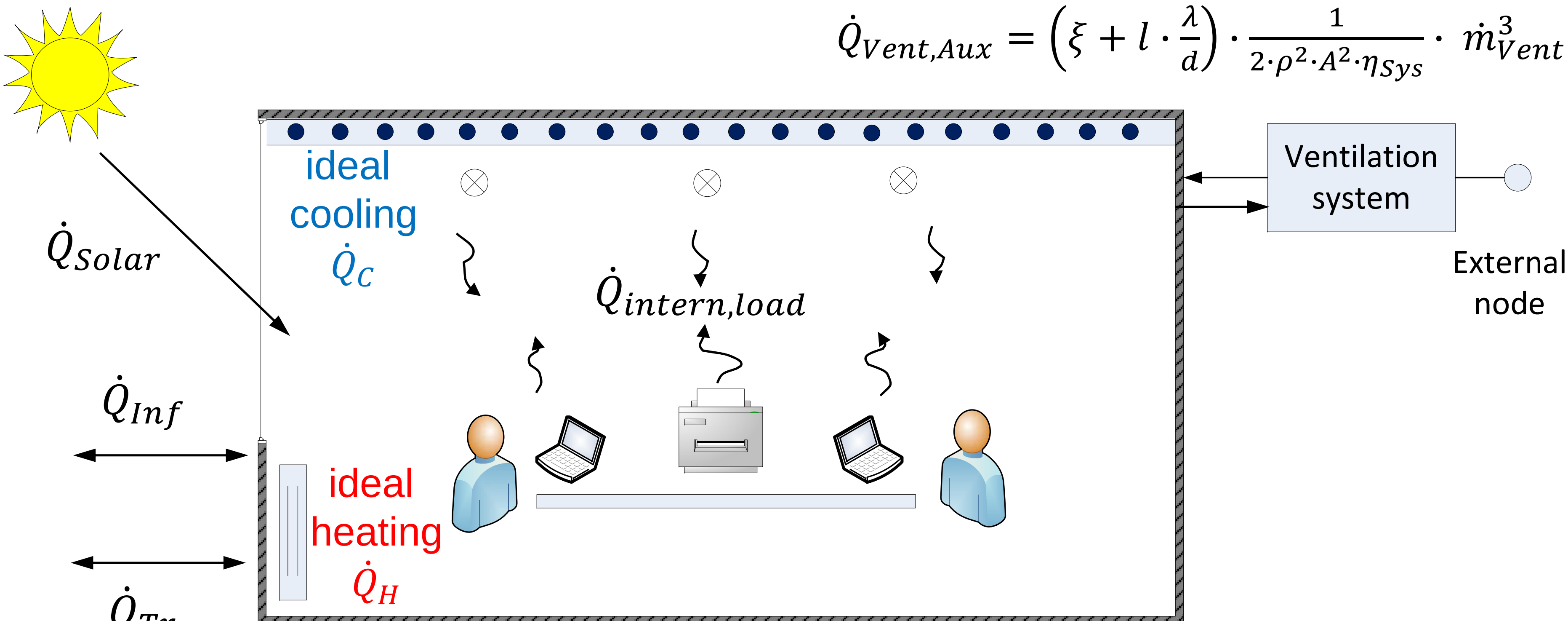
Background, objectives and methods of investigations

- A guarantee of indoor air quality is fulfilled by sufficient outside air flow rates according to national or European regulations as DIN EN 15251 or DIN EN 13779.
- The higher the outside air flow rates are, the higher is the useful energy demand; therefore the reduction of outside air flow rates is expected to be a common aspect for saving energy.
- The main objective is to minimize the annual useful energy demand of heating, cooling and the energy demand of the transport of the air of the mechanical ventilation system.
- A target function is developed for optimizing the outside air flow rate of mechanical ventilation and is combined with the software TRNSYS and TRNFLOW to calculate the energy demand.

Target function for optimizing the air flow rate of mechanical ventilation

$$\dot{Q}_{Vent} = \dot{m}_{Vent} \cdot c_p \cdot (\vartheta_O - \vartheta_R)$$

$$\dot{Q}_{Vent,Aux} = \left(\xi + l \cdot \frac{\lambda}{d}\right) \cdot \frac{1}{2 \cdot \rho^2 \cdot A^2 \cdot \eta_{Sys}} \cdot \dot{m}_{Vent}^3$$



$$\dot{Q}_{H/C} = \underbrace{\dot{Q}_{intern,load} + \dot{Q}_{Tr} + \dot{Q}_{Solar} + \dot{Q}_{Inf}} + \dot{Q}_{Vent}$$

$$\dot{Q}_{H/C} = \dot{Q}_{rest,load} + \dot{Q}_{Vent}$$

$$\dot{Q}_{Tot} = f_{H/C} \cdot \dot{Q}_{H/C} + f_{Aux} \cdot \dot{Q}_{Vent,Aux} = f_{H/C} \cdot (\dot{Q}_{rest,load} + \dot{Q}_{Vent}) + f_{Aux} \cdot \dot{Q}_{Vent,Aux}$$

Preconditions of investigations

- The thermal comfort in the room is ensured by a technical combination of ideal heating, cooling, humidification and dehumidification.
- The indoor air quality is guaranteed
  by the ventilation system with a sufficient outside air flow rate
  or by the combination of ventilation (at reduced outside air flow rates)
  and an ideal pollutant sink (air cleaner).
- The evaluation of energy demand is only confined
  to useful energy for heating and cooling of the room.
- Useful energy demand: generic term for effective (net) energy demand of heating, cooling, (de)humidification etc.
- Further more the primary useful energy demand includes not only
  the transport energy of the air flow but also the primary energy factors
  for the heating, cooling and auxiliary energy.

Investigated scenarios

Scenario	Air flow rate	Useful energy demand EnEV 2009 + WSchV 82	Primary useful energy demand EnEV 2009 + WSchV 82
4	60 m³/h const.	✓ (Reference)	✓ (Reference)
3	60 m³/h const. + HRV	✓	✓
2	Max. 60 m³/h optimized	✓	✓
1	0 m³/h	✓	✓

- EnEV 2009: German Energy Conservation Regulation 2009 (“modern”)
- WSchV 82: German Heat-Protection-Regulation 1982 (“old”)
- HRV: Heat Recovery Ventilation

Boundary conditions (1) - Room model

A room in an office building is defined for the investigations

- Dimensions of the room (L x W x H): 7.2 x 4.2 x 2.5 m
- The only external surface of the room orientates to the south
- Dimensions of the window (L x H): 7.2 x 1.5 m
- Dimensions of the breast (L x H): 7.2 x 1.0 m

Properties of room surfaces

	Type	U – Value [W/(m² K)]	G - Value
Window (EnEV 2009)	INS2_AR_1	1.40	0.622
Window (WSchV 82)	-	2.80	0.755
Breast (EnEV 2009)	-	0.24	-
Breast (WSchV 82)	-	0.64	-
Internal walls	-	1.00	-
Ceiling	-	0.42	-
Floor	-	0.33	-

Boundary conditions (2) – Loads / gains

Thermal loads / gains

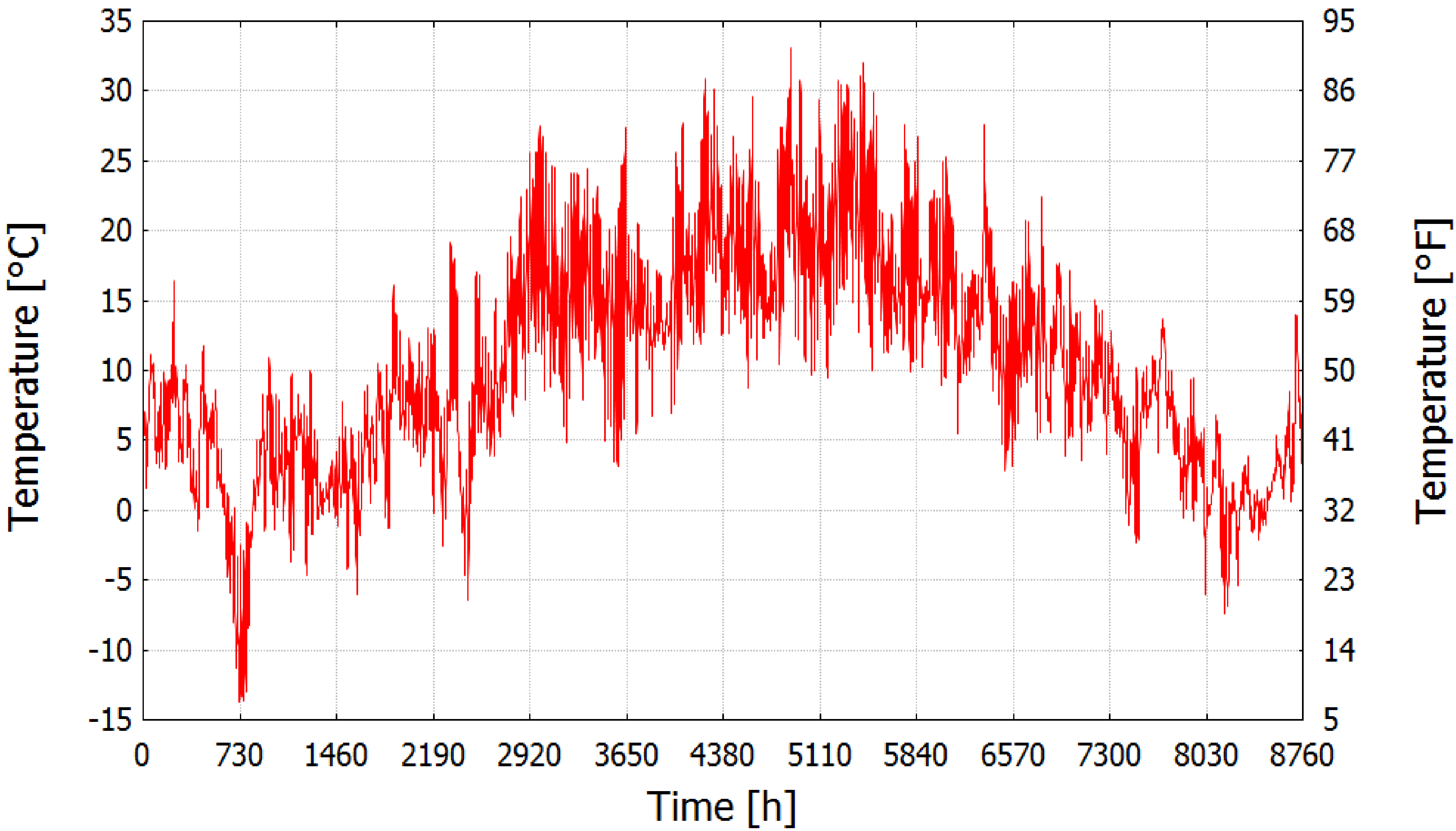
- 2 Persons: 70 W of sensible heat and 80 g/h of humidity per person
- Electric equipment (PC/laptop, monitor, printer and copy machine): 10 W/m²
- Lights: 15 W/m²

Material load

CO_2: 0.02 m³/h per person

Weather data: TRY 12 (Stuttgart) from German weather service.

Boundary conditions (3) – Weather data (TRY 12)



Boundary conditions (4) – Profiles and set values

- Ideal heating: **21°C** on work days from 7 to 18 o'clock and **18°C** beyond this time
- Ideal cooling: **26°C** on work days from 7 to 18 o'clock and **28°C** beyond this time
- The relative air humidity is kept between **30%** and **55%** also by ideal humidification and dehumidification
- Operating of the mechanical ventilation: from 8 to 18 o'clock on work days
- Factor of an external shading for the window: **0.5** from 10 to 15 o'clock

The HRV factor is **0.75** and operating only in December, January, February and March

The infiltration of the room is ignored.

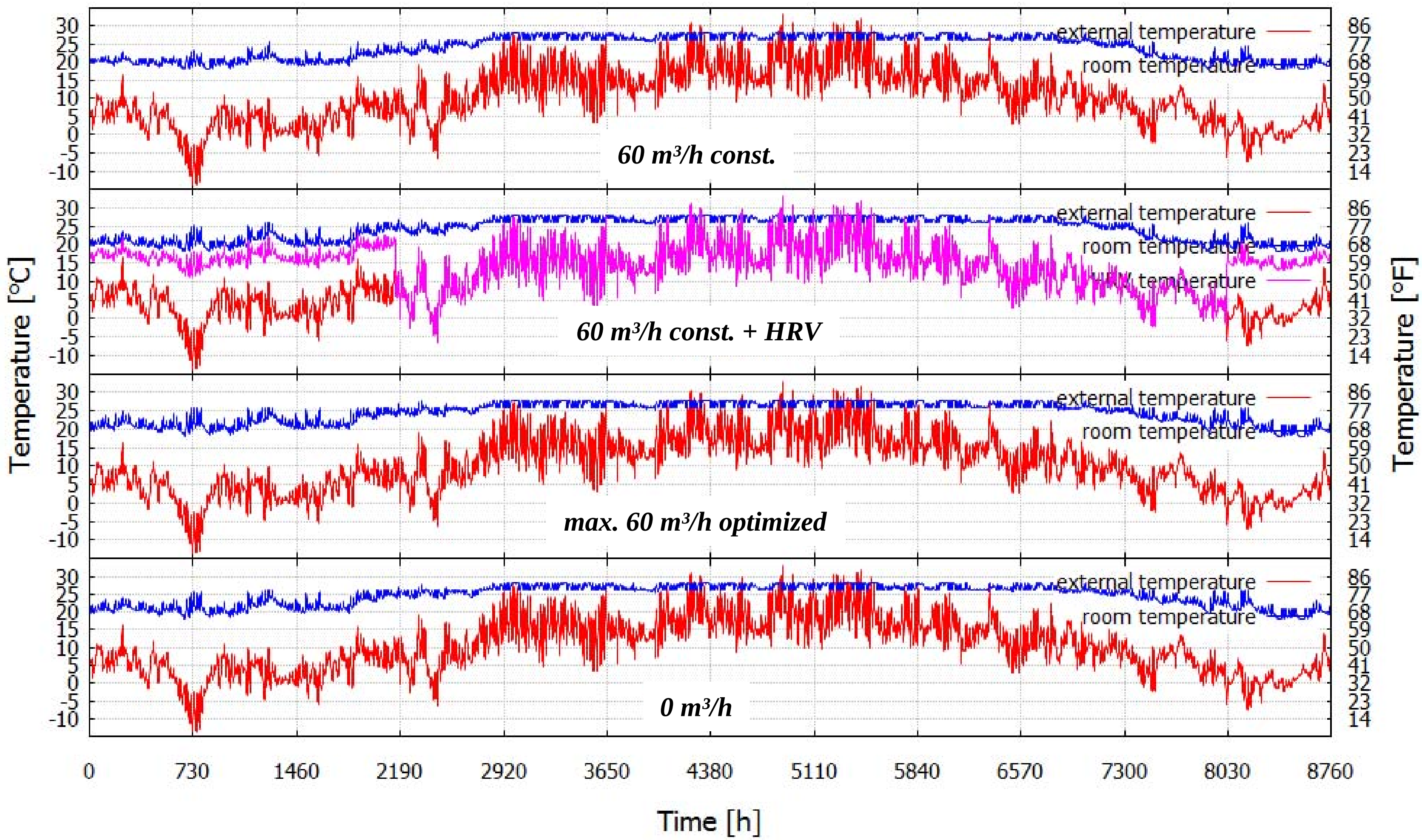
The supply air temperature is equal to the external air temperature or to the air temperature of HRV.

Values of parameters of the simulations

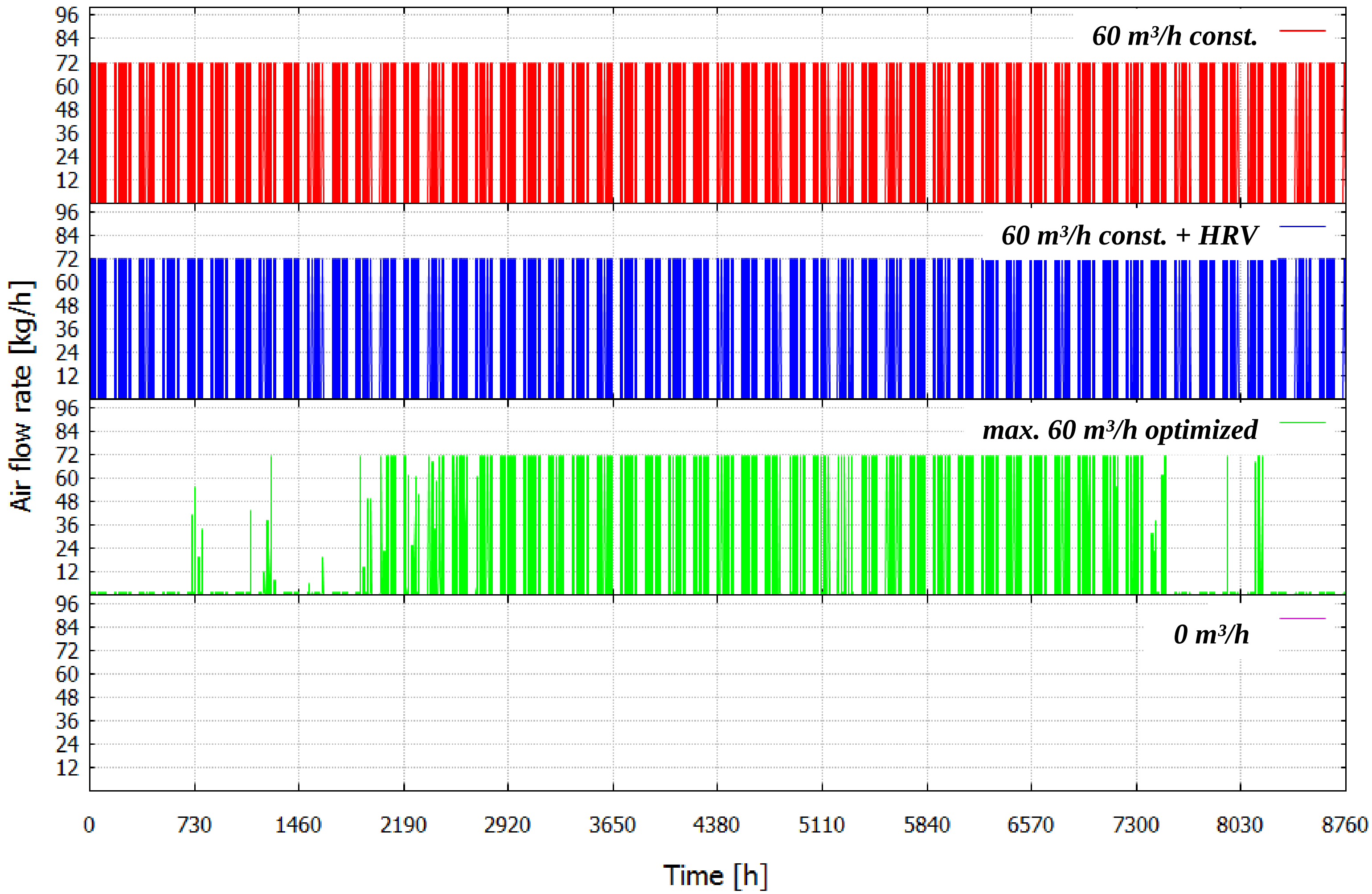
Description	Symbol	Value		Description	Symbol	Value
Heat capacity of air [kJ/(kgK)]	C_p	1.006		Primary energy factor for heating [-]	$f_{p,H}$	1.1
Local resistance [-]	ξ	4.6		Primary energy factor for cooling [-]	$f_{p,C}$	0.87
Efficiency of ventilation system	η	0.5		Primary energy factor for auxiliary energy [-]	$f_{p,Aux}$	2.6
Diameter of duct [m]	d	0.07		Minimal air flow rate [kg/h]	$\dot{m}_{Vent,min}$	1.44
Length of duct [m]	l	20		Maximal air flow rate [kg/h]	$\dot{m}_{Vent,max}$	72
Roughness of duct [mm]	ε	0.01		Step of air flow rate [kg/h]	$\Delta\dot{m}_{Vent}$	1.0
Kinematic viscosity [m²/s]	ν	1.58e-05				

Results

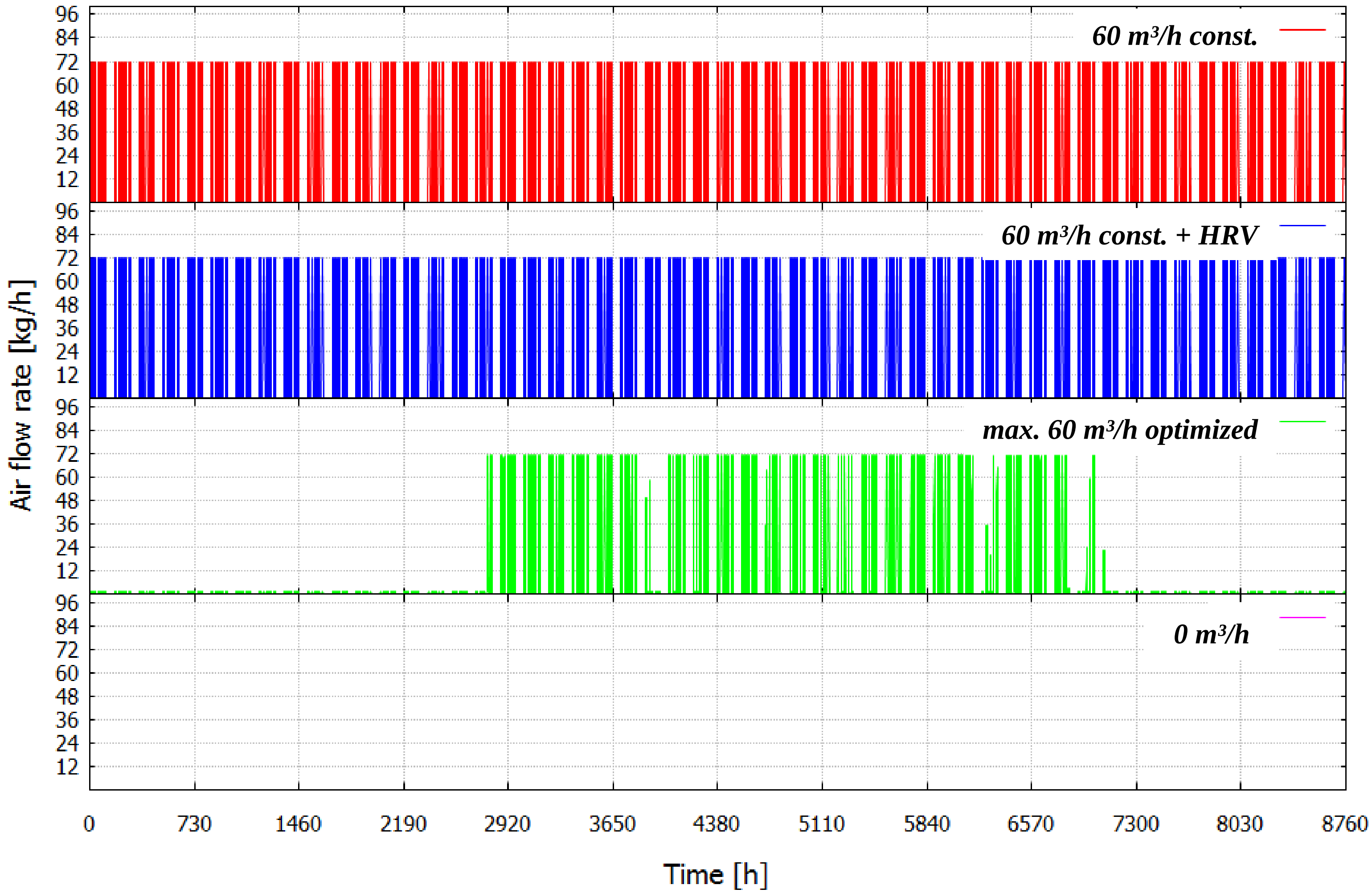
Annual hourly room air and supply air temperature for the EnEV 2009 (= "modern") building



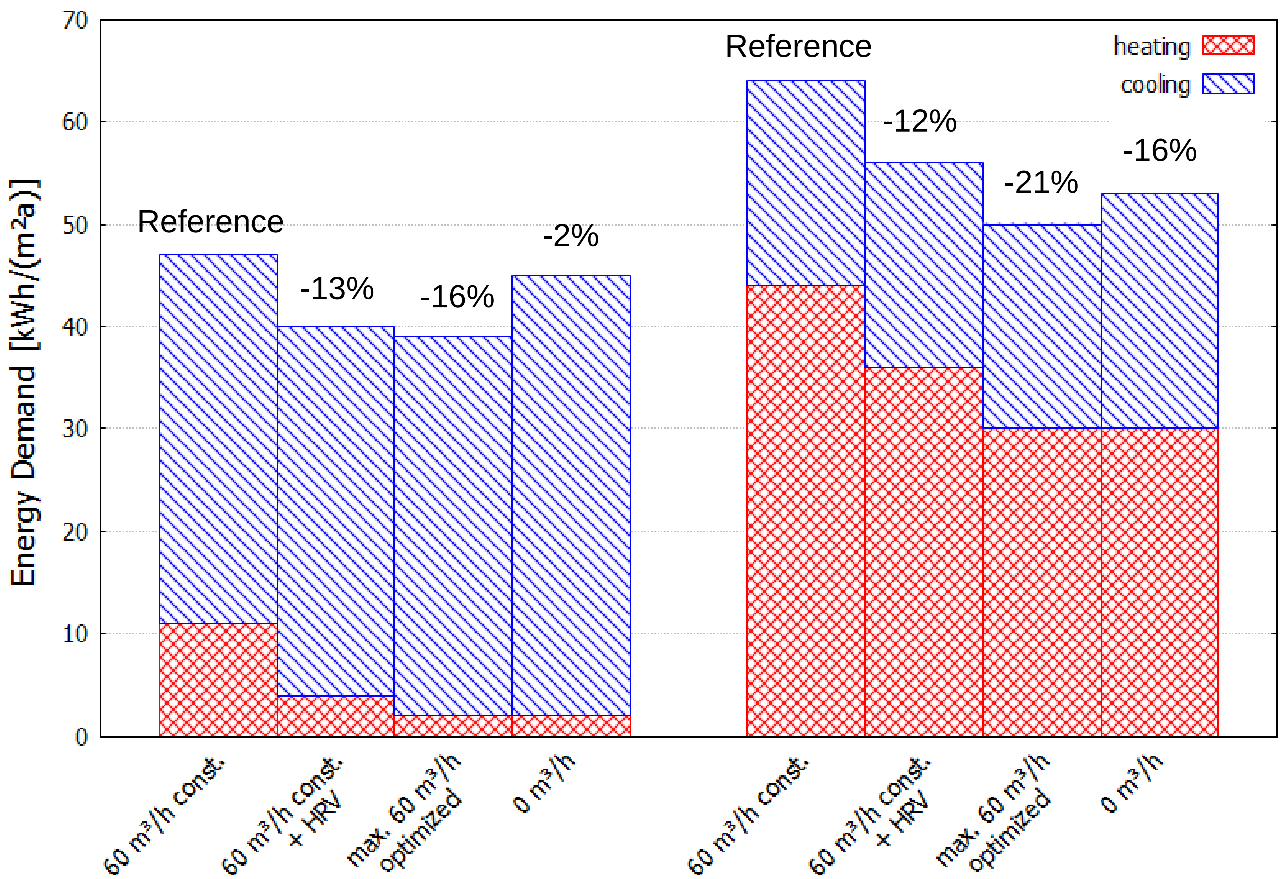
Annual hourly air flow rate of mechanical ventilation for the EnEV 2009 (= "modern") building



Annual hourly air flow rate of mechanical ventilation for the WSchV 82 (= "old") building



Comparison of primary useful energy demand



Primary useful energy
EnEV 2009

Primary useful energy
WSchV 82

Summary & prospect

- Energy conservation potential can be achieved by the control of the outside air flow rate of the ventilation.
- Higher air flow rates of the ventilation do not always have disadvantages as mostly expected.
- The optimizing strategy bares more benefits for the “old” WSchV 82 building.
- HRV can reduce the energy demand in case of operation only in winter; otherwise the energy demand would increase.

Further investigations:

- The upper limit of the air flow rate for the optimization should be investigated with this “tool”.
- Night cooling by outside air should be considered.