The Future for Sustainable Built Environments
Integrating the Low Exergy Approach

Conference 2009
April 21st 2009
Heerlen, The Netherlands
The Future
for Sustainable
Built Environments
Integrating the Low Exergy Approach

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Heerlen, The Netherlands

compiled and edited by:
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Fraunhofer Institute for Building Physics
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DE-34127 Kassel
Germany

Fraunhofer IBP
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**C 1.2** Olivier Pol, arsenal research, for CONCERTO Plus, Austria
"Planning of Sustainable Community Energy Systems: The Experience of CONCERTO Communities"

**C 1.3** Morad R. Atif, Chairman, ECBCS Executive Committee / National Research Council Canada
"ECBCS: R&D for Near-Zero Energy and Carbon Emission for the Built Environment"

**C 1.4** Dietrich Schmidt, Fraunhofer Institute for Building Physics, Germany
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**C 1.5** Sabine Jansen, Technical University Delft, The Netherlands
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**C 1.6** Masanori Shukuya, Tokyo City University, Japan
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"Human Thermoregulation – Consequences for Adaptive Comfort and Exergy Design"

**S 1.2** Bruno Lüdemann, Imtech, Germany
"Cooling without Chillers: Decentralised LowEx Air Handling Unit with Integrated PCM - Storage"

**S 1.3** Dirk Müller, E.ON Energy Research Center, Germany
"Utilisation of Capillary-Tube-Systems with PCM Storages"

**S 1.4** Ad van der Aa, CHRI, The Netherlands
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**S 1.5** Sabine Jansen, Technical University Delft, The Netherlands
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"LowEx Retrofit of a Printing Workshop in Germany"

**S 2.1** Peter Op’t Veld, CHRI, The Netherlands
"Transition in Energy and Process for Sustainable Community Development: Description and Problems"

**S 2.2** Jacques Kimman, Hogeschool Zuyd, The Netherlands
"Case Studies and Strategic Guidance for Urban Decision Makers"

**S 2.3** Jo Steefens, Open University
"Integrated Exergy Concepts for Sustainable Regional and Urban Planning"

**S 2.4** Ronald Rovers, Hogeschool Zuyd, The Netherlands
"Roadmap to a Sustainable Educational Campus in Heerlen UKP"

**S 2.5** Christina Sager, Fraunhofer Institute for Building Physics, Germany
"100% RES for the Community of Wolfhagen – Putting Community Efficiency on the Map"

**S 2.6** Peter Op’t Veld, CHRI, The Netherlands
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## Conference 2009

### The Future for Sustainable Built Environments
- Integrating the Low Exergy Approach

Program of the COSTExergy / IEA ECBCS Annex 49 Conference on the 21\textsuperscript{st} of April 2009 at Cornelishuis Heerlerheide, Heulsstraat 2, 6413EJ Heerlen

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<td>10:00 - 10:05</td>
<td>&quot;Welcome! Opening of the Conference&quot; Dietrich Schmidt (Conference Chair / Fraunhofer Institute for Building Physics, Germany)</td>
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<td>10:25 - 10:45</td>
<td>&quot;Planning of Sustainable Community Energy Systems: The Experience of CONCERTO Communities.&quot; Olivier Pol (arsenal research, for CONCERTO Plus, Austria)</td>
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<td>11:30</td>
<td><strong>The Low Exergy Approach</strong> (Chair: Dietrich Schmidt)</td>
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<td>11:30 - 12:00</td>
<td>&quot;Low Exergy Systems for High-Performance Buildings and Communities&quot; Dietrich Schmidt (Fraunhofer Institute for Building Physics, Germany)</td>
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<td>12:00 - 12:30</td>
<td>&quot;European Exergy Research Network – COSTExergy&quot; Sabine Jansen (Technical University Delft, The Netherlands)</td>
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<td>12:30 - 13:00</td>
<td>&quot;Exergetic Thinking: Its Fundamentals and Applications Looking into the Future&quot; Masanori Shukuya (Musashi Institute of Technology, Japan)</td>
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<td>13:00 - 14:00</td>
<td><strong>Lunch Break</strong> (Posters)</td>
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<td>14:00 - 17:00</td>
<td><strong>Session 1</strong> (Chair: Gudni Johannesson): Projects on Buildings/Technologies (Program see next page)</td>
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<td>17:00 - 17:15</td>
<td><strong>Coffee Break</strong> (Posters)</td>
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<td>17:15 - 18:30</td>
<td><strong>Round Table Discussion in Session 1 and 2 separately</strong></td>
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<td>18:30 - 19:30</td>
<td><strong>Summary Session</strong> Rapporteurs and general summary Masanori Shukuya (Musashi Institute of Technology, Japan)</td>
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<tr>
<td>20:00</td>
<td><strong>Conference Dinner</strong> (and Posters)</td>
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# Conference 2009 - The Future for Sustainable Built Environments

## Session Program of the COSTeXergy / IEA ECBCS Annex 49 Conference on the 21st of April 2009 at Corneliushuis Heerlerheide, Heulsstraat 2, 6413EJ Heerlen

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<tr>
<th>Time</th>
<th>Session 1: Projects on Buildings/Technologies (Chair: Gudni Johannesson)</th>
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| 14:00 - 17:00 | *Adaptive Comfort and Exergy Design*  
               Wouter Marken Lichtenbelt  
               (University of Maastricht, The Netherlands) |
| 14:00 - 14:25 | *Decentralised LowEx Air Handling Unit with Integrated PCM Storages*  
               Bruno Lüdemann  
               (Imtech, Germany) |
| 14:25 - 14:50 | *Utilisation of Capillary-Tube-Systems with PCM Storages*  
               Dirk Müller  
               (E.ON Energy Research Center, Germany) |
| 14:50 - 15:15 | *Design of Responsive Building Elements in an Integrated Design Process*  
               Ad van der Aa  
               (CHRl, The Netherlands) |
| 15:15 - 15:40 | *Exergetic System Approach for an Efficient, People-Friendly and Affordable Use of Energy in the Built Environment*  
               Sabine Jansen (Technical University Delft, The Netherlands) |
| 15:40 - 16:05 | *Demonstration and Training Houses in 'Tomorrows' Neighbourhood* - The Exergy Concept Versus the Passive House Concept*  
               Christoph Maria Ravesloot (Hogeschool Zuyd, The Netherlands) |
| 16:05 - 17:00 | *LowEx Retrofit of a Printing Workshop in Germany*  
               Doreen Kalz  
               (Fraunhofer Institute for Solar Energy Systems, Germany) |

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<th>Time</th>
<th>Session 2: Projects on Communities (Chair: Peter Op’t Veld)</th>
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| 14:00 - 17:00 | *Transition in Energy and Process for Sustainable Community Development: Description and Problems*  
               Peter Op’t Veld (CHRl, The Netherlands) |
| 14:00 - 14:30 | *Case studies and Strategic Guidance for Urban Decision Makers*  
               Jacques Kimman  
               (Hogeschool Zuyd, The Netherlands) |
| 14:30 - 15:00 | *Integrated Exergy Concepts for Sustainable Regional and Urban Planning*  
               Jo Steefens (Open University) |
| 15:00 - 15:30 | *Roadmap to a Sustainable Educational Campus in Heerlen UKP*  
               Ronald Rovers  
               (Hogeschool Zuyd, The Netherlands) |
| 15:30 - 16:00 | *100% RES for the Community of Wolfhagen - Putting Community Efficiency on the Map*  
               Christina Sager (Fraunhofer Institute for Building Physics, Germany) |
| 16:00 - 16:30 | *CONCERTO project Remining LowEx – Low Exergy in Practice in the Mine Water Project in Heerlen*  
               Peter Op’t Veld (CHRl, The Netherlands) |
Introduction

There is still an obvious and indisputable need for an increase in the efficiency of energy utilisation in buildings. Heating, lighting, and building systems in buildings account for more than one third of the world’s primary energy demand and there are great potentials, which can be obtained through better applications of the energy use in buildings. Also as a consequence of the latest reports on climate change and the needed reduction in CO₂ emissions, huge efforts must be made in the future to conserve high quality (primary) energy resources. Even though there is still considerable energy saving potential in the building stock, the results of latest research show that there is an equal or greater potential in exergy management. This implies working with the whole energy chain, taking into consideration the different quality levels involved, from generation via energy supply structures to final use, in order to significantly reduce the fraction of primary or high-grade energy used and thereby minimise exergy consumption. New advanced forms of technology have to be implemented. At the same time, as the use of high quality energy for heating and cooling is reduced, there is more reason to apply an integral approach, which includes all other processes where energy/exergy is used in buildings and in community structures. In recent years, we have made substantial progress in the development of new and integrated techniques for improving energy use, such as heat pumps, co-generation, thermally activated building components, and methods for harvesting renewable energy directly from solar radiation, from the ground and various other waste heat sources. These results obtained in research projects on optimised rational exergy consumption in buildings are promising and elucidate a huge potential for introducing new components, techniques and system solutions to create low exergy built environments. The exergy conversion, e.g. thermal energy or electricity production, plays a crucial part in possible future activities in the overall system optimisation of the entire energy system within a building.

These facts and ideas were taken up and have been discussed in several sessions during this one day conference on the subject “The Future for Sustainable Built Environments - Integrating the Low Exergy Approach” on the basis of latest research and on practical projects. The conference has been a joint activity from the partners of the international research project IEA ECBCS Annex 49 “Low Exergy Systems for High-Performance Buildings and Communities” (further information at: www.annex49.com) and the European project within the frame of the COST programme, the COSTeXergy project “Analysis and Design of Innovative Systems for Low Exergy in the Built Environment” (further information at: www.costexergy.eu). The conference took place on the 21st April 2009 with highly qualified international contributors and 96 participants from 13 countries and was a meeting of experts. The cooperation project Annex 49 is conducted within the frame of the Energy Conservation in Buildings and Community Systems Programme (ECBCS) of the International Energy Agency (IEA). The Annex 49 is a three-year project (2006 – 2009) which involves 17 research institutions and companies from 12 countries. Annex 49 is aimed at improving the design of energy use strategies, on a community and building level, based on the concept of exergy. Exergy analyses are seen to pinpoint new potentials for increasing the overall energy chain efficiency.

The main objective of the COSTeXergy project is to broadly disseminate new knowledge and practical design-support instruments that can facilitate practical application of the exergy concept to the built environment. The COSTeXergy project is one of the funded actions within the European COST programme.

COST is one of the longest-running instruments supporting co-operation among scientists and researchers across Europe. COST now has 35 member countries and enables scientists to collaborate in a wide spectrum of activities in research and technology.

Venue

The venue of the conference „Gen Coel“ in Heerlen (The Netherlands) is one of the main locations for the European CONCERTO II project REMINING-lowex (further information about the project at: www.remining-lowex.org), in the city of Heerlen. In this project the water reservoirs from old coal mines are used to run district networks for providing heat and cold to several building sites. It represents a great example of the application of low exergy principles in the built environment, both on the field of building components and community energy supply structures. Thus, it is the perfect place to hold the conference, allowing for technical tours and live experiences of the potential from the LowEx approach.

Organisers

Fraunhofer Institute for Building Physics
Kassel (Germany)
www.ibp.fraunhofer.de

CAUBERG-HUYGEN
Raadgevende Ingenieurs BV
Maastricht (The Netherlands)
www.chri.nl

SenterNovem
Sttard (The Netherlands)
www.senternovem.nl/senternovem

Technical University of Delft
(The Netherlands)
www.tudelft.nl
The Conference

This conference about the future of sustainable built environments was focused on providing front-edge results in the field of exergy analyses of buildings and communities. Additionally, a platform was created to exchange and discuss further information among participants. Thus, research institutions, universities and industry partners were invited next to interested operators and politicians to present their subjects, approaches, products and applications as well as questions referring to the concept.

The one-day conference was opened by the chairman Dr. Dietrich Schmidt from the Fraunhofer Institute for Building Physics in Germany.

Dietrich Schmidt opened the conference in his function as the chairman

The conference was structured in four main sessions. The first one started with the keynote presentation about sustainable community energy systems given by Dr. Morad Atif, the chairman the IEA ECBCS programme. The following talks concentrated on the Energy Transition Policies in The Netherlands and Primary Energy use in buildings. Furthermore, an introducing of the concept of exergy, the Low Exergy Systems for High-Performance Buildings and Communities was given to the audience and completed the morning programme.

During the lunch break, in addition, opportunity and time were given for poster sessions allowing demonstration projects or company information to be presented or just for open conversations.

In the afternoon, two sessions were offered in parallel. Under the chairman Prof. Gudni A. Johannesson from the National Energy Authority Orkugarði, Reykjavík, Iceland, in the first session presentations about Projects on Buildings and Technologies were presented, application and benefits of applying the exergy concept to building systems have been shown.

The second session was moderated by the chairman Peter Op’t Veld from Cauberg-Huygen Raadgevende Ingenieurs BV Maastricht, The Netherlands. Here, presentations about projects on LowEx in communities have been shown. The application of this thermodynamic method as a tool for improving the efficient energy supply on a community level has been presented.

After interesting sessions, each group discussed about the presented results from research projects as well as component developments of LowEx systems in buildings and communities in intense round table discussions.

Supporters

The German Federal Ministry of Economics and Technology (Germany) www.bmwi.de

European Cooperation in the field of Scientific and Technical Research www.cost.org

European Science Foundation www.esf.org

SenterNovem Sittard (The Netherlands) www.senternovem.nl/senternovem

Thereon, Prof. Masanori Shukuya (Tokyo City University, Japan) moderated the summary session. At this point, the results from the earlier discussions of each group have been presented.

Round Table Discussions in Session 1 on buildings technologies
The discussions with in the round table groups have been touching various items of the presentations. Within the first session on building technology the experts were concerned how a faster implementation of the upcoming ideas could be managed. While good technologies already exist, there is still room for a needed development of new technologies, but marketing measures are needed. Also demonstration, education and awareness rising is mandatory to succeed with the new ideas. In terms of the business cases there is a need to move from component based business to solution based business. Another group discussed the importance of the proper consideration of changing indoor conditions on human comfort and health, as well as the needed changes in HVAC system arrangements. A third group discussed intensively the use of so-called capillary tube systems in combination with PCM (phase change material) thermal storages. The technology is very promising, but more measured data from real built cases are needed. Moreover, the problem of better understanding of heat storage phenomena in buildings and the feedback on the new ideas has been discussed.

Within the second session on communities the discussion in the beginning focussed mainly on the planned developments on the Hoogeschool Zuyd campus. The participants all gathered in one large discussion group, therefore only one round table was set up. The participants discussed the different options for an energy and exergy efficient supply system. The connection to the Heerlen minewater grid was also a topic. The question on how to involve students in the proceeding building and energy concepts was raised. The participants agreed on the necessity to put effort into educational involvement to disseminate the ideas of exergy efficiency.

Besides, the conference was targeted on strengthening the political awareness of the importance and applicability of this thermodynamic approach to building systems and communities. Furthermore, the event has established contacts between industry and research partners for possible common projects in the future.

The exhibition of products, components and systems from industry partners as well as presentation of research results within the field of LowEx completed the conference. The conference day ended with a delicious dinner buffet and an exciting and lively discussion among participants and speakers and will be followed up by other events in the future.
C 1.1

Presentation
Paul Ramsak
SenterNovem, The Netherlands

Title
„Energy Transition Policies in The Netherlands – PEGO and the National Dutch Energy and Research Programme“
Energy Transition Policies in NL & EOS - The national Dutch Energy Research Programme

The National Agency for Innovation & Sustainability
- Central agency of the NL government, carrying out policies for various national/international authorities.

Work Areas
- Innovation
- Energy & Climate
- Environment

4 offices, workforce > 1000 people

Energy research coordination

Funding of Energy Research

Paul Ramsak
SenterNovem, The Netherlands
Title  "Energy Transition Policies in The Netherlands – PEGO and the National Dutch Energy and Research Programme"
C 1.1 Paul Ramsak
SenterNovem, The Netherlands
Title: "Energy Transition Policies in The Netherlands – PEGO and the National Dutch Energy and Research Programme"
Energy Transition Policy
from fossil \(\rightarrow\) to sustainable solutions

...a sustainable energy supply within 50 years

Energy Transition Policy
7 platforms developing transition strategies
- Biobased Raw Materials
- Sustainable Mobility
- Chain Efficiency
- New Gas
- Sustainable Electricity
- Energy in the Built Environment
- The ‘Greenhouse as Energy Source’

Platform members from industry, academia, and government

Energy Transition Platform - Built Environment

3 Working Groups
- Innovation Group
- Existing Building Group
- Regulations Group

2020 goals
- All new buildings (residential & commercial) energy-neutral
- 3 million homes/commercial buildings with 30% less energy demand

Total energy use in Built Environment by 2030 reduced by 50%
Working towards climate-neutral homes and suburbs
Energy Transition Built Environment - Instruments

R&D
- EOS = Energy Research Programme

Transition Experiments (Energy Innovation Agenda)
- Residential buildings (new/existing) with -45% CO₂ (phase II: -60%)
- Commercial buildings (new/existing) with -45% CO₂
- Towards climate neutral areas
  but also
- Renewable heating/cooling pilot projects
- Geothermal Energy Guarantee scheme
- ...

EOS - The NL national Energy Research programme

EOS = Greek Goddess of Dawn

EOS = Energie Onderzoeks Strategie
= Energy Research Strategy

End of 2004 a new National Energy Research Strategy has been formulated

EOS – focus areas 2005+

- Energy-efficiency in Industry & Agro
- H₂/Fuel Cells / Clean Fossil
- Biomass
  - Built Environment
- Power Generation & Networks

- NEO (New Energy Research) programme is available for renewable/innovative creative ideas, also outside focus areas
  – possible new (future) themes

- Evaluation of the NL Research Portfolio every 2 to 4 years

Subsidy schemes within EOS
**EOS LT Built Environment**

Research areas EOS LT Built Environment programme:

1. **System Approach in the built environment**
   - Theme 1: Integral conceptual studies into concepts for buildings or suburbs.
   - Theme 2: Innovative systems and their components

2. **PV solar conversion**

---

**EOS Built Environment - Strategy**

Applying the *Trias Energetica*:
- Reducing energy demand
- Using renewable resources
- Efficiently converting fossil fuels to meet the remaining demand

In addition:
- The general starting point assumes that high-grade energy (natural gas, electricity) will only be used for high-grade applications.

\[
\text{Trias Exergetica} \quad \text{= LowEx}
\]

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**The Concept of Exergy**

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<tr>
<th>Exergy</th>
<th>Energy</th>
<th>Enthalpy</th>
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<tr>
<td>100 kJ</td>
<td>100 kJ</td>
<td>100 kJ</td>
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</tbody>
</table>

1 kg water at 43°C

\[
\text{100 kJ} \quad \text{7.28 kJ} \\
(20 \degree \text{C omgevingstemperatuur})
\]
**EOS Built Environment projects**

Awarded projects in EOS focus area **Built Environment** since start in 2005

- **Long Term R&D** (7 calls)
- **8 projects** (+10 PV)
- **Short Term R&D** (3 calls)
- **6 projects** (+6 PV)
- **Demonstration** (9 calls)
- **34 projects**
  - Transition Experiments (4 broad demo calls)
  - 16 projects
  - +8 projects in -45% CO₂ residential call

[www.serternovem.nl/eos > projects](http://www.serternovem.nl/eos > projects)

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**EOS DEMO projects**

First time demonstration/field testing of innovative components, systems or concepts

- 34 EOS DEMO projects running

Types of demo-projects:

- **Individual components:** solar boilers, heat pumps, micro CHP, etc.
- **Various ventilation systems** (incl. ground heat)
- **Control systems**
- **Various passive house concepts**
- **Integral LowEx-concepts** on neighbourhood scale (incl. use of waste heat from green houses or industry and use of Geothermal Heat or Mine water)

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**EOS LT research projects**

8 EOS LT research projects running (without PV)

- **Exergetic System Approach** for an efficient, human-friendly, and cost-effective use of energy in the built environment
- **PD2015** Sustainable Project Development based on sustainable building, housing, and retrofitting after 2015
- **SNEX** Synergy between regional planning and exergy
- **WAELS** Dwelling as energy producing systems
- **Rigorous** Rigorous reduction of energy use at renovation
- **Earth, Wind and Fire** new concepts for climate control of buildings
- **Using Smart Agents and Domotics** To conserve energy in homes
- **Transep DGO** Sustainable district development

Runtime: 2008 – 2012 > 10 PhD’s

Consortia of experts from different disciplines > essential for system approach

---

**EOS LowEx research projects**

**Exergetic System Approach** - for an efficient, human-friendly, and cost-effective use of energy in the built environment

TU Delft, TU Eindhoven, U Twente

- WP People - Thermal comfort of LowEx systems
- WP Planex - Integral approach of the exergy chain
- WP Profit - Integral costs for the real estate sector in relation to LowEx systems

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Title: **Energy Transition Policies in The Netherlands – PEGO and the National Dutch Energy and Research Programme**
EOS LowEx research projects

PD2015 - Sustainable Project Development based on sustainable building, housing, and retrofitting after 2015
PGDPI: Uni Maastricht (Human Biology), TU Delft, TNO Built Environment, CHRI, Bouwhuip
- WP0 Invetaisation: building, housing and retrofitting > 2015
- WP1 Demand control & Indoor Environment
- WP2 Integrated climate responsive building elements
- WP3 Sustainable Building Services

EOS LowEx research projects

SREX - Synergy between regional planning and exergy
Uni Groningen, Univ Wageningen, TU Delft, TNO Geoscience
- Wp1 Exergetic System Analyses on a Regional Scale
- Wp2 Exergetic analyses in Urban systems
- Wp3 Regional Exergy-planning in North-NL and the 'Mijnstreek'
- Wp4 Design of Sustainable Landscapes

Special focus on the possibilities of the use of the Underground

International LowEx research cooperation

- IEA ECBCS Annex 49
  Low Exergy Systems for High Performance Built Environments and communities
- COST Action C24 - COSTexergy
  Analysis and Design of Innovative Systems for Low-exergy in the Built Environment
- LowExNet
  Network of International Society of Low Exergy in Buildings

EOS DEMO project – Tomorrow’s Neighborhood

- Joint project (HSZ initiative)
- Energy neutral area
  - 4 buildings:
    - Exergy concept
    - Passive concept
    - Training centre
- Real Life R&D lab for built environment of tomorrow
  - Test site for innovations
- Avantis
  Cross-border Science & Business park on NLD border (Heerle/Vachen)
LowEx approach for the Mine Water Project Heerlen balancing supply side (RES) with demand side (RUE) on basis of low exergy principles

Additional RES: biomass, solar

Distribution: LT DH&C, C gas system

Demand side: Buildings suitable for use of low valued energy (LTH and HTC)

Integral system approach for the total built environment
Thanks for your attention

Enjoy the conference!

To reduce environmental impact of the Built Environment, an integral system approach is essential.

In this the LowEx concept should be a key strategy.

Conclusion
C 1.2

Presentation

Olivier Pol
arsenal research, for CONCERTO Plus, Austria

Title

“Planning of Sustainable Community Energy Systems: The Experience of CONCERTO Communities”
Planning of sustainable community energy systems: the experience of CONCERTO communities

CONCERTO: many opportunities for cross-cutting analyses

CONCERTO as a combination of single measures

INTEGRATIVE APPROACH

Proof of concept - Renewable Energy

INTEGRATIVE APPROACH

Research

Training

Monitoring
Integration?

The risks of a traditional approach (local energy policies focused on single actions):
- Incoherent subsidising mechanisms; individual thermal energy systems might be subsidised in high density areas where district heating is already available and feed-in mechanisms could be supported.
- Focus on RES instead of prioritising energy efficiency in buildings.
- Incompatibility between building energy system design and supply infrastructure (e.g., buildings designed for low temperature heating systems but connected to high temperature energy supply infrastructure).
- Urban planning done without considering energy criteria.

The opportunities of an integrated approach at community level:
- Coherent local energy policy avoiding contradictory or inefficient actions (e.g., by coordinating the single actions in a whole programme, avoiding concurrence between single actions).
- Use of RES only in systems where the overall energy efficiency has been first improved.
- Comprehensive design of the overall energy transformation chain, avoiding exergy losses.
- Close collaboration between urban planners and energy experts at municipal level.

Measures implemented in CONCERTO to support integration

<table>
<thead>
<tr>
<th>Contribution of CONCERTO communities</th>
<th>Field of activity and context</th>
</tr>
</thead>
<tbody>
<tr>
<td>Implementation of synergies between buildings in one neighbourhood</td>
<td>- Involvement of universities and research centres in the projects - Support provided at municipal level (local energy agency) - Operational support (modelling, GIS-supported decision making)</td>
</tr>
<tr>
<td>Integration of urban planning and energy aspects</td>
<td>- Involvement of urban energy and urban planning departments - Operational issues</td>
</tr>
<tr>
<td>Integration in an overall approach towards sustainable communities (stable and mixed social structure, quality of life improvement, transport aspects, general low environmental impact,...)</td>
<td>- Involvement of all public stakeholders (energy, climate protection, transport authorities and urban planning departments) - Involvement of residents of the community - Local participation, bottom-up approach</td>
</tr>
</tbody>
</table>

Degree of integration

- Standards set at municipal level
- Energy experts supporting community developers and investors
- Quality control during the construction process
- Interdisciplinary design procedure, modelling and simulation
- Process depending on the legal context

Degree of integration

- Call for tenders for the design, construction and operation of the community energy system
- Process depending on the legal context

Decision making supported by Geographic Information Systems

Modelling and optimisation of district energy systems to support the design process
- Reduction of CO₂ emissions
- Costs reduction

Building energy performance simulation

Monitoring of energy flows at urban scale: use of actual energy balance to plan specific measures
Conclusions

Urban sustainable development strategies should be based on a holistic approach (instead of technical or sectoral approach). This approach is a "degree of integration" and is not the same in all communities.

A favourable legislative framework supporting the development of sustainable communities using integrated community energy systems is still missing in many countries, mainly because the legislations usually follow a sectoral approach or support only specific mechanisms.

However, the CONCERTO communities already propose and test solutions in different fields (decisional issues, operational support, interdisciplinary design procedures, stakeholder involvement, bottom-up approach and computational modelling) required in many cases to support decision making.

Computational modelling is required in many cases to support decision making.

Thank you for your attention!

Contacts

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olivier.pol@arsenal.ac.at
General information on the CONCERTO initiative
www.concertoplus.eu
Presentation

Morad R. Atif
Chairman, ECBCS Executive Committee / National Research Council Canada

Title

The Sector: Buildings and Communities

- Buildings = 30-40% of energy use
- Buildings = 30% of GHG emissions
- Construction = 25-40% solid waste
- Construction = + 50% primary resources
- GDP = 10-15%

Vision for the Built Environment

Adoption of near-zero primary energy use and carbon emission solutions

ECBCS Programme

- Collaborative R&D Agreement among 25 countries (since 1977)
- Objective: Near-zero energy use for the built environment
- Mission: Development and dissemination of energy conservation and sustainable technologies
- Vision: A world where buildings and communities operate efficiently and are environmentally sustainable

ECBCS: R&D for Near-Zero Energy and Carbon Emission for the Built Environment

Morad R. Atif, Ph.D.
Chairman, ECBCS Executive Committee / National Research Council Canada

Indoor Environment Research Program
Institute for Research in Construction

International Energy Agency
Energy Conservation in Buildings and Community Systems Programme - ECBCS
Title: "ECBCS: R&D for Near-Zero Energy and Carbon Emission for the Built Environment"
Cost-effective Commissioning of Existing and Low-Energy Buildings and Communities

Fuel Cell Technologies

Low Exergy for Cooling/Heating (Annex 37)

- Fuel Cell/Co-Gen - Cooling/heating (Annex 42)

Simulation of Building-Integrated Fuel Cell & Cogeneration Systems

- Simulation Models for Residential co-gen & Fuel Cell technologies
- Measured performance of residential cogen technologies
- Co-Gen performance (technical, economic, environ.)

Charging Station

- Electric Vehicle Charging Station
- Fuel Dispenser
- Outdoor Chamber
- Indoor Chamber

FCU

- Fuel Cell and Co-generator in buildings: Experimentation

International Energy Agency
Title “ECBCS: R&D for Near-Zero Energy and Carbon Emission for the Built Environment”
Energy Conservation in Buildings and Community Systems Programme - ECBCS

**Toward zero energy Innovation in Building Envelope Retrofit**

- High Performance Insulation for Buildings (Annex 37)
- Whole Building’s Heat, Air, Moisture for Energy Perform. (Annex 41)

**Prefabricated Systems for Low-Energy Renovation of Residential Buildings**

- Building energy retrofit
- Prefabricated Low-rise Residential Systems
- Demonstration projects
- 30-50 kWh/(m²·year) for heat, cooling & H-water

**Whole Building Retrofit- Energy and Environment**

- Integrating Environmentally Responsive Elements in Buildings

ECBCS: R&D for Near-Zero Energy and Carbon Emission for the Built Environment

**Moving Forward - Current Projects**

**Building Systems**
- Energy-efficient Electrical Lighting (LED) for Buildings
- Heat Pump & Reversible Air-Conditioning
- Advanced Commissioning of HVAC for Energy Savings
- Air Infiltration & Ventilation Centre

**Communities**
- Low-energy Systems for High Perfor. Building/communities
- Guidelines and case studies for Energy-efficient communities

**Low-Exergy in the Built Environment**
- Combine energy conservation with low-quality energy
- Low valued and sustainable energy for cooling and heating
- Low quality Sources: Solar thermal, air/ground heat...
- 3 Projects on buildings and Communities

**Integrated Building Systems**
- Prefabricated energy retrofit systems for Residential buildings
- Near-zero energy houses (demo)
- Environmentally responsive elements for buildings
- Energy retrofit toolkit for government buildings
- Total energy consumption of buildings - Methodology
Emerging Technologies
- Co-generation, fuel cell, material sciences
- Solid state lighting, low-exergy

Effective integration
- Energy positive (E+), Factor X
- Community systems

Integrated decision-making processes
- Applications of ICT for O&M
- Life-cycle based decision-making
Presentation

Dietrich Schmidt
Fraunhofer Institute for Building Physics, Germany

Title
“Low Exergy Systems for High-Performance Buildings and Communities”
Objectives

Energy savings and reduction of CO₂-emissions:

- By facilitating and accelerating the use of low valued and environmentally sustainable energy sources for heating and cooling of buildings.
- Through the utilization of the EXERGY concept

Approach: Exergy concept

- matching the Quantity AND Quality levels of supply and demand:
  - Quantity ⇒ Energy savings
  - Quality ⇒ use of low quality sources e.g. solar thermal heat, ground/air heat
"Low Exergy Systems for High-Performance Buildings and Communities"
Background: Energy
Energy flows through the building for the base case

Background: Energy and Exergy analysis

Comparison of different heating systems:
Electric radiator, Heat pump with floor heating

LowEx Building Systems:
Development of innovative LowEx Systems

Heat/cold emissioning systems and storages
Use of Phase Change Materials (PCM) in buildings - how to improve thermal comfort in summer?

- Light building without PCM
- Light building with PCM
- Massive construction

Room air temperature

1 week
2 weeks
3 weeks

Source: IBHauser, Germany

Decentralized AHU with PCM storage

Combination of night ventilation and discharging the storage
Additional heat exchanger for peak loads
Integration in the facade construction (Office use)

Source: Imtech, Germany

PCM storages in the building construction

In microcapsules
In packages

Source: IBHauser, Germany

PCM in light weight buildings (attics)

- Measurements of the indoor comfort in attics
- 4 cells, with and without PCM

Source: IBHauser, Germany
**Base technology: „Capillary Tubes“**

- Tubes of 4 mm in parallel, distance 15 mm
- Suitable for retrofit
- New applications:
  - Thermally activated surface
    (approx. 80 W/m² heating and 40 W/m² cooling)
  - Active facades
  - Heat exchanger
  - Combination: PCM – suspension

**Thermally activated surfaces with „Capillary Tubes“**

Displacement of heat between rooms with different thermal load structures (e.g. North-South-facades, server room)

Thermal activation of basements

**Thermally activated surfaces with „Capillary Tubes“**

PCMs storages
(macro scale or inside the plaster)

Thermally activated surfaces

Active exterior facade constructions
(active night cooling)

**Ground heat exchanger**

Use the ground as a energy source (mainly for cooling)

- Energy poles
- Bore holes
- Horizontal heat exchanger
- Horizontal heat exchanger with capillary tubes
Analyses tools for LowEx systems

Software tools for an energy/exergy assessment
Dynamic analyses of complex systems (room, building, supply)

Design Strategy

Concepts

Technology

Building concepts

Cleanest fossil fuels
Low energy systems
Apply Renewable Energy sources
Reduction of energy demands

Source: CHRI NL

Comparison of different heating systems:
Electric radiator, Heat pump with floor heating

Components

LowEx management

Flow of exergy

Components

Flow of energy

LowEx supply structures?
The Mine Water Project Heerlen:
Balancing supply side (low valued RES) with demand side

**Supply**
- Mine water
- Additional RES: biomass, solar

**Distribution**
- LT DH&C 3-pipes system

**Demand**
- Buildings suitable for use of low valued energy (LTH and HTC)

**Integral system approach** for the total built environment

---

Assessment of different options

<table>
<thead>
<tr>
<th>Ratio fossil fuel (PER)</th>
<th>Ratio fossil fuel (PER)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- Low temperature cooling (LTC)
- High temperature cooling (HTC)
- Low temperature heating (LTH)
- Combined heat and power (CHP)
- Domestic hot water (DHW)

---

LowEx Community cases

**Okotoks, Canada**
- 52 single family homes (140m²)
- 120m³ short term storage (water)
- 144 boreholes (35m deep, 15cm ø)

---

Conclusions

1. Exergy demands for heating/cooling are very small - Energy demands are high.
2. Supply as low exergy as possible to the room space.
3. Find suitable low-exergy sources in the immediate/local environment.
4. Development of system-components and their smart integration are necessary.

Rational exergy consumption patterns are possible.

*This is our challenge!*
C 1.5

Presentation

Sabine Jansen
Technical University Delft, The Netherlands

Title
“European Exergy Research Network – COSTeXergy”
European Exergy Research Network – COSTeXergy

On behalf of the chair: Elisa C. Boelman, Dr.Eng. MBA
Presented by Sabine Jansen

Objectives

• Strengthen Europe in scientific and technical research for peaceful purposes through the support of cooperation and interaction between European researchers
• 35 COST countries

Domains

• BMBS - Biomedicine and Molecular Biosciences
• CMST - Chemistry & Molecular Sciences & Technologies
• ESSEM - Earth System Science and Environmental Management
• FA - Food and Agriculture
• FPS - Forests, their Products and Services
• ISCH - Individuals, Societies, Cultures and Health
• ICT - Information and Communication Technologies
• MPNS - Materials, Physical and Nanosciences
• TUD - Transport and Urban Development

www.COSTeXergy.eu
**Title: European Exergy Research Network – COSTexergy**

**Objectives**
- Support to research & technology development
- Support to scientific networking

**Countries**
- 27 EU Member States
- EFTA Member States (Iceland, Norway, Switzerland)
- Accession & Candidate Countries (Croatia, FYR of Macedonia (FYROM), Turkey)
- Other Countries (Republic of Serbia)
- COST Co-operating States (Israel)

**Participation by non-COST Countries**

Total number of participations in running Actions: 155 (incl. 6 NGOs)
Analysis and Design of Innovative Systems for Low-EXergy in the Built Environment

General Objectives

- Disseminate new knowledge and practical design-support instruments that can facilitate the practical application of the exergy concept to the built environment
- Promote eXergy concept
- Demonstrate eXergy applicability
- Disseminate knowledge & instruments
Title: “European Exergy Research Network – COSTexergy”

- **WG 1**: Practical applicability of exergy analysis.
- **WG 2**: Use of insights from exergy analysis to identify and develop innovative concepts.
- **WG 3**: Interaction between human body and indoor environment.
- **WG 4**: Dissemination.

**COSTexergy Countries**

- AT, BE, DE, DK, FI, GR, HU, JP, IT, NL, NO, PL, PT, SE, SI, UK

> 30 members in 16 countries

> 35 young researchers actively participate

**COSTexergy Activities**

- Training schools (DK, SE, GR)
- Design workshops (SI, NL)
- Conferences (NL, GR, DE)
- “Short Term Scientific Missions” (STSM)

**COSTexergy Users & Actors**

- WP 1: Practical Applicability
- WP 2: Innovative Concepts
- WP 3: Human Body & Indoor Environment

**COSTexergy Structure**

- Buildings & Districts
- Users & Actors
- Components & Subsystems

- Energy Supply & Demand
- Control & Energy Demand
- Human Health & Comfort
- Definitions & System’s
- Design Tools & Practical Examples
COSTeXergy Activities

• Joint publications by (young) researchers
  • review of relevant exergy research (DE+IT)
  • exergy and thermal comfort (DK+SI+NL)
  • exergy and economics (AT+FI+SE+NL)

COSTeXergy Coming soon

ELCAS Workshop & Symposium: Exergy, Life Cycle Assessment, and Sustainability

• 4-6 June, 2009, Nysiros, GR
• Exergy and economics workshop
• www.ieees.org/elcas (see poster)

Thank you for your attention
Presentation

**Masanori Shukuya**
Tokyo City University, Japan

**Title**
“Exergetic Thinking: Its Fundamentals and Applications Looking into the Future”
What is the Built Environment?

- Our closest environmental space
- 80-90% of hours each day
- For a person with 80 years of lifespan: 64-72 years

Masanori Shukuya
Tokyo City University
(Fomer Musashi Inst. of Technology)

21st April, 2009

Nested Structure of Environmental Space

COSTexergy/IEA-ECBCS-Annex 49 Conference, Heerlen, the Netherlands

C 1.6

Shukuya lab.
Title  “Exergetic Thinking: Its Fundamentals and Applications Looking into the Future”

1. A > B
2. A = B
3. A < B

\[ A = \frac{\text{Emitted light}}{\text{Mass}} \]
\[ B = \frac{\text{Metabolic heat}}{\text{Weight}} \]

Sun

A

B

Earth

How large?

10 times

100

1000

10000

Sun

A

B

Earth

How large?

10 times

100

1000

10000
Human body, Built environment and Thermodynamics/Heat transfer

- Passive Technology - different from a region to another region
  Diversity

- Active Technology - all similar to each other
  Universality

Passive Technology

Active Technology

Passive Technology thrown away

Active Technology too gigantic

Two Problems to be solved

- External & Internal Environments
- Energy → Exergy

Advanced Renewed Passive Technology

Active Technology suiting to Passive Technology
Why is "Exergy" necessary?

Human Being and Built Environment

Thermodynamic Systems

Quoted from M. C. Escher (1961)

1674 kJ

1674 kJ

20 L of water

20°C

40°C

0°C

20°C

100°C

Environmental Temperature

Thermal Energy
16 persons, who weighs 73kg each, fall down from the roof of a 38-storied building (146.3m).
How does a Model Heat Engine work?

Exergy and Entropy Flows through a Model Heat Engine

Exergy Consumption (Entropy Generation)

Exergy Supply

Exergy Output

Entropy Disposal

The environment is where the entropy is discarded.
How does a Model Heat Engine work?

1. To prepare a heat source (exergy source)
2. To confine the working fluid in a closed space
3. To prepare a cold source (entropy sink)
4. To prepare a circulating pump

Energy and Entropy Flows through a Model Heat Engine

Exergy-Entropy Process

Masanori Shukuya
Tokyo City University, Japan
Title: "Exergetic Thinking: Its Fundamentals and Applications Looking into the Future"

An Example of Heating Exergy Calculation

\[ Q_H = W + Q_L \] (1)
\[ \frac{Q_L}{T_L} + S_{\text{ref}} = \frac{Q_L}{T_L} \] (2)
\[ (1 - \frac{T_L}{T_H}) \frac{Q_H}{T_H} - S_{\text{ref}} = W \] (3)

This is the Environment.

Energy and Mass Conservation
Entropy Generation
Exergy Consumption Theorem
Environmental Temperature

Exergy Balance Equation

[Exergy Input] - [Exergy Consumed] = [Exergy Stored] + [Exergy Output]
Human-Body Energy-Consumption Rate and Surrounding Temperatures (Winter)

Outdoor Environmental Condition: 0°C; 40 %rh
(Isawa & Shukuya, 2002)

Dispersion of Thermal Energy = Metabolic Energy Rate

Appropriate thermal insulation together with appropriate heat capacity to make use of "warm" and "cool" exergies

Solar exergy, which is very rich, to be consumed effectively for space and water heating
Pleasant outdoor environment with higher radiant and lower air temperatures

An old school in Iyo, Japan

Pleasant indoor environment with higher radiant and lower air temperatures

Human-body Exergy Consumption Rate [W/m²]

Room air: 26 °C; 50%rh
Outdoor Environmental Condition: 33 °C; 60%rh

Remodeling of an old Norwegian house

Retrofitting with a low-exergy heating system (Onbou) and a garden (Salon)
Human-body Exergy Consumption Rate [W/m²]

convective cooling

Room air: 26 °C; 50%rh
Outdoor Environmental Condition: 33 °C; 60 %rh
(Iwamatsu & Shukuya, 2008)

natural ventilation + radiant cooling

Room air: 30 °C; 65%rh
Outdoor Environmental Condition: 33 °C; 60 %rh
(Iwamatsu & Shukuya, 2008)

Human-body Exergy Consumption Rate [W/m²]

natural ventilation + radiant cooling

Room air: 30 °C; 65%rh
Outdoor Environmental Condition: 33 °C; 60 %rh
(Iwamatsu & Shukuya, 2008)

Effective external shading

Enhancement of air movement

Open space for natural ventilation

Masanori Shukuya
Tokyo City University, Japan
An Example of Cooling Exergy Calculation

Cool Radiant Exergy Available from the Sky
From High-Ex Systems
To Low-Ex Systems

[Conventional Exergy Input] - [Exergy Consumed] = [Cool Exergy] + [Warm Exergy]

[Cool Exergy Input from the immediate Nature] + [Less Conventional Exergy Input] - [Less Exergy Consumed] = [Cool Exergy] + [Less Warm Exergy]

An example of Cool Exergy Use from Snow
(Yasuzuka-machi, Niigata)

Snow stored in a parking lot

5th August, 2003

Rice-grain shells for thermal insulation

An example of Cool Exergy Use from Snow
(Yasuzuka-machi, Niigata)

Outside and inside surface temperatures of the grain-shell insulator

Snow storage for space cooling at a building in the area
“Exergetic Thinking: Its Fundamentals and Applications Looking into the Future”
Biological clock

Biological clock in harmony with nature

In a room with dehumidification (high air temperature and low air humidity)

Responsive

Not Responsive

Yokohama, Summer in 2003
Electric lighting as ‘warm’ radiant exergy sources to be reduced for an efficient radiant cooling

Human body, Built environment and Thermodynamics/Heat transfer

Radiation
Conduction
Convection
Evaporation
S 1.1

Presentation

Wouter Marken Lichtenbelt
University of Maastricht, The Netherlands

Titel

“Human Thermoregulation - Consequences for Adaptive Comfort and Exergy Design”
"Human Thermoregulation – Consequences for Adaptive Comfort and Exergy Design"
Adaptive dwellings include transient conditions and individualization. Dynamic thermal modeling topics include transient conditions and individualization. Dynamic thermal modeling is a tool for understanding comfort and health in buildings. Are they synonyms for individualization? Fanger's 1970 model links the body heat balance to comfort under different environmental conditions (including clothing) and activity levels. This model is a foundation for understanding metabolic implications and the energy balance of the human body. The SenterNovem EOS-LT project focuses on sustainable project development and evergetic system approach. Numerical modeling human thermoregulation and comfort predicting individual temperature distribution (changes) under transient non-uniform conditions and relation to thermal comfort.
Mathematical Models human thermoregulation

- Population based
- Fanger 1971
- Gagge 1975
- Liss 1991
- Tan 2002
- And others...
- Including individual characteristics
- Valid in steady state situations and near thermoneutrality
- Needed: dynamic modeling in non-uniform conditions
- Standard population
- Predictions on an individual level

Including individual characteristics
- Huizinga 2001/2004
- Havenith 2001 (heat stress response)
- Van Marken Lichtenbelt 2007 (heat stress response modified)
- And others...

Mathematical Models human thermoregulation

- Population based
- Fanger 1971
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Including individual characteristics
- Huizinga 2001/2004
- Havenith 2001 (heat stress response)
- Van Marken Lichtenbelt 2007 (heat stress response modified)
- And others...

ThermoSEM

- Physiologically based modeling
- Individualization
- Dynamic conditions (B. Kingma)
- Special attention to aging and obesity
- Link to Computational Fluid Dynamics Model
- Link to thermal comfort
- Non-uniform conditions (L. Schellen)
- Energy metabolism (heat production)
- Energy metabolism (heat production)
- Blood perfusion (heat loss and heat distribution)
Mathematical Models of Thermoregulation

Stolwijk 1971

6 segments + central blood pool
Control functions for blood flow, metabolism and sweating

Active model

Passive model

Individual variation in thermoregulation

S 1.1 Wouter Marken Lichtenbelt
University of Maastricht, The Netherlands
Body temperature

Body composition

Individual responses to mild cold

- Metabolic
  - Increase energy metabolism
  - Equal $T_{body}$

- Insulative
  - Equal energy metabolism
  - Decrease $T_{skin}$

Inter-individual differences in changes in heat production and heat loss
Validation study: inclusion individual characteristics

- Experiment
  - 1 hour comfort (22 °C) followed by 3 hours mild cold (15 °C)
  - 20 subjects
  - BMI: 19.2-30.3 kg/m²; body fat: 10.2-33.5%
  - Standardized clothing (0.71 clo)
  - Body composition (3-compartment model)
  - Energy expenditure (indirect calorimetry)
  - Body temperature (skin; rectal)

Short term (3 hour) mild cold exposure

- Metabolic Rate (kJ/min)

Model validation

Dynamic Thermosensation Model (DTS)

- Links physiological parameters to thermal sensation
- Standard subject

- DTS:
  - T skin
  - T core
  - Change in T skin
Thermal sensation = 0.24 Tair - 0.09 Tskin - difference - 5.23
Skin perfusion under variable conditions
Comparison young adults and elderly

Boris Kingma

- Major effector in body heat loss
- Relation to thermal comfort

\[ W = (w_0 + a \cdot CS)^2 \cdot \frac{T - T_0}{10} \]

Skin perfusion under variable conditions
Comparison young adults and elderly

Boris Kingma

Laser Doppler Flowmetry

Perfusion units

Cold sensitive nerve

Brain

Nerve terminal

Norepinephrine

Vessel
Effect local cooling

ThermoSEM modeling perfusion

User friendly interface

ThermoSEM

Individualization significant improvement of model predictions
Perfusion: modeling heat distribution
Link physiological parameters to thermal comfort

ThermoSEM

Computational Fluid Dynamics Model

Perfusion: modeling heat distribution
Link physiological parameters to thermal comfort

ThermoSEM
Is comfortable healthy?

Environmental temperature above or under thermo-neutral zone increases energy utilization

Brown adipose tissue (BAT)

PET-CT scan

S1.1 Wouter Marken Lichtenbelt
University of Maastricht, The Netherlands
Combining metabolic studies and PET/CT scans

• Relate BAT activity to metabolism

Brown Fat activity and body composition

Brown fat activity
Thermoneutral versus cold
Brown fat healthy?

Brown Fat activity and body composition

Regular cold exposure can be healthy

- Increase energy utilization
- Increase metabolic capacity (possible role brown fat)
- Increase energy utilization after dinner
- Possibly increase capacity of skin blood perfusion

Conclusion

Thermal comfort and health

Comfort zone < thermoneutral zone < healthy zone

Brown fat healthy?

Farmer Nature 2009

Brown Fat activity and body composition

Regular cold exposure can be healthy

- Increase energy utilization
- Increase metabolic capacity (possible role brown fat)
- Increase energy utilization after dinner
- Possibly increase capacity of skin blood perfusion

Conclusion

Thermal comfort and health

Comfort zone < thermoneutral zone < healthy zone

S 1.1  Wouter Marken Lichtenbelt
University of Maastricht, The Netherlands
S 1.2

Presentation
Bruno Lüdemann
Imtech, Germany

Title
“Cooling without Chillers: Decentralised LowEx Air Handling Unit with Integrated PCM - Storage”
The Future of Sustainable Built Environments
Integrating the Low Exergy approach

Prototype: Cooling power for various volume flows
operation mode: loading heat

PCM-appliance: possible materials
Ref.: Bine-Info

Development:
SGL-Carbon, ZAE Bayern
air-based storage module (regenerative) constructed out of storage plates

LowEx systems for heating, cooling and ventilation

Dr.-Ing. Bruno Lüdemann
Imtech Deutschland GmbH & Co. KG
Research and Development

Bruno Lüdemann
Imtech, Germany
"Cooling without Chillers: Decentralised LowEx Air Handling Unit with Integrated PCM - Storage"
Day: PCM loading heat (5 kg/m²)

Night: PCM unloading heat

\[ t_A < 22^\circ \text{C}, \quad V = 180 \text{ m}^3/\text{h per appliance} \]

PCM – reference plant: position in the building

Facade with exterior sunblind, max. cooling load 60 W/m²

PCM – reference plant with 50 appliances, operation since March 06

Installation situation in a south-west orientated office

Performance data are measured constantly for every single appliance

data-basis for the optimization of the control strategy
**Cooling without Chillers: Decentralised LowEx Air Handling Unit with Intergrated PCM - Storage**

- **Title:** "Cooling without Chillers: Decentralised LowEx Air Handling Unit with Intergrated PCM - Storage"

- **Abstract:**
  - **South facade office:** unit with external air, temperatures and ventilator control, September 2006, cloudless warm weather
  - **West facade office:** unit with external air, temperatures and ventilator control, July 2006, cloudless, extremely hot weather

- **Graphs:**
  - Graphs showing temperature, signal ventilator, ambient temperature, and temperature in the boundary layer.
  - Date, time [d, h]
  - Temperature [°C]
  - Signal ventilator [%]

- **Diagrams:**
  - Diagrams illustrating the constructional solutions for external air intake and removal of overheated air in the boundary layer.

- **Conclusion:**
  - Improvement in air handling through the use of decentralized low-energy air handling units with integrated PCM storage.

- **Keywords:**
  - LowEx air handling
  - Decentralized system
  - Integrated PCM storage
  - Sustainable Built Environments

---

**Forschung und Entwicklung**

**Sustainable Built Environments - Heerlen**
Energy efficiency: coupled simulation building – PCM-unit plant

thermal room model coupled modell appliance - room

Conclusion:

• New LowEx air handling unit with PCM storage works successful since 2006 in the Imtech headquarter: 5 kg PCM per m² office area is adequate for 60 W/m² cooling load
• Appliance and control concept have series production readiness
• Summer periods with temperatures in the night under 18 °C are mastered → Room temperatures are bordered under 26°C
• The design of the facade has to be adjusted with the unit concept → avoiding the overheating of the intake air
• Energy savings compared to conventional cooling-systems: between 55 % and 85 %
• Potentials for optimization: predictive control, storage dimension (for bigger loads), new materials (costs, energy density).

Actual Research – project with Fhg-ISE: storage concepts with PCM or PCS

actual projects:
• PCM-units for patient rooms in a hospital in Kiel
• PCS-Storage as backup cooling for machine tools in the automotive industry

PEM

macro encapsulated PCM

Quelle: BASF/ISE

PCM

PCS (Phase Change Slurries)
Title
“Cooling without Chillers: Decentralised LowEx Air Handling Unit with Integrated PCM - Storage”

Thank you for your attention
S 1.3

Presentation
Dirk Müller
E.ON Energy Research Center, Germany

Titel
“Utilisation of Capillary-Tube-Systems with PCM Storages”
History of Phase Changing Materials – Ice Storage

Heat source - room

Heat sink – chiller machine

time shift

Utilisation of the ambient air as heat sink?

Ambient Air as Heat Sink for Cooling Applications

Reference year Berlin, 19th of August

Temperature in °C

Utilisation of Capillary-Tube-Systems with PCM Storages

Institute for Energy Efficient Buildings and Indoor Climate
Dirk Miller, Alexander Hoh
Capillary tube mats & PCM storage tank

Day time: Capillary tube mats, PCM storage tank
Night time: PCM storage tank, Capillary tube mats

External heat exchanger

Classification of PCMs

- Water
- Salts hydrates
- Paraffins

Classification of PCMs

- Aluminum or plastic storage plate
- Large surface for better heat exchange process
- High packing density for compact storage devices
- Useable for paraffin and salt hydrates

TROX PCM Storage Plate

PCM Properties

- Depending on state
- Heat conductivity
- Density
- Hysteresis
- Depending on temperature
- Heat capacity
Title: “Utilisation of Capillary-Tube-Systems with PCM Storages”

- **PCM System Test Set-up**
  - Day time: cooling
  - Night time: regeneration

- **Experimental Set-up for the PCM Cooling System**
  - Test room
  - Cooling panel with capillary pipe mats
  - Each 36 m²
  - Facade integrated heat exchanger
  - Facade integrated heat exchanger

- **Experimental Set-up for the PCM Cooling System**
  - Test room
  - Cooling panel with capillary pipe mats
Experimental Set-up for the PCM Cooling System

- Hydraulic system
- Integration of measurement instrumentation
- Supply system for the storage device and facade heat exchanger
- Installation of the facade heat exchanger

Installation of the Capillary Tube Mats

- Window area 6 m²
- Each 36 m²
- Facade integrated heat exchanger
- South orientation

Pictures of the Construction Phase

- Reference room
- Technical facilities room
- Test room

Experimental Set-up for the PCM Cooling System

- Test room with latent heat storage
- Reference room (without latent heat storage)
Results – Thermal Power in W/kgPCM

Approx. four times higher than water

Object Oriented Dynamic Simulations using Modelica

Walls, door, windows
Capillary tube mats
Convection, radiation, humidity, solar radiation
Hydraulic, storage
Approx. 22,000 equations
Hydraulic Model and Controller

Outside temperature

Operative temperature

Return

Flow

Night time: storage regeneration

Cooled Ceiling, PCM 22 °C

Simulationsergebnisse: Plot

Days

Temperature in °C

Melt level

10. August

3.0 K

2.4 K

without PCM

with PCM

Cooled Ceiling, PCM 20 °C

Simulationsergebnisse: Plot

Days

Temperature in °C

Melt level

10. August

3.1 K

2.1 K

without PCM

with PCM

empty storage

Optimisation of the System Performance

Direct heat transfer to the ambient after storage regeneration during night time

Increasing the PCM storage size
Results for the Optimises PCM Cooling System

- Experiment with 1.7 kg/m² without nightly room cooling
  ⇒ up to 2.5 K
- Experiment with 1.7 kg/m² with nightly room cooling
  ⇒ up to 4 K
- Simulation with 8 kg/m² without nightly room cooling
  ⇒ up to 4 K

Conclusion and Outlook

- The new system with PCM shows sufficient potential for cooling applications for low load office applications
- Controlling of the complex system can be improved
  - Cooling and Regeneration control
  - Additional nightly room cooling
- Next steps:
  - Integration of the storage device in heat pump systems
  - PCM Emulsions as heat transfer and storages medium

Design of a Latent Heat Storage Tank

- First Prototype with RT20 (Rubitherm, Matino GmbH) as phase change material
- Capillary tube mat as heat exchanger
- Measuring of the thermal behavior at a test bed
Presentation

Ad van der Aa
CHRI, The Netherlands

Titel
“Designing with Responsive Building Elements: Concepts and integrated design approach”
Responsive building elements

Building construction elements that assist to maintain an appropriate balance between optimum interior conditions and environmental performance by reacting in a controlled and holistic manner to changes in external or internal conditions and to occupant intervention.

Examples include:
1. Facades systems (ventilated facades, double skin facades, adaptable facades, dynamic insulation)
2. Foundations (earth coupling systems, embedded ducts)
3. Storage (active use of thermal mass, material - concrete, massive wood - core activation for cooling and heating, phase change materials (PCM))
4. Roof systems (Green roof systems)

Responsive building concepts

Pattern A / Pattern B buildings

Fundamental principles

Design approach of buildings

Designing with Responsive Building Elements: Concepts and integrated design approach
Responsive Building Elements studied in IEA Annex 4

RBE’s principles

Responsive Action

Building Elements

Classification of Responsive Building Elements

RBE

Heat flux
Ventilation
Energy storage
Light flux

W/m²

°C

RBE’s principles

Physical behaviour

Intervention

Surface

Internal

Heat flux

Thermal storage

Transparency

Permeability

Building system

Ad van der Aa

CHRI, The Netherlands
Title  “Designing with Responsive Building Elements: Concepts and integrated design approach”
Title: “Designing with Responsive Building Elements: Concepts and integrated design approach”
### Integrated Building Concept

**Concept Level**
- Architectural Quality
- Indoor Climate
- Occupant Behavior

**System Level**
- Building Construction and Envelope System
- Building Services System
- Energy Supply and Renewable Energy System

**Component Level**
- Glazed Facade
- Counter Flow Heat Recovery
- PCM Energy Storage
- Heat Pump

### Integrated design process

**Step 1 + 2**
- Concept design phase
  - Preliminary design

**Step 3 + 4 + 5**
- System design phase
  - Final design

**Step 6**
- Component design phase
  - Detailing phase

### Design steps

<table>
<thead>
<tr>
<th>Step</th>
<th>Heating</th>
<th>Cooling</th>
<th>Lighting</th>
<th>Ventilation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Basic Design</td>
<td>Conservation</td>
<td>Heat Avoidance</td>
<td>Daylighting</td>
<td>Source Control</td>
</tr>
<tr>
<td>2. Climatic Design</td>
<td>Passive Heating</td>
<td>Passive Cooling</td>
<td>Daylight Optimization</td>
<td>Natural Ventilation</td>
</tr>
<tr>
<td>3. Integrated System Design</td>
<td>Application of Responsive Building Elements</td>
<td>Application of Responsive Building Elements</td>
<td>Lighting</td>
<td>Mechanical Ventilation</td>
</tr>
<tr>
<td>5. Design of Conventional Mechanical Systems</td>
<td>Heating System</td>
<td>Cooling System</td>
<td>Artificial Lighting</td>
<td>Mechanical Ventilation</td>
</tr>
</tbody>
</table>

**Step 1**
- Surface to volume ratio
- Zoning
- Insulation
- Infiltration

**Step 2**
- Direct solar heat gain
- Thermal storage wall
- Sunspace

**Step 3**
- Free cooling
- Night cooling
- Earth cooling

**Step 4**
- Windows (type and location)
- Glazing
- Skylights
- Lighting control

**Step 5**
- Radiators
- Cool air system
- Fans
- Lighting control

**Step 6**
- Univocal
- Detailed
- Makable

**What**
- Requirements of the climate and regulations
- Architectural and esthetics

**Where**
- Climate conditions and urban context
- Surface temperature and orientation

**Ad van der Aa**
- CHRI, The Netherlands
Title  “Designing with Responsive Building Elements: Concepts and integrated design approach”
Responsive building concepts are a next step forward in reducing the energy consumption in buildings. This refers to "traditional" design principles in combination with advanced, intelligent and smart building elements and concepts. Increasingly an integrated design approach is a prerequisite.
S 1.5

Presentation
Sabine Jansen
Technical University Delft, The Netherlands

Title
“Exergetic System Approach for an Efficient, People-Friendly and Affordable Use of Energy in the Built Environment”
INTRODUCTION

ORGANISATION

• Dutch research project
• financed within the EOS LT programme of Senternovem
• Carried out by the three Dutch technical universities:

INTRODUCTION

BACKGROUND:

• Need for sustainable energy supply systems
• Current use of high quality energy sources in the built environment
• The exergy as a measure of the quality of energy can support the development of improved systems.
INTRODUCTION

PROJECT OBJECTIVE:
• contribute to a substantial reduction of high quality energy use in the built environment,
by a better thermodynamic match between demand and supply
looking at the three important aspects of sustainability: people, planet and profit.

INTRODUCTION

LowEx.NL

3 Components: People, Planet, Profit

• People
  Assessment of thermal comfort in non-uniform environments.

• Planet
  Guidelines for a better thermodynamic match between demand and supply

• Profit
  Research on the financial benefits of exergetic optimization of real estate

Consisting of 3 PhD Projects:

Each component 1 individual PhD research

PEOPLE
Comfort

PLANET
Exergy

PROFIT
Finance

Lisje Schellen
Sabine Jansen
Bram Entrop

Title
“Exergetic System Approach for an Efficient, People-Friendly and Affordable Use of Energy in the Built Environment”
People: Objectives

Main objective:
Assessment of thermal comfort in non-uniform and transient conditions.

1. More insight in thermal comfort in relation to LowEx systems
2. Combine boundary conditions and thermophysiology to determine thermal comfort
3. Validation of method and practical applicability

People: Intended results

- Method to assess thermal comfort in relation to non-uniform environments
- Guidelines, regarding thermal comfort, for design and application of the studied HVAC systems.
- New knowledge of relation between skin temperatures, heat fluxes and environmental conditions.
- A combined model of radiation, air flow and thermophysiology to determine temperatures and heat fluxes around a human.

People: experiments

Planet: Problem

Current unsustainable energy supply systems

<table>
<thead>
<tr>
<th>Demand</th>
<th>Delivery</th>
<th>Source</th>
<th>Environmental impact</th>
</tr>
</thead>
</table>

Possibilities
- Reduce demand
- Efficient installations
- Sustainable resources

More insight by exergy analysis
By giving insight, Exergy analysis can help to:
- Reduce losses
- Further reduce the need for resources
- Increase the possibilities for the use of low quality (LOWEX) resources

**Main objective:** A better thermodynamic match between demand and supply
- Dynamic exergy analysis
- Improvement potential of current systems
- Ideas for the future: technological breakthroughs?

**People Planet Profit**

**LowEx.NL**

**Planet: communication**

**Source**
- Timber: 20 m³
- Furniture: 50 m³
- Total: 70 m³

**Material efficiency**
- Timber: 98%
- Furniture: 60%
- Total: 99%
**LowEx.NL**

**People**

**Planet**

**Profit**

### Planet: Intended results

Exergy flow [kW]

- Ex_HP_in
- Ex_TAS_out
- Ex_RA_out

Work ism afstudeerder Arnaud Blom

---

### Profit: Objectives

**Main objective:**
The financial benefits of exergetic optimization of real estate

1. Opportunities and restraints in adopting LowEx techniques in the construction process;
2. Exergy saving in residential and commercial real estate;
3. Financial benefits of exergy saving techniques

---

### Profit: Exergetic benefits financially

Three problems:

1. Financial benefits are related to different stakeholders on multiple levels;
2. The Dutch energy market uses energy prices;
3. Losses occur, when source and actual use are not on one and the same location.

---

### Profit: Dedicated adoption model

Decision making networks of actors in building process

- A. Actor's characteristics
- B. Project's context
- C. Macro drivers
- D. Technology

Factors influencing the diffusion of energy saving techniques
“Exergetic System Approach for an Efficient, People-Friendly and Affordable Use of Energy in the Built Environment”
S 1.6

Presentation

Christoph Maria Ravesloot
Hogeschool Zuyd, The Netherlands

Title

“Demonstration and Training Houses in Tomorrows Neighbourhood: The Exergy Concept vs. the Passive House Concept”
Title: “Demonstration and Training Houses in Tomorrows Neighbourhood: The Exergy Concept vs. the Passive House Concept”

Design with an old paradigm

Trias Energetica

1. Save energy
2. Produce renewable energy
3. Use fossil energy efficiently

Situation Avantis Heerlen

Several students designed a living machine, where people are supposed to live in. One plan (4) shows a exergy living machine, where you can actually live in.

Jury arguments

Several students designed a living machine, where people are supposed to live in. One plan (4) shows a exergy living machine, where you can actually live in.
Jury’s choices four and five

More than an average eXergy concept

function (can you live in it)

form (is there spatial quality)

structure (is there technical quality)

Personal favourite

Daring design with space to live in and eXergy to experiment with

With trias energetica you get

EPC calculated on 0.24 [-]

6487 kWh to close the eXergy balance

Considering 54m² of Photovoltaics

Student design contest

Winning design “KoK” building

Frits and Segers

Sleeping, living, working

SUN
Title: “Demonstration and Training Houses in Tomorrow's Neighbourhood: The Exergy Concept vs. the Passive House Concept”

With duos energetica you get:
- eXergy house technology
- Heat pump
- Heat recovery on ventilation
- PV
- Solar collector

INNOVATION is not the problem: It is the organisation of people that have to collaborate.

Wood connections:
- High u-value
- Air tight
Construction of a new innovation

Technology
Organisation
Collaboration

External dynamics

Economically feasible
marked turn-over
Socially feasible
acceptance by early
wide social acceptance

Technical potential
theoretical potential
practical potential

Economically feasible
marked turn-over
Socially feasible
acceptance by early
wide social acceptance

Construction of a new innovation

Investments and maintenance costs
Procurement

LCA calculation

Little higher investment
for much less maintenance
S 1.7

Presentation
Doreen Kalz
Fraunhofer Institute for Solar Energy Systems,
Germany

Title
“LowEx Retrofit of a Printing Workshop in Germany”
LowEx Retrofit of a Printing Workshop
Monitoring and Evaluation

Jens Pfafferott | D. Kalz
Martin Fischer | A. Wagner | B. Bagherian
Fraunhofer Institute for Solar Energy Systems ISE

The Future for Sustainable Built Environments
Heerlen, 21st April 2009

Content

- **Energy Demand**
  How much energy do our buildings need?

- **Comfort Criteria**
  Impact of cooling concepts on thermal comfort.

- **Energy + Comfort**
  Energy saving versus comfort?

- **ebdruck.de**
  Refurbishment concept of the ebdruck.de building.
Energy Demand
German + Swiss Office Buildings

Energy demand for heating, cooling, ventilation and lighting calculated with energy conversion factors according to German EnEV standard.

Before Refurbishment
- typical commercial property from the 1970's
- common weak points
  - High energy demand (electricity and fuels), poor insulation, insufficient day lighting, unsatisfying air quality, inadequate room acoustics and thermal discomfort both in winter and in summer.

Refurbishment Concept
Building Physics

 passive cooling
- e2a-HX and night ventilation
- Low-Energy Cooling water driven TABS
- Ground Cooling

Existing building
- light-weight
- natural ventilation
- solar shading
Refurbishment Concept
Heating – Cooling – Ventilation based on low-exergy systems

At the Construction Site
Ventilation + Heating

- Mechanical ventilation with heat recovery from printing machines
- Free night ventilation
- Waste heat from printing machines
- Low-temperature radiator heating
- Bore-hole heat exchanger
- PCM-radiant ceiling with capillary tubes

At the Construction Site
Cooling System

- Drilling machine
- Bore-hole heat exchanger
- Capillary-tube cooling system
- Radiant cooling system with phase change material

Long-term monitoring of building and plant performance as well as thermal comfort since May 2007 (high-time resolution)

Thermal Comfort
European Guideline EN 15251:2007-08

Operative room temperature [°C]

Running mean ambient air temperature

Comfort class C

European Guideline EN 15251:2007-08

Building allocated to comfort class C

1st floor

2nd floor

Running mean ambient air temperature
Energy performance

Useful heating energy

**IMPROVEMENTS**
- Designed heat recovery 85%, implemented just 65% → preheating of supply air
- Ventilation: 17 kWh/m²a
- Radiator/RFC: 63 kWh/m²a
- Heat loss to existing non-refurbished building
- Manual ventilation through windows by user

**Useful heating energy [kWh/m²NGF]**

<table>
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<tr>
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<tbody>
<tr>
<td></td>
<td>150</td>
<td>80</td>
<td>21</td>
</tr>
</tbody>
</table>

- 47%  - 58%

Energy Performance

End energy use

**IMPROVEMENTS**
- Waste heat covers just about 10% of heating load → improved control required
- 22% of heat required for ventilation
- Still high electrical energy use for lighting

**End energy use [kWh/m²NGFa]**

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</thead>
<tbody>
<tr>
<td></td>
<td>184</td>
<td>78</td>
<td>31</td>
</tr>
</tbody>
</table>

- 47%

Energy Performance

Primary energy use

**IMPROVEMENTS**
- Waste heat covers just about 10% of heating load → improved control required
- 22% of heat required for ventilation
- Still high electrical energy use for lighting

**Primary energy use [kWh/m²NGFa]**

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<th></th>
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</tr>
</thead>
<tbody>
<tr>
<td>Heat</td>
<td>233</td>
<td>126</td>
<td>-102</td>
</tr>
<tr>
<td>Cooling</td>
<td>203</td>
<td>102</td>
<td>-124</td>
</tr>
<tr>
<td>Lighting</td>
<td>167</td>
<td>102</td>
<td>-65</td>
</tr>
<tr>
<td>Ventilation</td>
<td>22</td>
<td>12</td>
<td>-10</td>
</tr>
</tbody>
</table>

- 48%

At the Construction Site

**Cooling System**

Radiant-cooling system with phase change material

**23 °C**

**29 °C**
**Cooling System**

environmental heat sink instead of active cooling

- environmental heat sink: GROUND
- BHEX: 12, 44 m depth
- direct cooling (no heat exchanger)
- suspended cooling panels (250 m²) and grid conditioning system
- integrated PCM in panels in order to enhance the thermal storage capacity

---

**Energy Efficiency**

Cooling System 2008

- efficiency (SPF) = electrical energy use
- incorrect dimensioning of hydraulic system
- missing hydraulic balancing
- compensated by pump with high electrical energy use
- BHEX do not provide anticipated cooling energy
- undisturbed ground temperature 15°C

---

**Building Signature**

Energy efficient cooling and thermal comfort

Successful cooling concept for a non-residential building:

- comfort class: B+ / II
- useful cooling energy: 20 kWh/m²a
- (optimized building envelope, passive cooling techniques)
- efficiency: 10 kWh/therm/kWhend
  (efficient plant with low auxiliary energy use)

---

**Building Signatures: Comparison**

- GROUND SYSTEM
- NEW OFFICE BUILDING
- GROUND WATER SYSTEM
- NEW SECONDARY SCHOOL
- GROUND SYSTEM
- REFURBISHED PRINT WORKSHOP

- BHEX 40, 100 m depth, SPF 14
- building in passive house standard
- ground water well, 70 m³/h, SPF 10
- TABS and conditioning of supply air
- BHEX 3.4, field of BHEX to small high internal loads (office equipment, lighting)
Conclusions

SUCCESS
- Low-energy concept successfully realized in refurbishment project
- Useful heating energy and total primary energy use reduced by 50%
- Good indoor environment (visual and thermal)
- Building envelope in high quality
- Phase Change Material in lightweight construction
- Hybrid ventilation system with free night ventilation
- TABS with (direct) ground cooling
- Use of waste heat

IMPROVEMENTS REQUIRED
- General contractor approach did not foster low-energy concept
- Optimization of the thermo-hydraulic system necessary
- Operation and control algorithms need to be improved
- Waste heat from production should cover at least 50% of the load
- Upgrade of heat-pump system including reversible mode in summer is planned
- Gas boiler only serves the non-refurbished building
S 2.1

Presentation

Peter Op’t Veld
CHRI, The Netherlands

Titel
“Transition in Energy and Process for Sustainable Community Development: Description and Problems”
Sustainable Communities – the current situation

- Energy, Global Climate Change, CO₂ reduction, Sustainability are highly ranked on communities’ political agendas
- Ambitious levels for ‘CO₂ neutral’ communities
- Nevertheless very difficult to realise in practice in concrete actions, long term implementation, process

Objectives

- To achieve fundamental and new knowledge and derived from this, the boundary conditions and contours for a transition on management and process level
- To facilitate energy transition and sustainable community planning, based on a balance between sustainable supply and optimised demand
- Removing the governmental, organizational, financial and legal barriers and constraints with that facilitating innovative technical and social solutions
Research Questions

Social science research related:
• What is the cohesion and are the interactions between the different tasks related to sustainable community planning?
• What are the governmental constraints to direct a transition in the total process from ambition to realization?
• What are the institutional barriers related to the different energy demand and supply ratios, energy carriers, conversion possibilities
• What are the generic implications, boundary conditions and constraints for real estate development?

Technical research related:
• What are the available and favourable concepts or what new concepts need to be (further) developed?
• How to optimise and what governmental boundary conditions are necessary to implement these?

How did we come to the proposal?

• First (rough) ideas after the IEA Annex 51 meeting in Sittard and EOS LT meeting TUe on social scientific research in Long Term Research
• Experiences and questions from the ‘demand side’ i.e., municipalities and the building sector, were leading for the research questions and the final approach
• Experiences and faced barriers on current projects on sustainable community planning (Dutch EC CONCERTO projects in Almere, Amsterdam, Apeldoorn, Delft, Heerlen)
• Identification of multidisciplinary problems by a multidisciplinary team
• Emphasis on the social scientific aspects, technology is not the main problem
• No real need and necessity for advanced modelling and calculation methods (yet); first solve the institutional barriers, address the transition needed for process and organisation to achieve an energy transition
• Input from other related EOS LT projects (SREX, DP2015, WAELS etc.)

The approach – the Work Packages

• WP 0: Management
• WP 1: Process and Policy
• WP 2: Instruments
• WP 3: Technical Concepts
• WP 4: Pilots and Implementation

The approach – the consortium

• Multidisciplinary research tasks demand a multidisciplinary consortium:
  Building sector (demand side):
  – Project group Sustainable Energy Housing Development (PGDEPW, 30 real estate developers, housing corporations etc.) coordinator
  – ECN
  – TNO
  Research Centres (practical applied research):
  – Technical University Delft – Climate Design (incl. 1 PhD)
  – Erasmus University Rotterdam – DRIFT (incl. 1 PhD)
  – University Amsterdam – IVAM
  Universities (fundamental scientific research):
  – Technical University Delft – Climate Design (incl. 1 PhD)
  – Erasmus University Rotterdam – DRIFT (incl. 1 PhD)
  – University Amsterdam – IVAM
  Education (embedding in education):
  – Hogeschool Zuyd
  Consultants (liaison between demand side and researchers):
  – BuildDesk
  – Cauberg-Huygen RI
  Communities (pilots):
  – Almere, Apeldoorn, Nijmegen, Tilburg
Cohesion and integral approach needed for sustainable community development: people – planet – profit

WP 1 Process and Policy

- Objective: development of transition steps for process, management and organisation to enable sustainable energy development
- Participants: BuildDesk, Erasmus, IVAM, TUD, ECN
- Tasks:
  1.1 Description of management concepts and structures
  1.2 Literature study, interviews analyses current structures
  1.3 Development of new management and organisation structures based on new technology concepts and instruments
- Result: Blueprint for the necessary process and energy transition on community level

Characteristics of transition

- unpredictable, unsteady, but nevertheless with differentiated phases:
  - Pre-development
  - Take-off
  - Acceleration
  - Structural change
  - Stabilisation, new balance

Transition on three levels

Title

“Transition in Energy and Process for Sustainable Community Development: Description and Problems”
WP 2 Instruments

Objective: development of instrument(s) for the facilitation of community development processes and knowledge exchange

Participants: CHRI, PGDEPW, TNO, IVAM, TUD

Tasks
1. Description of process with identification of development steps, necessary knowledge, communication
2. Description of process realisation pilot projects, monitoring policies
3. Quality profiles on community level
4. Financial models and exploitation
5. Educational structures (process side)

Result: framework for a ‘toolkit’ sustainable community development

Tools: Positioning of concepts in qualities of exergy and PER (Primary Energy Ratio)

Positioning in Exergy/PER diagram
WP 3 Technical Concepts

- Objective: development of number (4 – 6) technical concepts for CO₂ neutral communities
- Participants: ECN, TNO, CHRI
- Tasks:
  1. Development of a ‘sustainable community matrix’ (density, energy policy, concepts)
  2. Identification of blank spots and development of new technologies (bidirectional grids, energy/exergy organisers on community scale, storage)
  3. Elaboration of 4 – 6 favourable system concepts
  4. Determination of the ecological, economical and social side effects
  5. Identification of necessary further development steps, technical and non-technical
- Result: Blueprint for 4 – 6 new innovative system concepts on community level, integrated approach with balance between renewable supply and optimised demand side

WP 4 Pilots and Implementation

- Objective: application and evaluation of the new transition approach on process and governmental level
- Participants: Hogeschool Zuyd, BuildDesk, CHRI, municipalities Almere, Apeldoorn, Nijmegen, Tilburg
- Organisation of 4 pilots (Almere, Apeldoorn, Nijmegen, Tilburg), soundboard group of other communities (Heerhugowaard, Heerlen, Venlo, Den Haag)
- Tasks:
  1. Inventory and analyses existing evaluations, translation to the pilots
  2. Inventory of constraints and boundary conditions for the transition approach on the pilots
  3. Drafting and assessment of relational links between conditions on district, community and regional level
  4. Drafting of plans and assessment for local long term vision based on the proposed transition approach
  5. Assessment and adjustment of plans of approach by evaluation of the experiences and results of the pilots
- Result: 4 concrete long term visions and policies with the results of this research embedded leading to 4 CO₂ neutral communities
Main grid and distribution grid

- Blue: districts to connect
- Circle numbers: branches

Main route DE system

- Track by bridges, no divers
- Waalfront 4.5 km, Waalsprong 6.6 km

System configurations:
1. 'open' without return to source
2. closed with return to source

Hybrid system with or without cooling

Opie 1:

Peter Op’t Veld
CHRI, The Netherlands
Some conclusions

- Test house necessary for the hybrid installations
- Hybrid grid and house installation are suitable for every LT/renewable source (residual heat, shallow geothermal).
- Extra research on chemo thermal storage (ECN EOS LT)
- Quality Control (commissioning) during building and construction process is necessary (HP, ventilation systems, control tightness etc.)

Links EOS LT TRANSEP-DGO with IEA ECBCS Annex 51
(how we link national research to international actions)

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<th>EOS LT TRANSEP-DGO</th>
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<td>WP 2 Instruments</td>
</tr>
<tr>
<td>Subtask B: Case-studies Local Energy Planning for City Quarters and Implementation</td>
<td>WP 4 Pilots and implementation</td>
</tr>
<tr>
<td>Subtask C: Case Studies Integrated Energy Planning for Communities and Implementation Strategies</td>
<td>WP 3 Technology and WP 4</td>
</tr>
<tr>
<td>Subtask D Knowledge transfer and dissemination</td>
<td>WP 4 and WP 2</td>
</tr>
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</table>
S 2.2

Presentation
Jacques Kimman
Hogeschool Zuyd, The Netherlands

Title
“Case Studies and Strategic Guidance for Urban Decision Makers”
IEA Annex 51: Energy Efficient Communities
Case studies and strategic guidance for urban decision makers

Dr. Jacques T.N. Kimman
Professor New Energy at the Zuyd University
Programme manager at SenterNovem
(Agency of the Ministry of Economic Affairs)
Is solar energy expensive? A new way of thinking!

- Highest building (Rotterdam)

CIS-tower (Manchester)

New Energy in the Built Environment

Roof integration!

New Energy in the Built Environment

Conventional method

New Energy in the Built Environment

What do we mean by “New Energy”? Trias Energetica!

New Energy in the Built Environment

Trias Energetica

1. Implement renewable energy sources
2. Use remaining energy
3. Use fossil fuels, if necessary, as efficiently and cleanly as possible
Energy Hill, Avantis, 26 April 2007

Grid parity in Europe – 2010

Irradiation (kWh/m²·yr) Cost (€/kWh)

- 600 €0.50
- 1000 €0.25
- 1400 €0.18
- 1800 €0.14

Grid parity in Europe – 2015

Irradiation (kWh/m²·yr) Cost (€/kWh)

- 600 €0.42
- 1000 €0.25
- 1400 €0.18
- 1800 €0.14

Grid parity in Europe – 2020

Irradiation (kWh/m²·yr) Cost (€/kWh)

- 600 €0.33
- 1000 €0.20
- 1400 €0.14
- 1800 €0.11

New Energy in the Built Environment

Energy transition (roadmap)

- Sustainable Energy Supply
- Bottlenecks, issues
- Cooperation, interactions
- Innovations, opportunities
- Social importance
- Commercial importance

Vision

Now

Future

Sustainable Energy Supply

Jacques Kimman

Hogeschool Zuyd, The Netherlands
Is solar energy expensive? A new way of thinking!

- Highest building (Rotterdam)
- CIS-tower (Manchester)

What do we mean by “New Energy”? Trias Energetica!

1. Use renewable energy to fulfill remaining demand
2. Use fuel (fuel used to generate renewable) as efficiently and cleanly as possible
3. Limit demand for energy

Title: “Case Studies and Strategic Guidance for Urban Decision Makers”
New financial concepts for zero-energy houses

New financial concept

- Payback-time included in the mortgage
- Seinen project development (Friesland)
- Costs: €500 per month
- No energy bill!

Roof integration in the “city of the sun” (Heerhugowaard)

Experiences on village level (City of Amersfoort)

New Energy, a different way of thinking
Carbon, climate and energy neutral: definitions

- **Carbon neutral (+)**
  - Considers only the greenhouse gas CO₂
  - Climate forests and Carbon capture & storage are allowed

- **Climate neutral (+++)**
  - Does not influence the climate, because it does not emit any of the greenhouse gases CO₂, CH₄ (methane), N₂O (laughing gas) and certain fluor compounds

- **Energy neutral (++++)**
  - In an energy neutral municipality not more energy is used by end users than is supplied by sustainable energy sources
  - Focus on the development of a sustainable energy supply system
  - Climate forests and Carbon capture & storage do not tribute to energy neutrality

Energy neutral in 2030?

```
<table>
<thead>
<tr>
<th>Year</th>
<th>Wind on Sea</th>
<th>Wind on Land</th>
<th>Solar</th>
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<td>0.07</td>
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```
### Starting point: energy use

#### Example: Apeldoorn

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</table>

#### Medium influence municipality

<table>
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<td>0.5</td>
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<td>1.5</td>
<td>2.0</td>
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</table>

#### Small influence municipality

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<td>0.5</td>
<td>1.0</td>
<td>1.5</td>
<td>2.0</td>
<td>2.5</td>
<td>3.0</td>
<td>3.5</td>
<td>4.0</td>
<td>4.5</td>
<td>5.0</td>
<td>5.5</td>
</tr>
</tbody>
</table>

### Example: Climate Change Plan Freiburg 1995

- **Forecast in 2005:**
  - **Target 1995:**

#### Wish and reality

- **Wish:**
  - **Reality:**
Solar installations in Freiburg

- PV: 9.8 MW, output: 9.8 m kWh p.a.
- Solar thermal: 13,000 m²

Electricity demand in FR: ~ 200 MW el
PV-Capacity: ~ 2.5%

Freiburg 2004 (200,000 inhabitants)

CO₂ emissions in Freiburg: planning and reality

- Target (1996)
- real/forecast 2003
- new downtown DH
- new cogeneration plant in FR
- Landwasser (long-term target)
- "Solar neighborhood", Schlierberg/Freiburg
50 "Plus-energy" single-family buildings
At least 40% Energy savings!

City of Maastricht, 55,000 households and 60 km² area:
- CO₂-neutral: 458 km² new forest (7.6 x area)
- Energy neutral: 229 windmills of 2 MW and 100 m high (6 km²)
  Or 1 km² PV-plant
  Or 55,000 zero-energy houses

Total city of Maastricht, including traffic and industry:
- CO₂-neutral: New forest 43x total area
- Energy neutral: 1289 windmills (36 km²) or 6 PV-plants (6 km²)

New Energy, a different way of thinking

Social transition: Bio-based Economy

New Energy, a different way of thinking

Bottle-neck analysis
Changes for new energy in the region

**Parkstad Limburg**

**Parkstad City N281 Boulevard**

**Sources for energy:**
- RWZI Hoensbroek, biomass centre for NW-Parkstad, gas, electricity + heat
- Industry Hoensbroek for rest heat
- City heat ‘t Loon, Heerlen Centrum

**Storage of energy:**
- Minewaterproject

**Use of energy:**
- Educational cluster
- Offices, railway station / Parkstad City
- Shopping malls
- Living areas
Energy-Space system:

Upper: Rwzi, green waste collection, co-combustion, gas production, transport

Middle: cascading on basis of industry supplied by own gas, shopping malls, offices, SON, low-ex village, storage in mines

Lower: collective heat system, re-use of heat on different temperatures for different functions

New Energy needs more coordination

Central control unit for renewable energy
New Energy in the Built Environment

Title: "Case Studies and Strategic Guidance for Urban Decision Makers"

The transition

Situation now

The sustainable future
Urban Harvest: Collecting, capturing, converting and feedback in system

Energy Assessment of Districts

District to assess: Demand

Performance Rating

<table>
<thead>
<tr>
<th>Type of heating</th>
<th>Energy need for heating</th>
<th>Energy use for heating</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low-energy house</td>
<td>80 kWh/m²</td>
<td>no</td>
</tr>
<tr>
<td>Central power plant</td>
<td>170 m²</td>
<td>no</td>
</tr>
</tbody>
</table>

Energy Concept Adviser for Districts

EnEff:Stadt

Evaluate the energy consumption of your district with national averages

- Learn different energy efficient district strategies
- Compare with national averages

- Energy Concept Adviser
- Performance Rating
- Energy Assessment of Districts
- EnEff:Stadt
- Contact
The village of tomorrow: living and working

- Application of a Microgrid
  - Share with you neighbours!
  - Central coupling to the grid

- Increased use of electricity during daytime
- But also:
  - More activities during daytime
  - Social control
  - Reduction of traffic jams

The village of tomorrow: living and mobility

- Connection to the micro-grid
- Using electric car for shopping etc.
- Using battery for storage

Efficient equipment
- Led-lights and daylight systems
- Dryers with heatpumps
- Domotics

Renewable energy sources
- Photovoltaics, wind, solar thermal systems
Urban Harvest: Collecting, capturing, converting and feedback in system

New Energy in the Built Environment

The village of tomorrow: goals

- Demonstration of sustainable houses (zero-energy!)
- Platform for "Open Innovation" (Real Life Laboratory) of necessary knowledge and technologies
- Optimal integration of available techniques
- Show what tomorrow is possible with the techniques of today!

Goals:

- Demonstration of sustainable houses (zero-energy!)
- Platform for "Open Innovation" (Real Life Laboratory) of necessary knowledge and technologies
- Optimal integration of available techniques
- Show what tomorrow is possible with the techniques of today!

Energy Assessment of Districts

Performance Rating

Energy Assessment of Districts

Performance Rating

Energy Concept Adviser for Districts

- Performance Rating
- Energy Efficient Districts
- Energy Strategy
- Energy Assessment of Districts
- Energy Concept Adviser
- Detailed Planning
- Contact

Compare the energy consumption of your district with national averages

Learn from X realized energy efficient districts

Access different energy concepts (demand and supply) for districts

Download of reports from the research project EnEff:Stadt

Information on different detailed planning tools

Contact the participating organizations of EnEff:Stadt
Energy Assessment of Districts

Choice
- heat - decentral - standard
- heat - decentral - renewable energies
- district heating
- district cooling
- electricity: etc.

District to assess
Supply:

The “village of tomorrow”, technical design

- ‘Passief Haus’ Techniques
  - Optimal isolation
  - Ventilation with heat recovery
  - Cold and heat storage
  - Efficient low temperature heating and cooling

- Efficient equipment
  - Led-lights and daylight systems
  - Dryers with heatpumps
  - Domotics

- Renewable energy sources
  - Photovoltaics, wind, solar thermal systems

The village of tomorrow: living and working

- Application of a Microgrid
  - Share with you neighbours!
  - Central coupling to the grid

- Increased use of electricity during daytime
- But also:
  - More activities during daytime
  - Social control
  - Reduction of traffic jams

The village of tomorrow: living and mobility

- Connection to the micro-grid
- Using electric car for shopping etc.
- Using battery for storage
New Energy in the Built Environment

Design the first house

Computer animation

The city of tomorrow: house bend towards the sun

The winners

Jacques Kimman
Hogeschool Zuyd, The Netherlands
Organic solar cells between double layered glass?

New Energy in the Built Environment

Largest solar hot water system (City of Den Bosch)

Privacy

Bright

Dark

Centre for research on new materials in cooperation with the faculties Built Environment, Technology and Life Science

Productontwikkeling in het kader van Nieuwe Energie

Title

“Case Studies and Strategic Guidance for Urban Decision Makers”
Situation in winter

New Energy in the Built Environment

Quartierskonzept Rintheim
a bottom-up approach

Jacques Kimman
Hogeschool Zuyd, The Netherlands
Title  "Case Studies and Strategic Guidance for Urban Decision Makers"
Titel
“Roadmap to a Sustainable Educational Campus in Heerlen UKP”
The Educational Campus Project Heerlen

The extension of the Campus site, the construction of completely new buildings and the renovation/rehabilitation of existing buildings must be realized as sustainable as possible; this implies also a thorough consideration of the energy supply system and demand reduction.

FOCUS ON THE ENERGY SUPPLY SYSTEM

C24 WP2 / Heerlen
THE RELATED ENERGY GOALS ARE:
A reduction of CO2 emissions of 50% by:
1. Energy savings
2. The use of renewable resources
3. Efficient use of fossil resources

A reduction of CO2 emissions of 80% by:
1. The use of sustainable energy
2. An optimal energy supply infrastructure
3. The use of low exergy sources from the direct surroundings
C24 WP2 / Heerlen

THE RELATED ENERGY GOALS ARE:

A reduction of CO2 emissions of 50% by:
1. Energy savings
2. The use of renewable resources
3. Efficient use of fossil resources

A reduction of CO2 emissions of 80% by:
1. The use of sustainable energy
2. An optimal energy supply infrastructure
3. The use of low exergy sources from the direct surroundings

The reductions must be realized compared to energy use in 2005

The final goal is a CO2 emission reduction of at least 50% but if possible of 80%

C24 WP2 / Heerlen

CONTEXT

• Now HT heating and LT cooling is used in the existing buildings
• The new, renovated/rehabilitated buildings can use LT heating and HT cooling
• Relatively large amounts of hot water are needed for the showers of the Sintermeerten high school (in the future possible use of solar thermal energy)
• It is possible to make a connection to the mine water grid. First the capacity will not be enough but later the capacity may increase. Later, the Campus is able to provide this grid with cooled and heated water
• It is an option to think about a bio mass fired power plant on site. In this case, only a very limited amount of natural gas based electricity from the public grid is necessary and thermal energy can be supplied to the mine water grid

C24 WP2 / Heerlen

SOME IMPORTANT POINTS NOT MENTIONED BEFORE

• Emphasis is on demand reduction of electricity and to make use of renewable resources for its production
• Make use of PV cells
• Also, demand reduction for the use of thermal energy has a high priority and use as much as possible renewable resources
• New buildings and renovation/rehabilitation of existing buildings lead to discontinuous changes in energy demand and, consequently, will have consequences for the energy supply system
• In the period of 2010 to 2025 some HT heating is still necessary
• From 2025 on, all buildings will be low exergy buildings
• A mini grid for energy supply and exchange at the Campus site is a necessity
• The project must be economically viable

COST Action C24 WP2 / HEERLEN

Over view of the Campus Site
C24 WP2 / Heerlen

Some other relevant data

<table>
<thead>
<tr>
<th>Institute</th>
<th>Gross floor area [m²]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arcus Valk.</td>
<td>26,987</td>
</tr>
<tr>
<td>Arcus Corio.</td>
<td>8,760</td>
</tr>
<tr>
<td>Zuyd</td>
<td>38,041</td>
</tr>
<tr>
<td>OU old</td>
<td>20,385</td>
</tr>
<tr>
<td>OU new</td>
<td>10,000</td>
</tr>
<tr>
<td>Sintermeerten</td>
<td>10,350</td>
</tr>
</tbody>
</table>

C24 WP2 / Heerlen

Over view energy demand mainly based on data for 2006 or 2007

<table>
<thead>
<tr>
<th>Energy demand</th>
<th>CO2 emission</th>
</tr>
</thead>
<tbody>
<tr>
<td>Institution</td>
<td>Electricity [MWh/a]</td>
</tr>
<tr>
<td>Arcus</td>
<td>2,013</td>
</tr>
<tr>
<td>Zuyd</td>
<td>2,965</td>
</tr>
<tr>
<td>OU</td>
<td>1,600</td>
</tr>
<tr>
<td>Sintermeerten</td>
<td>310</td>
</tr>
<tr>
<td>Sub total</td>
<td>6,888</td>
</tr>
</tbody>
</table>

C24 WP2 / Heerlen

Energy demand after building related improvements

<table>
<thead>
<tr>
<th>Energy demand</th>
<th>CO2 emission</th>
</tr>
</thead>
<tbody>
<tr>
<td>Institution</td>
<td>Electricity [MWh/a]</td>
</tr>
<tr>
<td>Arcus</td>
<td>1,720</td>
</tr>
<tr>
<td>Zuyd</td>
<td>2,131</td>
</tr>
<tr>
<td>OU</td>
<td>1,000</td>
</tr>
<tr>
<td>Sintermeerten</td>
<td>250</td>
</tr>
<tr>
<td>Sub total</td>
<td>6,888</td>
</tr>
</tbody>
</table>
C24 WP2 / Heerlen

Building related improvements lead to an energy demand reduction of

1700 MWh of electricity, this is – 25%

470,000 m³ of natural gas, this is – 40%

This is already more than half of the goal of a reduction of 50% in CO2 emission.

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Three different energy supply concepts were investigated in more detail:

Concept 1:
For each building heating and cooling is realized by a connection to the mine water grid and the use of a heat pump and a HR boiler to supply extra heating in peak load situations.

Concept 2:
Use is made of a Combined Heat and Power station fuelled by mainly solid bio mass in combination with absorption cooling.

Concept 3:
This is a combination of the energy supply possibilities mentioned in concepts 1 and 2

<table>
<thead>
<tr>
<th>Institute</th>
<th>Heating power [kW]</th>
<th>Heating energy demand [MWh/a]</th>
<th>Cooling power [kW]</th>
<th>Cooling energy demand [MWh/a]</th>
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</thead>
<tbody>
<tr>
<td>Arcus (Valk.)</td>
<td>1,799</td>
<td>1,620</td>
<td>1,526</td>
<td>1,092</td>
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<tr>
<td>Arcus (Corio.)</td>
<td>433</td>
<td>351</td>
<td>351</td>
<td>269</td>
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<tr>
<td>Zuyd</td>
<td>2,554</td>
<td>2,382</td>
<td>900</td>
<td>666</td>
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<tr>
<td>OU old</td>
<td>1,424</td>
<td>984</td>
<td>367</td>
<td>534</td>
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<td>OU new</td>
<td>720</td>
<td>600</td>
<td>600</td>
<td>400</td>
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<td>Sintermeerten</td>
<td>830</td>
<td>319</td>
<td>162</td>
<td>100</td>
</tr>
<tr>
<td>Total</td>
<td>7,760</td>
<td>5,656</td>
<td>3,306</td>
<td>2,660</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Institute</th>
<th>Transformer power [kVA]</th>
<th>Electricity demand [MWh/a]</th>
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</thead>
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<tr>
<td>Arcus (Valk.)</td>
<td>2,000</td>
<td>1,344</td>
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<tr>
<td>Arcus (Corio.)</td>
<td>630</td>
<td>376</td>
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<tr>
<td>Zuyd</td>
<td>2,280</td>
<td>2,131</td>
</tr>
<tr>
<td>OU old</td>
<td>350</td>
<td>1,000</td>
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<tr>
<td>OU new</td>
<td>300</td>
<td>600</td>
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<tr>
<td>Sintermeerten</td>
<td>250</td>
<td>230</td>
</tr>
<tr>
<td>Total</td>
<td>5,810</td>
<td>5,681</td>
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</table>
**C24 WP2 / Heerlen**

**Concept 1:** heating and cooling supply by using two possibilities:
- Via connection to the mine water grid
- Making use of heat pumps

In the near future, the mine water can only be used for the new buildings that have to be build for Arcus at the two different locations:

<table>
<thead>
<tr>
<th></th>
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<tbody>
<tr>
<td>Heating</td>
<td>2,232</td>
<td>665</td>
<td>1,306</td>
</tr>
<tr>
<td>Cooling</td>
<td>1,877</td>
<td>952</td>
<td>408</td>
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</table>

This leads to a CO2 emission reduction of 348 tons/a

The same data in the case that the rest of the Campus could make use of the same two supply options:

<table>
<thead>
<tr>
<th></th>
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</thead>
<tbody>
<tr>
<td>Heating</td>
<td>7,040</td>
<td>1,414</td>
<td>4,242</td>
</tr>
<tr>
<td>Cooling</td>
<td>3,306</td>
<td>1,596</td>
<td>610</td>
</tr>
</tbody>
</table>

For the rest of the Campus a CO2 emission reduction of 775 tons/a can be realized

**C24 WP2 / Heerlen**

In concept 2, electricity is generated mainly making use of a power plant located at the Campus site.

Power and yearly energy demand are shown in the Table below:

<table>
<thead>
<tr>
<th></th>
<th>Power</th>
<th>Yearly demand [MWh]</th>
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</thead>
<tbody>
<tr>
<td>Electricity</td>
<td>5,500 kVA</td>
<td>5,080</td>
</tr>
<tr>
<td>Heating</td>
<td>7,040 kW</td>
<td>5,660</td>
</tr>
<tr>
<td>Cooling</td>
<td>3,300 kW</td>
<td>2,660</td>
</tr>
<tr>
<td>Electricity via PV</td>
<td>1,250 kW</td>
<td>1,250</td>
</tr>
</tbody>
</table>

**C24 WP2 / Heerlen**

Over view of the reduced energy demand per institute:

<table>
<thead>
<tr>
<th></th>
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<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Arcus Valk.</td>
<td>5,832</td>
<td>3,931</td>
<td>1,344</td>
</tr>
<tr>
<td>Arcus Corio.</td>
<td>1,264</td>
<td>968</td>
<td>376</td>
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<tr>
<td>Zuyd</td>
<td>11,577</td>
<td>3,237</td>
<td>2,131</td>
</tr>
<tr>
<td>OU old</td>
<td>4,782</td>
<td>2,595</td>
<td>1,000</td>
</tr>
<tr>
<td>OU new</td>
<td>2,161</td>
<td>1,457</td>
<td>498</td>
</tr>
<tr>
<td>Sintermeerten</td>
<td>1,310</td>
<td>411</td>
<td>250</td>
</tr>
</tbody>
</table>
Sankey diagram for the new situation: connection to the mine water grid and bio-mass fired power plant on site

Sankey diagram for this situation when only fossil fuels are used

Over view and CO2 emission reduction:

<table>
<thead>
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<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Conventional energy supply</td>
<td>60,720</td>
<td>33,750</td>
<td>94,470</td>
<td>0</td>
<td>6,200</td>
</tr>
<tr>
<td>Bio mass + mine water</td>
<td>4,470</td>
<td>0</td>
<td>4,470</td>
<td>46,220</td>
<td>320</td>
</tr>
</tbody>
</table>

Avoided CO2 emission: 5,580 tons/a

The Educational Campus Project Heerlen
S 2.4

Presentation
Ronald Rovers
Hogeschool Zuyd, The Netherlands

Title
“Integrated Exergy Concepts for Sustainable Regional and Urban Planning”
Title: Integrated Exergy Concepts for Sustainable Regional and Urban Planning

Caring Region Energy Vision:

**Urban focus**

**Rural focus**

Global Solidarity

Global market

Secur region

What are the most robust

Visualization Energy Vision

Global market

Visualize energy vision

Caring region

Global Solidarity

Secur region

What are the most robust

Visualization Energy Vision

Global market

Visualize energy vision

Caring region

Global Solidarity

Secur region

What are the most robust

Visualization Energy Vision

Global market

Visualize energy vision

Caring region

Global Solidarity

Secur region

What are the most robust
We have to look at cities not as consumptive but as productive!
Urban Harvest: Collecting, capturing, converting and feedback in system.
Dutch average Harvest potential urban tissue - 1 ha

Harvest potentials/Tissue output:
- UQ-C&D: 50 tonnes/year
- UQ-wood: 2,75 tonnes/year (part of C&D)
- US-Space: 10 m²/ha empty office
- US-space: 440 empty shops
- UF-paper: 14 tonnes/year
- UF-energy: --

Harvest potentials tissue output (primary):
- U-Energy: 10 million kWh/ha-year
- UQ-wood: 5 m³/ha-year
- UQ-end: 15 m³/ha-year
- UQ-rain: 8.9 million ltr/ha-year

Conversion to new product:
- US-space: 4 m² empty shop
- UF-paper: 14 tonnes/year
- UF-energy: --

Cascading
Delay downscaling as long as possible and effective

Upscale where possible and efficient

1.300.000 tonnes per year wood residue

2.75 tonnes /per urban average

Conversion to new product:
chipboard: 0.80%

2,20 tonnes chipboard /UHa

URBAN
secondary
resources

+ energy&resources

URBAN ENERGY
To implement potentials, and deal with competition between resources, in existing and new buildings and urban environments, we need tools.

In a first exploration we found that we need

**Principles**: *valid in all cases*, and these provide rules to follow

And within the borders set by system and rules, we use

**Strategies**

These can be *different from project to project*, and locally set
principles

UH principles:

- Nothing goes out of the system anymore.
- To collect and convert all these resources, and (re-)use these within that same system.
- UH does not address consumption, nor the need of resources.
- UH is applied without influencing or changing the working of that environment significantly.
- Urban harvest does not address non-renewable (re-)sources.

rules

From principles, (to be studied more in detail)

- The need determines the chosen qualities in a existing situation.
- System limits set (to be defined).
- Building connected solutions go before community level solutions.
- Define renewables.
- (re-)sources are used at the highest quality level, cascading applies. (Detail cascading between different kind of sources.

strategies

Different per location. Examples:

- To maximize harvest, possibly exporting.
- To have “Meeting demand” as the decisive rule for choices.
- To use external connections for balancing resources, or create autarkic situation.
- etc.
System Levels

So what's quality?

And why always start calculating with oil or gas, or 100% exergy electricity?

Where does the gas and oil come from?
"Integrated Exergy Concepts for Sustainable Regional and Urban Planning"

**Title**

**Electriciteit via PV**

**Tijd relatie:**
Oliefuison verbruikt en voorraad 2005: 336.000 miljard ltr.
Aarde: 510.066.000 km²; > 65 miljoen jaar
Per dag: ~14.000 ltr (wereldwijd)

**Ruimte-tijd relatie:**
0.0108 ltr olie per km²-jaar of
~0.0000000001% (1 x $10^{-12}$)

Efficiency?
Efficiency in % van zon naar electriciteit:
~0.0000000001% (1 x $10^{-12}$)

Efficiency in % van zon naar electriciteit:
14%

So: time and Space

Cement/kalksteen bijv. vergelijkbare relatie met tijd en ruimte

15 m³ = 3ha-year

1 average timberframe house, 15 m³ wood 50y

And where does Mass come from?

Cement: 5 GJ/ton, ~1 ton cement from 1 ton wood-biomass

1 average timberframe house, 15 m³ wood 50y

½ house.
1 average street lantern - 50 years

1 average timberframe house, 15 m³ wood 50y

Cement: 5 GJ/ton, = ~1 ton cement from 1 ton wood-biomass

+ 1 av. Lantern 50y

+ 0 rest value

½ house.

0.0123 ha/year

1 average street lantern - 50 years

1 average timberframe house, 15 m³ wood 50y

Cement: 5 GJ/ton, = ~1 ton cement from 1 ton wood-biomass

+ 1 av. Lantern 50y

+ 0 rest value

½ house.

0.0123 ha/year
Adobe line, erosion dust route, if imported to site

20 ha
jaar

3 ha-jaar

15 m3 = wood

1 wood house + 1 av. Lantern
50 y

+ 300 m3 clay

+ 0 ha-jaar

Also for mass:

Time and space again …

And food, the same, as you know.
A: total, no relation with location, consequences, etc (=F?)
B: Building bordered, ...
C: building bordered, no limit in height or depth: geothermal or solar or soil is in the system
D: plotsize bordered, no limit in height or depth: 
E: plotsize and 3D bordered, aquifer in system, geothermal not, solar not, free view included
F: global border, all consequences in system, calculate in system

Voor de liefhebber:
als een systeem, of dat nu gedefinieerd is als een gebouwlacatie, een stad, of de aarde
meer energie (is ook massa) consument dan dat er uit zonne-energie wordt gebruikt en
vastgelegd, er ergens uinputting plaatsvindt en dus de kwaliteit van het systeem als
totaal verminderd.
Shift for renewables:
phases out waste from fossil fuelled processes as planning parameter

Quality management for energy mass and food together:
Phases out biobased energy as option and as planning instrument

- Energy and mass are two of the same kind
- Nature has no qualities, quality only exist in human valued systems
- System is a global one: the earth is an island. (in human perspective – in capability of mastering conversions)
- Shift for renewables (if not renewable: depletion and quality decrease)
- Its space in time that’s the ultimate decisive factor

There is in general no sense in universe:
There exist certain substances in certain places in certain time in certain forms. And there is certain quality to establish something that is valued in a system.
However nature has no values, nature just is, accidentally (for us humans, that is). Therefore there is only quality in a subsystem: in this case the exceptional event in space of Humans on a planet that create values, to rank qualities, needed to sustain their subsystem. Which is of no value to the overall nature of universe or its parts in solar systems.

In other words, Optimise Time and Space in capturing quality, within human limited knowledge to make the necessary conversions, is what we need to value, in order to secure the highest level of welfare. How high, is depending on level of consumption (or shift towards services) and amount of people:
Time and Space, To Sow and Harvest

With energy, materials and food together optimised
"Integrated Exergy Concepts for Sustainable Regional and Urban Planning"

Title

"Orbanism" – Regional conferences in preparation of world conference:

1. SB10 Euregio
   - Focus: 0-energy, 0-material, 0-water, 0-land buildings and environments
   - In Technologies and typologies
   - (partners and sponsors welcome)

**May 13 2009:**

Dag van de nieuwe energie

www.dagvandenieuweenergie.nl

- Spain: mid-April
- New Zealand: 12-13 or 19-20 May
- Malaysia: 8-10 June
- Czech Rep: end of June / early July
- Brazil: 16-18 August
- Netherlands/Euregio 30 August - 10 September
- Finland: mid to late September
- Canada: possible, early May
- South Africa: possible, date uncertain

*Post Crash - Vitality*

Of the Urban organism – “Orbanism”
Thank You for your patience

Ronald Rovers
Hogeschool Zuyd, The Netherlands
Presentation

Christina Sager
Fraunhofer Institute for Building Physics, Germany

Title
"100% RES for the Community of Wolfhagen - Putting Community Efficiency on the Map"
Functions of city

- The City as...
  - place of encounter and cultural interaction
  - centre of life
  - place of social balance and equal opportunities
  - place of diverse lifestyles
  - strategy of survival
  - business location
  - eco-system

Seite 3

Complex interactions within the city and rural systems

- energy
- water
- waste
- traffic
- resources

Seite 4

Green cities vision

- increase regional return of capital
- decrease capital flux from the region
- by increasing energy independency
- creation of new employment
- maximization by renewable energy production and use

Seite 2

"100% RES for the Community of Wolfhagen"

Putting Community Efficiency on the Map

Dipl.-Ing. Christina Sager

Fraunhofer Institute for Building Physics, Germany

Seite 2
"100% RES for the Community of Wolfhagen – Putting Community Efficiency on the Map"

**City of Wolfhagen**
- 14,000 inhabitants
- 11 boroughs, 112 km²
- rural community in central Germany
- structurally weak, mostly agricultural area

**Goals and Targets 2008**
- Wolfhagen reduces the heating demand of private households annually by 2-3%.
- Wolfhagen transforms the entire household electricity and 20% of the fuel equivalent of mobility by local renewable sources.
- Wolfhagen installs a load management system in the electricity grid.
- Wolfhagen increases the use of heat pumps in private households to 20%.

**Borough Council Decision on "100% RES until 2015" April 17th 2008**

**City of Wolfhagen**
- 14,000 inhabitants
- 11 boroughs, 112 km²
- rural community in central Germany
- structurally weak, mostly agricultural area

**Federal Ministry of Education and Research: Energy Efficient Cities Contest – summer 2008**

**Pressemitteilung**

Staatssekretär Meyer-Krahmer: "The potential for energy savings is great."

...72 initiative groups from cities of different sizes turned in their proposals. A jury under direction of Prof. Niklaus Kohler of the ETH Zürich decided in December last year on 15 proposals for the second round...
Proposed Wind Turbines - TG E82

- Specially designed for medium wind speeds
- Rated power: 2,000 kW
- Rotor diameter: 82 m
- Hub height: 78 - 138 m
- Annual energy output: 5,400 - 5,700 MWh/a

Source: Stadtwerke Wolfhagen

Monitoring and Balancing Model – First steps

Key questions:
- How can energy demand and supply structures and relationships be described and evaluated to allow a strategic long-term planning on community scale?
- How can these relationships be optimized on a municipal level to reduce the dependencies on foreign fossil energy sources and to utilize locally available sources?
- What indicators are the most useful to describe and monitor a long term sustainable development?
- Can the results be visualized using adaptations of tools that municipal decision makers are most used to regarding strategic development?

Status Quo:
- Fragmented data situation
- Energy related data only in electricity sector available

Approach to energy demand data base – existing buildings
S 2.6

Presentation
Peter Op't Veld
CHRI, The Netherlands

Title
"CONCERTO project Remining LowEx – Low Exergy in Practice in the Mine Water Project in Heerlen"
What is REMINING-Lowex about?

- Developing sustainable communities in mining and former mining areas and mining areas
- Developing abandoned mines in combination with other local renewable sources for heating and cooling of buildings
  - At ~800 m: 35°C > low temperature heating
  - At ~200 m: 16°C > high temperature cooling
- Balancing the local energy demand (buildings) with the local available low valued energy sources (renewables, i.e. mine water, but also other renewables)

Total eligible costs €39,565,400
Total funding €7,226,357
Duration: five years (June 2007 – June 2012)

The REMINING Communities

- Communities and partners involved:
  - Heerlen Netherlands (investments)
  - Zagorje Slovenia (investments)
  - Czeladz Poland (feasibility)
  - Bourgas Bulgaria (feasibility)
- Dissemination, training, additional research
  - Climate Alliance EU
  - EURACOM EU
  - Fraunhofer DE (Training)
  - CHRI, The Netherlands
Simulations and reservoir models:

Supply side:
- Warm reservoirs (800m): 30 – 35 °C
- Cold reservoirs (200m): 15 – 18 °C

Distillation corridors on nowadays topographies:

Distribution: Low temperature (‘lowex’) H&C distribution system

measured DT (t0 = 27.7°C) at HH1
modelled DT
re-injected water - tracer 1
stone drift - zone 2
mined zone - tracer 2
mined zone - tracer 3
mined zone - tracer 5

...in combination with the old mine maps to determine drilling locations.......

Heerlen the Netherlands. Warm and cold water from abandoned coalmines.

Incorporation of the old mine maps to determine drilling locations.

Heerlen Centre.

H&C primary grid.

Projection corridors on nowadays topographies.
From a schematic approach to a LT H&C grid in practice.

Some decision parameters:
- Length of the grid
- Type of paving
- Drilings (road crossings)
- Existing infrastructures
- Impact on wells
- Flow directions
- Ecology
- Archaeology
- Soil (pollution)
- Permits
- Costs
- …

Some design constraints:
- Chemical quality of the mine water
  - sediments and sludge’s
  - scaling
  - corrosion
  - bacterial corrosion
  - gas (CH₄ and CO₂)
- Pressure ~ 1 bar = enough
- Velocity: ~ 1.5 m/s
- Leakage detection
- Cleaning (foam pigs)
- Transport energy (pumps)
Demand side:
The buildings

Boundary conditions: What is “extra” needed to make a building minewater proof/lowex (NL)?

<table>
<thead>
<tr>
<th>Building Reg’s NL</th>
<th>Practice 2007 NL</th>
<th>Mine water Lowex</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thermal insulation</td>
<td>Thermal insulation</td>
<td>Thermal insulation</td>
</tr>
<tr>
<td>Envelope U = 0.37</td>
<td>Envelope U = 0.30</td>
<td>Envelope U &lt; 0.25</td>
</tr>
<tr>
<td>Glazing U = 3.0</td>
<td>Glazing U = 1.5</td>
<td>Glazing U &lt; 1.2</td>
</tr>
<tr>
<td>Ventilation</td>
<td>50% ME/50% MVHR</td>
<td>50% ME/50% MVHR</td>
</tr>
<tr>
<td>No system requirements</td>
<td>MVHR (\eta = 95% )</td>
<td>MVHR (\eta = 95% )</td>
</tr>
<tr>
<td>Air tightness (n_50 = 3)</td>
<td>Air tightness (n_50 &lt; 2)</td>
<td>Air tightness (n_50 &lt; 1)</td>
</tr>
<tr>
<td>Emission system</td>
<td>Emission system</td>
<td>Emission system</td>
</tr>
<tr>
<td>No requirements (but in EPR)</td>
<td>Radiators</td>
<td>Floor heating and cooling</td>
</tr>
<tr>
<td>HVAC system/efficiency</td>
<td>HVAC system/efficiency</td>
<td>HVAC system/efficiency</td>
</tr>
<tr>
<td>No requirements</td>
<td>Condensing boilers</td>
<td>Mine water with heat pumps</td>
</tr>
<tr>
<td>(\eta = 95%)</td>
<td>No cooling</td>
<td>(boiler back up)</td>
</tr>
<tr>
<td>EPC dwellings 0.8</td>
<td>EPC dwellings 0.8</td>
<td>Sustainable cooling</td>
</tr>
</tbody>
</table>

Direct heating and cooling
Indirect heating and cooling

Boundary conditions

- Hydraulic separation between the mine-water system and the building services
- The heating and cooling capacity of thermally activated building parts is limited. The system is sensitive to excessive transmission and ventilation losses.

Optimization by using Load Duration Curves

- Dynamical buildings simulations by TRNSYS
- Temperature levels for heating, cooling and DHW
- Ratio RES (and HP) and conventional
- Balancing H and C storage
- Optimization transmission and ventilation losses and seasonal operation
- Enlarging the ‘dead-zone’ = period without H or C demand > conflict with energy exploitation and economical feasibility! (decrease of energy demand = decrease of profits)

Optimizing ratio RES/conventional by using a LD curve Heerlerheide
"CONCERTO project Remining LowEx – Low Exergy in Practice in the Mine Water Project in Heerlen"
Economical barriers

- High investments for infrastructure
  - Wells (if needed)
  - Distribution system
- Hardly any energy to sell for heating and cooling in very energy efficient buildings
  - Shift from selling GJ’s to connection fees and/or one-off contribution fees
  - HT Cooling can give more profits
- Cost for electricity (pumps, heat pumps) are still substantial
  - Buildings really need to have optimal low-ex emission systems
    - to limit additional use of heat pumps
    - to have relative large ΔT
  - Pump energy: how to reduce?

Electricity consumption pumps
New additions:
Education Campus Heerlen
- Education Campus ambition for CO₂ reduction of 80% in 2025
  - Open University
  - Zuyd University
  - Arcus college
  - Sintermeerten college
- Bio cogeneration plant (with absorption cooling)
- Solar (Thermal and PV)
- Connection to minewater grid
- Lowex principles:
  - Existing buildings higher temperatures (cogen)
  - New buildings low temperatures (minewater)
  - Out coupling of residual heat and cold with minewater grid
  - Energy management: direct use in other buildings, recharging wells (?)

New additions:
Spatial development Czeladz - Poland
- Temperature 12.2-14.4°C: suitable for indirect heating (heatpumps) and free cooling
- Building density for district heating: 75 apartments / ha
- 11 mln m³ minewater / year:
  - 400.000 GJ heat (= 28.000 apartments)
  - OR 250.000 GJ cold (= 50.000 apartments)
- Domestic hot water?
- Pumping 24/7?

Summary
- Integrated design of a LT energy supply structure (based on use of mine water) is possible if supply and demand side are balanced on the basis of exergy principles
- Supply: geological research is crucial, reservoir modelling and technologies for (controlled and steered) drilling
- Municipal organisation for large scale projects often barrier > new structures and transition investigated in new Dutch Long Term research project TRANSEP-DGO
- The energetic and financial performance of minewater as an energy source depends on a variety of parameters. Therefore, a field of expertises is needed to come up with a solid overall view.
- Demand: how to make buildings mine water/lowex proof
  - Extra needed in comparison with building regulations:
    - Extra thermal insulation (but not to passive house standard)
    - Airtight building, energy efficient ventilation systems (MVHR)
    - LT heating, HT cooling systems
    - Limitation of internal and solar heat gains in summer
Summary

- Demand: how to make buildings mine water/lowex proof
  - How to use heat load duration curves
  - Temperature levels for heating, cooling and DHW
  - Ratio RES (and HP) and conventional
  - Balancing H and C storage
  - Optimization transmission and ventilation losses and seasonal operation
  - Enlarging the ‘dead-zone’

- Problems with DHW in LT grids; solutions are still necessary
- Exploitation: high investment costs, little consumption of GJ’s
- What is the financial value of a low-ex energy source?

General recommendations

- A small as possible distance between the renewable energy source (e.g. minewater) and the energy demanders
- Matching temperatures for minewater and building services
- An open business model with a clear financial forecast appoints the economic and energetic return of the system
**EXERGY PLANNING FOR CAMPUS HEERLEN (NL)**

**Leo Gommans and Ferry Van Kann**

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**What?**

The development of an optimal energy system for the Heerlen campus, based on the principles of exergy planning. Exergy-planning is the realisation of spatial conditions for improved use of unused (residual) energy flows. This means:

- Improved use of the quality of energy
- Realisation of spatial energy cascades
- Use of residual energy flows (waste = food)
- Realisation of low-exergy energy demand (LowEx)
- Better use of high-exergy residual energy supply

---

**Why?**

- 30-40% of the energy demand comes from the built environment.
- Energy saving efforts are mostly done on the scale of the building.
- Potentials of the regional scale have been undervalued till now.
- Principles of exergy are not often used to reduce energy demand.

---

**Method**

- Inventory of local present (residual) energy sources
- Inventory of sinks (demand for heat, cold, electricity and fuel)
- Apply techniques for conversion, transport and storage of energy
- Develop a plan based on up- and downcycling (cascade) of energy

---

**Results**

The result will be a plan for the campus in east Heerlen, making use of the local potentials and the principles for up- and downcycling energy:

- Use roof area for solar gain (electricity and heat).
- Windturbines along road for electricity production.
- Use waste biomass from agriculture, maintenance of nature and residential garbage for producing biogas.
- Transport biogas in pipelines to urban areas to CHP.
- Convert biogas in CHP to electricity and heat for grid.
- Cascade heat demand for different temperatures.
- Create a LowExergy energy demand for the buildings.
- Create LowExergy thermal grids for new districts
- Use existing heat grids in heat cascades
- Use local former colite mines for heat and cold storage.
- Connect heat and cold grid to regional thermal network
- Regional (Parkstad Limburg) thermal network is connected to industrial areas for residual heat, sand quarry lakes for cold, and Colemines for large scale storage.
- Clean residual from biogas production returns as fertilizer to the agricultural area around Heerlen.

---

**References and acknowledgments**

- Minewater, a geothermal source or a storage for sustainable energy in a Low Exergy Thermal Network - Gommans, Minewater 2008 - Heerlen
- An Exergy planning approach for the region Parkstad Limburg – Gommans & Van Kann, 2009, Delft (NL)
- Energievisie Onderwijscampus Heerlen – Cauberg-Huygen Raadgevend ingenieurs BV, Maastricht (NL) 2009
- Mogelijkheden voor het gebruik van geothermische energie voor de Open Universiteit te Heerlen (NL) – VITO NV Mol (B) 2007
- J. Stefens, Open Universiteit Heerlen (NL)
Exergy as a Design Principle for Integrated Energy-Space Concepts in Parkstad Limburg (NL)

Ferry Van Kann and Leo Gommans

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Delft University of Technology, Faculty of Architecture, Julianalaan 134, 2628 BL Delft, l.j.j.h.m.gommans@tudelft.nl

Significance of Research Project / Background

• Energy and spatial disciplines lack linkages
• Regional scale (above local) is not used to develop linkages between energy, spatial planning, and spatial design
• Exergy is not used at all to reach synergies between energy and spatial planning on a regional scale
• Although (f.i.) Dincer and Rosen (2005-183) state understanding and appreciation of exergy… is essential to discussions of sustainable development, exergy is still hardly part of regional planning debates, even if a sustainable development is a goal

Objective

• Develop strategies for spatial planning and design to reach a sustainable energy transition
• Understand how the exergy principle can be used to reach optimal systems and design of regions
• Explore an exergy conscious spatial planning as a guide to a sustainable energy transition in Parkstad Limburg
• Develop a design scheme to integrate an exergy approach in the spatial structure and design of regions
• Understand how to upscale interesting energy-space examples to an integrated robust regional energy-space system

Results from an energy-space example of Park Gravenrode to an integrated concept for Parkstad Limburg

Example 1a: Park Gravenrode (Gommans and Van Kann 2009)

Sources of energy:
Left: residual heat industry, bakeries, chemical industry + snowworld
Right: biomass → gas / electricity + heat, RWZI (sewer treatment) Kaffeberg
Middle: biomass: manure, restaurant Zoo Gaiapark
Sinks for energy:
On top: company grounds, offices Essent + tropical greenhouses "Wereldtuinen"
Middle: exchange within industrial site
All around: housing areas, various ages
Bottom: Zoo Gaiapark, tropical animals

Example 1b: Park Gravenrode (Gommans and Van Kann 2009)

Energy-Space system:
Left: Snowworld as heat supplier (large fridge), heat used in cascaded housing areas, company grounds and tropical greenhouses “Wereldtuinen”
Right: RWZI (Sewer treatment) as energy roundabout, collection of biomass from zoo and sewer, production of biogas, to be burned for process heat at industrial site, residual heat used in cascaded housing areas and tropical animals Zoo Gaiapark
Middle: connection between both system for reasons of robustness

Method
1. Spatial analysis of the structure of spatial functions in the region
2. Categorize spatial functions on the basis of the qualities of energy flows they need and waste (input and output)
3. Apply a suitable ecological design principle here a source-sink principle (figure 1a)
4. Connect various spatial functions by means of energy flows → create an energy cascade with on top sources and subsequently sinks (figure 1b) → try to make the system itself robust (storage facilities, back-up)
5. Look to same kind of examples nearby, try to upscale to an integrated concept, from a link (1) + a ring (2) to links in a chain (3)

Results (continuation in text)

• On the left two figures are shown with above so called energy sources and energy sinks defined in Park Gravenrode (exergy approach), below an exergy approach based energy-space system for the region
• On the right we combine example projects (here only one example is shown, for the example of Campus Heerlen see other poster, or SREX Report 2008.1) to a more robust system on a bigger scale: an energy ring (Van Kann, 2009)

Acknowledgement

Thanks to SenterNovem, University of Technology Delft, University of Groningen, Wageningen University, SREX – www.exergieplanning.nl
Exergy Planning at the Regional Scale Case-study South Limburg (NL)

Wouter Leduc and Sven Stremke

Wageningen University, Environmental Sciences Group, Urban Environment Group and Landscape Architecture, P.O. Box 47, Wageningen, 6700 AA, The Netherlands

email: wouter.leduc@wur.nl

Significance / Background
• Energy and spatial disciplines lack linkages
• Regional scale (above local) is not used to develop linkages between energy and spatial planning / design
• Exergy is not used at all to reach synergies between energy and spatial planning on a regional scale
• Although 40% of energy consumption is influenced by spatial organization of human environment

Objective
• Develop strategies for spatial planning and design to reach a sustainable energy transition
• Understand how the exergy principle can be used to reach optimal energy systems on a regional scale
• Exergy conscious spatial planning as a guide to a sustainable energy transition in South Limburg
• Develop a design strategy to deal with long-term possible trends both in energy system and the region

Method
1. Data analysis of historical and present conditions of the regional energy system and spatial structure
2. Mapping of near-future changes in regional system
3. Scenario approach to identify possible futures and indicate critical uncertainties
4. Develop integrated energy-space visions
5. Select robust strategies for regional sustainable energy transition based on used scenarios / critical uncertainties

Figure (right side) shows the different steps

Acknowledgement
• Thanks to SenterNovem, University of Technology Delft, University of Groningen, Wageningen University, SREX – www.exergieplanning.nl

Conclusions
• Knowledge gap long-term strategic spatial planning
• In order to reach synergies between regional planning and exergy, there is a need for an integrated approach
• Integrated energy visions are capable of accounting for possible future trends, expressed in scenario studies
• Robust strategies are a basis to initiate a transition from fossil fuels to renewables

Next steps
• Identify robust strategies based on case-study South Limburg and second case-study in South-East Drenthe
• Develop generic applicable integrated planning concepts and spatial design principles based on exergy

References
Abstract

Ground source heat pumps are one of the best systems for lowEx buildings. Still, when considering the ground as a source of heat from the exergetic perspective, there is already value in that higher temperature before a heat pump is used to lift the temperature to a building heating level. It is true that the performance of the heat pump is good with the small temperature lift, but other factors affect the performance such as the maximum load the system must be capable of providing versus the typical load, as well as the inefficiencies due to cycling of the system on and off or dynamic changes in variable speed systems. A new concept has been developed and analyzed in which the heat from the ground is used at its existing temperature in a thin lightly insulated layer on the outside of the building wall. This reduces the heat loss through the wall as it is now at the temperature of the ground instead of the outside conditions, and it eliminates large maximum loadings while at the same time creating a relatively constant heat demand for the heat pump. The analysis shows that at design conditions for Zurich, the 7cm thick system is equivalent to 18cm of passive insulation, and that over the heating system the heat pump with additional wall circulation pump energy demand is about 1000 kWh less than an insulation system of equivalent thickness and typical heat pump with cyclic losses.

Low exergy active insulation heat barrier

Luca Baldini, Forrest Meggers, Hansjürg Leibundgut

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Wall Concept

The idea is to, in principle, make the building wall be virtually underground in a warmer environment, the equivalent to moving it to a warmer climate zone. The wall can be provided with water from a borehole 100-300m of 10°-17°C (Zurich). Figure 1 shows how part of the heat from the ground is now directly used in the building to minimize the heat demand, and although the heat put into the wall is immediately lost to the environment, because it is freely available 'energy' the only exergetic cost is the pumping power to circulate it through the wall.

Water Wall System

The piping is installed in the final layer of the wall and covered with a few cm of insulating plaster, which limits the temperature difference between the pipes that are spaced every 5 cm, and also prevents an excessive flow rate to maintain a reasonable temperature drop across the wall.

Prototype and Pilot

A rendering of the lowEx B35 project (www.viagialla.com) displaying the concept of the active insulation is shown in Figure 2a. A prototype retrofit installation under construction in Italy is shown in Figure 2b.

Results and Analysis

The wall system was first analyzed for its static performance at various design conditions. This allowed for the appropriate sizing and spacing of the tubing as well as the inner and outer insulation supporting the system. Figure 3 shows the temperature profile between the tubing for different spacings, which showed that 5 cm was sufficient. Figure 4 shows the effect on the energy demand of the system with various amounts of inner and out insulation and 3 cm of inner and 3 cm of outer was selected. Next the energy demand for the heating season in Zurich was analyzed and the losses through the active wall compared to a concrete wall with no insulation and one with an equivalent thickness of passive insulation (Fig. 5). This was done for an assumed 10x10x10m cubic building will 5 active walls. The effect of the incoming source temperature on the total demand showed that the higher temperatures caused an increased heat loss from the piping and thus a higher pumping demand, reducing the benefit of higher temperatures (Fig. 6). The active system was compared to a wall with an equivalent amount of insulation and a heat pump with standard cyclic losses and showed about 20% better performance (Fig. 7).
Understanding the Heerlen minewater reservoir

Results from flow tests and numerical modelling

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The poster illustrates results of flow tests and numerical modelling in view of understanding the underground processes in the Heerlen minewater reservoir. The first minewater power station for city district heating and cooling at Heerlen uses minewater produced from the abandoned Oranje-Nassau mine complex. Five wells at different depth (and temperature) levels were realized allowing production/storage at high (~30°C), low (~17°C) and intermediate temperatures.

Since no access to the mine has been preserved after closure, the only way to know what happens underground when pumping/injecting is to monitor pressure, temperature and chemistry at the different wells. Chemical analyses of water samples taken at regular base reveal changes in source areas of the water.

FLOW TESTS

During three different flow tests three production wells, as well as the interconnectivity and reaction of the reservoir were tested. Production and simultaneous injection at a different well resulted in a pressure redistribution throughout the entire reservoir. Downstream pressure builds-ups and releases revealed a cyclic storage pattern associated with critical flow rates and pressure thresholds.

CHEMICAL ANALYSES

Ha – Cl plot for water samples taken from the tested production wells

EC evolution during the HLN1 → HLN3 flow test

FLOW TESTS

Pressure head evolution in the reservoir during the HLN1 → HLN3 flow test as monitored at the different wells

NUMERICAL MODELLING

Based on our 2D GIS model of the mine a simplified geometry (considering the main connections in the reservoir) has been discretized into a rectangular grid. The results of the flow tests were simulated by coupled mass & heat transport modeling to come to a useful model of the mine that can explain the underground flow and predict processes. The main flow through several levels of stoneworks that are interconnected by shafts can be predicted. The challenge now is to refine the basic models to incorporate local effects (e.g. fractured zones) and buffer capacity (influence of mined-out panels etc.).
Local distributed heat pumping
Minimizing $\Delta T$ - maximizing Exergy

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Abstract

In most heat distribution networks many different temperatures have to be supplied. To meet the different demands the temperature of the supply side is often adjusted to the highest temperature. But for the use of a heat pump low temperatures and small temperature differences between supply and return are favorable. In order to lower the temperature in a heating network, a system with a central distribution in conjunction with small local heat pumps is being developed. This allows for a local adjustment of the supply temperature. It is expected that such a system will increase exergetic efficiency of the central distribution, as well as increase the comfort due to faster heating and cooling of rooms. The purpose of this work is to model such a network and to optimize it in regard to several parameters.

Background

In heat distribution networks, such as domestic central heating or district heating, usually components with different temperature requirements are being supplied. The heat is being supplied with the same temperature to all components and can be adjusted by mixing hot and cold water. A basic setup is shown in Figure 1.

![Figure 1: Scheme of a conventional heating network](image1)

This is no problem when exergically inefficient furnaces are being used, as they can produce a wide range of temperatures. But when efficient heat pumps are being used for heating or cooling lower temperatures and a small temperature difference between supply and return are necessary to achieve a good exergetic performance of the heat pump.

This can cause problems for the retrofit of existing supply networks. In order to reduce the temperatures for a given demand the heat exchange areas have to be increased. If this is not feasible the system will become ineffective with significant heating and cooling lag times, reducing the user’s comfort.

Resulting Concept

In this work an integrated network is being introduced which combines a distribution network with small local heat pumps as shown in Figure 2. Such heat pumps could be thermoelectric or magnetocaloric ones. Thermoelectric heat pumps are already used for cooling applications but not yet in the context of heat distribution networks.

![Figure 2: Scheme of a network with central and local devices](image2)

With such a setup it is possible to lift or lower the temperature of the supply locally to meet demands that can’t be sufficiently covered by the supply. This allows for reducing the base temperature in the supply, therefore increasing the efficiency of the heat pump in the central distribution loop. Ideally the temperature in the supply could be chosen in such a way that it is not necessary to be changed during the heating or cooling period.

Furthermore such a system can react faster on sudden changes of internal and external loads or heating and cooling demand, therefore increasing the comfort for the user.

Project Goal

The focus of this work is to develop a model which can be applied to describe a system which combines a central heat source and local heat pumps. Such a system can be a domestic central heating or a local or district heating network.

The model is used to determine optimal operating conditions for the central heat source and for the local heat pumps. Especially the temperature for the supply and the operating hours for the local units are of interest.

The setup shall be compared to a conventional heating network using exergy and energy analysis. Preliminary designs show large potential for exergy and energy demand reduction.
The value of waste: Exergetic optimization of heat recovery from wastewater

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Abstract
The wastewater heat recovery system shows great potential for exergy savings, cost reduction, and environmental benefit. The operation was optimized for the maximal annual exergy extraction. This provides an optimized heat source to create a low temperature lift heat pump to regenerate used hot water. The system was modeled for one, two, four, six, and eight residence buildings with a realistic hot water usage profile and a 30°C wastewater stream. Compared to conventional natural gas (NG) and electric (Elec) boiler systems, the heat recovery systems reduces the primary energy demand and therefore also operational costs and the greenhouse gas emissions (CO2). Replacing an electric boiler with a heat pump that uses the wastewater heat recovery can save over 500 CHF per year per building residence and over a ton of CO2.

System Operation
A LowEx building concept has been developed to minimize the temperature lift of an integrated heat pump. This smaller ΔT increases the performance (COP) of the heat pump as shown in Equation 1 where \( T_{\text{Max}} \) is the supply temperature and \( T_{\text{Carnot}} \) is the Carnot efficiency relative to ideal.

\[ \text{COP} = \frac{T_{\text{Carnot}}}{\Delta T} \]

\( \Delta T = T_{\text{Hot}} - T_{\text{Cold}} \)

This is done by exploiting the higher temperature sources of free heat (energy). Here we are focused on the usage of heat from wastewater.

Motivation
Heat recovery from exhaust air is already common with products on the market. Contrary to this, warm water heat recovery is rare, yet it is a significant loss of energy and more importantly, exergy. In collaboration with Gebert Int. AG a new wastewater recovery product is being developed.

Results and Analysis
The operation of a the heat recovery system was analyzed using a annual hot water usage profile with 6 minute time steps and statistically randomized events of bath, shower, sink, clothes washing, and dish washing. The statistics used were for various sized buildings with an annual energy demand for hot water of 3000 kWh per unit. Exergy analysis provided an optimal tank size and heat exchanger flow rate shown in Figure 3. The performance of the system was compared to a standard electric boiler with 95% efficiency and to a standard natural gas boiler with 90% efficiency. The results are summarized in Table 1 for all building sizes and in Figure 4 for one unit.

<table>
<thead>
<tr>
<th>Table 1: Energy and Exergy per unit for wastewater heat recovery system</th>
<th>Energy</th>
<th>Exergy</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Units</td>
<td>Savings</td>
</tr>
<tr>
<td>vs NG Boiler</td>
<td>kWh</td>
<td>115</td>
</tr>
<tr>
<td></td>
<td></td>
<td>600</td>
</tr>
<tr>
<td>vs Elec Boiler</td>
<td>kWh</td>
<td>98</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1,300</td>
</tr>
<tr>
<td>vs Elec Tank</td>
<td>Litrers</td>
<td>160</td>
</tr>
</tbody>
</table>

Outlook
The project will be prototyped by Gebert in the coming year and a pilot system will be installed in the B35 building project (see www.viagialla.ch). The compressor development for the low temperature heat pump system is under further investigations by researchers at the Technical University in Horn, Switzerland.
INTRODUCTION

Energy performance of the built environment is crucial for sustainable development, in particular for reducing energy use and demand and improving the energy efficiency of existing buildings. Exergy is a measure of the capability of energy to do work, and it is a key concept in understanding the performance of thermal systems. Exergy can be calculated using the equation:

\[ E_x = T_0 (Q - W) \]

where \( E_x \) is the exergy, \( T_0 \) is the temperature of the surroundings, \( Q \) is the energy transferred or work done, and \( W \) is the work done by the system.

In building processes, a common problem regarding exergy saving investments is that the stakeholders who benefit from exergy saving techniques do not necessarily include the investing stakeholders. Furthermore, little is known about the potential financial benefits of exergy saving techniques.

SUMMARY

This research project aims to contribute to sustainable building by investigating the potential financial benefits of exergy saving techniques. In building processes, investors can use life cycle costing to calculate the returns on their investments. The University of Twente focuses on the financial aspects of exergy saving techniques, which contain three elements: the built environment, a collaborative research environment, and financial analysis.

The authors would like to express their gratitude to SentroNovem for providing financial support to the present research.
The Heerlen Minewater Project

Purpose & Execution

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In the Heerlen Minewater Project, water from the four (4) flooded Oranje Nassau coal mines is used for low-enthalpy heating (winter) and cooling (summer) of domestic housing, offices, shops, and community buildings.

Together with the former infrastructure of the mines, the huge amount of mined-out (coal) panel-areas of the mines constitute (a) large, human induced reservoir(s) with various depth levels. The complete minewater-reservoir consists of the combined, but semi-separated ON-I, -III and - IV, and the ON-II mine parts. Rough calculations indicate water volumes of 7.8 and $3 \times 10^6$ m$^3$ for each reservoir part respectively. Combined with an averaged geothermal gradient of ca. 3$^\circ$ C / 100 m, the various former mining levels in the mines either have relatively warm (> 25$^\circ$ C) intermediate (19$^\circ$ -25$^\circ$ C) or cool (< 19$^\circ$ C) temperatures. The warm water is used for heating, the cold water for cooling purposes.

When warm water is cooled-off during its use till < 19$^\circ$ C (e.g. in winter) it is re-injected into the cold water part(s) of the reservoir. When cold water is heated-up during the summer as a result of its (deep) cooling applications, it is re-injected into the relatively warm part of the reservoir. Especially to this purpose the warm water ‘buffer’-well was created.

When water is unfit for either type of storage it is injected into a separate well in the ‘intermediate’ part of the reservoir. Next to the always present and acting flow of ‘geothermal heat’, the reservoir also can be used to either store heat or cold from external sources, to enhance its overall energy capacity.

Five (5) wells have been drilled in the project.

They all hit their targeted stone-drifts at varying depth levels. Hitting stone-drifts was necessary due to the demanded water-flows.

At the figure the stone-drift levels are indicated. The lowest levels are grouped together (red).

The shallow levels are blue and green, the intermediate brown (or red).

HH-1 (Heerlerheide-1) to produce warm water (up to 150 m$^3$).

HH-2 (Heerlerheide-2) to store re-heated cooling water and in this way ‘buffer’ the initially small volume of warm water in the reservoir due to the limited mining at deeper levels. At later stages the well may be (shortly) used to produce warm water.

HLN-1 (Heerlen-1) to produce cold water (up to 250 m$^3$/h).

HLN-2 (Heerlen-2) to produce cold water (up to 250 m$^3$/h).

HLN-3 (Heerlen-3) to re-inject water of ‘intermediate’ temperatures; the well may also limitedly produce warm water.
transport of an energy playground for small ΔT’s

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Abstract

District heating networks normally operate at high temperatures, with high exergetic value. LowEx-district heating and cooling networks have been recently implemented that run at low temperatures. This research looks at heat/energy reservoirs at even lower temperatures which can be augmented by heat pumps. The value of these reservoirs with small ΔT’s compared to the ambient temperature is assessed and thus the viability to transport energy from source to utilisation. Two case studies of energy masterplans are presented that both transport water energy with absolutely low but relatively high temperature reservoirs.

Background

Man has always transported energy from the source to the place of utilisation. Transportation cost necessitate that only high-exergy carriers have been moved, like fossil fuels and electricity. In the context of climate change and reduction of fossil fuels, the (temporary) lack of CO2-free exergy now makes it financially viable to transport LowEx-carriers.

Motivation

District heating systems have been run at temperatures often exceeding 90°C, ideally using excess heat from waste incinerators but often additionally fueled. Applying LowEx-building principles (low temperature for heating, high temperature for cooling) allows the use of low temperature district networks e.g. fed from abandoned mines (like Remining-LowEx CONCERTO projects).

In this context, an energy source is defined as a (heat) reservoir that can deliver free energy from the environment and that is ideally at a higher quality than the ambient environment.

The best situation occurs if an energy source supplies energy at a quality that can be used directly. If the quality of the heat reservoir is below that needed for comfort generation, then the quality can be augmented using heat pumps, making many more lower ΔT energy reservoirs available. The COP for heat pumps with these ΔT is high, minimising the use of exergy.

Case study: Tunnel water in alpine resort Andermatt

An entirely new tourism resort is being built in Andermatt, an alpine region. The cold climate implies a high heating demand with a low cooling demand. The energy provision for the resort is aimed at being CO2-free.

The energy masterplan includes a low temperature anergy loop around the resort with decentralised heat pumps. The anergy loop is fed by a seasonal geothermal storage field of borehole ground heat exchangers of 300m length, with a temperature of 0-5°C. The other source is the Furka tunnel which entrance is located at a distance of 6 km. From it sorts a constant flow of drainage water at 13°C which is piped to the resort.

The tunnel water is of special interest in the mountains. Because of the low ambient temperature, the exergetic value of the relatively low temperature of the energy source is high.

Research includes feasibility of the energy network, interplay between the two reservoirs and the relation between exergetic value of reservoirs and transport cost.

Case study: Thermotunnel Letten

Concepts for the central campus’s energy provision of the ETH Zurich are studied to be in line with its energy strategy. As far as structural and building infrastructure is concerned, this means halving CO2-emissions by 2020.

One concept considers reopening a refilled train tunnel with microtunneling that passes underneath the campus. This Thermotunnel connects the lake of Zurich with the river Limmat creating an anergy track at low temperature. Compared to thermal networks with only one reservoir, this system makes use of the temperature differences between the two reservoirs. The larger ΔT reduces the mass flow through the tunnel, reducing thus infrastructure cost and environmental impact.

The energy from the water can be used for direct cooling and for heating with a central heat pump. With T_anergy = 6°C and a low temperature emission system, a COP larger than 5.5 can be expected to minimise the need for exergy.

The research covers feasibility of the system, benefit of using two reservoirs instead of one and infrastructure cost for this anergy track.

Acknowledgements to Amstein+Walther, responsible for both case studies.
Design Performance Viewer (DPV): A BIM Application Including Exergy Analysis

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Abstract
The Design Performance Viewer is a building design tool that takes information from a parametric building model or building information model (BIM) and rapidly generates graphics and easy to understand information on the energetic and exergetic performance of the building. The tool displays in simple to read diagrams where a design can be improved, what the weak points are, and how the exergy is transferred through the building system. This allows architects to understand starting in the first stages of building design how changes in systematic and more importantly, geometric and aesthetic aspects influence the performance of a building. The tool has been used extensively at the ETH in Zurich with architecture students to successfully integrate energy and exergy analysis into their architectural design processes. The large facade firm, Schüco has also supported the further development for integration into parametric analysis and implementation of its high performance facade systems.

Tool Operation
The tool as shown in Figure 1 is built on top of an existing BIM software platform. Within the model are all the data on the properties of the building components and they are exported to the DPV (Fig. 2). Within the DPV a few system characteristics are input based on the Annex 37 Excel Tool (Fig. 3) [1]. A building energy footprint is output as shown on top of Figure 1 and an exergy flow diagram is produced as shown in Figure 4. The designer can make changes on the fly and have the results instantly recalculated.

Tool Verification
The results from the calculations of the simplified energy model implemented were compared to the results of a commercial and certified software, which is used to verify the conforming of the EnEV regulation. The results show variations below 5%, proving the sufficiency for the proposed early stage performance assessment. In contrast to the software used for the comparison, the assessment of the performance analysis of a specific building takes only a few seconds using the DPV. In addition to the calculation of total energy and exergy demands, the building designer can find the most suitable optimization for the building concept and context. Most important, balancing between form, materialization and technical systems is possible from the beginning on. [2]

Tool Utilization
Utilizing building information modeling to realize fast energy and exergy performance assessment opens up the possibility of an more integrated view on buildings during their early design stages. The parameterized model enables capturing the complexity resulting from manifold dependencies of building components and environment. Implementing the concept of exergy proved to make more precise definitions of efficiency in building possible. It enables balancing between different qualities of energy for different purposes. The concept of “low-exergy” offers more flexibility for the building designer to choose appropriate measures for an optimization. [2]

Product Availability
The DPV software is currently being developed as an add-on to the Autodesk Revit platform. It has been successfully implemented in several course projects at the ETH helping architects better understand energy/exergy and also in collaboration with Schüco Facade systems. Currently the project is being launched as part of a spinoff at the ETH Zurich. For more information see www.keoto.org.

References
Decentralized Systems integrated into facades of LowEx Architecture
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Abstract
Buildings constructed according to the LowEx principles contain a greater number of decentralized building systems located in the facade. They are part of a network of building systems/components and controls. Although they are small in size, they often conflict with the initial design of the facade, since parameters and dependencies are not obvious for the designer and architect. A lot of time can be wasted, if and when the design of a facade has to be revised. This result is often either a compromise of the aesthetic or the system efficiency.

This process could be enhanced in LowEx building design by a method, which controls the design flow according to the parameters of the decentralized systems, their limits and their necessary connections. Part of the research is to define these parameters and transfer these information to a tool. Here we present the parameters and methods that will be exploited and used to create such a tool.

Characteristics of LowEx facades
A) The thermal resistance of the facade can be optimized to satisfy the comfort level of the interior surface temperature. Further optimization is possible, but not mandatory.

LowEx constructions are optimized as one entire system, where each member of the system aims to reduce the use of exergy. Since they are part of a greater network, there is no need to optimize each one individually, but rather the system. As such the facade is just one member along other building systems. Therefore the envelope is not optimized only to reduce the heat losses of the interior spaces, but also to minimize the development of large temperature gradients between the surface temperatures of the interior walls.

B) The facade can contain integrated, decentralized units, which are part of a network of building systems.

Facades divide the interior space (with an almost constant climate and conditions) from the exterior space (with natural fluctuations of daylight, temperature, air pressure, humidity etc.).

Decentralized systems in the facade can reduce the demand of exergy, since they run with low flow and low temperature gradients, while also being individually adjustable.

Since more decentralized devices are located in the facade, it is important to consider from the architectural point of view how they influence the design in combination with other equipment.

Facade as a part of a network
The facade is part of a greater network of building systems and components in combination with controls and sensors.

Specifications
Beside the predetermining interconnections of the building system, a range of physical attributes and building codes have to be considered to correctly localize the decentralized units.

The following specifications are four of many prerequisites:

- The area of unobstructed view based on the use of the building
- The area of transparent material according to daylight studies
- The ratio of opaque to transparent material, based on building orientation, material, site conditions, etc.
- Physical prerequisites, like size, weight, distance, etc. of the units

Final Goal / Outlook
Based on an abstract model, which takes all the interconnections of the building system into account and also combines them with the building specifications, the performance and design of a facade can be tested and optimized.

This method will also help to validate and implement the decentralized air supplies.
Occupant Behaviour Within the Residential Built Environment

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Abstract

Recently more and more studies not only try to look at the energy use of a building, but also at the exergy consumption. At the same time, more scientists then ever before have recognised that occupants’ behaviour, together with its relation to energy use within the built environment, as being very important. Results of field studies as well as simulations are stating differences in the energy use solely due to the occupant behaviour of up to 600%. Although these studies have shown those differences, they do not try to look into the reasons behind such differences nor intend to explain them. This research project therefore analyses the individual differences between occupants and looks at the exergy consumption pattern of an individual as well as a community of persons.

Background

The amount of exergy consumption of a certain built-environmental system is influenced not only by the characteristics of hardware such as the thermal insulation level of the building envelopes, but also much by that of software, the human behaviour. In reality, the occupants have different options to achieve comfortable conditions in their indoor environment. Which of the options they take, e.g., whether switching on an air-conditioning unit or opening a set of windows for cross ventilation, influences significantly the exergy consumption pattern of the built-environmental system.

Methods

Data collection methods:
- field measurements in dwellings including questionnaire surveys and personal interviews
- field-workshops with occupants in their dwellings
- multi-language online-questionnaire-survey including information distribution and evaluation (www.tezhic.com)

Data analysis methods:
- different statistical analyses with emphasis on multivariate logistic regression analysis methods

Results

The main findings so far are given below together with Figures 1-5 on the right. The interested reader is kindly referred to the articles appended to this poster for more details.

- multivariate logistic regression analysis is an useful tool to analyse the general occupant behaviour as well as the influencing factors
- among the factors with the highest influence on the occupant behaviour are preference, the current thermal conditions as well as past thermal conditions such as during the foregoing nights but also during the childhood
- the individual differences lead to huge variations in the exergy consumption rate of an individual and a community

Conclusion

The findings so far show that a close look at the individual differences between occupants leads to useful findings, which can be applied in order to improve the simulation and the design of the thermal environment.

Next Steps

The next tasks are the completion of the Internet’s survey summer version, further analysis of the data obtained and an advanced exergy simulation of the built environment.

References

The interested reader is kindly referred to the references given in the appended papers.
Performance Analysis of Heat Pump Systems with Vertical Ground Heat Exchanger

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Abstract
Heating and cooling buildings by ground source heat pump (GSHP) can be both environmentally and economically favourable solutions. However, it is essential to keep the winter energy extraction and the summer energy recharge balanced. Otherwise, temperature shift of the soil may proceed around the heat exchangers after some year operation, which has negative effects for system performance. To increase the long-term efficiency and sustainability, it is needed to adjust the system arrangement and operational mode to the local weather and geothermal conditions as well as to the annual heating and cooling profile of the building.

Introduction / Background
In the Carpathian Basin the average soil temperature is considerably high because of the higher geothermal gradient.

It is definitely advantageous in winter. Will it cause any problem in summer?

Different building types have different annual heating and cooling profiles. Sometimes the profile is unbalanced. How can the long-term efficiency and the sustainability be strengthened?

Conclusions
To reach the highest system performance and sustainability:
- balanced annual system operation is needed (balanced extraction and recharge)
- seasonal heat storage should be realized.

Next steps
Continue the evaluation of the measured data of the monitored ground source heat pump system.

Different vertical ground heat exchanger arrangements and operational modes will be constructed for different building types with different heating and cooling profile, which enhance the balanced operation and long-term efficiency.

Methods
Evaluation of the measured data of an existing building heated and cooled by GSHP

The soil temperature is measured in different depth and different distance from the vertical heat exchangers.

Investigation of the natural soil temperature without any kind of influences.

Results
Because of the temperature drop in winter there will not be any problem in summer.

The unbalanced heat extraction and recharge has caused the temperature shift of the soil around the heat exchangers.

The energetic soil regeneration can only be assured by balanced annual operation (extraction and recharge).

The exergetic soil regeneration can be significant even without summer recharge. Consequently it can postpone the negative effect of the insufficient energetic regeneration. It needs sufficient amount of soil volume around the tubes.
In situ measurements of thermal conductance and thermal bridge analysis in building envelopes

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Abstract
A way to test the thermal behaviour of a building is to measure the thermal conductance $C$ in situ (or transmittance $U$) of its walls. For this operation the heat flux on the internal surface, the internal and external surface temperatures are needed (see fig. on the right); then these data are elaborated according to different methods in the post-processing phase.

Background
The measure of thermal conductance in situ and the study of thermal bridges are intended for energy saving in buildings.

Methods
In situ thermal conductance: we test different kinds of building structures which design conductances are known; we adopt different methods (Average Method, Black Box Method and Electrical Analogy) to analyze the recorded data, then we compare these values with the measured ones.
Thermal bridges analysis: we simulate different solutions with softwares implementing the finite difference method and the finite element method, collecting all this information to help the designer in operating for energy saving.

Results/Data Analysis
In situ thermal conductance: for an example which design C-value is known, the pictures show the analysis steps from the recorded data to the measured C-value. Then the final results are reported for two analysis methods.
Thermal bridges: an example of the analysis is shown comparing the ‘bad’ solution — with its relative results — and the corrected one.

Discussion
For the studied cases the in situ thermal conductance is higher than the design value: this could be for different reasons, such as the negative influence of humidity in materials and mistakes during construction operations. Thermal bridges can be corrected: with a careful design it is possible to avoid condensation problems and reduce the heat exchange between internal and external environment.

Next Steps
In situ thermal conductance: to evaluate the best conditions to dispose measurements and the possibility to have them in summer. Thermal bridges: to collect and compare further different constructive solutions.

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Ing. Sergio Marinetti, ITC CNR Padova.
Thermal comfort in relation to applied low exergy systems

Assessment of thermal comfort in non-uniform environmental conditions

Introduction

The primary goal of this project is to obtain more insight in the thermal comfort of occupants in relation to non-uniform environments, as may result due the application of low-exergy systems. The project will be conducted within the ECOS-LT research, funded by SentielNovem, and will be carried out by the 3 TU federation. Each university within this collaboration performs her own part of the project. Eindhoven will focus on the topic people. The main focus is the assessment of thermal comfort in non-uniform environments. Furthermore, this study will be performed in close collaboration with Maastricht University.

Objective

The IEA Annex 37 study revealed that an optimal energy use not always results in an increased comfort level. In some cases it proved to be more difficult to achieve thermal comfort, for example to compensate the slow response of floor and wall heating and/or cooling by means of ventilation. Application of LowEx systems can result in local and/or global discomfort by for example unintended flows, in case of application of a natural ventilation system in combination with low temperature heating, or local differences in thermal comfort and temperature fluctuations. The indoor air flow is most critical, for both cooling and heating cases. More knowledge on the interaction between the system, indoor climate and the human body is indispensable to design optimal systems in the future. The main objective of this research is the development and verification of a tool to assess the thermal comfort of occupants under non-uniform and transient conditions, which can occur in buildings where LowEx systems are applied (e.g., low temperature heating).

Methodology

To meet the objectives several activities will be and have been conducted during the PhD study:

Literature review

An extensive literature study on thermal comfort, existing methods to assess thermal comfort, existing relations between non-uniform conditions, local skin temperatures and thermal comfort, and problems regarding the thermal comfort, which occur due to the application of low exergy (lowex) systems has been performed. This study revealed, among others, that application of lowex systems can result in local and/or global discomfort by for example unintended flows, in case of application of a natural ventilation system in combination with low temperature heating, or local differences in thermal comfort and temperature fluctuations.

Laboratory experiments

Experiments form an important part of the work. To determine the conditions and the problems which will occur due to application of lowex systems, measurements will be conducted under laboratory conditions with test subjects. With these measurements thermal responses will be obtained, and thermal comfort at these specific conditions will be assessed. Furthermore the relations between local skin temperatures and thermal sensation of occupants will be studied. The measurements will be used for the validation of the CFD model and thermophysiological model as well.

Numerical modelling

Besides experimental work, the use of numerical tools is important to allow assessment in the design phase of a building. To determine the temperature distributions and flow patterns which will occur in a room due to non-uniform environmental conditions, Computational Fluid Dynamics will be used.

Thermophysiological modeling

The ThermoSEM model, which is developed by the department of mechanical engineering at the Eindhoven University of Technology and the Maastricht University, will be used for the prediction of the local skin temperatures, core temperature and Dynamic Thermal Sensation based on the mean skin temperature, core temperature and the rate of change of mean skin temperature. The main advantage of this model is that symmetric boundary conditions and individual body characteristics (height, weight and fat percentage) can be taken into account [Van Marken Lichtenbelt, 2004 and 2007].

References


DESIGN OF INNOVATIVE LOWEX SYSTEMS FOR HOSPITAL ENVIRONMENT

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Abstract
Hospital presents very complex inside environment. It should be treated as 3-D system of user-environmental factors-specific activity. State-of-art analysis of 576 relevant sources of literature (1941-2006) focuses on two problems in hospital environment: high building exergy consumption and individual comfort dissatisfaction. Two main problems will be solved with a developed method for holistic mastering of the problems and by searching alternative solutions. The main contribution presents a design of innovative LowEx system that enables fulfillment of regulated demands and comfort conditions for individual user and minimal possible exergy consumption for heating and cooling of spaces.

Introduction/Background
A new method will enable to take into consideration all aspects of individual user in relation to specificity of active space and will present the basis for LowEx design. The main goal is to find the system for heating and cooling that enables to create optimal comfort conditions and regulated demands for individual user (health worker, visitor and patient), attain designed exergy consumption inside the human body and minimal possible building exergy consumption for space heating and cooling.

Methods
Design methodology is based on: 1. Definition of needs, demands and conditions, 2. Problem design and 3. Synthesis of solutions. Conventional and LowEx system of heating and cooling will be installed in 2 active spaces. System comparison will be carried out with exergy analyses due to numerical calculation and simulation of individual human body and building exergy.

Results/Data Analysis

![Diagram showing results and data analysis]

Fig 1. Results of preliminary analysis of human body exergy for average sitting subject

Discussion/Conclusion
Results show the influence of different levels of RH (32%-96%) and Ta=30°C on human body exergy consumption. At lower RH and lower Ta (15°C, 30%), the exergy consumption is the highest (4.23 kJ/m²). Due to higher internal production by metabolism. At high Ta and high RH (35°C, 96%), the exergy consumption is the lowest (0.288 kJ/m²). Due to low internal production and low exergy output. High RH releases sweat from skin surface and causes lower sweat losses and high skin wetness (0.48). At 32% skin wetness is only 0.02. 2 cases result in similar exergy consumption: low Ta and low RH and high Ta and low RH (15°C and 30%, 35°C and 30%). But more precise input and output flows are needed. Sweat losses, warm radiation and cool convection are lower, if Ta is higher. Even if RH is the same. The blue line represents 0.05. In summer conditions people feel most comfortable, if Ta is constant 22°C. RH could variate and exergy consumption is 2.2-2.8 kJ/m². In winter case the situation is different. In comfortable conditions human body exergy is the lowest.

Next Steps
Numerical calculation of individual human body exergy, simulation of building exergy consumption, system optimization.

References

Acknowledgments
Energy and exergy balance of the traditional and passive single family houses

Zygmunt Wiercinski, Aldona Skotnicka-Siepi ski and Maciej Wesolowski
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INTRODUCTION

One of the most important differences between the notion of energy and exergy is that energy is subject to the conservation requirement. The windows of advanced technology are unsubject to the conservation requirement. The windows of advanced technology are unsubject to the conservation requirement. The windows of advanced technology are unsubject to the conservation requirement.

DESCRIPTION OF HOUSES UNDER CONSIDERATION

One of the conditions for the assessment of the building is the building's energy balance. The building's energy balance is determined by the energy balance of the building. The building's energy balance is determined by the energy balance of the building. The building's energy balance is determined by the energy balance of the building.

Thermodynamic quantities of energy and the conditional thermodynamic variables are equal to

\[ \text{energy} = \text{exergy} \]

According to the simplest representation the energy balance equation can take a following form:

\[ E = E_{\text{in}} - E_{\text{out}} + E_{\text{loss}} + E_{\text{gain}} \]

(A) where \( E_{\text{in}} \) is the internal energy, \( E_{\text{out}} \) is the output energy, \( E_{\text{loss}} \) is the energy losses, and \( E_{\text{gain}} \) is the energy gain.
Towards „Energy Efficient Cities“

Optimising energy, exergy and resource efficiency on settlement and community level by analysis and visualization of building related energy demand and supply structures on the basis of a GIS-system.

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Abstract
To improve the overall energy efficiency in community systems the mere focus on single component optimisation runs short in effect. To display and analyse a holistic energetic community system is a promising approach and solution for decision makers and urban planners. Based on a GIS data base the city of Wolfsburg attempts to create a tool which will enable them to optimise their overall energy performance as a complex and interactive system. This includes the analysis of the energy demand side represented mainly by the building stock, the electricity sector and the transportation sector. The heat demand for thermal comfort in buildings accounts for approximately on third of the total energy demand profile of the community. To step forward in the analysis, a heat demand cadastre forms a basic data source for further optimisation on the supply infrastructure.

Introduction/Background
Despite the fact that energy, climate and sustainability rank high on the political agenda and many municipalities have set ambitious targets on this issue (zero-CO₂ commune), the successes in practice, particularly in the building sector, often fail to fulfill the high expectations. This is caused by numerous obstacles that span the administrative and judicial level, as well as planning and technical sectors. Nevertheless communities are obliged to take their burden-share in fulfilling the Kyoto-protocol targets of their countries. The building sector in Germany and many other central European countries accounts for more than one third of the total energy demand followed by the transport and industry sectors. The necessity to use energy in the most efficient and economical way should therefore be an essential interest in municipal policy strategies since may have very central influence the energy related fields. Looking at the present situation of the realization of energy projects on a community level, it can be stated that, that in the majority of cases single measures are being applied without a general energy implementation strategy (renovation of one single municipal building, photovoltaic plant, biomass plant).

Methods
The key concept is to regard the municipality as “energy system” in a geographically defined system area, as it represents a collective system of energy consumers (sinks) and energy sources in the form of different actors (residents, local government, utilities, industry and trade) with different profiles of energy use. In the context of the energy system “municipality”, the building stock is only next to transportation and consumer sector one of the largest energy demanders and of the highest saving potential. For the time being, the majority of residential buildings appears to be on the demand side due to heating and electricity consumption. Yet buildings of other usage like industry, trade and service buildings as well as future high efficiency residential buildings (plus-energy-buildings) can offer the potential to become energy producers at times. The evaluation is carried on from final and primary energy approaches (CO₂ emissions) to an exergetic perspective and is displayed on basis of simplified categories (electricity, burnable fuels, heat at different temperatures). Both renewable and fossil energy portions are balanced. On the demand side this results in a geo-referenced energy and exergy inventory of the municipality that exhibits the distribution of sinks in the first step. The work is set upon available research on the different aspects of building related energy demand and eventually harmonizes them on a geo-data based platform.

Data Analysis
To come to a map-based GIS database the following work steps will be done:
• analysis of existing data sources and procedures
• definition and harmonisation of existing studies on settlement types
• development of strategies to fill data gaps
• analysis of energetic and exergetic sources and sinks relations on municipal level
• development of a GIS based application to display the system interactions

Next steps
Data analysis of energy system of the city of Wolfsburg (case study)
Development of data representation and structural interactions
**Development of strategies for an enhanced use of renewable energies for heating and cooling of buildings**

**Abstract**

The main aim of this doctoral thesis is to pinpoint best-use possibilities for solar thermal and couple heat pumps in the supply of different energy demands in buildings. To compare the performance of these systems exergy analysis on a system level is carried out. Furthermore, results are expected also to show the suitability and usability of exergy analysis for assessing energy systems in buildings.

**Introduction/Background**

Most of the energy in the building sector is used for heating and cooling purposes is low, due to the low required indoor temperatures (20-26°C). Yet, high quality fossil fuels are widely used to supply these demands. Environmental heat (e.g. ground or solar heat) have a low exergy content and allow supplying building energy demands with lower exergy losses, thereby being suitable energy sources for this purposes. Matching the quality (i.e. exergy) levels of the energy demanded and supplied more efficient and suitable energy systems can be developed.

**Methods**

In Figure 1 the main building systems which will be analyzed from an exergy perspective are shown. Furthermore, the main steps and method for the research are also pinpointed.

**Results/Data Analysis**

An example of steady state energy and exergy analysis for several building systems is shown in Figure 2. Results refer to the heating case. Calculations have been performed with the Excel-based simplified calculation Tool from IEA ECBCS Annex 49.

Exergy analysis allows comparing different energy sources, renewable and fossil on an equal and scientifically founded bases. The suitability of low-temperature available heat (e.g. solar and ground source heat) can be recognized in terms of better matching between exergy supplied and demanded. In turn, high exergy renewable sources (such as wood) are not suitable for space heating purposes and should be used for supplying high exergy demands instead.

**Next Steps**

Currently dynamic analysis is being performed on solar thermal and ground-coupled heat pump systems by means of the simulation software TRNSYS.

**Acknowledgments**

DBU – Deutsche Bundesstiftung Umwelt
Tekn. Dr. Dietrich Schmidt (Fraunhofer Institute for Building Physics)
Prof. Dr. Gerd Hauser (TU München)
Development of resource efficient building services for tempering achievement-oriented interior spaces

Kirsten Lück
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Department Energy Systems
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Abstract
In the focus of this doctoral thesis is the development and improvement of innovative integral concepts for the well-being of human, their performance and hence to have the efficiency as an objective and to be concurrent exergetic high efficient.
In focus of this investigation are the results of the project: "High Performance Indoor Environment – HIPIE", which was created by the Fraunhofer-Institute for building physics. Further fundamentals for the implementing of results in the domain of LowEx-Systems are i.e. the results of Annex 49 and the utilization of extern sources about Exergy and thermal comfort.
Different working areas with longer occupancy will be examined for example: offices, hotels. In rooms with different utilization profile, humans will be differently influenced. Therefore moreover the heat generator level of the exergy-concept, it is necessary to have a look at hygric and interior lighting parameter.

Introduction/Background
In the past investors planned and built interiors primarily by economic considerations. A look at the aspect of achievement-oriented interior spaces did not take place. For forward-looking planning the careful use of resources and the optimisation of performance promoting rooms have to be considered equally.

Methods

Determination of general conditions
- Heating
- Cooling
- Ventilation

Analyses/assessment of system configuration
- Dyn. Simulation of selected systems
- Cost/benefit analysis of the system solution
- Strategies for optimal exergy flux of the system configuration / possible savings strategies

Developing of methods / optimization overall systems
- Technical plant overall solution

Next Steps
A literature review about high performance Indoor Environment analyses, Exergy and Comfort and determination of general conditions.

Acknowledgments
Tekn. Dr. Dietrich Schmidt (Fraunhofer Institute for Building Physics)
Prof. Dr. Klaus Sedlbauer (Univ. Stuttgart / Fraunhofer Institute for Building Physics)
Reducing the CO₂ emissions by optimization of cooling strategies in buildings

Marlen Schurig

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Department Energy Systems
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Abstract

The studies within this PhD project are concentrated on the development of strategies for the optimum cooling systems of buildings with specific focus on applications of passive and natural cooling strategies like Phase Change Materials (PCM), natural cooling and systems using renewable energies like heat pumps or solar climatisation in Germany. The development is based on the thermodynamic concept of exergetic analysis and uses dynamical object-oriented modeling of plant technical processes in buildings. The most important question is the problem of the humidity treatment in context of cooling applications under dynamically varying conditions.

The aim of this work is the development of improved cooling systems using renewable energy sources or passive systems that are adjusted to the buildings and their utilization. This is done with the integration of national and international evaluation procedures and under specific consideration of the comfort of the users or residents.

Methods

DIN 18599-7 (convnetual cooling systems)   „LowEx“-Method (heating systems / cooling systems)
Exergetic valuation method for cooling systems
convnetual cooling systems

Next Steps

Applying a scholarship at the Deutsche Bundesstiftung Umwelt DBU
Anticipated beginning: August 2009

Supervisors

Tekn. Dr. Dietrich Schmidt (Fraunhofer Institute for Building Physics)
Univ.-Prof. Dr.-Ing. Gerd Hauser
COSTeXergy
Analysis and Design of Innovative Systems for LOW-EXergy in the Built Environment

MAIN OBJECTIVE:

Broadly disseminate new knowledge and practical design-support instruments that can facilitate the practical application of the exergy concept to the built environment.

WORKING OBJECTIVES:

- Definition of the practical applicability of exergy analysis to the built environment.
- Use of insights from exergy analysis to identify and develop innovative concepts and assess their potential.
- Generation of innovative insights into the interaction between human body and indoor environment.

WORKING STRUCTURE:

The work within the COSTeXergy project is divided into four workpackages:

1. Practical applicability of exergy analysis: Its fundamental part is concerned with exergy metrics and analysis tools, while its practical part is concerned with evaluating and enhancing the application potential of exergy analysis to the built environment.

2. Identify / develop innovative concepts: WP 2 is concerned with the assessment, design and development of concrete technologies with a foreseeable application potential. WP2 receives insight on fundamental issues from WP 1 and WP 3.

3. Human body and indoor environment, innovative insights: WP3 explores aspects related to the emerging field of exergy and the human body, and has a mainly fundamental character.

4. Dissemination: WP 4 will provide a common framework for facilitating communication and diffusion, and for avoiding work duplication. Dissemination is to be carried out within each WP.

Further information can be found: www.costexergy.eu
Annex 49

Low Exergy Systems for High-Performance Buildings and Communities

This poster outlines the internationally co-operative research project Annex 49 “Low Exergy Systems for High Performance Buildings and Communities”, which takes place within the Energy Conservation in Buildings and Community Systems Program (ECBCS) of the International Energy Agency (IEA). The Annex 49 is a three year project (2006 - 2009) which involves about 17 research institutions and companies from 12 countries.

THE EXERGY CONCEPT

Exergy is a concept which characterises an energy flow not only by its quantity, but also by its quality. Only the exergy part of any energy flow can be converted into some kind of high-grade energy (e.g. mechanical work or electricity). Thus exergy can be regarded as the valuable part of energy.

Exergy points out where further optimization of the building systems is possible: a boiler can have energy efficiencies close to 100%, however its exergy efficiency amounts to only 8%. The LowEx approach entails MATCHING the quality (exergy) levels of energy demand to those of the supply structures in the built environment.

Desirable energy/exergy flow to the building stock and industry. The energy required for heating and cooling of buildings is very low. To make a more appropriate use of energy in buildings mainly low quality energy sources / systems shall be implemented. In turn, energy should mainly be used in industry to allow for the production of high quality products.

When the demands for heating and cooling have already been minimized, the low-exergy approach aims at satisfying the remaining thermal energy demand using only low quality energy. This paves the way for a wider and more efficient use of renewable energies (waste heat, ground and solar heat, etc.) in the building sector.

www.annex49.com
The German LowEx Alliance Project

STRUCTURE OF THE GERMAN ALLIANCE PROJECT

The German alliance project “LowEx” is a cooperation between industry partners, research institutions and universities and has been initiated to enhance the development of new and more efficient heating and cooling systems for buildings, which are also able to use more renewable and natural (environmental) energy sources.

In the sector of „Building systems“ the increase of the heat storage capacity in building constructions using phase change materials (PCM) (Fig. 1) are analyzed. As in old buildings with massive walls, a balanced room-temperature should also be reached in light constructions. In the sector of „Supply systems“ one of the main technologies for the development of heating and cooling systems are the so-called capillary tube systems. Through their combination with phase change materials, the usage of its buffer capacity can be regulated and consequently optimized depending on the situation.

OBJECTIVES

The general goals of the project are the development of so called LowExSystems (for heating and cooling of buildings) and the knowledge transfer in the related fields.

For the consideration of “integral solutions” a third alliance field has been arranged. Main working items in integral sub-projects are the development of software tools (Fig. 6) for an energy/exergy assessment or for special studies, and dynamic analyses of complex systems. Other integral projects working with demonstration activities are being set up as dissemination platforms, like the website of the project.

Development of:
- systems to use low exergy sinks and sources (e.g. ambient air, ground etc.) (Fig. 2)
- efficient heat carriers and transport systems, which consume low amounts of exergy
- LowEx transfer systems in rooms that are able to operate with small temperature differences
- thermally active façade constructions (Fig. 3 and 4) and LowEx storage systems (Fig. 5)

System integration and operation of LowEx systems.

Supplied by Federal Ministry of Economics and Technology

The German LowEx Alliance Project

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System integration and operation of LowEx systems.
ASHRAE, founded in 1894, is an international organization of 51,000 members. ASHRAE fulfills its mission of advancing heating, ventilation, air conditioning and refrigeration to serve humanity and promote a sustainable world through research, standards writing, publishing and continuing education. ASHRAE also publishes norms and guidelines in the area of Climate technology to which is referred in building codes.

**ASHRAE Technical Group 1. Exergy**

**ASHRAE Mission**

To advance the arts and sciences of heating, ventilating, air conditioning and refrigerating to serve humanity and promote a sustainable world.

**TG 1 Exergy Analysis for Sustainable Buildings**

The Technical Group TG 1 within ASHRAE is concerned with all exergy aspects of energy and power utilization of systems and equipment for comfort and service, assessment of their impact on the environment, and development of analysis techniques, methodologies and solutions for environmentally safer, sustainable low-exergy systems.

This TG 1 will establish a robust road map for a comprehensive set of scientific and technical steps for an environmentally safer building technology and HVAC systems and facilitate the new ASHRAE theme of Engineering for Sustainability.

TG1 is concerned with identifying, developing and disseminating optimization techniques that enhance the performance of HVAC&R components, systems and building systems that are not application or tool specific.

Further information on ASHRAE TG 1 and contact: http://tg1.ashraetcs.org
The Network of the International Society for Low Exergy Systems in Buildings

LowExNet is an informal network of scientists and researchers from several countries which promotes the knowledge exchange, discussion and collaboration. Important outcomes are front-edge common research projects.

The LowExNet has been founded as a result of the work of the IEA ECBCS Annex 37, "Low Exergy Systems for Heating and Cooling in Buildings", which was an international co-operative research project carried between 1999 and 2003 within the general framework of the IEA (International Energy Agency).

The Network joins currently 36 researchers from 16 countries as members.

OBJECTIVE

The overall objective of the LowExNet’s work is to promote a more rational and effective use of energy by enhancing the utilisation of low valued and renewable energy sources.

To promote a rational use of energy the LowExNet facilitates and accelerates the use of low valued environmentally-sustainable energy sources by:

- investigating potential ways of replacing high valued energy, like fossil fuels and electricity, with low valued energy sources, and assessing the impact on global resources and the environment.
- assessing existing components and forms of technology for low exergy systems in buildings to enhance the development of new technology, and providing the necessary tools for the analysis and evaluation of such systems.
- developing strategic means for the introduction of low exergy solutions in buildings via the implementation of case studies, design tools and guidelines.

STRATEGY

To reach this goal the LowExNet focuses on promoting the networking and exchange among researchers working in the field of exergy analysis of building systems.

By this means, knowledge on and tools for exergy analyses, to be applied in the built environment are widespread.

Therefore, workshops and seminars in combination with other international events, such as conferences in the field of energy use in buildings and sustainable buildings are organised.

Further information and contact:

www.lowex.net
The Workshop & Symposium (ELCAS) will provide a multidisciplinary international forum for researchers, scientists, engineers and practitioners from all over the world to exchange information, to present high-quality research results and new developments in the wide domain covered by exergy, life cycle assessment, the environment and sustainability issues.

4th - 6th of June, 2009
Nisyros /Greece

The Workshop & Symposium (ELCAS) will provide a multidisciplinary international forum for researchers, scientists, engineers and practitioners from all over the world to exchange information, to present high-quality research results and new developments in the wide domain covered by exergy, life cycle assessment, the environment and sustainability issues.
The Future for Sustainable Built Environments

Integrating the Low Exergy Approach

Conference 2009

April 21st 2009
Heerlen, The Netherlands