Overview of existing integrated building concepts

Ernst Blümel
Annex 44 symposium „Responsive + Building + Elements“
May 14th ´08, Delft
Contents

- Aims for tomorrow’s buildings
- Approaches, how to reach that goals
- Quality requirements, quality assurance
- Building examples with IBC
- Lessons learned and the way forward
Aims for buildings of tomorrow

- Maximum user comfort
- Best indoor air quality and living health
- Lowest energy demand / costs
- Protection of resources within the energy and water supply
- Maximum building quality with a long term value guarantee
- Active contribution for the climatic protection
Quality requirements

- Excellent insulated, airtight and thermal bridges reduced building envelope
- Ecological materials
- Ventilation system with heat recovery
- Reduction of the cooling load by structural measures
- Considering of storage masses
- Daylight usage
- Covering the additional energy demand with renewable energy
The IBC Energy Design Pyramid by Annex 44

IBC = Integrated Building Concepts
RBE = Responsive Building Elements
CFF = Cleanest Fossil Fuels
FFT = Fossil Fuel Technology
> 1000 realized projects

source: IG Passivhaus Österreich
Quality assurance

- Integrated building concept
  - High quality realisation
  - Proof of quality (calculation of thermal bridges, airtightness check, etc.)
  - Monitoring, on-site measurements
Monitoring of pilot projects

- Office building ChristophorusHaus, OÖ
  straw office building, Böheimkirchen, NÖ
  clay office building Tattendorf, NÖ
  Sol4, Mödling, NÖ

- Municipal buildings:
  Kindergarten Ziersdorf, NÖ
  municipal office Ludesch, Vorarlberg
  school Schwanenstadt, OÖ

- Multi-family buildings:
  Solarcity Linz, OÖ
  Utendorfgasse, Vienna
  Makartstraße, Linz, OÖ
  Mühlweg, Vienna
  Pantucekgasse, Vienna
ChristophorusHaus

- Passive house construction (light building)
- 1,215 m² heated area
- Air tightness: $n_{50} = 0,4$ h$^{-1}$
- 2 ventilation plants with heat recovery
- 43 kW heat pump
- 8 x 100 m piles
- Heating and cooling ceilings
- 10 kW$_{\text{peak}}$ PV-cells, 6 m² solar heating system
- Sustainable (waste-)water management

PHPP (Passive House Planning Package):
- Heat demand 14 kWh/(m²a)

TRNSYS:
- Heating 8 – 19 kWh/(m²a)
- Cooling 4,5 – 10 kWh/(m²a)

(up to 85% less than conventional buildings)
Kindergarten Ziersdorf

- Passive house construction (light building)
- 750 m² heated area
- Air tightness: n50 = 0.37 h⁻¹
- Ventilation system with heat recovery and earth to air heat-exchanger (CO₂-controlled system)
- 8 m² solar heating system
- Pellets fired boiler
- Wall heating system

**PHPP:**
- Heat demand 14.3 kWh/(m²a)

(75% less than standard buildings)
EBS Haus 1, Solarcity Linz

- Passive house construction (massive building)
- 5 flats, 514 m² heated area
- Air tightness: n50 = 0,4 h-1
- Ventilation systems with heat recovery and a water-carried heating of the supply air
- 24 m² solar heating system
- 2-pipes system with local heat transfer stations
- District heating
- In addition 2 radiators per flat

**PHPP:**
- Heat demand 12.2 kWh/(m²a)

(80% less than standard buildings)
ChristophorusHaus - CHH
Summer – room temperature
Energy balance

- Q_Wärmepumpe HZ
- Q_Verteiler2_HZ
- Q_Verteiler1_HZ
- Q_lüftung_Büro_HZ
- Q_lüftung_Seminar_HZ
- Q_Wärmepumpe Kühlung
- Q_Verteiler2_Kühlung
- Q_lüftung_Büro_Kühlung
- Q_lüftung_Seminar_Kühlung
- Q_Erdsonden Kühlung
- Q_Erdsonden_HZ

Energy balance [kWh/(m² month)]
Heating

Heat demand
19/23 kWh/m²\textsubscript{TFA} a

Standardised for a room temperature of 20°C:
15,8/19,3 kWh/m²\textsubscript{TFA} a

Max. heating load:
13 W/m²\textsubscript{TFA}
Cooling

Cool demand
7/10 kWh/m² TFA a

Max. cooling load:
11 W/m² TFA
Evaluation after 2 years of operation

- The whole building works since the occupation very well.
- The comfort parameters (T, rH) are over the whole year comfortable and consistent. (winter 21 – 23°C, summer 23 – 26°C).
- Technical components operate efficiently and accords to the service specifications.
- 100% of the cooling demand is covered by passive cooling measurements.
- The users’ comfort in the buildings is very high.
Comparison with CEPHEUS-projects

Electricity consumption [kWh/(m²a)]

01 - Hannover: 18.1
02 - Kassel: 27.9
04 - Egg: 20.3
05 - Hörbranz: 27.0
06 - Wolfurt: 14.0
07 - Dornbirn: 20.4
08 - Gnigl: 49.9
09 - Kuchl: 41.0
11 - Horn: 19.5
12 - Steyr: 22.3
13 - Luzern: 25.6
Ziersdorf: 11.3
Solarcity Linz: 38.4
ChristophorusHaus: 43.3
<table>
<thead>
<tr>
<th>City</th>
<th>Primary Energy Consumption (kWh/(m²a))</th>
</tr>
</thead>
<tbody>
<tr>
<td>01 Hannover</td>
<td>72.1</td>
</tr>
<tr>
<td>02 Kassel</td>
<td>133.0</td>
</tr>
<tr>
<td>04 Egg</td>
<td>20.3</td>
</tr>
<tr>
<td>05 Hörbranz</td>
<td>109.1</td>
</tr>
<tr>
<td>06 Wolfurt</td>
<td>56.5</td>
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<tr>
<td>07 Dornbirn</td>
<td>128.6</td>
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<tr>
<td>08 Gnigl</td>
<td>132.3</td>
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<tr>
<td>09 Kuchl</td>
<td>126.6</td>
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<tr>
<td>11 Horn</td>
<td>71.5</td>
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<td>12 Steyr</td>
<td>108</td>
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<tr>
<td>13 Luzern</td>
<td>118.5</td>
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<tr>
<td>Ziersdorf</td>
<td>48.5</td>
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<tr>
<td>Solarcity Linz</td>
<td>150.6</td>
</tr>
<tr>
<td>Christophorus Haus</td>
<td>118.6</td>
</tr>
<tr>
<td>Name of building, country</td>
<td>Type of use</td>
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<tr>
<td>--------------------------</td>
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</tr>
<tr>
<td>BedZED, UK</td>
<td>Residential + office</td>
</tr>
<tr>
<td>Commerzbank, Germany</td>
<td>Naturally ventilated 80% of the year</td>
</tr>
<tr>
<td>Gleisdorf City Hall, Austria</td>
<td>50% reduction in peak cooling load</td>
</tr>
<tr>
<td>Itoman City Hall, Japan</td>
<td>22% reduction in primary energy use</td>
</tr>
<tr>
<td>Kansai Electric Power, Japan</td>
<td>30% less than standard (predicted)</td>
</tr>
<tr>
<td>Kvadraturen School, Norway</td>
<td>40% less than standard (predicted)</td>
</tr>
<tr>
<td>Kvernhuset School, Norway</td>
<td>40% less than standard (predicted)</td>
</tr>
<tr>
<td>Longley Park, UK</td>
<td>N/A</td>
</tr>
<tr>
<td>The Lowry, UK</td>
<td>Theatre</td>
</tr>
<tr>
<td>Mabuchi Motor, Japan</td>
<td>25% less CO$_2$-emissions (predicted)</td>
</tr>
<tr>
<td>Marzahn, Germany</td>
<td>Residential 20% less than code (predicted)</td>
</tr>
<tr>
<td>Menara Mesiniaga, Malaysia</td>
<td>Office</td>
</tr>
<tr>
<td>MIVA, Austria</td>
<td>Office 75% less than standard</td>
</tr>
<tr>
<td>M+W Zander, Stuttgart, Germany</td>
<td>Office</td>
</tr>
<tr>
<td>Nikken Sekkei, Japan</td>
<td>Office 50% less than standard</td>
</tr>
<tr>
<td>Passive Hauptschule, Austria</td>
<td>School 70% less than standard</td>
</tr>
<tr>
<td>Photo-Catalytic Material Building, Japan</td>
<td>Experimental</td>
</tr>
<tr>
<td>Pourous building, Vietnam</td>
<td>Residential</td>
</tr>
<tr>
<td>RWS Terneuzen, The Netherlands</td>
<td>Office 20-30% less than standard</td>
</tr>
<tr>
<td>Sakai, Japan</td>
<td>67% less than standard</td>
</tr>
<tr>
<td>W.E.I.Z, Austria</td>
<td>75% less than standard</td>
</tr>
<tr>
<td>ZUB, Kassel, Germany</td>
<td>Office 80% less than standard</td>
</tr>
</tbody>
</table>
Kanden Office Building, Japan

Low energy skyscraper in hot and humid climate

Location: Osaka, Japan
Owner: Kanden Industries Inc
Net conditioned area: 60 000 m²

Start of operation: 2005
Architect: Nikken Sekkei Ltd
Engineering: Takenaka etc., Kinden etc., Sanki etc., Sanko etc.

Space Heating: 36 kWh/m² Design, 42 kWh/m² Operation
Space Cooling: 113 kWh/m² Design, 182 kWh/m² Operation

→ 30% less energy use than conventional building (estimated). To be monitored.
Kanden Office Building, Japan

Low energy skyscraper in hot and humid climate

- "Eco-Frame" columns and beams integrate solar shading and natural ventilation openings
- Thermal mass activation by night flushing
- Heating/Cooling: DHC System: heat pump utilizing river water and air-conditioning rejection heat
- Automated "climber blinds"
- Task ventilation
- 30% less energy use than conventional building (estimated). To be monitored.
The Lowry, UK

Theatre with earth coupled and building integrated ventilation

**Location:** Salford, UK  
**Owner:** The Lowry Centre Trust  
**Net conditioned area:** 23,930 m²

**Start of operation:** 2000  
**Architect:** Jim Stirling, Michael Wilford  
**Engineering:** Buro Happold

The main focus of that project is, to demonstrate and determine the cooling provided by the thermal mass of the earth duct and the concrete plenum beneath the theatre. -> up to 50% less cooling energy use than conventional buildings (estimated)
The Lowry, UK

Theatre with earth coupled and building integrated ventilation

- Concrete earth tube and plenum provides 4°C cooling
- Project was within budget
- Monitoring program to be carried out by Brunel University / Buro Happold
- Control strategies will be optimised
Office building ‘Pynten’, Norway

Passive climate control combined with indoor environment friendly materials

Location: Nydalspynten, Oslo, Norway
Owner: Avantor ASA
Net conditioned area: 2484 m2
Start of construction: 2008
Architect: Sintef Byggforsk

Space Heating: 26 kWh/m² Design
Space Cooling: 0 kWh/m² Design

→ 50% less energy use than conventional buildings
Office building ‘Pynten’, Norway

Passive climate control combined with indoor environment friendly materials

- Super insulation and air tightness (passive house)
- Earth coupling: A culvert is preheating and precooling air
- Solid and indoor environment friendly materials
- Passive solar heating in the atrium
- Optimal demand control of ventilation, lighting and heating
Annex 44 State-of-the-art Review of IBC

Content:

- **Building Applications**
  - climate and context, energy systems, performance (indoor environment, energy, cost), architectural issues, design and construction process, lessons learned.

- **Process methods and guidelines**

- **Design and simulation tools**

- **Barriers and opportunities for implementation**

www.civil.aau.dk/Annex44

Annex 44
Integrating Environmentally Responsive Elements in Buildings

B1: Integrated Building Concepts

State-of-the-Art Review Working Report

Editors:
Inger Andresen, SINTEF Building Research, Trondheim, Norway
Tommy Kleiven, SINTEF Building Research, Trondheim, Norway
Mari-Ann Knudstrup, Architecture and Design, Aalborg University, Denmark
Per Helseberg, Indoor Environment Engineering, Aalborg University, Denmark

December 20, 2005
**Model - Geometry**

**Reference Building**

The reference building is a three-storey building with a quadratic floor plan. The cubature (variation parameter) is \( A/V = 0.49 \). The location (variation parameter) of the reference building is Vienna, Austria.
Model - Glazing

Reference Building

The reference building shows a glazing proportion of 35% (variation parameter) with an equal share in each direction.
Thermal protection

The reference building conforms to the maximum federal requirements of thermal protection in Austria (exterior wall 0.35, partition 0.9, roof 0.2, ceilings to uncooled spaces 0.37, ceilings 0.7, window 1.7; U-values in W/m²K).
### Thermal protection

Surface construction und building physics of the reference building

<table>
<thead>
<tr>
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<tbody>
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<td>Normalbeton</td>
<td>0,200</td>
<td>2400</td>
<td>2,100</td>
<td>1,00</td>
<td>0,29</td>
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<tr>
<td></td>
<td>D. mmung</td>
<td>0,100</td>
<td>30</td>
<td>0,032</td>
<td>0,83</td>
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<td></td>
<td>Normalbeton</td>
<td>0,080</td>
<td>2400</td>
<td>2,100</td>
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<td>Dach (schwer)</td>
<td>Kalkzement</td>
<td>0,010</td>
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<td>1,00</td>
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<td>Normalbeton</td>
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<td>2400</td>
<td>2,100</td>
<td>1,00</td>
<td></td>
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<tr>
<td></td>
<td>D. mmung</td>
<td>0,160</td>
<td>30</td>
<td>0,032</td>
<td>0,83</td>
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<td>Geschossdecke (schwer)</td>
<td>Kalkzement</td>
<td>0,010</td>
<td>1800</td>
<td>0,870</td>
<td>1,00</td>
<td>1,99</td>
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<td></td>
<td>Normalbeton</td>
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<td>2400</td>
<td>2,100</td>
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<td>Luftsicht</td>
<td>0,300</td>
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<td>Zementmoertel</td>
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<td>2000</td>
<td>1,400</td>
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<td>Kunststoffbelag</td>
<td>0,003</td>
<td>1500</td>
<td>0,230</td>
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<tr>
<td>Außenwand (schwer)</td>
<td>Kalkzement</td>
<td>0,015</td>
<td>1800</td>
<td>0,870</td>
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<td>0,35</td>
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<td></td>
<td>D. mmung (EPS-F)</td>
<td>0,100</td>
<td>18</td>
<td>0,040</td>
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<td>1800</td>
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<td>0,015</td>
<td>1800</td>
<td>0,870</td>
<td>1,00</td>
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</tbody>
</table>
Parameter study - conclusion

- The **location** proves to be the **most influential parameter** in the study (range of annual heating demand: 0-208%, range of annual cooling demand: 44%-410%; 100% = Vienna/Austria).

- The peak loads as a mere image of extreme weather conditions differ far less than the annual values. For an assessment of the energy efficiency the annual values defining the consumption are the most important criteria.

- Referring to the annual values three regions can be labeled: main-heating, main-cooling and heating and cooling region. For these regions different sets of (i) evaluation criteria and (ii) building concepts have to be developed.

- Energy effects of the parameters cubature, glazing ratio and building function should be considered in connection with the location / the labeled region.
The resulting annual heating / cooling load for one and the same reference building depends considerably on the location. One can distinguish between main-heating, main-cooling as well as heating-and-cooling locations.
Peak Heating / Cooling Load

The peak loads as a mere image of extreme weather conditions differ far less.
## Conclusion - Location

### Total Heater / Cooling Load [kWh/m²]

<table>
<thead>
<tr>
<th>Location</th>
<th>Heating</th>
<th>Cooling</th>
<th>Main-Heating Regions</th>
<th>Heating and Cooling Regions</th>
<th>Main-Cooling Regions</th>
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</thead>
<tbody>
<tr>
<td>Helsinki, Finland</td>
<td>31</td>
<td>52</td>
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<tr>
<td>Oslo, Norway</td>
<td>35</td>
<td>56</td>
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<tr>
<td>Berlin, Germany</td>
<td>20</td>
<td>37</td>
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<tr>
<td>London, U.K.</td>
<td>35</td>
<td>56</td>
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<tr>
<td>Paris, France</td>
<td>20</td>
<td>37</td>
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<tr>
<td>Vienna, Austria</td>
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<td>Zurich, Switzerland</td>
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<td>56</td>
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<td>Milan, Italy</td>
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<td>Lyon, France</td>
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<td>Rome, Italy</td>
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<tr>
<td>Naples, Italy</td>
<td>35</td>
<td>56</td>
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<tr>
<td>Athens, Greece</td>
<td>73</td>
<td>56</td>
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<tr>
<td>Lisbon, Portugal</td>
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<td>Hongkong</td>
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<tr>
<td>Bangkok, Thailand</td>
<td>56</td>
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</tbody>
</table>

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**Total Heater / Cooling Load [kWh/m²]**

- **Helsinki, Finland**: 31 heating, 52 cooling
- **Oslo, Norway**: 35 heating, 56 cooling
- **Berlin, Germany**: 20 heating, 37 cooling
- **London, U.K.**: 35 heating, 56 cooling
- **Paris, France**: 20 heating, 37 cooling
- **Vienna, Austria**: 35 heating, 56 cooling
- **Zurich, Switzerland**: 35 heating, 56 cooling
- **Milan, Italy**: 35 heating, 56 cooling
- **Lyon, France**: 35 heating, 56 cooling
- **Rome, Italy**: 35 heating, 56 cooling
- **Naples, Italy**: 35 heating, 56 cooling
- **Athens, Greece**: 73 heating, 56 cooling
- **Lisbon, Portugal**: 56 heating, 56 cooling
- **Hongkong**: 56 heating, 56 cooling
- **Bangkok, Thailand**: 56 heating, 56 cooling

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**Conclusion**

The total heater and cooling load for various locations is shown above. The locations range from Helsinki, Finland to Bangkok, Thailand. The load values are given in kWh/m² and are categorized into main-heating, heating and cooling, and main-cooling regions.
Conclusion - location
Lessons learned and way forward

- Excellent IBC are available
- The implementation of “buildings of tomorrow” is still a challenge
- Committed clients and dedicated inter-disciplinary co-operation from the project start are factors of success
- Different basic conditions require different approaches to find the best IBC solution (e.g. climate)
- IBC is an important requirement for comfortable living/working/playing/..
- Performance need to be documented by measurements
- If there are differences in the operation data: detailed analysis instead of “snapshot”
- Prediction tools need to be improved
- Standardized components need to be developed
- Design guidelines
The Annex44 building design stories in this presentation were contributed by:

- Matthias Haase, SINTEF, Norway
- David Warwick, Buro Happold, UK
- Mitsuki Miua, KEPCO, Japan
IBC in buildings of tomorrow