Integrated Building Concepts-
Actual developments and trends within the IEA

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SINTEF Buildings and Infrastructure, Norway

www.sintef.no

www.civil.aau.dk/Annex44
www.ecbcs.org/annexes/annex44.htm
What are Integrated Building Concepts (IBC)?

“Integrated design solutions where responsive building elements together with service functions are integrated into one system to reach an optimal environmental and cost performance”

- An IBC has elements that **react** to changing internal and external environment
- An IBC has elements that **communicate** with technical systems for control of the energy usage and indoor environment

<table>
<thead>
<tr>
<th>External conditions</th>
<th>Internal conditions</th>
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<tbody>
<tr>
<td>seasonality variations</td>
<td>occupant intervention</td>
</tr>
<tr>
<td>diurnal variations</td>
<td></td>
</tr>
<tr>
<td>weather changes</td>
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<table>
<thead>
<tr>
<th>Elements</th>
<th>Services</th>
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<tr>
<td>facades</td>
<td>ventilation</td>
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<tr>
<td>roofs</td>
<td>heating</td>
</tr>
<tr>
<td>foundation</td>
<td>cooling</td>
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<tr>
<td>storage</td>
<td></td>
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<tr>
<td>rooms</td>
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<table>
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<tr>
<th>Performance</th>
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<tr>
<td>energy/environment</td>
</tr>
<tr>
<td>cost</td>
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</tbody>
</table>
What are Integrated Building Concepts (IBC)?

Responsive Building Elements

Outdoor climate

Heat flux

Ventilation

Energy storage

Indoor climate

*Adaptive human comfort parameters*

Illustration: Ad van der Aa, Cauberg-Huygen Consultants, The Netherlands
To integrate several functions into one......
4 main subtasks

- B1: Review of design processes for IBC
- B2: Investigation of performance of existing IBCs
- B3: Development and optimization of new IBCs
- B4: Analysis of robustness, performance sensitivity and accuracy of IBCs
- B5: Expert Guide
Integrated Building Concepts
State-of-the-Art Review
Working Report

Editors:
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Per Heiselberg, Indoor Environment Engineering, Aalborg University, Denmark

July 26, 2006

B1: Review of Design Processes for IBC

172 pages

Chapter 1: Introduction
Chapter 2: Building Applications
Chapter 3: Design process methods and tools
Chapter 4: Design and simulation tools
Chapter 5: Barriers and opportunities for implementation
Chapter 2: Review of building applications

- 22 buildings
<table>
<thead>
<tr>
<th>Name of building, country</th>
<th>Type of use</th>
<th>Energy performance</th>
<th>Responsive building elements</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>AIF</td>
</tr>
<tr>
<td>BedZED, UK</td>
<td>Residential + office</td>
<td>50% less than standard</td>
<td>x</td>
</tr>
<tr>
<td>Commerzbank, Germany</td>
<td>Office</td>
<td>Naturally ventilated 80% of the year</td>
<td>x</td>
</tr>
<tr>
<td>Gleisdorf City Hall, Austria</td>
<td>City Hall</td>
<td>50% reduction in peak cooling load</td>
<td>x</td>
</tr>
<tr>
<td>Itoman City Hall, Japan</td>
<td>City hall</td>
<td>22% reduction in primary energy use</td>
<td>x</td>
</tr>
<tr>
<td>Kansai Electric Power, Japan</td>
<td>Office</td>
<td>30% less than standard (predicted)</td>
<td>x</td>
</tr>
<tr>
<td>Kvadraturen School, Norway</td>
<td>School</td>
<td>40% less than standard (predicted)</td>
<td>x</td>
</tr>
<tr>
<td>Kvernhuset School, Norway</td>
<td>School</td>
<td>40% less than standard (predicted)</td>
<td>x</td>
</tr>
<tr>
<td>Longley Park, UK</td>
<td>Office</td>
<td>N/A</td>
<td>x</td>
</tr>
<tr>
<td>The Lowry, UK</td>
<td>Theatre</td>
<td>N/A</td>
<td>x</td>
</tr>
<tr>
<td>Mabuchi Motor, Japan</td>
<td>Office</td>
<td>25% less CO₂-emissions (predicted)</td>
<td>x</td>
</tr>
<tr>
<td>Marzahn, Germany</td>
<td>Residential</td>
<td>20% less than code (predicted)</td>
<td>x</td>
</tr>
<tr>
<td>Menara Mesiniaga, Malaysia</td>
<td>Office</td>
<td>N/A</td>
<td>x</td>
</tr>
<tr>
<td>MIVA, Austria</td>
<td>Office</td>
<td>75% less than standard</td>
<td>x</td>
</tr>
<tr>
<td>M+W Zander, Stuttgart, Germany</td>
<td>Office</td>
<td>N/A</td>
<td>x</td>
</tr>
<tr>
<td>Nikken Sekkei, Japan</td>
<td>Office</td>
<td>50% less than standard</td>
<td>x</td>
</tr>
<tr>
<td>Passive Hauptschule, Austria</td>
<td>School</td>
<td>70% less than standard</td>
<td>x</td>
</tr>
<tr>
<td>Photo-Catalytic Material Building, Japan</td>
<td>Experimental</td>
<td>N/A</td>
<td></td>
</tr>
<tr>
<td>Pourous building, Vietnam</td>
<td>Residential</td>
<td>N/A</td>
<td>x</td>
</tr>
<tr>
<td>RWS Terneuzen, The Netherlands</td>
<td>Office</td>
<td>20-30% less than standard</td>
<td>x</td>
</tr>
<tr>
<td>Sakai, Japan</td>
<td>Office</td>
<td>67% less than standard</td>
<td>(x)</td>
</tr>
<tr>
<td>W.E.I.Z, Austria</td>
<td>Office</td>
<td>75% less than standard</td>
<td>x</td>
</tr>
<tr>
<td>ZUB, Kassel, Germany</td>
<td>Office</td>
<td>80% less than standard</td>
<td>x</td>
</tr>
</tbody>
</table>
Chapter 3: Review of design process methods and tools

7 methods, in 3 groups:

- **Process focused methods**
  How to work in integrated design teams, what to consider when and by whom

- **Design evaluation methods**
  Structured evaluation of potential design solutions, design criteria

- **Technology prioritizing methods**
  What technologies to apply, and in what order
1. Integrated Design Process (IDP) by IEA Task 23

Integrated Design Process

A Guideline for Sustainable and Solar-Optimised Building Design
1. Integrated Design Process (IDP) by IEA Task 23

- Review goals and requirements
- Qualified cost estimation
- Calculations
- Simulations
- Quantifications

Check Interfaces:
- Proportions
- Multifunctionality
- Flexibility

Design and gross sizing of system solutions

from structure to systems

- Building system and energy system
- Spatial structure and Construction
- Envelope design, daylighting, solar control
- Traffic systems and HVAC systems

External specialists
- General dispositions
- Functional structure
- System limits
- Target values

- Structural dispositions
- Rough mass quantification

Pre-Design

Design Development
2. Integrated Design Process (IDP) by Knudstrup, Aalborg University
3. Integrated Building Design System (IBDS) by Steemers, Cambridge University

Urban planning
- Compact or open
- Regular or irregular
- Orientation of spaces
- Mixed use or zoned

Building form
- Deep or shallow plan
- Cellular or open plan
- Façade orientation
- Courtyards or atria

Façade design
- Glazing ratio
- Glazing distribution
- Ventilation openings
- Shading strategies

Building fabric
- Insulation value
- Thermal mass
- Toxicity and health
- Embodied energy
4. **Eco-Factor** Method by Wahlgren, Bjørn and Brohus

- **Eco-factor** = 75%

- **Improvement Potential**
  - **Appliances**
  - **Lighting**
  - **HVAC systems**
  - **Heating/combustion**
  - **Indoor Air Quality**
  - **Thermal comfort**

- **% of total Eco-factor**
5. **Trias Energetica** by Novem, Delft University and Cauberg-Huygen

[Diagram showing three sections:

1. Reduce demand (energy saving)
2. Maximise the use of renewable energy sources
3. Use fossil fuels in the cleanest possible way]
5. **Trias Energetica** by Novem, Delft University and Cauberg-Huygen
5. **Trias Energetica** by Novem, Delft University and Cauberg-Huygen

Diagram:

- **Design goals**
  - Energy use
  - CO₂-reduction
  - Comfort requirements

- **Calculate load-duration curve**
  - Heating
  - Cooling

- **STEP 1 TRIAS**
  Reduction of heating and cooling gains

- **STEP 2 TRIAS**
  Determine amount of applicable sustainable energy

- **STEP 3 TRIAS**
  Determine heating and cooling installations

- **Calculation of energy**
  - Energy use
  - Energy performance
  - Reduction of CO₂

- **Performance spec’s**
  - Building physics
  - Installations
  - Storage system

- **Calculation of costs**
  - Investment
  - Exploitation
  - Energy costs
6. **Energy Triangle** by Haase and Amato, Hong Kong University

1. Energy conservation: The building should be planned by making use of all energy conservation strategies.

2. Increasing efficiency: all necessary energy consuming units in the building should be optimised by using the latest energy efficient devices and components.

3. Utilization of renewable energy resources: for the remaining amount of necessary energy all renewable energy resources should be exploited and implemented.
7. **Kyoto Pyramid** by Rødsjø and Dokka, Norway

![Diagram of the Kyoto Pyramide]

- **Reduce heat loss**
- **Reduce electricity consumption**
- **Utilize solar heat**
- **Display and control energy consumption**
- **Select energy-source**

**The Kyoto Pyramide**
Passive energy design process
Design strategy

- Efficient CFF

Technology

- Low exergy systems
- Responsive building elements
- Conventional reduction

The IBC Energy Design Pyramid by Annex 44 – second draft version

IBC = Integrated Building Concepts
CFF = Cleanest Fossil Fuels
RBE = Responsive Building Elements
Chapter 4: Review of design and simulation tools

4 “in-house” methods, an overview of commercial simulation tools, and a method for uncertainty modelling

- Design support tools
  Typically used in the early design stages to get an idea of what strategies to pursue

- Design evaluation tools
  Typically used in the later design stages to evaluate alternative design solutions

- Simulation tools
  For performance prediction at all stages of design
1. **E-quartet**
tool by Satake, MAEDA Corporation, Japan
2. **Eco-Façade** tool by Kolokotroni et al, Brunel University, UK
3. **LEHVE** design guide by NILIM and BRI, Japan

Quantification of energy performance for 13 energy measures, determined by comparative measurements:

- **Utilization of natural energy:**
  - Cross ventilation
  - Daylight
  - Photovoltaics
  - Solar radiation heat
  - Solar hot water

- **Insulation and shading of façade:**
  - Thermal insulation
  - Solar radiation shielding

- **Energy conservation equipment:**
  - Air-conditioning equipment
  - Ventilation equipment
  - Hot water apparatus
  - Lighting equipment
  - Household appliances
  - Water saving equipment
4. **VentSim** ventilation system analysis tool by BRI, Japan

Calculates the air flow rate among multi zones based on the ventilation network analysis
### Overview of commercial simulation tools

#### Tools:
- **ESP-r**
- **TRNSYS**
- **EnergyPlus**
- **APACHE**
- **Energy-10**
- **IBLAST**
- **DOE-2**
- **BSIM 2002**
- **SCIAC Pro**
- **IDA**
- **Microflo**
- **Flovent**
- **CFX**
- **FLOWENT**
- **COMIS**
- **COMTAM**
- **Radiance**
- **ADELINE**
- **Window 5**

#### Air flow and IAQ-related:
- **Airflow network with ext. pressure**
  - ESP-r: Y3, YL, Y2, YN
  - TRNSYS: Y3, YL, Y2, YN
  - EnergyPlus: Y3, YL, Y2, YN
  - APACHE: Y3, YL, Y2, YN
  - Energy-10: Y3, YL, Y2, YN
  - IBLAST: Y3, YL, Y2, YN
  - DOE-2: Y3, YL, Y2, YN
  - BSIM 2002: Y3, YL, Y2, YN
  - SCIAC Pro: Y3, YL, Y2, YN
  - IDA: Y3, YL, Y2, YN
  - Microflo: Y3, YL, Y2, YN
  - Flovent: Y3, YL, Y2, YN
  - CFX: Y3, YL, Y2, YN
  - FLOWENT: Y3, YL, Y2, YN
  - COMIS: Y3, YL, Y2, YN
  - COMTAM: Y3, YL, Y2, YN

#### General contaminants/CO₂ transport:
- **N**: No

#### Moisture transport:
- **N**: No

#### Contaminant source/sink effects:
- **N**: No

#### Air cleaning:
- **N**: No

#### Contaminant gradients:
- **N**: No

#### Computational fluid dynamics:
- **N**: No

#### Energy flow and HVAC:
- **N**: No

#### Heat Balance:
- **N**: No

#### Solar and lighting:
- **N**: No

#### Various other capabilities:
- **N**: No

<table>
<thead>
<tr>
<th>TOOLS:</th>
<th>ESP-r</th>
<th>TRNSYS</th>
<th>EnergyPlus</th>
<th>APACHE</th>
<th>Energy-10</th>
<th>IBLAST</th>
<th>DOE-2</th>
<th>BSIM 2002</th>
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<th>COMIS</th>
<th>COMTAM</th>
<th>Radiance</th>
<th>ADELINE</th>
<th>Window 5</th>
<th>Airflow network with ext. pressure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Y3 YL</td>
<td>Y3 YL</td>
<td>Y2 YN</td>
<td>Y3 YL</td>
<td>Y2 YN</td>
<td>Y1 Y3</td>
<td>Y3 YN</td>
<td>Y2 YN</td>
<td>Y1 Y3</td>
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<td>Y3 YL</td>
<td>Y2 YN</td>
<td>Y1 Y3</td>
<td>Y3 YL</td>
<td>Y2 YN</td>
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<td>Y2 YN</td>
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</table>

#### Signification:
- Y1 = Yes, with “standard” features, models and/or capabilities.
- Y2 = Yes, with “state of the art” features, models and/or capabilities.
- Y3 = Yes, with general features, models and/or capabilities.
- Y = a general Yes.
- N = No.

**Table by Bjørn J. Wachenfeldt, SINTEF**
Uncertainty modeling in building performance assessment by Aalborg University, Denmark

- Sensitivity analysis by the Morris method
- Uncertainty analysis by Monte Carlo Simulation

1. Identify parameters influencing indoor environment, energy use, etc.
2. The sensitivity analysis identifies the most important parameters
3. The uncertainty analysis determines the uncertainty of the simulation and the related contribution of the different parameters

A naturally ventilated office building

Most important parameters influencing IAQ were:
- temperature set point for venting
- the opening area
- background ventilation level
- the level of infiltration
Chapter 5: Review of barriers and opportunities for integration

1. Process related issues:

- Lack of integrated design
- Lack of holistic design (sub-optimizing)
- Difficult liability issues
- No well established contracts
- Lack of appropriate performance prediction tools
- Lack of knowledge/guidelines
- Difficulties in communication between architects and engineers
- Difficulties in planning for future occupancy changes
Chapter 5: Review of barriers and opportunities for integration

2. Technology related issues:
   - Lack of standard components
   - Lack of performance measurements
   - Lack of experience, lack of demonstrated technologies and concepts for different climates
   - Concerns about risks and failures
   - Lack of integration between different technologies and building components
   - Lack of appropriate/optimised controls
Chapter 5: Review of barriers and opportunities for integration

3. Cost related issues:
   - The case studies demonstrates that the investment costs of Integrated Building Concepts may be both lower and higher than standard buildings.
   - Running costs are usually lower than for standard buildings
   - Extra time and resources needed in early design phase

4. User related issues:
   - Lack of user satisfaction surveys
Thank you!