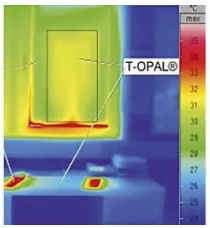
Retrofitting German School Buildings to Achieve the Energy Performance Standards of Plus-Energy Schools and 3-Litre Building Schools

SOLAR HEATING & COOLING PROGRAMME
INTERNATIONAL ENERGY AGENCY

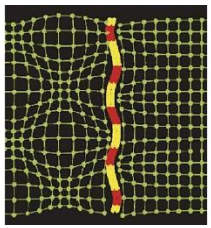
Johann Reiß

Fraunhofer-Institut für Bauphysik IBP

03. April 2014






© Fraunhofer IBP

Building on knowledge

Fraunhofer IBP

Background

- There are many schools in Germany which must be retrofitted
- These buildings have a high energy consumption
- The communities as building owners have high annual energy costs
- The thermal comfort does not comply with today's standard
- The indoor-air quality is poor in many schools
- A large portion of the schools must be retrofitted within the next 10 years
- By integrating teachers and pupils in the retrofitting process the awareness for saving energy can be increased

© Fraunhofer IBP

The aim

- Germany’s Federal Ministry of Economics and Technology (BMWi) has established a promotion concept entitled “Energy efficient schools".
- Existing school buildings should be retrofitted with the aim to achieve plus-energy standard or 3-litre building standard
- New school buildings should be built with the aim to achieve plus-energy standard or 3-litre building standard
- All buildings should assure good thermal comfort and an indoor climate that is beneficial for learning
- The demonstration projects shall have example character
- The demonstration projects shall represent multipliers

© Fraunhofer IBP

SCHOOL		LOCATION	TARGET
	Science College	Overbach	3-litre building standard
	Primary school	Hohen-Neuendorf	Energy-plus school
	Special school	Olbersdorf	3-litre building standard
	High school	Rostock	Energy-plus school
	High school	Cottbus	3-litre building standard
	High school	Marktoberdorf	3-litre building standard
	Primary and secondary modern school	Stuttgart	Energy-plus school

New construction

Refurbishment

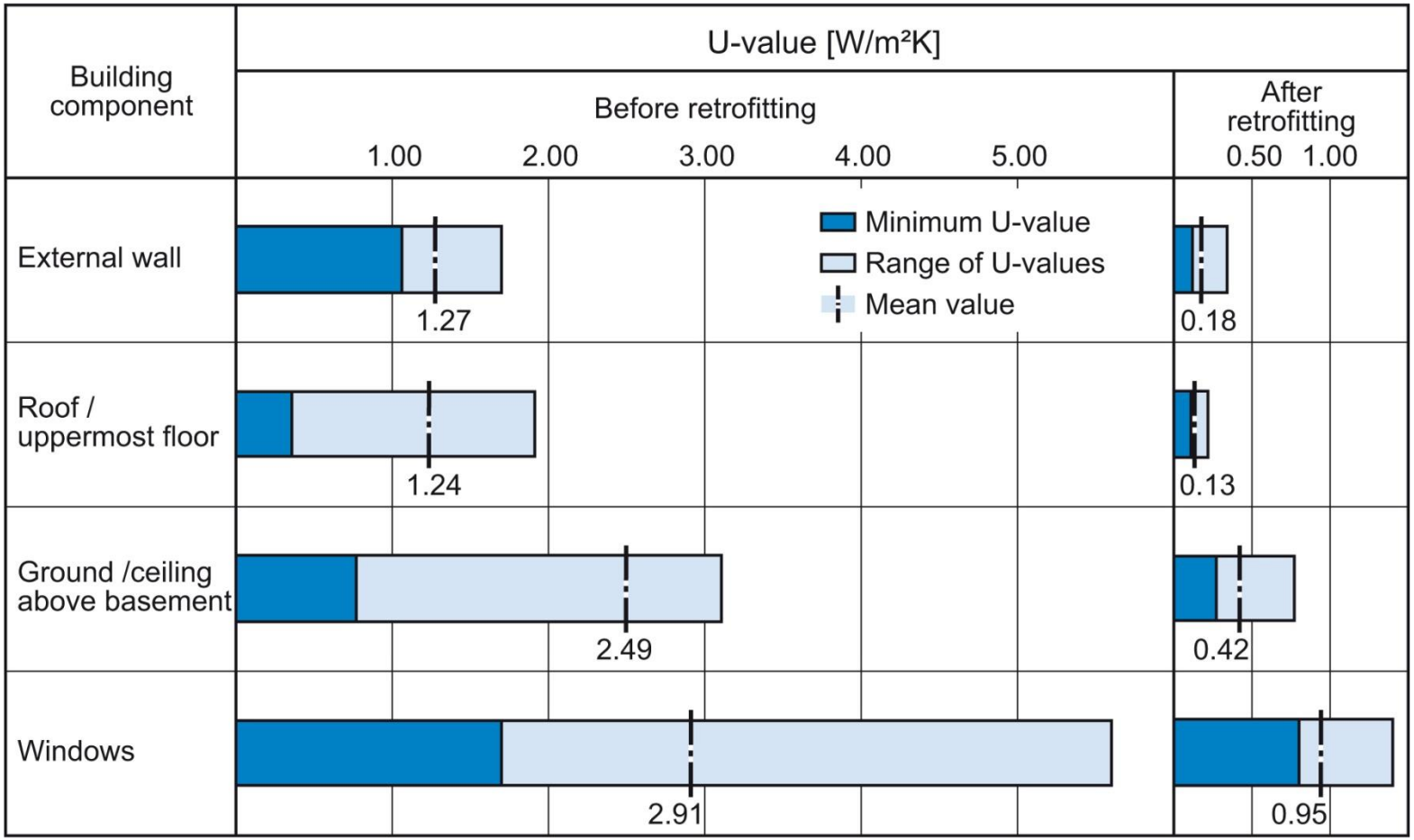
© Fraunhofer IBP

Locations of Energy-efficient Schools

© Fraunhofer IBP

Fraunhofer
IBP

Overview of the U-value in the demonstration buildings before und after retrofitting



© Fraunhofer IBP

Fraunhofer IBP

Innovative Komponenten	Sanierung				
	Obersdorf	Rostock	Cottbus	Marktoberdorf	Stuttgart
High-performance ther. insulation		●	●	●	●
Triple glazing	●	●	●		●
Electrochromic glazing	●				
Automatic mechanical shading	●	●	●	●	●
Daylight redirection	●	●	●		●
Phase change materials			●		
Ventilation system with heat recovery		●	●	●	●
Passive cooling	●		●		
Night-time ventilation					●
Photovoltaics		●		●	●
Solar thermal systems			●	●	
Geothermal energy	●		●		●
Biogas				●	
Biomass				●	
Wind power		●			
District heating		●	●	●	
Building automation	●	●	●	●	●

Survey of the technologies deployed in surplus-energy and 3-Litre educational buildings

© Fraunhofer IBP

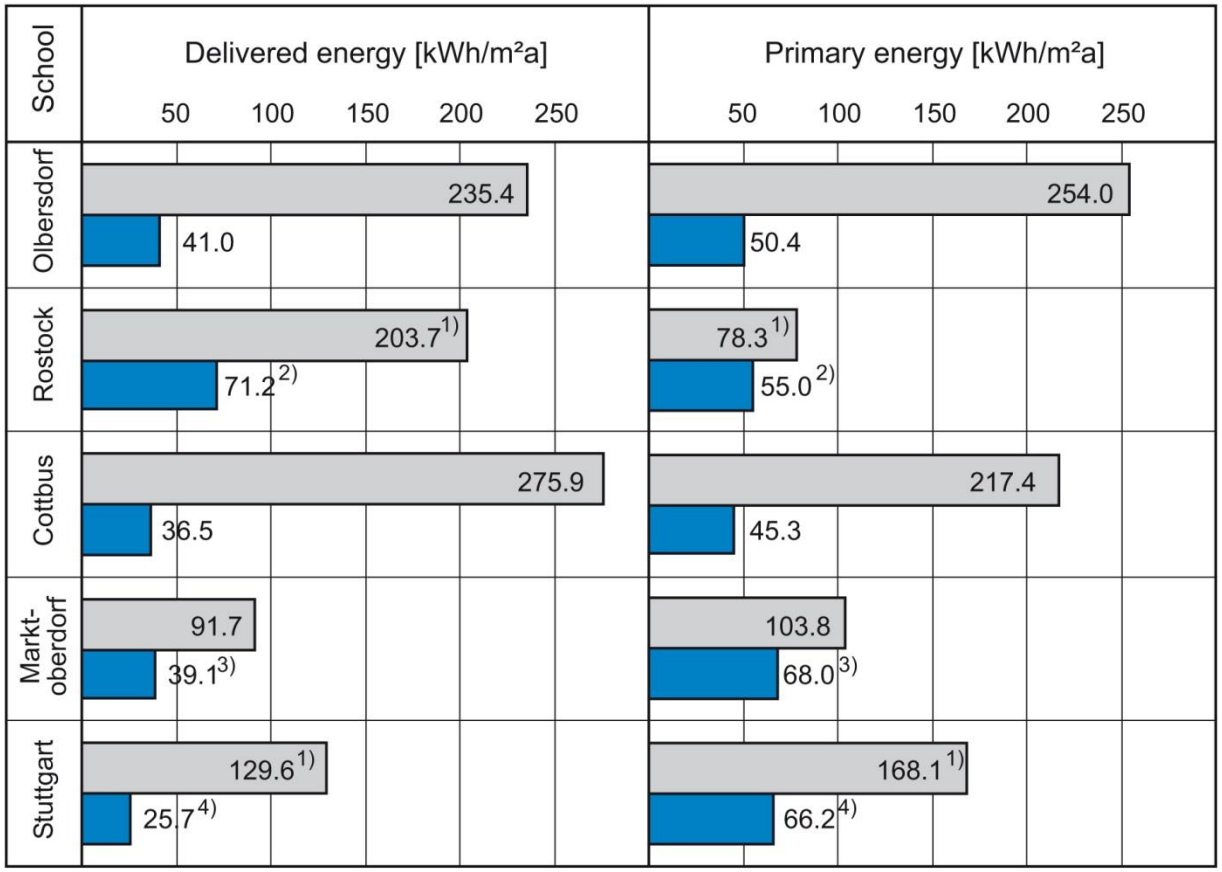
Overview of the ventilation systems that were installed in the demonstration buildings

Ventilation	Olbersdorf 	Rostock 	Cottbus 	Marktoberdorf 	Stuttgart 
Air extraction system	X				
Centralised ventilation system using heat recovery		X	X		
Decentralised ventilation system using heat recovery				X	X

© Fraunhofer IBP

Fraunhofer IBP

Delivered energy and primary energy before and after retrofitting



1) Consumption data (no data on energy need available)

2) Energy yields from PV, wind, ORC not included

3) Energy yields from PV, and CHP not included

4) Energy yield from PV not included

Before retrofitting

After retrofitting

© Fraunhofer IBP

Fraunhofer IBP

3-Litre-School Building at Olbersdorf

(Refurbishment, listed building)

Location: Schulweg 3,
02785 Olbersdorf, Germany

Year(s) built:	**1927-1928**
Retrofitting period:	**2009 to 2011**
Number of students:	**180**
Number of classrooms:	**22**
Heated net floor area:	**4439 m²**
Delivered energy for heating:	**145 kWh/m²a**
Delivered energy for lighting:	**11.5 kWh/m²a**

View

© Fraunhofer IBP

Fraunhofer IBP

Energy concept

Building

- External wall, 510 mm brickwork, with 70 mm EPS insulation layer (U=0.34 W/m²K)
- Double air-supply windows, outside single, inside double (U=1.0 W/m²K)
- Double air-supply windows, outside electrochr. , inside double (U=0.9 W/m²K)
- Brick ceiling, 50 mm floor screed, 150 mm mineral wool, OSB panel (U=0.22 W/m²K)
- 100 mm concrete, 20 mm vacuum insulation panels, 40 mm floor screed (U=0.36 W/m²K)
- 100 mm XPS-insulation, 100 mm concrete, 40 mm floor screed (U=0.32 W/m²K)
- Passive cooling via capillary tube mats
- Combined acoustic/ cooling ceiling
- Reactivation of existing light wells using highly reflective panels
- Daylight redirection

© Fraunhofer IBP

Energy concept

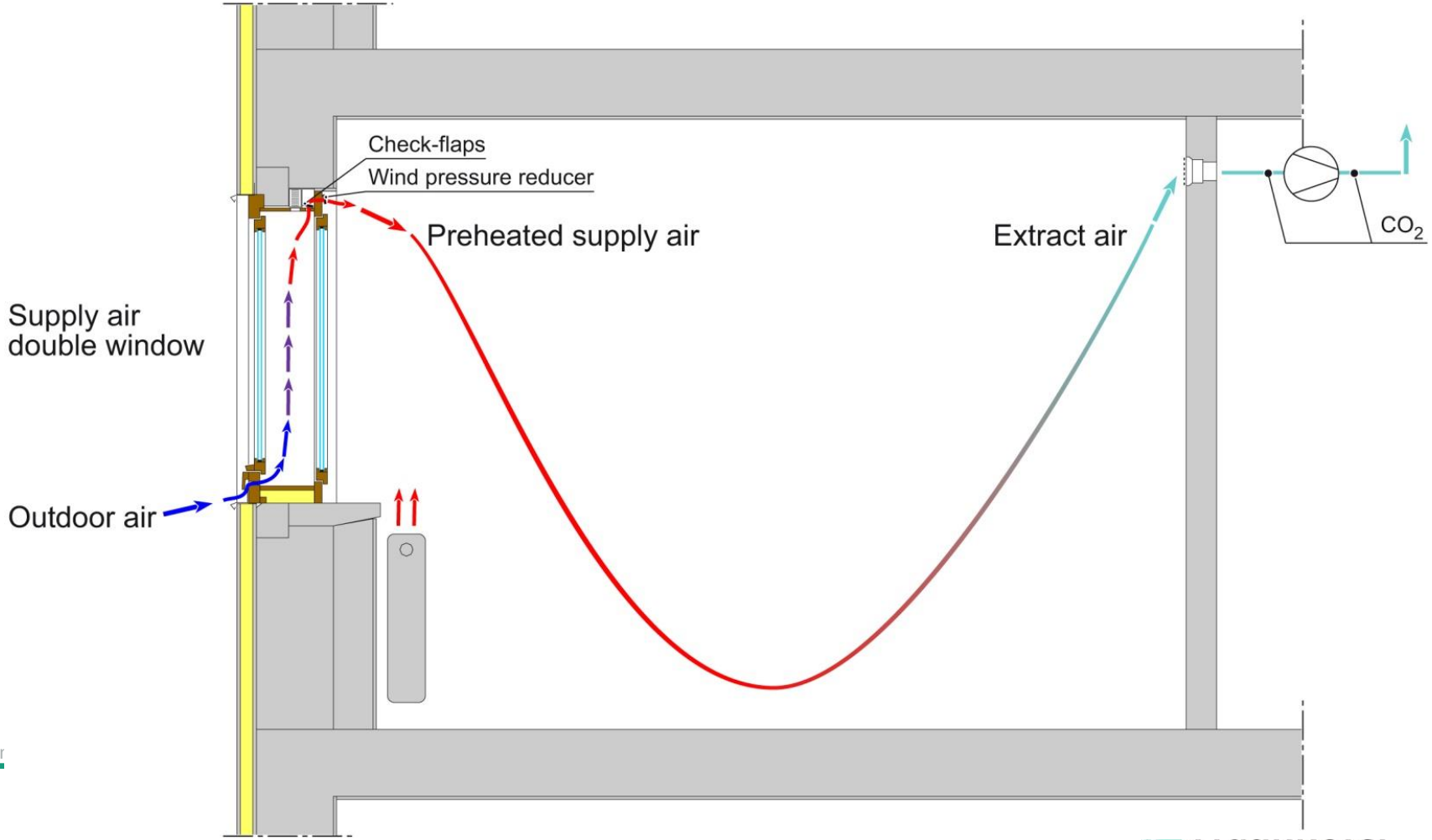
Technical building systems

- Two gas-absorption heat pumps, 35 kW each
- 10 geothermal heat pipes, with a depth of 100 m each
- Two gas condensing boilers to cover peak demand situations, 80 kW each
- Heat transfer via radiators
- Sanitary spaces: presence-controlled air-extraction system
- Class rooms: CO_2-controlled air extraction system. Fresh air supplied through double air-supply windows.

© Fraunhofer IBP

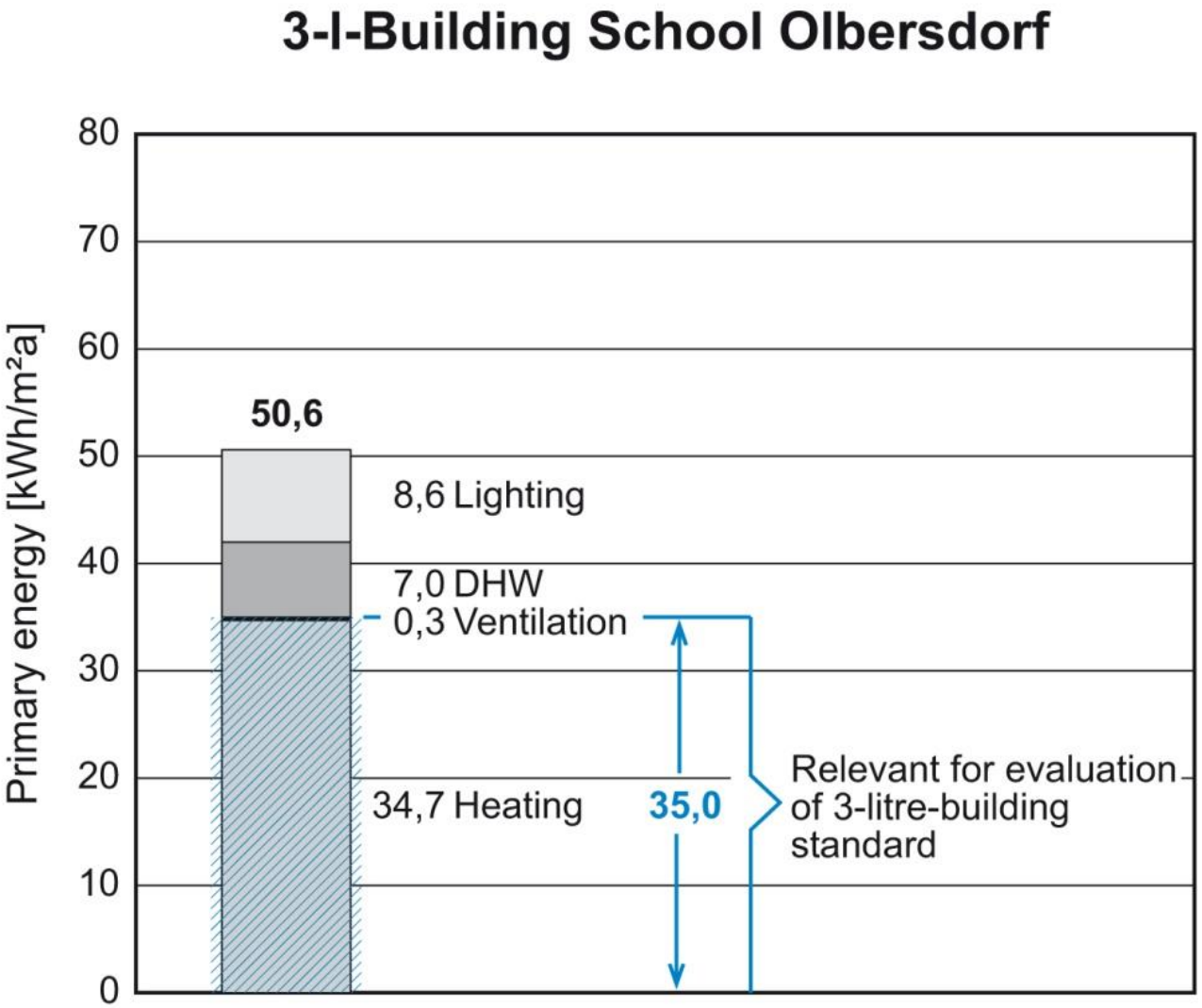
Ventilation concept

CO_2-controlled air extraction system, fresh air supplied through double air-supply windows



© Fraur

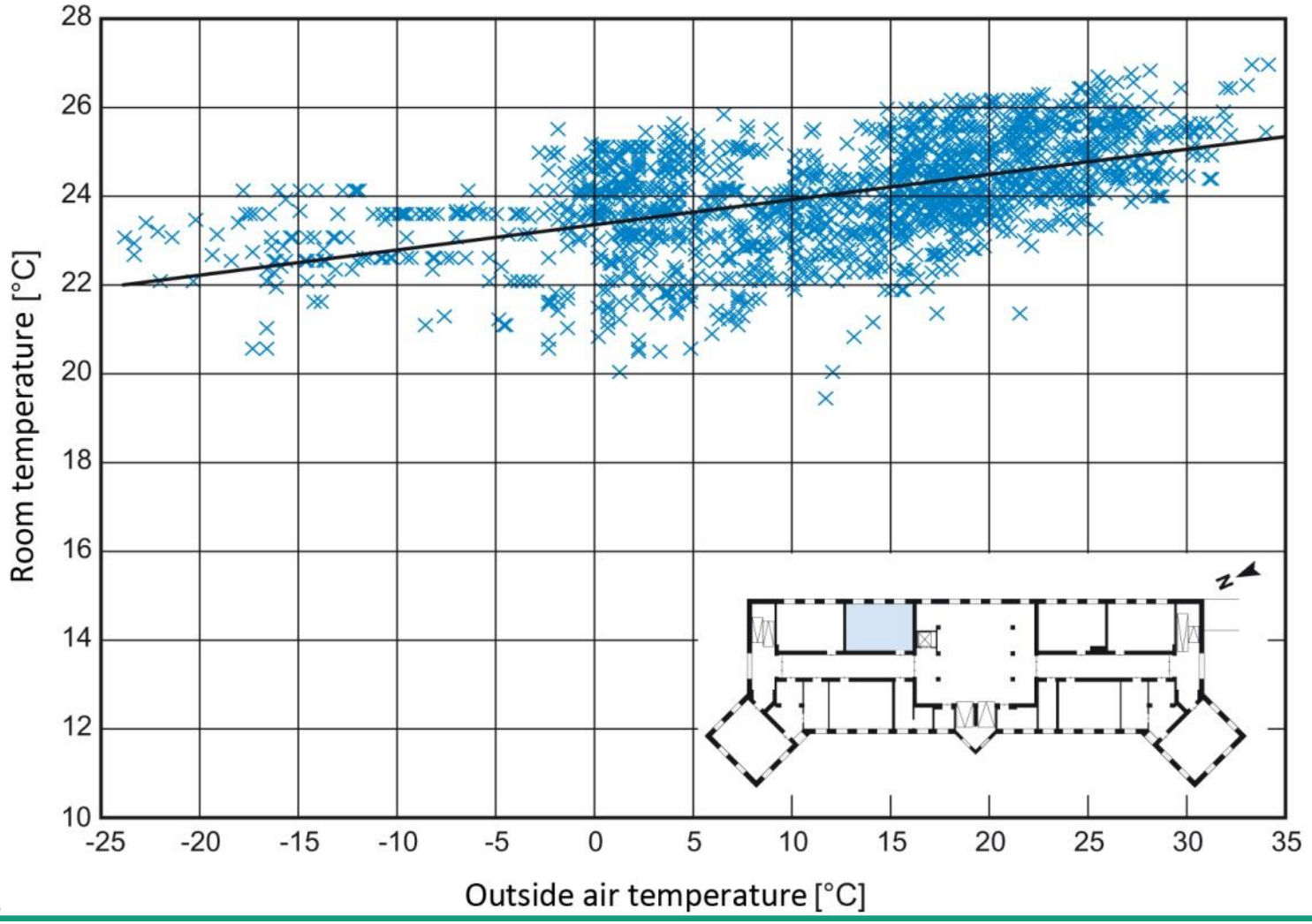
Primary energy demand



© Fraunhofer IBP

3-Litre-School Building
at Olbersdorf

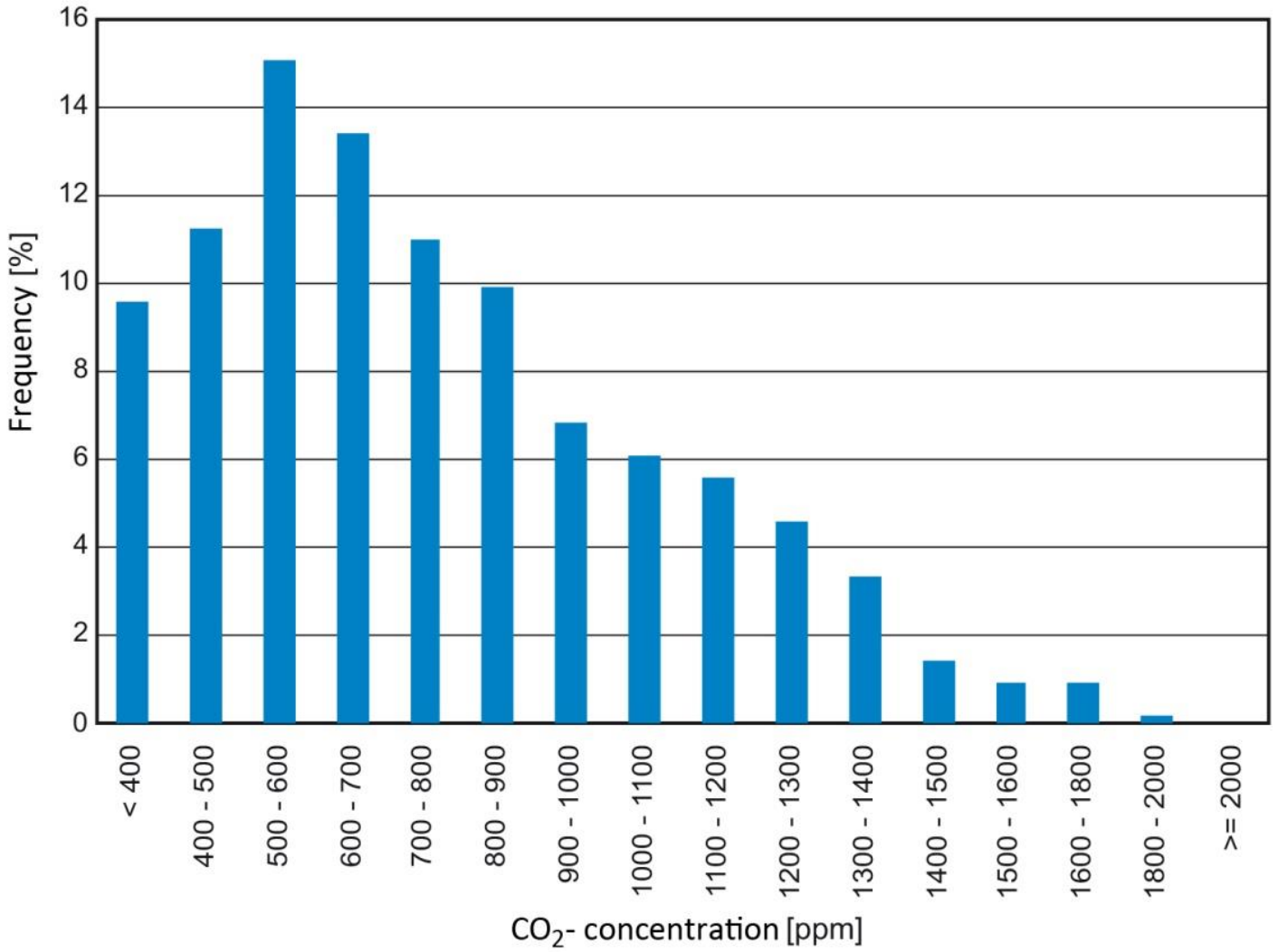
Indoor air temperatures in classroom during occupancy for the period from April 2011 to February 2012



© Frau

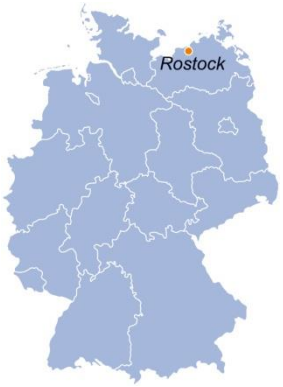
Fraunhofer IBP

3-Litre-School Building at Olbersdorf
Percentage frequency of occurrence for CO_2 concentrations during occupancy for the period from April 2011 to February 2012



© Fraunhofer IBP

Fraunhofer IBP



Plus energy school at Rostock

(Refurbishment)

Location: Mathias-Thesen-Str. 17,
18069 Rostock, Germany

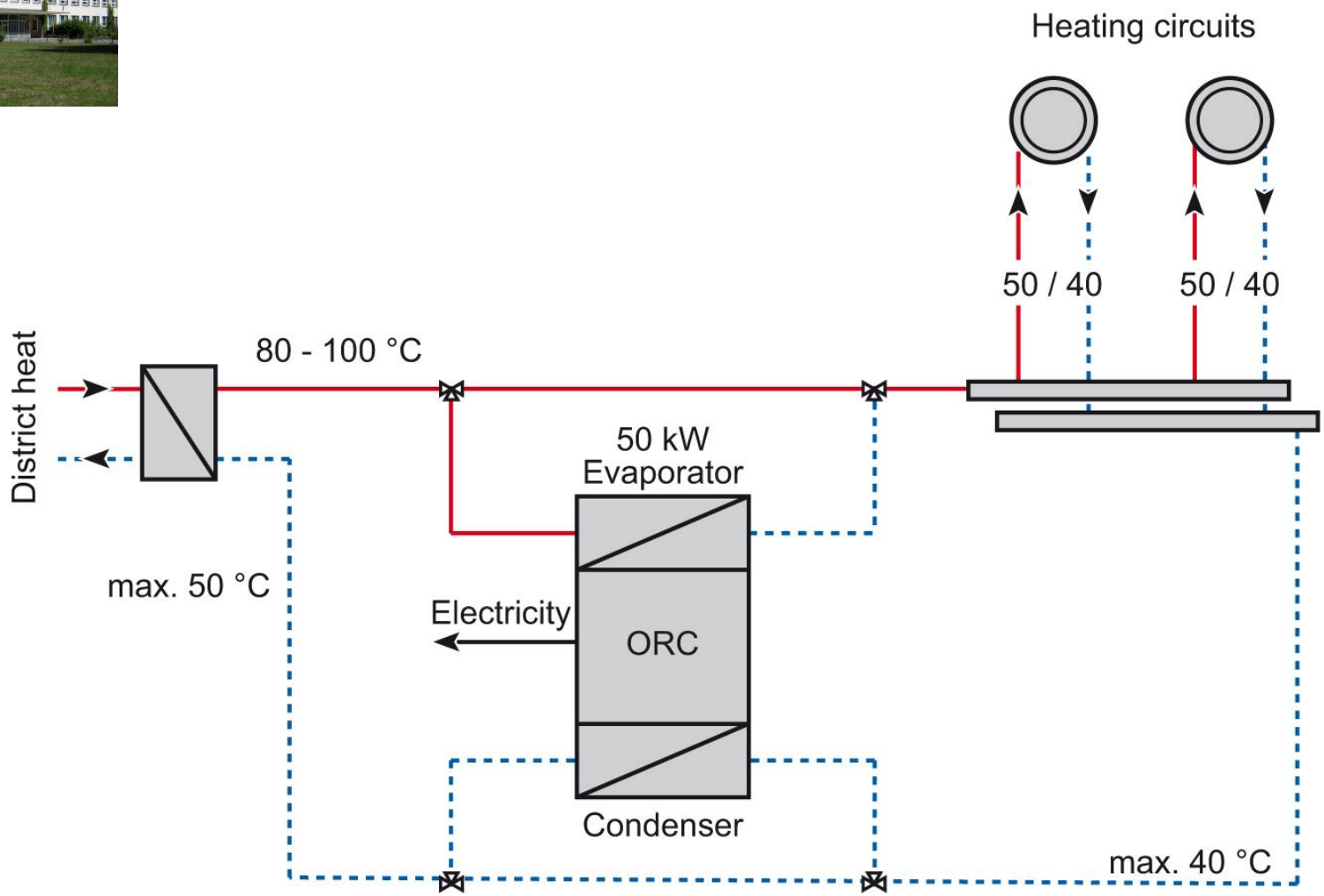
View before retrofitting

Year(s) built:	**1960-1961**
Retrofitting period:	**2009 to 2014**
Number of students:	**234**
Number of classrooms:	**25**
Heated net floor area of entire school complex:	**3422 m²**
Delivered energy for space and DHW heating:	**193 kWh/m²a**
Delivered energy for lighting:	**10.4 kWh/m²a**

© Fraunhofer IBP

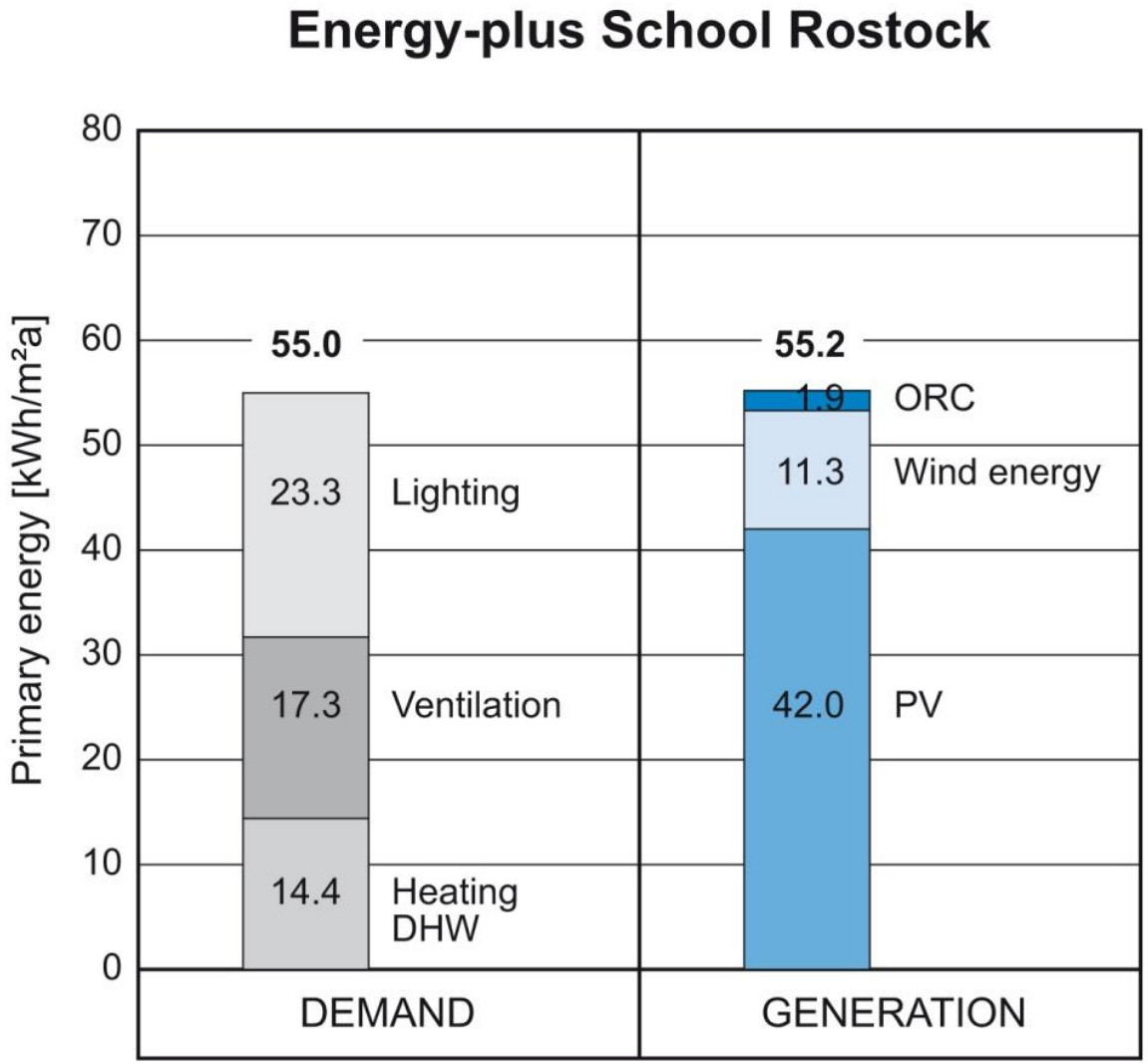
Fraunhofer IBP

Heating system



© Fraunhofer IBP

Primary energy demand



Generation > Demand
→ Energy-plus school

© Fraunhofer IBP

Fraunhofer IBP

General recommendations for the renovation of school buildings

- Monitoring

  Assure continuous monitoring to verify efficient performance of all technical building systems and to record all shares of energy consumption

- Visualizing the energy consumption
- Display the continuous visualization of the energy consumption at a central place (for instance, in the school entrance area)

- Convincing users to save energy
- Carry out joint school projects on energy saving (in collaboration with teachers, students, and caretakers)

© Fraunhofer IBP