Anhang A

Protokoll des Meetings in Stockholm Oktober 2006

Annex 49

Low Exergy Systems for High-Performance Buildings and Communities

Report to the Executive Committee
Status Report No 2 / October 2006

Dietrich Schmidt
Fraunhofer-Institute for Building Physics
Gottschalkstrasse 28a
DE-34127 Kassel
Germany

Phone: +49 561 804 1871
Fax: +49 561 804 3187
E-mail: dietrich.schmidt@ibp.fraunhofer.de

ECBCS Annex 49: *Low Exergy Systems for High-Performance Buildings and Communities*

STATUS REPORT NO 2

1. GENERAL BACKGROUND INFORMATION

The ECBCS ExCo decided during its meeting in November 2005 in Korea to launch the preparation phase for Annex 49 on “Low Exergy Systems for High-Performance Buildings and Communities”. Germany agreed to lead the annex and offered to provide the operating agent for it. This second status report outlines the activities and achievements of the second six months of the Annex 49 preparation phase.
The second preparation meeting for Annex 49 on October 2 and 3, 2006 was hosted by Gudni Jóhannesson at the Division of Building Technology at the KTH, the Royal Institute of Technology in Stockholm. The meeting was attended by participants from Austria, Canada, Finland, Germany, Italy, Japan, Poland, Sweden and the Netherlands.

After Gudni Jóhannesson had welcomed all participants, they introduced themselves, their organisations, and their main fields of interest related to the activities of Annex 49.

Dietrich Schmidt gave a short overview on the structure of the meeting and highlighted the main expected outcomes of it. The most important goal to be addressed was the development of the working plan for the whole Annex 49 working phase.

The following objectives were underlined:
1. Define the working plan for Annex 49 identifying working items / deliverables
2. Check status preparation phase for Annex 49
3. Report on activities related to Annex 49
4. Discuss technical view on related projects

2. STRUCTURE OF THE MEETING

The second preparation meeting was organised into five different topics:

- Status of the preparation phase for Annex 49
- Presentation and discussion of the working program
- Report on related activities
- Presentation of related projects
- Updating of the annex text and definition of tasks until next meeting

2.1. Topic 1: Status of the preparation phase for Annex 49

The operating agent of Annex 49, Dietrich Schmidt, from the Fraunhofer Institute for Building Physics (Germany), presented the main working items that were to be carried out before the meeting:

- ✓ **Update of Annex 49 text**
- ✓ **Condensed version of the minutes**
- – **Definition of subtask leaders:** the leader for subtask B has yet to be defined
- ✓ **Contact to Annex 44 and Annex 46:** Great interest on **contacting Annex 50** was shown**,** since this annex receives large input from industries and is closely focussed on retrofitting and building services.
- – **Preparation of and comments on working plan**.
- – **Collect papers and documents** to be published on the LowExNet website
- – **Contact to potentially interested countries**: Some further possible countries/organisations to be contacted were pointed out. The status of many of the contacts to be made is unknown. The responsible persons shall contact the respective countries. The operating agent shall check the status of the contact after some time. A detailed list of the countries and persons in charge of contacting them can be seen in the minutes of the 1st preparation phase meeting. All potentially interested persons shall be kept informed about the activities related to Annex 49.

2.2. Topic 2: Presentation and discussion of the working plan

The first proposal for the working plan was presented. Each of the designated subtask leaders gave a closer presentation on the working items and main objectives of his/her task. The final deliverables for each task were defined and their expected contents and scope were discussed.
As a result of the discussion, the following deliverables were identified for each task:

Subtask A: Methodologies

Subtask leader: FINLAND, Mia-Ala Juusela from VTT

Main Objective: *development, assessment and analysis of methodology, including tools for design and performance analysis of community systems and buildings.*

Working items:

- *Exergy flow analyses of complex systems for thermodynamic performance and sustainability evaluation. New dynamic exergy analysis methods accounting for changing ambient conditions.*
- *System optimisation strategies.*
- *Procedures, models and software tools for design and performance analyses.*
- *Life cycle economical impacts of LowEx design rules.*
- *Pre-normative proposals: of special interest to the Netherlands and Germany.*

Identified deliverables:

Deliverables		Participating coutries	Scheduled/Ready
1.	System optimisation strategies	FI, AU, IT-P[1], SE CA	First draft: Mar. 19, 2007 (for Padova meeting)
2.	Procedures for design and performance analysis	GER-K[2], FI, GER-B[3]	Dec. 1, 2006
3.	Models for design and performance analysis	GER-K, SE, FI, GER-B	Oct. 31, 2007
4.	Tools for design and performance analysis	GER-K, GER-B, FI, AU, SE, IT-V[4], IT – M[5] (P), GER-B	End of Annex – May 31, 2009
5.	Life cycle economical impacts – Analysis of cost effectiveness of different LowEx systems	FI, NL, SE, AU, PL	Mid Annex – Nov. 30, 2008
6.	LowEx systems and thermal comfort	FI, NL, IT-M (A)(P), IT-P, JP, DK	Dec. 31, 2008
7.	Definition of LowEx systems	FI, SE, GER-B, IT	First draft: Mar. 19, 2007 (for Padova meeting)
8.	Pre-normative proposals	FI, IT – V, DK, GER-B/K	First draft: Mar. 19, 2007 (for Padova meeting)

---

[1] P - Padova
[2] K- Kassel
[3] B – Berlin
[4] V – Venezia
[5] M – Milan: (P) – Paola Caputo
(A) – Adriana Angelotti

Subtask B: Exergy efficient community supply structures

Subtask leader: THE NETHERLANDS, Peter Op´t Veld from Cauberg-Huygen R.I. B.V.

Main Objective: *development of energy distribution, and generation and storage systems and concepts that meet all demands of community members with a minimum input of primary energy.*

Working items:

- *Innovative types of technology for energy supply structures at different exergy levels.*
- *Innovative types of technology for maximising the local utilisation of renewable and ambient resources, e.g. heat pumps.*
- *Advanced system concepts and solutions for the distribution, local generation and storage of energy/exergy.*

Identified deliverables:

Deliverables		Participants	Scheduled/Ready
9.	Innovative types of technology for LowEx energy supply structures	NL, GER-B, SE	Nov. 1, 2007
10.	Innovative types of technology for LowEx energy supply structures – RE based	JP, IT-M(A), SE, GER	Nov. 1, 2007
11.	Advanced system concepts for distribution, generation and storage of energy/exergy	CA, IT-M(P), NL, SE ALL	Oct. 31, 2008

Subtask C: Exergy efficient building technology

Subtask leader: SWEDEN, Gudni Jóhannesson from KTH –The Royal Institute of Technology

Main Objective: *the reduction of exergy demand for heating, cooling and ventilating buildings.*

Working items:

- *Innovative types of technology for low exergy heating and cooling.*
- *Innovative control concepts and strategies for a demand controlled exergy supply.*
- *System concepts and solutions, including innovative exergy storage systems.*
- *Exergy as an innovation driver in buildings and building service systems.*

Identified deliverables:

Deliverables		Participants	Scheduled/Ready
12.	Innovative types of technology for low exergy heating and cooling	GER-B, SE, NL, IT-P and M (a)	Sep. 30, 2008
13.	Innovative control concepts and strategies for a demand controlled exergy supply	IT-P, DK	June 30, 2008
14.	Advanced system concepts and solutions, including exergy storage systems	SE, GER-B	Oct. 31, 2007
15.	Advanced system concepts for retrofitting energy/exergy Link to: Annex 46 Annex 50 SHC Task 37	PL, IT-P, SE	May 30, 2009
16.	Exergy as innovation driver in buildings and building service systems		Nov. 30, 2008

Subtask D: Knowledge transfer, dissemination

Subtask leader: GERMANY, Dietrich Schmidt from the Fraunhofer Institute for Building Physics (Germany)

Identified deliverables:

Deliverables		Participants	Scheduled/Ready
17.	Industry workshops	ALL	*Next:* March 19 and 21, 2007 in Padova (Italy)
18.	Newsletters	GER-K	
19.	Website	GER-K	
20.	Brochure	GER-K	
21.	Design guide	GER-K (Edition) ALL	
22.	Full version	ALL	
23.	Summary	ALL	
24.	IEA Future Building Forum “Think Tank”	GER	
25.	LowExNet workshops		

2.3. Topic 3: Report on related activities

Dietrich Schmidt from the Fraunhofer Institute for Building Physics (Germany) presented different national and international working projects whose activities are closely related to those of Annex 49. The following projects were presented:

- The **LowExNet**. The network is a platform of 15 countries aimed at widely spreading the concept of exergy efficiency within the building sector. One of its core aims is to promote the education of researchers in the field.

- The **LowEx Workshops**, which take place regularly, are also organised by the network, thus sharing its aims. The next LowEx workshop will take place in EPIC2006AIVC November 20-22, 2006 in Lyon.

- The **CosteXergy** action. It has already been approved within the European COST program. The first meeting is on November 17, 2006 in Brussels.

- The **Dutch LowEx** projects involve several universities from the Netherlands.

- The **German LowEx Alliance**. The alliance is an initiative co-funded by the private sector, whose main aim is the development of LowEx systems.

- The new technical group within ASHRAE**, TG1: Exergy Analysis for Sustainable Buildings.** This group aims at using exergy analysis for assessing the environmental impact of buildings and developing techniques and solutions for environmentally safer and sustainable low-exergy buildings.

- **LowEx supply structures** – **“Re-Mining LowEx”** project is a project within the frame of the EU-Concerto II program with highly replicable opportunities in Germany.

2.4. Topic 4: Presentation of related projects

Gudni Jóhannesson, from the KTH-The Royal University of Technology (Sweden), introduced the Symphony project, and the Research Tower as part of it. Cost-efficiency is a crucial issue of it. One of the aims was to make use of prefabricated elements. Hollow core elements are the basic component for façade constructions. These lightweight elements are made of steel and an insulation layer (PS or mineral wool). Apart from transport comfort, the building services are also integrated in the elements, thus additionally reducing the costs and time on site. The roof elements shall be placed before the walls are mounted.
The tower is built up of these elements, serving as a test field and laboratory for them. Flexibility for interconnecting the prefabricated cavities is complete due to a suspended floor construction.

Alexander Engström, from the Swedish company, Termodeck, gave an introduction on the history and profile of the company. Initially, the main markets for the company were Sweden and Norway. In the 1990’s, its commercial activities expanded to Saudi Arabia, and regions close to the Red Sea and the Middle East. A mobile hollow core factory was developed in order to allow for penetration into the South African market, where no production of hollow core concrete plates is being done. The company’s objectives include extending its commercial activities into many other countries.

Masanori Shukuya, from the Musashi Institute of Technology in Yokohama (Japan), presented the main research fields of the institute related to exergy. One of their main research fields is the use of cool exergy, specially for hot and humid climates and in particular applied to open (cross-ventilation) built environments. Passive measures and hybrid ventilation systems are two of their main fields of interest.
The test facilities consist of two identical buildings, one being an ES (environmentally symbiotic) and the other one a typical building. There, comfort measurements (via occupants’ votes) were carried out, showing that, for radiant cooling, very low exergy values (20 mW/m^2) were sufficient. The potential of the cool exergy contained in the environment is far greater than the required amount shown by the thermal comfort experiments. This shows the necessity of finding materials or strategies, especially those available locally, to make use of cool exergy. He pointed out the great importance of external shading and night ventilation.

He also mentioned the importance of reviewing the thermal exergy comfort chart for summer conditions (or warmer climates).
Regarding the lighting systems, he mentioned the necessity of reducing the surface temperature of lamps.

Zygmut Wiercinski, from the University of Warmia and Mazury (Poland), presented the main features of the school to be retrofitted, as well as the expected energy consumption of the building before and after modernisation. The system to be implemented shall be a hybrid heating system combining conventional radiators and floor heating systems.
The main features to be monitored on the system, for a complete analysis of its energy/exergy flows, were presented.
The use of renewable forms of energy, as well as the optimisation of the system based on energy and exergy based analysis, were identified as basic objectives of the project.

Ken Church, from the CANMET Technology Centre (Canada), presented the oil shortage, energetic crisis, and energy efficiency problems as the main motivational factors for improving energy supply structures in Canada. In this task, all the decision makers shall be involved. Thus, one of their major goals is to produce a tool for assessing municipalities in the creation/design of sustainable communities that have a higher potential of “surviving” in their environment and long-term impacts on the community.
The final layout and contents of the tool have yet to be defined, but a desirable output would be a check-list based guideline for municipalities.

Michele Di Carli, from the University of Padova (Italy), introduced a research project for comparing continuous and intermittent control strategies. The project is being carried out on two identical buildings and some of their main features were presented. Models for the buildings should also be defined in order to check the best control strategy. The main conclusion is that continuous operation saves 20-30% of energy.

Dietrich Schmidt, from the Fraunhofer Institute for Building Physics (Germany), presented the German LowEx Alliance, whose main aim is reducing CO_2 emissions in the built environment. The main means for achieving this is the development of lowex systems that allow for the use of lowex energy resources, emission, storage systems, and heat carriers, as well as lowex building components (façades, thermally activated building components).
The advantages of the use of phase change materials (PCMs) in the built environment were shown. Some forms of technology for the processing of PCMs (microencapsulated or slurry type PCMs), as well as some application fields (integrated in building components or in AHU), were also presented.
A closer look at “capillary tubes” systems was presented, as well as at heat transfer between different parts of the same building, and thermally activated building components. Ground heat uses were also mentioned.
Since the alliance is an initiative co-financed by the private sector, many of these projects involve direct product development for companies.

Peter Op´t Veld, from Cauberg-Huygen Consulting Engineers (The Netherlands), introduced the “Re-mining LowEx” project, which is part of a EU-Concerto II program. The project deals with the re-development of old mining areas, but mainly aims at integrating supply and demand side based on lowex principles. The partners and countries involved in the project were also presented.
A closer view of the projects in Heerlen and Zargorje was presented. The different work packages defined were also presented, including one dealing with legal issues concerning the use of low valued energy resources.

2.5. Topic 5: Updating of the annex text and definition of tasks until next meeting

2.5.1. Changes in the ECBCS Annex 49 text

It was agreed that, at this point, no major changes in the annex text are required.

2.5.2. Tasks until next meeting

Action	Responsibility	To whom
1. Contact organisations	See “Minutes for 1st and 2nd meetings”	Dietrich Schmidt
2. Check contact with countries / organisations	Dietrich Schmidt	all
2. Contact Annex 50	Dietrich Schmidt	all
3. Annex 49 brochure	Dietrich Schmidt Mia-Ala Juusela Peter Op´t Veld	Michele di Carli all
4. Define structure of industry workshop in Padova	Michele di Carli	Dietrich Schmidt all
5. Prepare workshop for Climate 2007	Dietrich Schmidt	all
6. Articles and documents published up to now are to be collected and included on the LowExNet website for marketing and dissemination purposes	all	Dietrich Schmidt
7. Define leader for Subtask B.	Dietrich Schmidt	Paola Caputo Ken Church
8. Define synergy meeting with Annex 44 in the Netherlands	all	Dietrich Schmidt
9. Check status of Cost Action CosteXergy.	Dietrich Schmidt	

The date and location of the next meeting has already been defined as follows:

- **1st working meeting:**
  March 19-21, 2007 – Mon-Wed.
  (the last day may be reserved for a CosteXergy meeting)
  Place: Padova, Italy

Small industry workshops of around two to three hours, directed to local industries that may be interested in the topic, shall be organised at the meeting.

3. CLOSING REMARKS

The operating agent would like to thank the host institution for the successful and pleasant organisation of the meeting, and for giving it the chance to take place there, as well as the participants for their active commitment and constructive input in Annex 49.

APPENDIX I: LIST OF PARTICIPANTS

Austria	Lukas Kranzl Vienna University of Technology, Institute of Power Systems and Energy Gusshausstraße, 25-29 /373-2 A-1040 Vienna, AUSTRIA	Phone: +43 1 58801 37351 Fax: +43 1 58801 37397 E-mail: Lukas.Kranzl @tuwien.ac.at
Canada	Ken Church Sustainable Buildings & Communities/Natural Resources Canada 1Hannel Drive Ontario K1A 1M1, CANADA	Phone: +1 613 947 8952 Fax: +1 613 947 0291 E-mail: kchurch@nrcan.gc.ca
Finland	Mia Ala-Juusela VTT P.O. Box 1000 FIN - 02044, FINLAND	Phone: +358 2 072 26947 Fax: E-mail: mia.ala-juusela@vtt.fi
Germany	Olaf Zeidler Technical University of Berlin Hermann-Rietschel-Institute, HL 45 Marchstr. 4 DE - 10587 Berlin, GERMANY	Phone: +49 30 314 79458 Fax: +49 30 314 21141 E-mail: olaf.zeidler@tu-berlin.de

Germany	Dietrich Schmidt Fraunhofer-Institute for Building Physics Gottschalkstrasse 28a 34127 Kassel, GERMANY	Phone: +49 561 804 1871 Fax: +49 561 804 3187 E-mail: dietrich.schmidt @ibp.fraunhofer.de
Germany	Herena Torío Fraunhofer-Institute for Building Physics Gottschalkstrasse 28a 34127 Kassel, GERMANY	Phone: +49 561 804 1871 Fax: +49 561 804 3187 E-mail: herena.torio @ibp.fraunhofer.de
Italy	Paola Caputo Politecnico di Milano BEST v. Garofalo, 39 I - 20133 Milano, ITALY	Phone: +39 022399 9488 Fax: +39 022399 9491 E-mail: paola.caputo@polimi.it
Italy	Michele De Carli Dipartimento di Fisica Tecnica University of Padova Via Venezia 1 I - 35131 Padova, ITALY	Phone: +39 049827 6882 Fax: +39 049827 6896 E-mail: michele.decarli@unipd.it
Italy	Piercarlo Romagnoni Department of Construction of Architecture University IUAV of Venezia Dorsoduro 2206 I – 30123 Venezia, ITALY	Phone: +39 041 257 12 93 Fax: + 39 041 522 36 27 E-mail: pierca@iuav.it
Japan	Masanori Shukuya Musashi Institute of Technology 1-3-1 Ushikubo-Nishi, Tsuzuki-ku 224-0015 Yokohama, JAPAN	Phone: +81-45-910-2552 Fax: +81-45-910-2553 E-mail: shukuya @yc.musashi-tech.ac.jp
Poland	Zygmunt Wiercinski University of Warmia and Mazury, Chair of Environmental Engineering Jana Heweliusza, 4 10-724, Olsztyn, POLAND	Phone: +48 89 523 4756 Fax: +48 89 523 4760 E-mail: zygmunt.wiercinski @uwm.edu.pl
Sweden	Gudni Jóhannesson KTH Building Technology Brinellvägen 34 10044 Stockholm, SWEDEN	Phone: +46 8 790 8670 +46 8 595 3073 Fax: +46 8 411 8432 E-mail: gudni.johannesson @byv.kth.se

The Netherlands	Peter Op´t Veld Cauberg-Huygen R.I. B.V. PO Box 480 6200 AL Maastricht, The NETHERLANDS	Phone: +31 43 346 7842 Fax: +31 43 347 6347 E-mail: p.optveld@chri.nl

Anhang B

Protokoll des Meetings in Padua März 2007

Annex 49

Low Exergy Systems for High-Performance Buildings and Communities

Report to the Executive Committee

Status Report No 3 / March 2007

Dietrich Schmidt
Fraunhofer-Institute for Building Physics
Gottschalkstrasse 28a
DE-34127 Kassel
Germany

Phone: +49 561 804 1871
Fax: +49 561 804 3187
E-mail: dietrich.schmidt@ibp.fraunhofer.de

ECBCS Annex 49: *Low Exergy Systems for High-Performance Buildings and Communities*

STATUS REPORT NO 3

1. GENERAL BACKGROUND INFORMATION

The ECBCS ExCo decided during the November 2005 meeting in Korea to launch the preparation phase for Annex 49 on “Low Exergy Systems for High-Performance Buildings and Communities”. Germany agreed to lead the annex and offered to provide the operating agent. This third status report outlines the activities and achievements of the first six months of the Annex 49 working phase.
The first working phase meeting for Annex 49 on March 18 and 19, 2007 was hosted by Michele de Carli in the Department of Technical Physics at the University of Padova/Italy. The meeting was attended by participants from Austria, Denmark, Canada, Finland, Germany, Italy, Japan, Poland, Sweden, Switzerland, the Netherlands and the USA.

After Michele de Carli had welcomed all participants, they introduced themselves, their organisations, and their main fields of interest related to the activities of Annex 49.

Dietrich Schmidt gave a short overview on the structure of the meeting and highlighted the main expected outcomes. The discussion of future working items, what they involve and the outcomes expected were the most important goals mentioned. Additionally, the status of working items to be delivered by the meeting was checked over.

The following objectives were underlined:
1. Discuss working items
2. Check status of working program for Annex 49

2. STRUCTURE OF THE MEETING

The first working phase meeting was divided into four main topics:

- Status of Annex 49
- Discussion of working program by subtasks
- Presentations and discussion on related topics
- Update of annex text and tasks until next meeting

2.1. Topic 1: Status of Annex 49

The operating agent of Annex 49, Dietrich Schmidt, from the Fraunhofer Institute for Building Physics (Germany), presented the main working items that were to be carried out before the meeting:

- ✓ **Annex 49 brochure**
- ✓ **Workshop for Clima2007**
- ✓ **Definition of subtask leaders**
- – **Collect articles and documents for LowExNet website** for marketing and dissemination purposes
- ✓ **Contact to Annex 50 and Annex 46:** Annex 50 has not shown interest in cooperative work with Annex 49. Annex 46 is willing to collaborate, but a collaboration strategy has not yet been defined.
- ✓ **Check status of COST Action C24**
- – **Define synergy meeting with Annex 44**
- – **Contact to potentially interested countries**: Further possible countries/organisations have been contacted, but in many cases no response has been obtained. Informal contact may be kept with interested countries, however, due to lacking funds, they are unable to formally participate in Annex 49 activities. At this point, 13 countries are participating, and future efforts will not be directed towards involving more parties.

In addition, the **status of the internal working reports** to be provided by the meeting in Padova was verified.

2.2. Topic 2: Discussion of working program by subtasks

The first proposal for the working plan was presented. Each of the designated subtask leaders gave a detailed presentation on the working items and main objectives of his/her task. The final deliverables for each task were defined and their expected contents and scope were discussed.
As a result, the following deliverables were identified for each task:

Subtask A: Methodologies

Subtask leader: FINLAND, Mia-Ala Juusela from VTT

Main Objective: *the development, assessment and analysis of methodology, including tools for the design and performance analysis of community systems and buildings.*

Working items:

- *Exergy flow analyses of complex systems for thermodynamic performance and sustainability evaluation. New dynamic exergy analysis methods accounting for changing ambient conditions.*
- *System optimisation strategies.*
- *Procedures, models and software tools for design and performance analyses.*

- *Economic life cycle impacts of LowEx design rules.*
- *Pre-normative proposals: of special interest to the Netherlands and Germany.*

Identified deliverables:

Deliverables		Participating countries	Scheduled/Ready
A1	System optimisation strategies	FI, AU, IT-P[1], SE CA, USA	First draft: May 1, 2007
A2	Procedures for design and performance analysis	GER-K[2], FI, GER-B[3], USA	June 30, 2007
A3	Models for design and performance analysis	GER-K, SE, FI, GER-B, USA	Oct. 31, 2007
A4	Tools for design and performance analysis	GER-K, GER-B, FI, AU, SE, IT-V[4], IT – M[5] (P), GER-B, USA	End of Annex – May 31, 2009
A5	Life cycle economical impacts – Analysis of cost effectiveness of different LowEx systems	FI, NL, SE, AU, PL, USA	Mid Annex – Nov. 30, 2008
A6	LowEx systems and thermal comfort	FI, NL, IT-M (A)(P), IT-P, JP, DK, USA	Dec. 31, 2008
A7	Definition of LowEx systems	FI, SE, GER-B, IT, USA	First draft: Mar. 19, 2007 (for Padova meeting)
A8	Pre-normative proposals	FI, IT – V, DK, GER-B/K, USA	First draft: Mar. 19, 2007 (for Padova meeting)

Comments on the deliverables:

A1 - Identified more as a description or decision making process rather than a tool. It is meant to outline the ***"steps to be followed by planners in order to come up with an optimised building and community level".***

A4 – The tools to be developed include both simplified and dynamic simulation levels.

---

[1] P - Padova
[2] K- Kassel
[3] B – Berlin
[4] V – Venezia
[5] M – Milan: (P) – Paola Caputo
(A) – Adriana Angelotti

A7, A8 – Strategies for benchmarking LowEx systems, such as buildings and their components, are under development. Several participants are already working on the identification of parameters for characterising the systems.

Subtask B: Exergy efficient community supply structures

Subtask leader: CANADA, Ken Church from NRC

Main Objective: *the development of concepts concerning energy distribution, generation and storage systems to satisfy all demands of community members with a minimum input of primary energy.*

Working items:

- *Innovative types of technology for energy supply structures at different exergy levels.*
- *Innovative types of technology for maximising the local utilisation of renewable and ambient resources, e.g. heat pumps.*
- *Advanced system concepts and solutions for the distribution, local generation and storage of energy/exergy.*

Identified deliverables:

Deliverables		Participants	Scheduled/Ready
B1	Innovative types of technology for LowEx energy supply structures	NL, GER-B, SE	Nov. 1, 2007
B2	Innovative types of technology for LowEx energy supply structures – RE based	JP, IT-M(A), SE, GER	Nov. 1, 2007
B3	Advanced system concepts for the distribution, generation and storage of energy/exergy	CA, IT-M(P), NL, SE ALL	Oct. 31, 2008

Comments on the deliverables:

B1 – A template for identifying the most suitable case studies is being produced.

B2 – Renewable forms of energy and their potential uses in the built environment will be analysed from an exergy perspective. The expected outcome is an article showing how the exergy concept can be used as a tool to limit primary energy use, thereby limiting CO_2 emissions, as well as making the most efficient use of the energy available.

B3 – A simple decision making tool will be produced, based on exergy criteria. It will be specially oriented for policy makers and planners. Additionally, optimisation opportunities and best practice examples for the systems will be analysed.

Subtask C: Exergy efficient building technology

Subtask leader: SWEDEN, Gudni Jóhannesson from KTH –The Royal Institute of Technology

Main Objective: *the reduction of exergy demand for heating, cooling and ventilating buildings.*

Working items:

- *Innovative types of technology for low exergy heating and cooling.*
- *Innovative control concepts and strategies for a demand controlled exergy supply.*
- *System concepts and solutions, including innovative exergy storage systems.*
- *Exergy as an innovation driver in buildings and building service systems.*

Identified deliverables:

Deliverables		Participants	Scheduled/Ready
C1	Innovative types of technology for low exergy heating and cooling	GER-B, SE, NL, IT-P and M (a)	Sep. 30, 2008
C2	Innovative control concepts and strategies for a demand controlled exergy supply	IT-P, DK	June 30, 2008
C3	Advanced system concepts and solutions, including exergy storage systems	SE, GER-B	Oct. 31, 2007
C4	Advanced system concepts for retrofitting energy/exergy - link to: Annex 46 Annex 50 SHC Task 37	PL, IT-P, SE	May 30, 2009
C5	Light structures for warm climates	JP, IT, SE	May 30, 2009
C6	Exergy as an innovation driver in buildings and building service systems		Nov. 30, 2008

Comments on the deliverables:

C5 – A new deliverable is needed to address the storage capacity of buildings when different insulation standards are considered, focusing on the conditions in warm climates.

Subtask D: Knowledge transfer, dissemination

Subtask leader: GERMANY, Dietrich Schmidt from the Fraunhofer Institute for Building Physics (Germany)

Identified deliverables:

	Deliverables	Participants	Scheduled/ Ready
D1	Dissemination Activities • Industry workshops + proceedings of workshops • IEA Future Building Forum “Think Tank” • LowExNet workshops • Website • Brochure • Newsletters (biannual)	ALL	Next: June 12, 07
		GER	
		All	Next: June 12, 07
		GER-K ©	May 01, 2007
		GER-K ©	March 01, 2007
		GER-K ©	
D2	State of the Art • State-of the art report	NL + deliv.	June 30, 2008
D3	Design Guidebook • Design guide • Full version • Summary	GER-K © Edition ALL	
		ALL	October 30, 2009
		ALL	

Comments on the deliverables:

A State of the Art report has been identified as a new deliverable. It will be a mid-term report, produced towards the middle of the activities in Annex 49. The State of the Art Report (D2.1) will include a description of the framework for exergy analysis at a building and community level, as well as an article summarising the legal framework and legal/policy issues hindering advancements.

During the meeting, the first issue of the Annex 49 newsletter was presented and the Annex 49 brochure was distributed. The next LowEx workshop will be held in Helsinki as part of the CLIMA 2007 conference. The start of the Annex 49 home page has been postponed to May 1st 2007.

2.3. Topic 3: Presentations and discussion on related topics

2.3.1. LowEx Communities, *Ken Church*

The introduction by Ken Church described the energy problems concerning the current use and availability of the energy resources, with a focus on Canada. He emphasised the necessity for new supply structures and resources in the communities. An overview of the key steps in political decision making was also outlined. The opportunity of using exergy to highlight the best-use practices of certain energy resources and the idea of disseminating the exergy concept through its benefits, using the concept to define sustainability indicators, was pointed out.

2.3.2. Systems used for heat recovery from sewage water, *Hans Cauberg*

Hans Cauberg presented the energy regulation for buildings in the Netherlands, pointing out that domestic hot water demand represents about 40% of the total energy demand in dwellings. Furthermore, innovative systems for domestic hot water production (DHW), based upon case studies in Switzerland, were presented.
He then pointed out the main research directions, based firstly on an assessment of the losses on the supply side (ventilation, transmission and waste water). Finally, the main ways of utilising those losses to cover part of the demand of the space heating and DHW were presented.

2.3.3. EntryMaster, *Mia Ala-Juusela*

Mia Ala-Juusela presented an overview on the current status of the simulations in the industry, as well as platforms typically used for the simulations. After this introduction, the EntryMaster tool was presented. EntryMaster is a tool aiming at integrating the supply and demand sides into one tool, unlike the typical method. The results and input data for some test cases, calculated using this tool, were summarised as well.

2.3.4. Exergy analysis of different cooling and heating systems, *Adriana Angelotti and Paola Caputo*

Adriana Angelotti introduced results, using current, simple methods, from the analysis of several systems. First and second law efficiencies for different available systems were derived, both from a system and a primary conversion level. The analysis was carried out both for cooling and heating conditions.
From the results, a direction for future work was pointed out, namely the dynamic analysis of promising systems. From this, parameters for characterising the exergy evaluation of renewable forms of energy and the systems can be derived.
Paola Caputo presented some tools which could be used for community level analysis. The idea of introducing a “community mix” for the definition of the community level was presented. She described two possible case studies, both at a community and a building level. All energy demands, including transport, were included. Steady-state calculations were also carried out.

2.3.5. Exergy analysis of solar thermal and ventilation systems, *Herena Torío*

Herena Torío presented results from dynamic simulations of a building with different building systems, namely with ventilation and solar thermal systems. Several parameters for characterising the performance of the buildings were introduced, as well as some key differences between energy and exergy analyses of the systems. The necessity of defining primary en(x)ergy factors for renewable forms of energy was also mentioned.

2.3.6. Single family passive house, *Zygmut Wiercinski*

The main constructive features of the Lipinscy family house were presented, as well as its heat requirements.

2.3.7. LowEx definitions, *Mia Ala-Juusela*

- **The necessity of redefining the use of the exergy concept for renewable forms of energy was clearly stated and discussed by the group.**

While the scope of Annex 37 only includes electricity used for heating and cooling, in Annex 49 electrical energy required for lighting will also be included. A more detailed discussion has been postponed until the next meeting, when the opinions of a number of Annex participants can be collected by the operating agent.

2.4. Topic 4: Updating of the annex text and definition of tasks until next meeting

2.4.1. Changes in the ECBCS Annex 49 text

It was agreed at this point that no major changes in the annex text are required.

2.4.2. Tasks until next meeting

2.4.3. LowEx Workshop at CLIMA 2007, June 12th, 07 in Helsinki

“*Low Temperature Heating and High Temperature Cooling Systems for High Performance Built Environments”,* from 12:30 to 2:30 p.m..
The program for the workshop will be presented.
Following the industry workshop, a Low Exergy Research seminar for PhD students will be held.

2.4.4. Workshop for PhD students in CLIMA 2007

An informal PhD student session will be carried out to present the recent results and to join together to establish networking among PhD students.
Short presentations and activities will be conducted by the chairman (Gudni Johànneson) to introduce activities in the exergy field.
The workshop is to take place from 6:00 to 8:00 p.m., after the LowEx workshop.

2.4.5. LowEx session at the IAQVEC2007 Sendai, October 2007

Sendai Conference -> October 28th - 31st, 2007, with a special LowEx session to be held under the title:
“*Low Exergy Systems for Better Indoor and Global Environments*”

- **Next Annex 49 meeting:**

2nd expert meeting: Fall 2007 – October
October 25th – 26th, 2007
Location: Yokohama, Japan
at the Musashi Institute of Technology

Determination of more meeting dates:

- Meeting in spring 2008 in Vienna, possibly combined with the Cost action:

April 14th – 15th for the third Annex 49 expert meeting
-> April 16th - Cost action COSTeXergy meeting

3. CLOSING REMARKS

The operating agent would like to thank the host institution for the successful and pleasant organisation of the meeting and for allowing the meeting to take place there, as well as the participants for their active commitment and constructive input in Annex 49.

APPENDIX I: LIST OF PARTICIPANTS

Austria	Lukas Kranzl Vienna University of Technology, Institute of Power Systems and Energy Gusshausstraße, 25-29 /373-2 A-1040 Vienna, AUSTRIA	Phone: +43 1 58801 37351 Fax: +43 1 58801 37397 E-mail: Lukas.Kranzl @tuwien.ac.at
Canada	Ken Church Sustainable Buildings & Communities/ Natural Resources Canada 1Hannel Drive Ontario K1A 1M1, CANADA	Phone: +1 613 947 8952 Fax: +1 613 947 0291 E-mail: kchurch@nrcan.gc.ca
Denmark	Bjarne Olesen International Centre for Indoor Environment and Energy Technical University of Denmark, Building 402 Lyngby, 2800 DENMARK	Phone: +45 45 25 41 17 Fax: + E-mail: bwo@mek.dtu.dk
Finland	Mia Ala-Juusela VTT P.O. Box 1000 FIN - 02044, VTT FINLAND	Phone: +358 2 072 26947 Fax: +358 2 072 27027 E-mail: mia.ala-juusela@vtt.fi
Germany	Dirk Müller Technical University of Berlin Hermann-Rietschel-Institute, HL 45 Marchstr. 4 DE - 10587 Berlin, GERMANY	Phone: +49 30 314 79458 Fax: +49 30 314 21141 E-mail: dirk.mueller@tu-berlin.de
Germany	Dietrich Schmidt Fraunhofer-Institute for Building Physics Gottschalkstrasse 28a DE - 34127 Kassel, GERMANY	Phone: +49 561 804 1871 Fax: +49 561 804 3187 E-mail: dietrich.schmidt @ibp.fraunhofer.de

Germany	Herena Torío Fraunhofer-Institute for Building Physics Gottschalkstrasse 28a DE - 34127 Kassel, GERMANY	Phone: +49 561 804 1871 Fax: +49 561 804 3187 E-mail: herena.torio @ibp.fraunhofer.de
Italy	Paola Caputo Politecnico di Milano BEST v. Garofalo, 39 I - 20133 Milano, ITALY	Phone: +39 022399 9488 Fax: +39 022399 9491 E-mail: paola.caputo@polimi.it
Italy	Adriana Angelotti Politecnico di Milano BEST v. Bonardi 3 I - 20133 Milano, ITALY	Phone: +39 02 2399 5183 Fax: +39 02 2399 5118 E-mail: adriana.angelotti @polimi.it
Italy	Michele De Carli Dipartimento di Fisica Tecnica University of Padova Via Venezia 1 I - 35131 Padova, ITALY	Phone: +39 049827 6882 Fax: +39 049827 6896 E-mail: michele.decarli@unipd.it
Italy	Fabio Peron Department of Construction of Architecture University IUAV of Venezia Dorsoduro 2206 I – 30123 Venice, ITALY	Phone: Fax: + 39 041 522 36 27 E-mail: fperon@iuav.it
Italy	Massimiliano Manfren Politecnico di Milano BEST v. Garofalo, 39 I - 20133 Milano, ITALY	Phone: +39 338 6245039 Fax: + E-mail: massimiliano.manfren@polimi.it maxmanfren@yahoo.it
Japan	Masanori Shukuya Musashi Institute of Technology 1-3-1 Ushikubo-Nishi, Tsuzuki-ku 224-0015 Yokohama, JAPAN	Phone: +81-45-910-2552 Fax: +81-45-910-2553 E-mail: shukuya @yc.musashi-tech.ac.jp
Poland	Zygmunt Wiercinski University of Warmia and Mazury, Chair of Environmental Engineering Jana Heweliusza, 4 10-724, Olsztyn, POLAND	Phone: +48 89 523 4756 Fax: +48 89 523 4760 E-mail: zygmunt.wiercinski @uwm.edu.pl

Sweden	Gudni Jóhannesson KTH Building Technology Brinellvägen 34 SE - 10044 Stockholm, SWEDEN	Phone: +46 8 790 8670 +46 8 595 3073 Fax: +46 8 411 8432 E-mail: gudni.johannesson @byv.kth.se
Switzerland	Petra Karlström Basler & Hofmann Ingenieure und Planer AG Forchstrasse 395 CH - 8032 Zürich, SWITZERLAND	Phone: +41 44 387 1338 Fax: +41 44 387 1100 E-mail: petra.karlstroem@bhz.ch
The Netherlands	Hans Cauberg. Delft University of Technology Berlageweg 1 Delft, the NETHERLANDS	Phone: +31 (0) 1527 83387 Fax: +31 (0) 1527 84178 E-mail: j.j.m.cauberg@tudelft.nl h.cauberg@chri.nl
The Netherlands	Peter Op´t Veld Cauberg-Huygen R.I. B.V. PO Box 480 6200 AL Maastricht, the NETHERLANDS	Phone: +31 43 346 7842 Fax: +31 43 347 6347 E-mail: p.optveld@chri.nl
The Netherlands	Hedzer van der Kooi Delft University of Technology Faculty of Technical Natural Sciences and Architecture, Berlageweg 1 Delft, the NETHERLANDS	Phone: +31 703 99 5027 Fax: E-mail: jvdkooi@wanadoo.nl
USA	Dave Solberg HVAC Systems Technology Inc. 5939 Clinton Avenue 55419 Minneapolis, USA	Phone: +1 612 869 6052 Cell : +1 612 770 5405 Fax: + E-mail: dwsolberg @hvacsystemstechnology.com

Anhang C

Protokoll des Meetings in Yokohama Oktober 2007

Annex 49

Low Exergy Systems for High-Performance Buildings and Communities

Report to the Executive Committee

Status Report No 4 / November 2007

Dietrich Schmidt
Fraunhofer-Institute for Building Physics
Gottschalkstrasse 28a
DE-34127 Kassel
Germany

Phone: +49 561 804 1871
Fax: +49 561 804 3187
E-mail: dietrich.schmidt@ibp.fraunhofer.de

ECBCS Annex 49: *Low Exergy Systems for High-Performance Buildings and Communities*

STATUS REPORT NO 4

1. GENERAL BACKGROUND INFORMATION

The ECBCS ExCo decided during the November 2006 meeting in New Zealand to launch the working phase of Annex 49 on “Low Exergy Systems for High-Performance Buildings and Communities”. Germany agreed to lead the annex and offered to provide the operating agent. This fourth status report outlines the activities and achievements of the second six months of the Annex 49 working phase.
The second working phase meeting for Annex 49 on October 25 and 26, 2007 was hosted by Masanori Shukuya in the Musashi Institute of Technology in Yokohama/Japan. The meeting was attended by participants from Canada, Finland, Germany, Japan, Sweden, the Netherlands and the USA.

After Masanori Shukuya had welcomed all participants, they introduced themselves, their organisations, and their main fields of interest related to the activities of Annex 49.

Dietrich Schmidt gave a short overview on the structure of the meeting and highlighted the main expected outcomes. The discussion of future working items, what they involve, and the outcomes expected, were the most important goals mentioned. Additionally, the status of working items to be delivered by the meeting was checked over.

The following objectives were underlined:
1. Discuss working items
2. Check status of working program for Annex 49

2. STRUCTURE OF THE MEETING

The second working phase meeting was divided into four main topics:

- Status of Annex 49
- Discussion of working program by subtasks
- Presentations and discussion on related topics
- Update of annex working program and tasks until next meeting

2.1. Topic 1: Status of Annex 49

The operating agent of Annex 49, Dietrich Schmidt, from the Fraunhofer Institute for Building Physics (Germany), presented the main working items that were to be carried out before the meeting:

- ✓ **Industry and PhD workshops organised in Clima2007**
- – **Collect articles and documents for LowExNet website** for marketing and dissemination purposes
- ✓ **Contact to Annex 46:** a collaboration strategy has not yet been defined.
- – **Potential synergy meetings with Annex 44 are to be outlined**
- – **Templates for collecting best-practice examples on a community and building levels**

In addition, the **proposed contents of the final guidebook and the state of the art report were reviewed.**

2.2. Topic 2: Discussion of working program by subtasks

The status of the working plan was presented by subtasks. Each designated subtask leader gave a detailed presentation on the working items and main objectives of his/her task. The status of the defined deliverables for each task was checked and their expected contents and scope were discussed.

Subtask A: Methodologies

Subtask leader: FINLAND, Mia-Ala Juusela from VTT

Main Objective: *the development, assessment and analysis of methodology, including tools for the design and performance analysis of community systems and buildings.*

Working items:

- *Exergy flow analyses of complex systems for thermodynamic performance and sustainability evaluation. New dynamic exergy analysis methods accounting for changing ambient conditions.*
- *System optimisation strategies.*
- *Procedures, models and software tools for design and performance analyses.*
- *Economic life cycle impacts of LowEx design rules.*
- *Pre-normative proposals: of special interest to the Netherlands and Germany.*

Identified deliverables:

Deliverables		Participating countries	Scheduled/Ready
A1	System optimisation strategies	FI, AU, IT-P[1], SE CA, USA	First draft: May 1, 2007
A2	Procedures for design and performance analysis	GER-K[2], FI, GER-B[3], USA	June 30, 2007 – (delayed first draft OK)
A3	Models for design and performance analysis	GER-K, SE, FI, GER-B, USA	Oct. 31, 2007 – (delayed)
A4	Tools for design and performance analysis	GER-K, GER-B, FI, AU, SE, IT-V[4], IT – M[5] (P), GER-B, USA	End of Annex – May 31, 2009
A5	Life cycle economical impacts – Analysis of cost effectiveness of different LowEx systems	FI, NL, SE, AU, PL, USA	Mid Annex – Nov. 30, 2008
A6	LowEx systems and thermal comfort	FI, NL, IT-M (A)(P), IT-P, JP, DK, USA	Dec. 31, 2008
A7	Definition of LowEx systems	FI, SE, GER-B, IT, USA	First draft: Oct. 25, 2007 (for Yokohama meeting)
A8	Pre-normative proposals	FI, IT – V, DK, GER-B/K, USA	First draft: Oct. 25, 2007 (for Yokohama meeting)

Comments on the deliverables:

A1 - Identified more as a description or decision making process rather than a tool. It is meant to outline the **“*steps to be followed by planners in order to come up with an optimised building and community level”.***

A5 – Related to projects in the University of Twente and activities at the KTH

A7 – The definitions were enhanced with discussions from the COSTeXergy group, held during the meeting in Novo Mesto/Slovenia (September 2007).

A8 – Two strategies for benchmarking LowEx systems, such as buildings and their components have been developed by two participants of the Annex 49.

---

[1] P - Padova
[2] K- Kassel
[3] B – Berlin
[4] V – Venice
[5] M – Milan: (P) – Paola Caputo
(A) – Adriana Angelotti

Subtask B: Exergy efficient community supply structures

Subtask leader: CANADA, Ken Church from NRC

Main objective: *the development of concepts concerning energy distribution, generation and storage systems to satisfy all demands of community members, with a minimum input of primary energy.*

Working items:

- *Innovative types of technology for energy supply structures at different exergy levels.*
- *Innovative types of technology for maximising the local utilisation of renewable and ambient resources, e.g. heat pumps.*
- *Advanced system concepts and solutions for the distribution, local generation and storage of energy/exergy.*

Identified deliverables:

Deliverables		Participants	Scheduled/Ready
B1	Innovative types of technology for LowEx energy supply structures	NL, GER-B, SE	Nov. 1, 2007 (delayed) April 30, 2008
B2	Innovative types of technology for LowEx energy supply structures – RE based	JP, IT-M(A), SE, GER	April 1, 2008
B3	Advanced system concepts for the distribution, generation and storage of energy/exergy	CA, IT-M(P), NL, SE ALL	Oct. 31, 2008

Comments on the deliverables:

B1 – A template for identifying the most suitable case studies has been produced.

B2 – Renewable forms of energy and their potential uses in the built environment will be analysed from an exergy perspective. The expected outcome is an article showing how the exergy concept can be used as a tool to limit primary energy use, thereby limiting CO_2 emissions, as well as making the most efficient use of the energy available.

B3 – A simple decision making tool will be produced, based on exergy criteria. It will be specially oriented towards policy makers and planners. Additionally, optimisation opportunities and best practice examples for the systems will be analysed.

Subtask C: Exergy efficient building technology
Subtask leader: SWEDEN, Gudni Jóhannesson from KTH –The Royal Institute of Technology

Main objective: *the reduction of exergy demand for heating, cooling and ventilating buildings.*

Working items:

- *Innovative types of technology for low exergy heating and cooling.*
- *Innovative control concepts and strategies for a demand controlled exergy supply.*
- *System concepts and solutions, including innovative exergy storage systems.*
- *Exergy as an innovation driver in buildings and building service systems.*

Identified deliverables:

Deliverables		Participants	Scheduled/Ready
C1	Innovative types of technology for low exergy heating and cooling	GER-B, SE, NL, IT-P and M (a)	Sep. 30, 2008
C2	Innovative control concepts and strategies for a demand controlled exergy supply	IT-P, DK	June 30, 2008
C3	Advanced system concepts and solutions, including exergy storage systems	SE, GER-B	Oct. 31, 2007
C4	Advanced system concepts for retrofitting energy/exergy - link to: Annex 46 Annex 50 SHC Task 37	PL, IT-P, SE	May 30, 2009
C5	Light structures for warm climates	JP, IT, SE	May 30, 2009
C6	Exergy as an innovation driver in buildings and building service systems		Autumn 2008 – Spring 2009

Comments on the deliverables:

C1 – Reports and experiences from many related research projects are to be included. In addition, a template for enhancing the list of types of technology to be regarded has been created.

C3 – A template for collecting best-practice examples of buildings to be analysed has been produced.

Subtask D: Knowledge transfer, dissemination

Subtask leader: GERMANY, Dietrich Schmidt from the Fraunhofer Institute for Building Physics (Germany)

Identified deliverables:

	Deliverables	Participants	Scheduled/ Ready
D1	Dissemination Activities • Industry workshops + proceedings of workshops • IEA Future Building Forum "Think Tank" • LowExNet workshops • Website • Brochure • Newsletters (biannual)	ALL	Next: June 12, 07
		GER	
		All	Next: June 12, 07
		GER-K ©	May 01, 2007
		GER-K ©	March 01, 2007
		GER-K ©	Nov. 1, 2007
D2	State of the Art • State-of the art report	NL + deliv.	June 30, 2008
D3	Design Guidebook • Design guide • Full version • Summary	GER-K © Edition ALL	
		ALL	October 30, 2009
		ALL	

Comments on the deliverables:

A State of the Art report has been identified as a new deliverable. It will be a mid-term report, produced towards the middle of the activities in Annex 49. The State of the Art Report (D2.1) will include a description of the framework for exergy analysis at a building and community level, as well as an article summarising the legal framework and legal/policy issues hindering advancements.

During the meeting, the second issue of the Annex 49 newsletter was presented. The Annex 49 home page has been up and running since May 1st 2007. Its structure, with internal space for discussion, exchange of materials and a forum, as well as a public area for disseminating the activities within the Annex 49, was shown to the participants once again.

2.3. Topic 3: Presentations and discussion on related topics

2.3.1. Definition of Low-Ex Sytems – Views of COSTeXergy group, *Mia-Ala Juusela*

In Novo Mesto/Slovenia, within the COSTeXergy meeting held on September 20 and 21, 2007, the definition of lowex systems and lowex sources was discussed.
The definition from Annex 37 was used as the basis for starting discussion. However, in Annex 37, the scope was limited to heating and cooling systems, whereas, in Annex 49 the scope includes as well other applications (daylighting, building appliances,…). Different approaches from the participants were shown. The necessity of linking the definition with benchmarking strategies (quantitative definition) was pointed out. It would be desirable to include the embodied exergy in the quantitative definition of the systems.

2.3.2. Benchmarking of Low-Ex buildings, *Dietrich Schmidt*

A benchmarking framework, based on a combined energy and exergy analysis was presented. The “exergy expenditure figure” was introduced as a key parameter in the proposed benchmarking schema. It allows a link to the energy regulations existing in many countries.

2.3.3. Exergy and the assessment of solar energy sources, *Herena Torio*

Considerations on the physical inconsistency and incorrectness of the current evaluation framework for systems making a direct use of solar radiation were presented. A boundary for these systems, consistent with that for other systems, was proposed.

2.3.4. Strategies for low-ex buildings, *Gudni Johannesson*

Results from dynamic simulations of an air based solar thermal system coupled with rock bed as storage and gravel under foundation as distribution system, behaving as a semi-infinite body were presented. The hot airflow is coupled with a heat pump for space heating and DHW.

2.3.5. First ideas for total use of energy/exergy flows in dwellings, *Peter Op´t Veld*

Current “energy transition plan” taking place in the Netherlands was introduced. The plan includes two main points: the Passive-house approach and the Exergy-house approach. Both were compared to each other on the basis of action packages to allow certain level of CO_2-emission reductions. Innovative technology related to the exergy-house approach and application of the exergy principles was also presented.

2.3.6. Remining LowEx, *Peter Op´t Veld*

He presented the European project: “Remining-LowEx” within the Concerto II programme, where “integrating supply and demand sides” is a key idea.

Special attention was paid to the training module and activities to be done in working packages 6 and 7 of the project. Within this working package, a LowEx European conference is to be prepared and held in the near future.
A decision tool for the specific application of lowex principles in heating/cooling in ex-mining areas is to be prepared.

2.3.7. Annex 49 tool, *Dietrich Schmidt*

Based on the Excel tool produced in Annex 37, a new Excel tool has been developed. Improvements and changes in the structure of the tool were shown to the participants.

2.4. Topic 4: Updating of the annex text and definition of tasks until next meeting

2.4.1. Tasks until next meeting

- ✓ Template for analysing legal framework in the different countries related to the introduction of exergy, based on the experience in Germany (D2.1). Who: Dietrich Schmidt
- ✓ Update and report on the results from the analysis of thermal comfort related to exergy principles, conducted in Uni Maastricht. Who: Peter Op’t Veld
- ✓ Report on the toolkit for retrofitting in the Netherlands (related to deliverable C4.2). Who: Peter Op’t Veld
- ✓ Draft of organisation for the workshop on exergy as an innovation driver in buildings and building service systems (C6). It might be a combined Remining+COST Workshop (funding from COST). Who: Peter Op’t Veld and Gudni Johannesson.
- ✓ Presentations on proposed best-practice cases for buildings and communities. Who: all
- ✓ Contact Robin Wiltshire, from DHC Implementing Agreement, for possible input on the community level and best-practice examples. Who: Dietrich Schmidt

2.4.2. LowEx session at the IAQVEC2007 Sendai, October 2007

Sendai Conference -> October 28th - 31st, 2007, with a special LowEx session to be held under the title: **“*Low Exergy Systems for Better Indoor and Global Environments*”**

- **Next Annex 49 meeting:**

3rd Expert meeting: Spring 2008
April 14th – 15th, 2008
Location: Vienna, Austria
at the Technical University of Vienna

Determination of more meeting dates:

- COSTeXergy meeting: April 16th 2008, in Vienna

- COSTeXergy PhD workshop at the Indoor Air Conference, August 2008, Copenhagen (Denmark)
- 4th Annex 49 expert meeting, August 27th – 28th, 2008 in Iceland.
- Joint workshop of DHC Implementing Agreement and Annex 49 on August 29th, 2008 in Iceland.
- 5th Annex 49 expert meeting, April 20th-21st, 2009 in the Netherlands(Maastricht or Heerlen)

3. CLOSING REMARKS

The operating agent would like to thank the host institution for the successful and pleasant organisation of the meeting and for allowing the meeting to take place there, as well as the participants for their active commitment and constructive input in Annex 49.

APPENDIX I: LIST OF PARTICIPANTS

Canada	Ken Church Sustainable Buildings & Communities/Natural Resources Canada 1Hannel Drive Ontario K1A 1M1, CANADA	Phone: +1 613 947 8952 Fax: +1 613 947 0291 E-mail: kchurch@nrcan.gc.ca
Finland	Mia Ala-Juusela VTT P.O. Box 1000 FIN - 02044, VTT FINLAND	Phone: +358 2 072 26947 Fax: +358 2 072 27027 E-mail: mia.ala-juusela@vtt.fi
Germany	Dietrich Schmidt Fraunhofer-Institute for Building Physics Gottschalkstrasse 28a DE - 34127 Kassel, GERMANY	Phone: +49 561 804 1871 Fax: +49 561 804 3187 E-mail: dietrich.schmidt@ibp.fraunhofer.de
Germany	Herena Torío Fraunhofer-Institute for Building Physics Gottschalkstrasse 28a DE - 34127 Kassel, GERMANY	Phone: +49 561 804 1871 Fax: +49 561 804 3187 E-mail: herena.torio@ibp.fraunhofer.de
Japan	Masanori Shukuya Musashi Institute of Technology 1-3-1 Ushikubo-Nishi, Tsuzuki-ku 224-0015 Yokohama, JAPAN	Phone: +81-45-910-2552 Fax: +81-45-910-2553 E-mail: shukuya@yc.musashi-tech.ac.jp
Japan	Masaya Saito Lab Built Environmental Systems, School of Design, Sapporo City University Geijutsu-no-mori 1 cho-me, Minami-ku, Sapporo 005-0864, JAPAN	Phone: +81-11-592-2631 Fax: +81-11-592-2771 E-mail: masahome@jcom.home.ne.jp
Japan	Marcel Schweiker Musashi Institute of Technology 1-3-1 Ushikubo-Nishi, Tsuzuki-ku 224-0015 Yokohama, JAPAN	Phone: +81-45-910-2552 Fax: +81-45-910-2553 E-mail: schweike@yc.musashi-tech.ac.jp

Japan	Toshiya Iwamatsu Musashi Institute of Technology 1-3-1 Ushikubo-Nishi, Tsuzuki-ku 224-0015 Yokohama, JAPAN	Phone: +81-45-910-2552 Fax: +81-45-910-2553 E-mail: iwamatsu@ yc.musashi- tech.ac.jp
Sweden	Marco Molinari KTH Building Technology Brinellvägen 34 SE - 10044 Stockholm, SWEDEN	Phone: +46 8 790 8670 +46 8 595 3073 Fax: +46 8 411 8432 E-mail: marco.molinari @byv.kth.se
Sweden	Gudni Jóhannesson KTH Building Technology Brinellvägen 34 SE - 10044 Stockholm, SWEDEN	Phone: +46 8 790 8670 +46 8 595 3073 Fax: +46 8 411 8432 E-mail: gudni.johannesson @byv.kth.se
The Netherlands	Peter Op´t Veld Cauberg-Huygen R.I. B.V. PO Box 480 NL - 6200 AL Maastricht, The NETHERLANDS	Phone: +31 43 346 7842 Fax: +31 43 347 6347 E-mail: p.optveld@chri.nl
USA	David Thomson The Pennsylvania State University Marion Place, Suite 414 135 East Nittanty Avenue State College, PA 16801, USA	Phone: +1 814 865 9418 Fax: +1 814 865 9303 E-mail: dbt102@psu.edu
USA	Dave Solberg HVAC Systems Technology Inc. 5939 Clinton Avenue 55419 Minneapolis, USA	Phone: +1 612 869 6052 Cell : +1 612 770 5405 E-mail: dwsolberg @hvacsystemstechnology.com

Anhang D

Protokoll des Meetings in Wien April 2008

Annex 49

Low Exergy Systems for High-Performance Buildings and Communities

Report to the Executive Committee
Status Report No 5 / May 2008

Dietrich Schmidt
Fraunhofer-Institute for Building Physics
Gottschalkstrasse 28a
DE-34127 Kassel
Germany

Phone: +49 561 804 1871
Fax: +49 561 804 3187
E-mail: dietrich.schmidt@ibp.fraunhofer.de

Annex 49

ECBCS Annex 49: *Low Exergy Systems for High-Performance Buildings and Communities*

STATUS REPORT NO 5

1. GENERAL BACKGROUND INFORMATION

The ECBCS ExCo decided during the November 2006 meeting in New Zealand to launch the working phase of Annex 49 on “Low Exergy Systems for High-Performance Buildings and Communities”. Germany agreed to lead the annex and offered to provide the operating agent. This fifth status report outlines the activities and achievements of the third six months of the Annex 49 working phase.
The third working phase meeting for Annex 49 on April 14 and 15, 2008 was hosted by Lukas Kranzl at the Vienna University of Technology, in Vienna/Austria. The meeting was attended by participants from Austria, Canada, Denmark, Finland, Germany, Italy, Japan, Poland, Sweden, Switzerland, the Netherlands, the USA and guest from China and Greece.

After the host Lukas Kranzl had welcomed all participants, they introduced themselves, their organisations, and their main fields of interest related to the activities of Annex 49.

Dietrich Schmidt gave a short overview on the structure of the meeting and highlighted the main expected outcomes. The discussion of future working items, what they involve, and the outcomes expected, were the most important goals mentioned. Additionally, the status of working items to be delivered by the meeting was checked over.

2. STRUCTURE OF THE MEETING

The third working phase meeting was divided into three main topics:

- Status of Annex 49
- Discussion of working program by subtasks, including presentations and discussion on related topics
- Definition of new meeting dates and places, activities and tasks until next meeting

Topic 1: Status of Annex 49

The operating agent of Annex 49, Dietrich Schmidt, from the Fraunhofer Institute of Building Physics (Germany), presented the main working items that were to be carried out before the meeting:

- ✓ **Template for analysis of legal framework for the introduction of exergy concept (and example from German situation)**
- – **Collect articles and documents for LowExNet website** for marketing and dissemination purposes: links to publications will be uploaded in the web.
- ✓ **List of cutting edge technologies**
- – **Templates for building and community best practice examples**
- – **Report from analysis of ongoing research on thermal comfort at the University of Maastricht**

Topic 2: Discussion of working program by subtasks

The status of the working plan was presented by subtasks. Each designated subtask leader gave a detailed presentation on the working items and main objectives of his/her task. The status of the defined deliverables for each task was checked and their expected contents and scope were discussed. Furthermore, presentations on related topics and research activities from the participants were also discussed in relation to the deliverables for each subtask.

Subtask A: Methodologies

Subtask leader: FINLAND, Mia-Ala Juusela from VTT

Main Objective: *the development, assessment and analysis of methodology, including tools for the design and performance analysis of community systems and buildings.*

Working items:

- *Exergy flow analyses of complex systems for thermodynamic performance and sustainability evaluation. New dynamic exergy analysis methods accounting for changing ambient conditions.*
- *System optimisation strategies.*
- *Procedures, models and software tools for design and performance analyses.*
- *Economic life cycle impacts of LowEx design rules.*
- *Pre-normative proposals: of special interest to the Netherlands and Germany.*

Identified deliverables:

Deliverables		Participating countries	Scheduled/Ready
A1	System optimisation strategies	FI, AU, IT-P[1], SE CA, USA	First draft: May 1, 2007
A2	Procedures for design and performance analysis	GER-K[2], FI, GER-B[3], USA	June 30, 2007 – (delayed first draft OK)
A3	Models for design and performance analysis	GER-K, SE, FI, GER-B, USA	Aug. 2008 – Reykjavik meeting
A4	Tools for design and performance analysis	GER-K, GER-B, FI, AU, SE, IT-V[4], IT – M[5] (P), GER-B, USA	End of Annex – May 31, 2009
A5	Life cycle economical impacts – Analysis of cost effectiveness of different LowEx systems	FI, NL, SE, AU, PL, USA	Mid Annex – Nov. 30, 2008
A6	LowEx systems and thermal comfort	FI, NL, IT-M (A)(P), IT-P, JP, DK, USA	Dec. 31, 2008
A7	Definition of LowEx systems	FI, SE, GER-B, IT, USA	Final draft: Aug. 2008 – Reykjavik meeting
A8	Pre-normative proposals	FI, IT – V, DK, GER-B/K, USA	New deadline will be defined

Comments on the deliverables:

A5 – Related to projects at the University of Twente and activities at the KTH

A8 – Two strategies for benchmarking LowEx systems, such as buildings and their components have been developed by two participants of the Annex 49.

PRESENTATIONS ON RELATED PROJECTS AND ACTIVITIES

I. Dynamic exergy analysis in Modelica, *Timo Haase*

Advantages and main features of the Modelica language were introduced. Results from a dynamic exergy simulation (corresponding to the second article in the 3rd Newsletter) were also presented.

---

[1] P - Padova
[2] K- Kassel
[3] B – Berlin
[4] V – Venice
[5] M – Milan: (P) – Paola Caputo
(A) – Adriana Angelotti

II. Design Performance Viewer, *Forrest Meggers*

A tool for energy/exergy modelling focused on building level was presented. Energy calculations are based on the German regulation and steady-state conditions. The tool would be coupled to other more complex building systems tools (e.g. TRNSYS). Since the target group are mainly architects and planners, the tool includes a well developed graphical interface. Future work: economical/costs analysis.

III. Annex 49 simplified Excel Tool, *Herena Torío*

The main new features/structure and differences to the Annex 37 excel tool were introduced.

IV. Italian simplified tool for buildings (including exergy) based on prEN 13790 and CEN, *Piercarlo Romagnoni*

The Italian tool, which is currently under development, was introduced. Results from steady state calculations from this tool will be compared with results from simplified excel-base Annex 49 tool.

V. New results from human body exergy balance, *Masanori Shukuya*

Results from experimental analysis on thermal comfort and exergy consumption rate for summer conditions were presented.

VI. Relationship between human behaviour and human exergy consumption, *Masaya Saito*

Results from experimental investigations at the University of Sapporo were shown. Results show that a first correlation between EBI (Environmental Behavioural Index), which is strongly related to actual window surface temperature, and exergy consumption rate could be drawn.

Subtask B: Exergy efficient community supply structures

Subtask leader: CANADA, Ken Church from NRC

Main objective: *the development of concepts concerning energy distribution, generation and storage systems to satisfy all demands of community members, with a minimum input of primary energy.*

Working items:

- *Innovative types of technology for energy supply structures at different exergy levels.*
- *Innovative types of technology for maximising the local utilisation of renewable and ambient resources, e.g. heat pumps.*
- *Advanced system concepts and solutions for the distribution, local generation and storage of energy/exergy.*

Identified deliverables:

Deliverables		Participants	Scheduled/Ready
B1	Innovative types of technology for LowEx energy supply structures	NL, GER-B, SE	Nov. 1, 2008 (delayed) Aug. 2008 – Reykjavik meeting
B2	Innovative types of technology for LowEx energy supply structures – RE based	JP, IT-M(A), SE, GER	Aug. 2008 - Reykjavik meeting
B3	Advanced system concepts for the distribution, generation and storage of energy/exergy	CA, IT-M(P), NL, SE ALL	Oct. 31, 2008
B4	Concepts on community scales	NL	Aug. 2008 - Reykjavik

Comments on the deliverables:

B1 – A first report will be delivered by the next working meeting in Reykjavik.

B3 – Several case studies were presented (Huai Rou (China); Parma (Italy)). Furthermore, a survey comparing different planning tools was also introduced.

B4 – identified as new deliverable based on the experience and new research project (TRANSEP – DGO) in the Netherlands.

Subtask C: Exergy efficient building technology

Subtask leader: SWEDEN, Gudni Jóhannesson from KTH –The Royal Institute of Technology

Main objective: *the reduction of exergy demand for heating, cooling and ventilating buildings.*

Working items:

- *Innovative types of technology for low exergy heating and cooling.*
- *Innovative control concepts and strategies for a demand controlled exergy supply.*
- *System concepts and solutions, including innovative exergy storage systems.*
- *Exergy as an innovation driver in buildings and building service systems.*

Identified deliverables:

Deliverables		Participants	Scheduled/Ready
C1	Innovative types of technology for low exergy heating and cooling	GER-B, SE, NL, IT-P and M (a)	Sep. 30, 2008
C2	Innovative control concepts and strategies for a demand controlled exergy supply	IT-P, DK	June 30, 2008
C3	Advanced system concepts and solutions, including exergy storage systems	SE, GER-B	Oct. 31, 2007
C4	Advanced system concepts for retrofitting energy/exergy - link to: Annex 46 Annex 50 SHC Task 37	PL, IT-P, SE	May 30, 2009
C5	Light structures for warm climates	JP, IT, SE	May 30, 2009
C6	Exergy as an innovation driver in buildings and building service systems	A possible workshop item, all.	Autumn 2008 – Spring 2009

Comments on the deliverables:

C1 – Reports and experiences from many related research projects are to be included. In addition, a list of types of technology to be analyzed has been made to be actualized by the participants.

C3 – A template for collecting best-practice examples of buildings to be analysed has been produced.

C6 – Joint workshop with DHC will take place on the 29th August, in Reykjavik.

PRESENTATIONS ON RELATED PROJECTS AND ACTIVITIES

I. LowEx Ventilation: a decentralized approach, *Luca Baldini*

Main advantages and disadvantages of decentralized ventilation systems were presented against centralized systems based on an example. Open questions include the topology of the ventilation unit and control strategies.
In the system studied, exhaust and supply airflows are controlled decentralized. However, the exhaust air of the whole system is coupled with heat pump so that the heat recovery can also be done centralized.

II. LowEx heat recovery from waste water, *Forrest Meggers*

Different systems and research concepts for exhaust air and hot water heat recovery in buildings were introduced.

III. Exergy analysis of indirect evaporative chiller, *Xie Xiaooyun*

Operation principle and analysis of a novel indirect evaporative chiller were presented.

IV. Exergy analysis on the air-conditioning process within the building, *Xiaohua Liu*

Performance of different cooling systems based on an indirect evaporative cooling and liquid desiccant cooling system. The system was investigated and tested in dry and humid regions.

V. Heat pumps in Japan, *Takahiro Yamaguchi*

Products and main market interests of the company Daikin were presented.

VI. High efficient cooling systems for building retrofit – An attempt to raise the awareness of architects a d building owners, *Petra Karlström*

Several water-based cooling emission systems are analyzed as retrofitting options and characterised according to different parameters (energy/exergy/costs/structural analysis). Results will be integrated in a decision matrix for architects and planners.

VII. Energy and exergy analysis of the passive and traditional single family house, *Zygmunt Wiercinski*

Passive and low energy building technologies (according to current polish energy standards) were applied to a single family house and compared to each other on energy and exergy terms, by using the latest version of Annex 49 tool.

VIII. An active insulation system for LowEx buildings, *Luca Baldini*

An active insulation system based on water circulation on the outside layer of uninsulated massive walls was presented.

Subtask D: Knowledge transfer, dissemination

Subtask leader: GERMANY, Dietrich Schmidt from the Fraunhofer Institute for Building Physics (Germany)

Working items:

- *Initiation of demonstration projects and development of new activity formats between research and business.*
- *Documentation of best practice examples.*
- *Newsletters, website and seminars/workshops.*
- *Design guide.*

Identified deliverables:

	Deliverables	Participants	Scheduled/ Ready
D1	Dissemination Activities • Industry workshops + proceedings of workshops	ALL	Next: August 29, 2008
	• IEA Future Building Forum “Think Tank”	GER	Postponed: end of annex?
	• LowExNet workshops	All	Next: August 29, 2008
	• Website	GER-K ©	May 01, 2008
	• Brochure	GER-K ©	March 01, 2007
	• Newsletters (biannual)	GER-K ©	May 1, 2008 (3rd)
D2	Annex mid term report • State-of the art report	NL, GER-K, IT-M	Sept. 30, 2008
D3	Design Guidebook • Design guide • Full version • Summary	GER-K © Edition ALL	
		ALL	October 30, 2009
		ALL	

Comments on the deliverables:

A State of the Art report has been identified as a new deliverable. It will be a mid-term report, produced towards the middle of the activities in Annex 49. The State of the Art Report (D2.1) will include a description of the framework for exergy analysis at a building and community level, as well as an article summarising the legal framework and legal/policy issues hindering advancements. Experiences from training activities in the Netherlands will also be included.

During the meeting, the third issue of the Annex 49 newsletter was presented. The Annex 49 home page has been up and running since May 1st 2007. Its structure, with internal space for discussion, exchange of materials and a forum, as well as a public area for disseminating the activities within the Annex 49, was shown to the participants once again.

Topic 4: Tasks until next meeting and new meeting dates

a. Tasks until next meeting

- Distribute Annex 51 text. Who: Dietrich Schmidt
- Ask the ExCo for guidance on official reports and documents. Who: Dietrich Schmidt

- Send links of published articles to be updated to the internal area of Annex 49 website. Who: ALL
- Define best practice examples for buildings and community level based on the final version of the templates. Who: ALL

b. Next meetings and coming activities

Joint Annex 49 – DHC Workshop -> August 29th 2008, **"*Future energy saving potential from DHC and LowEx activities*"**, in Reykjavik (Iceland)

- **Next Annex 49 meeting:**

  4th Expert meeting: Autumn 2008
  August 27th – 28th, 2008
  Location: Reykjavik, Iceland

Determination of more meeting and activity dates:

- **COSTeXergy PhD Workshop** at the DTU Technical University Copenhagen, 26-31 May 2008, Copenhagen (Denmark)

- **Joint Annex 49 – CosteXergy LowEx Conference**, Limburg region, 21st April 2009, the Netherlands

- **5th Annex 49 expert meeting**, April 22nd-23rd, 2009 in the Netherlands(Maastricht or Heerlen)

- **Final (6th) Annex 49 expert meeting,** September 2nd-4th 2009 in Espoo (Finland)

- **Final Annex 49 Conference**, Spring 2010, Munich, Germany

CLOSING REMARKS

The operating agent would like to thank the host institution for the successful and pleasant organisation of the meeting and for allowing the meeting to take place there, as well as the participants for their active commitment and constructive input in Annex 49.

Items to be considered by the ExCo:

- Letters of national participation are still missing from Austria, Denmark, Japan, and Sweden.
- Guest or possible new participants form China and Turkey declared interest in joining Annex 49. Iceland would also be an interest candidate to collaborate with Annex 49.
- Also during the Vienna meeting some work items were postponed to the next working meeting in Iceland. For the work progress it would be needed to deliver a number of items, at least as drafts. This would enable the Annex team to continue the work successfully. Part of that problem might be the fact that subtask leaders were not able to work on their leading tasks actively because of missing/lacking funding, change in occupation etc. .

APPENDIX I: LIST OF PARTICIPANTS

Austria	Lukas Kranzl Vienna University of Technology, Institute of Power Systems and Energy Gusshausstraße, 25-29 /373-2 A-1040 Vienna, AUSTRIA	Phone: +43 1 58801 37351 Fax: +43 1 58801 37397 E-mail: Lukas.Kranzl @tuwien.ac.at
Canada	Ken Church Sustainable Buildings & Communities/Natural Resources Canada 1Hannel Drive Ontario K1A 1M1, CANADA	Phone: +1 613 947 8952 Fax: +1 613 947 0291 E-mail: kchurch@nrcan.gc.ca
China	Xiaohua Liu Tsinghua University, Dept. Building Science Chengu Road, Haidian District, Beijing, 100084, CHINA	Phone: +8610-6277-3772 Fax: +8610-6277-9461 E-mail: lxh@ mail.tsinghua.edu.cn
China	Xie Xiaoyun Tsinghua University, Dept. Building Science Chengu Road, Haidian District, Beijing, 100084, CHINA	Phone: +86 10-6277- Fax: + 86 10-6277-0544 E-mail: xy-xie03@ mails.tsinghua.edu.cn
Denmark	Bjarne Olesen International Center for Indoor Environment and Energy Technical University of Denmark, Building 402 DK - 2800 Lyngby, DENMARK	Phone: +45 45 25 41 17 Fax: E-mail: bwo@mek.dtu.dk
Finland	Mia Ala-Juusela VTT P.O. Box 1000 FIN - 02044, VTT FINLAND	Phone: +358 2 072 26947 Fax: +358 2 072 27027 E-mail: mia.ala-juusela@vtt.fi
Germany	Dietrich Schmidt Fraunhofer-Institute for Building Physics Gottschalkstrasse 28a DE - 34127 Kassel, GERMANY	Phone: +49 561 804 1871 Fax: +49 561 804 3187 E-mail: dietrich.schmidt @ibp.fraunhofer.de

Germany	Herena Torío Fraunhofer-Institute for Building Physics Gottschalkstrasse 28a DE - 34127 Kassel, GERMANY	Phone: +49 561 804 1871 Fax: +49 561 804 3187 E-mail: herena.torio @ibp.fraunhofer.de
Germany	Timo Haase Technical University Berlin, HRI Marchstr. 4 DE-10587 Berlin, GERMANY	Phone: +49-30-314 24178 Fax: +49-30-314 2114 E-mail: timo.haase@tu-berlin.de
Greece	Costas G. Theofylaktos Theofylaktos and associates 7 Loustinianou street GR-11473 Athens, GREECE	Phone: Fax: E-mail: cgtheo@otnet.gr
Italy	Paola Caputo Politecnico di Milano BEST v. Garofalo, 39 I - 20133 Milano, ITALY	Phone: +39 022399 9488 Fax: +39 022399 9491 E-mail: paola.caputo@polimi.it
Italy	Michele De Carli Dipartimento di Fisica Tecnica University of Padova Via Venezia 1 I - 35131 Padova, ITALY	Phone: +39 049827 6882 Fax: +39 049827 6896 E-mail: michele.decarli@unipd.it
Italy	Piercarlo Romagnoni Department of Construction of Architecture University IUAV of Venezia Dorsoduro 2206 I – 30123 Venice, ITALY	Phone: +39 041 257 12 93 Fax: + 39 041 522 36 27 E-mail: pierca@iuav.it
Japan	Masanori Shukuya Musashi Institute of Technology 1-3-1 Ushikubo-Nishi, Tsuzuki-ku 224-0015 Yokohama, JAPAN	Phone: +81-45-910-2552 Fax: +81-45-910-2553 E-mail: shukuya @yc.musashi-tech.ac.jp
Japan	Masaya Saito Sapporo City University Geijutsu-no-mori 1 chome 005-0864, Sapporo; JAPAN	Phone: +81-11-592-2631 Fax: +81-11-592-2771 E-mail: msaito@suc.ac.jp

Japan	Takahiro Yamaguchi DAIKIN Industries Ltd. 1304, Kanaoka-cho 591-8511, SKAI-shi; JAPAN	Phone: +81-803-1065-182 Fax: +81-722-50-1900 E-mail: takahiro.yamaguchi @daikin.co.jp
Poland	Zygmunt Wiercinski University of Warmia and Mazury, Chair of Environmental Engineering Jana Heweliusza, 4 10-724, Olsztyn, POLAND	Phone: +48 89 523 4756 Fax: +48 89 523 4760 E-mail: zygmunt.wiercinski @uwm.edu.pl
Sweden	Marco Molinari KTH Building Technology Brinellvägen 34 SE - 10044 Stockholm, SWEDEN	Phone: +46 8 595 3073 Fax: +46 8 411 8432 E-mail: marco.molinari @byv.kth.se
Sweden	Gudni Jóhannesson KTH Building Technology Brinellvägen 34 SE - 10044 Stockholm, SWEDEN	Phone: +46 8 790 8670 Fax: +46 8 411 8432 E-mail: gudni.johannesson @byv.kth.se
Switzerland	Luca Baldini ETH Zürich, Chair of building systems Wolfgang-Pauli-str. 15 HIL E 15.1 8093, Zürich, SWITZERLAND	Phone: +41-44-633-2812 Fax: E-mail: baldini @hbt.arch.ethz.ch
Switzerland	Forrest Meggers ETH Zürich, Chair of building systems Wolfgang-Pauli-str. 15 HIL E 15.1 8093, Zürich, SWITZERLAND	Phone: +41-44-633-2860 Fax: E-mail: meggers @hbt.arch.ethz.ch
Switzerland	Petra Karlström Basler & Hofmann, AG Forchstr., 395 CH - 8032 Zürich, SWITZERLAND	Phone: +41 44 387 1338 Fax: +41 44 387 1100 E-mail: petra.karlstroem@bhz.ch
The Netherlands	Peter Op´t Veld Cauberg-Huygen R.I. B.V. PO Box 480 NL - 6200 AL Maastricht, The NETHERLANDS	Phone: +31 43 346 7842 Fax: +31 43 347 6347 E-mail: p.optveld@chri.nl

The Netherlands	Elisa Boelman Delft University of Technology Faculty of Technical Natural Sciences and Architecture, Berlageweg 1, NL – 2600 GA Delft, The NETHERLANDS	Phone: +31-15-278-3386 Fax: +31-15-278-4178 E-mail: e.boelman@tudelft.nl
The Netherlands	Hedzer van der Kooi Delft University of Technology Faculty of Technical Natural Sciences and Architecture, Berlageweg 1, NL – 2600 GA Delft, The NETHERLANDS	Phone: +31 703 99 5027 Fax: E-mail: jvdkooi@wanadoo.nl
USA	Dave Solberg HVAC Systems Technology Inc. 5939 Clinton Avenue 55419 Minneapolis, USA	Phone: +1 612 869 6052 Cell: +1 612 770 5405 Fax: + E-mail: dwsolberg@hvacsystemstechnology.com

Anhang E

Protokoll des Meetings in Reykjavik 2008

Annex 49

Low Exergy Systems for High-Performance Buildings and Communities

Report to the Executive Committee
Status Report No 6 / September 2008

Dietrich Schmidt
Fraunhofer-Institute for Building Physics
Gottschalkstrasse 28a
DE-34127 Kassel
Germany

Phone: +49 561 804 1871
Fax: +49 561 804 3187
E-mail: dietrich.schmidt@ibp.fraunhofer.de

Annex 49

ECBCS Annex 49: *Low Exergy Systems for High-Performance Buildings and Communities*

STATUS REPORT NO 6

1. GENERAL BACKGROUND INFORMATION

The ECBCS ExCo decided, during the November 2006 meeting in New Zealand, to launch the working phase of Annex 49 on “Low Exergy Systems for High-Performance Buildings and Communities”. Germany agreed to lead the annex and offered to provide the operating agent. This sixth status report outlines the activities and achievements of the fourth six month period of the Annex 49 working phase.

The fourth working phase meeting for Annex 49 on August 27 and 28, 2008 was hosted by Gudni Jóhannesson at Hamar Hotel in Borgarnes (Iceland). The meeting was attended by participants from Austria, Canada, Finland, Germany, Italy, Japan, Poland, Sweden, Switzerland, the Netherlands, and the USA. Four guests from Germany, Japan, Poland and Slovenia also attended the meeting.

The meeting was organised in combination with a joint workshop with the IEA implementing agreement on district heating and cooling (DHC). The joint activity LowEx-DHC was held on the 29 August, at the University of Reykjavik.

2. UPDATED WORKING PROGRAM

During the expert meeting, the working program and the list of deliverables were discussed in detail, by subtask, and updated:

Subtask A: Methodologies

Subtask leader: FINLAND, Mia-Ala Juusela from VTT Finland

Deliverables		Participating countries	Scheduled/Ready
A1	System optimisation strategies	FI, AU, IT-P[1], SE CA, USA	in discussion (community level)
A2	Procedures for design and performance analysis	GER-K[2], FI, GER-B[3], USA	October 2008 – common report

---

[1] P - Padova

[2] K- Kassel

[3] B – Berlin

A3	Models for design and performance analysis	GER-K, SE, FI, GER-B, USA	
A4	Tools for design and performance analysis	GER-K, GER-B, FI, AU, SE, IT-V[4], IT – M[5] (P), GER-B, USA	End of Annex – May 31, 2009
A5	Life cycle economical impacts – Analysis of cost effectiveness of different LowEx systems	FI, NL, SE, AU, PL, USA	Mid Annex – Dec. 2008
A6	LowEx systems and thermal comfort	FI, NL, IT-M (A)(P), IT-P, JP, DK, USA	Dec. 31, 2008
A7	Definition of LowEx systems	FI, SE, GER-B, IT, USA	Final draft: Nov. 2008
A8	Pre-normative proposals	FI, IT – V, DK, GER-B/K, USA	Jan. 2009

Subtask B: Exergy efficient community supply structures

Subtask leader: CANADA, Ken Church from NRC

Deliverables		Participants	Scheduled/Ready
B1	Innovative types of technology for LowEx energy supply structures	NL, GER-B, SE	Nov. 1, 2008
B2	Innovative types of technology for LowEx energy supply structures – RE based	JP, IT-M(A), SE, GER	Aug. 2008 – submitted to scientific journal
B3	Advanced system concepts for the distribution, generation and storage of energy/exergy	CA, IT-M(P), NL, SE ALL	Dec. 2008
B4	Concepts on community scales	NL	Aug. 2008

---

[4] V – Venice

[5] M – Milan: (P) – Paola Caputo
(A) – Adriana Angelotti

Subtask C: Exergy efficient building technology

Subtask leader: SWEDEN, Gudni Jóhannesson from KTH –The Royal Institute of Technology

Deliverables		Participants	Scheduled/Ready
C1	Innovative types of technology for low exergy heating and cooling	GER-B, SE, NL, IT-P and M (a)	Jan.- May 2009
C2	Innovative control concepts and strategies for a demand controlled exergy supply	IT-P, DK	March 01, 2009
C3	Advanced system concepts and solutions, including exergy storage systems	SE, GER-B	Dec. 01, 2008
C4	Advanced system concepts for retrofitting energy/exergy - link to: Annex 46 Annex 50 SHC Task 37	PL, IT-P, SE	May 30, 2009
C5	Light structures for warm climates	JP, IT, SE	May 30, 2009
C6	Exergy as an innovation driver in buildings and building service systems	A possible workshop item, all.	Autumn 2008 – Spring 2009

Subtask D: Knowledge transfer, dissemination

Subtask leader: GERMANY, Dietrich Schmidt from the Fraunhofer Institute for Building Physics (Germany)

	Deliverables	Participants	Scheduled/ Ready
D1	Dissemination Activities • Industry workshops + proceedings of workshops	ALL	Next: COST-LowEx Conference, April 21, 2009 NL
	• IEA Future Building Forum “Think Tank”	GER	Postponed: end of annex?

	• LowExNet workshops	All	Joint IEA DHC-LowEx WS August 29, 2008
	• Website	GER-K ©	Oct. 1, 2008
	• Brochure	GER-K ©	March 01, 2007
	• Newsletters (biannual)	GER-K ©	May 1, 2008 (3rd)
D2	Annex mid term report • State-of-the-art report	NL, GER-K, IT-M	Sept. 30, 2008
D3	Design Guidebook • Design guide	GER-K © Edition ALL	October 30, 2009
	• Full version	ALL	October 30, 2009
	• Summary	ALL	October 30, 2009
D4	Exergy training houses	NL	October 2008

3. OUTCOMES FROM LAST EXPERT MEETING

During the last expert meeting, an internal revision process was agreed upon by the participants. An Annex 49 participant will be in charge of reviewing each deliverable and, in this way; quality and coherence of the outcomes of the Annex are to be ensured.

3.1. Working phase during the meeting

After the four subtasks and their corresponding deliverables were discussed, a working phase related to each of the particular subtasks began. The group split up into smaller groups, providing room for more intensive and deeper discussions on ongoing research issues within the subtasks.

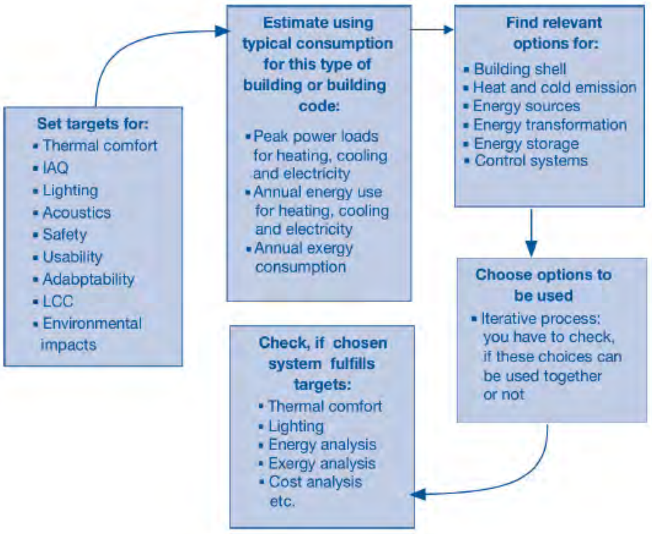


Figure 1. The design process of a building as a system.

During this working phase, integral optimisation strategies for buildings and communities were discussed in detail. The design and decision making processes for community planning were discussed, as well as the design strategy for the building level elaborated within Annex 37 (Figure 1), and the main actors were identified. Based on the characteristics of community planning, an effort is being made to identify the main niches for exergy optimisation

Furthermore, case studies to be analysed as best-practice examples, both at a community and building level, were thoroughly discussed and collected. An overview and list of the main case studies discussed is presented in section 4.

3.2. Scientific exchange and input from ongoing research activities

Several presentations were given by the participants during the meeting in order to enhance and promote further discussions on related ongoing research issues.

I. Environmental (reference) temperature for exergy calculation,

Itaru Takahashi

Considerations on possible (steady/dynamic) definitions of reference state were given. The choice of a dynamic environment might be justified by the great relative variations of exergy in building systems with varying outdoor temperature (reference). Results from an exergy analysis of a wastewater recycling system were also presented.

II. Report on human-body exergy calculation and thermal comfort,

Masanori Shukuya

A paper describing the method and fundamentals for the calculation of human-body exergy consumption, which is still in the draft stage, was presented. The report contains a detailed derivation and explanation of the human body exergy balance calculation (including thermal and humidity regards), as well as a comprehensive introduction to the thermodynamic concept of exergy.

III. Evaluating a cost-efficient exergy saving potential for the Austrian space heating supply-methods of the ERNSTL model,

Herena Torío

Exergy analysis of space heating and domestic hot water systems for the Austrian building stock have been calculated by means of the Annex 49 Excel-based tool. Energy scenarios, upon which exergy analyses have been performed, have been carried out with the ERNSTL tool. The Austrian building stock is characterised by means of a database at the local, community level. The study includes a comparative economic analysis of LowEx systems and exergy analysis of bio-energy chains.

IV. Review article on exergy analysis of renewable energy systems,

Herena Torío

The main structure of the review work on exergy analysis of heating and cooling systems for buildings was introduced. Special focus has been given to the analysis of renewable energy based energy systems. Steady-state and dynamic approaches, as well as different boundaries for the analysis were identified and compared to each other.

V. New concept for the development of new neighbourhoods,

Ken Church

The Canadian concept for utilising exergy as a planning tool at the community level was presented. The key idea is to categorise demands and supply into “quality classes”, according to their exergy content, and to try to match the different available loads and sources. A draft for an Excel-based tool quantifying the level of matching by means of the exergy efficiency and exergy losses at different steps of the energy supply chain was also presented.

VI. LowEx research,

Saso Medved

Several LowEx research items and systems, such as building envelope integrated solar collectors, decentralised ventilation units and PCM storage systems, being investigated at the University of Ljubljana, were introduced. They could be integrated as case studies for innovative forms of technology.

VII. Ecological settlement “Oberzwehren” (Kassel, Germany),

Christina Sager

The energy supply concept for the new housing site located in the city of Kassel (Germany) was presented.

VIII. Initial results of exergy optimisation of wastewater heat recovery,

Forrest Meggers

A heat recovery unit based on grey wastewater coupled with a heat pump is being analysed and optimised by means of the exergy concept. First results concerning the optimisation of the mass flow for the operation of the recovery heat exchanger were presented.

IX. Energy and exergy analysis of the passive and traditional single family house,

Zygmunt Wiercinsky

A single family house using traditional Polish construction was analysed and compared from an energy and exergy basis against the same building with passive house standards. The latest option also includes the application of low-energy building systems such as an air source heat pump and ground heat exchanger. Energy and exergy analyses were carried out on a steady-state basis using the Annex 49 Excel-based tool.

X. “IEQ vs. Energy Conservation”,

Michele de Carli

Results from the comparison of two radiant cooling systems, combined with ventilation cooling units with and without dehumidification, were presented. Although the system with dehumidification results in lower indoor air humidity and thus higher thermal comfort, its primary energy consumption is also significantly higher. Furthermore, results from a case study with hybrid and mechanical ventilation systems for heating and cooling were shown.

3.3. INNER ERA-NET / LowEx Workshop

During the meeting, a common workshop was organised to show current activities and trends on the innovative energy research in a European context. Paul Ramsak from SenterNovem (the Netherlands) presented the main outline for strategic short, medium, and long-term energy research. Some of the main goals of the INNER-ERA NET programme are the networking and co-operation among European countries, identification and stimulation of novel research topics, and influence strategic direction of energy related R&D. Furthermore, results from the first “Ideas factory” on “Zero energy buildings” held on May 2008 in Marvão (Portugal) were also introduced.

4. ACTIVITIES AND ONGOING WORK

4.1. Joint ECBCS LowEx / DHC Workshop

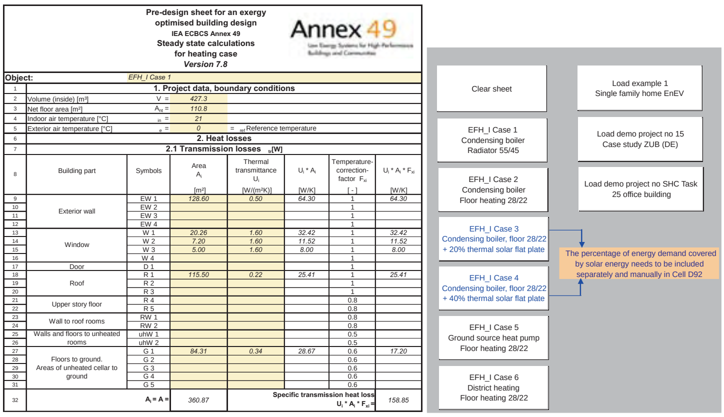
On the 29th of August, a common workshop with participants from IEA ECBCS Annex 49 and the Implementing Agreement on District Heating and Cooling took place in Reykjavik. A detailed agenda of the workshop can be found in Appendix I. District heating and cooling supply structures, specially those providing waste heat from industrial processes or residual heat from CHP units, are very suitable systems, from an exergy perspective, for supplying energy demands in buildings. Yet, optimisation possibilities for these systems still exist for their application in the built environment, particularly if low temperature heating and high temperature cooling systems are implemented in buildings (“LowEx” systems). To reach this goal, a holistic approach, which includes the combined analysis of the district heating and cooling structures with the buildings and their thermal loads, is of great interest. In the workshop, an introduction to the LowEx approach as well as its application to several case studies was given. In addition, the main future development trends for DHC structures were pinpointed. In this way, important synergies between both research fields were identified.

4.2. Methodologies and tools for exergy analysis

To bring the application of the exergy concept into the built environment, and to the wider public, several tools are under development:

- A simplified Excel-based tool for steady-state exergy analysis of different building heating systems is being developed. This tool is focused at the building level and allows the combination of several building systems to be analysed, giving an idea of their exergy performance and suitability for meeting heating demands.
- Several models for dynamic analysis of building systems have also been developed in Modelica language. Although not compiled into a single tool, the models can be combined as modules allowing a great variety of building systems to be evaluated
- A simplified tool, also Excel-based, is being developed for analysing the exergy performance of energy supply structures at a community level. It is thought to help municipalities and decision makers involved in the community design process in

the planning of optimised energy supply structures by gaining a quantitative and qualitative view on potential improvements to them.


Pre-design sheet for an exergy optimised building design
IEA ECBCS Annex 49
Steady state calculations for heating case
Version 7.8

Object: *EFH_I Case 1*

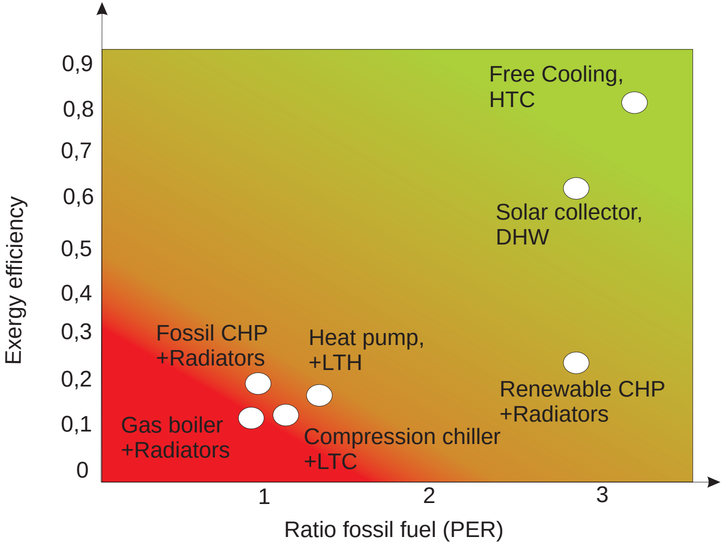
1	**1. Project data, boundary conditions**
2	Volume (inside) [m³] V = *427.3*
3	Net floor area [m²] A_{nt} = *110.8*
4	Indoor air temperature [°C] $_{in}$ = *21*
5	Exterior air temperature [°C] $_{e}$ = *0* = $_{ref}$ Reference temperature
6	**2. Heat losses**
7	**2.1 Transmission losses $_{tr}$[W]**

8	Building part	Symbols	Area A_i [m²]	Thermal transmittance U_i [W/(m²K)]	$U_i * A_i$ [W/K]	Temperature-correction-factor F_{xi} [-]	$U_i * A_i * F_{xi}$ [W/K]
9	Exterior wall	EW 1	*128.60*	*0.50*	*64.30*	1	*64.30*
10		EW 2				1	
11		EW 3				1	
12		EW 4				1	
13	Window	W 1	*20.26*	*1.60*	*32.42*	1	*32.42*
14		W 2	*7.20*	*1.60*	*11.52*	1	*11.52*
15		W 3	*5.00*	*1.60*	*8.00*	1	*8.00*
16		W 4				1	
17	Door	D 1				1	
18	Roof	R 1	*115.50*	*0.22*	*25.41*	1	*25.41*
19		R 2				1	
20		R 3				1	
21	Upper story floor	R 4				0.8	
22		R 5				0.8	
23	Wall to roof rooms	RW 1				0.8	
24		RW 2				0.8	
25	Walls and floors to unheated rooms	uhW 1				0.5	
26		uhW 2				0.5	
27	Floors to ground. Areas of unheated cellar to ground	G 1	*84.31*	*0.34*	*28.67*	0.6	*17.20*
28		G 2				0.6	
29		G 3				0.6	
30		G 4				0.6	
31		G 5				0.6	
32		**A_i = A =**	*360.87*		**Specific transmission heat loss $U_i * A_i * F_{xi}$ =**		*158.85*

The percentage of energy demand covered by solar energy needs to be included separately and manually in Cell D92

Figure 2: Screenshot from simplified Excel-based tool for exergy analysis on building level

Furthermore, a suggestion for quantification and graphical interpretation of this approach has been worked out (Figure 3). The suitability of a given system to fulfil a certain purpose can be seen by comparing its exergy efficiency in fulfilling its purpose against the Primary Energy Ratio (PER), representing the ratio between total primary energy supplied and the fossil part of that primary energy flow. In Figure 3, several energy systems for heating and cooling are analysed following this criteria: higher PER ratios and higher exergy efficiency stand for an optimised system.



LTC, Low Temperature Cooling
HTC, High Temperature Cooling (LowEx)
LTH, Low Temperature Heating (LowEx)
CHP, Combined Heat and Power
DHW, Domestic Hot Water

Figure 3: PER ratios and exergy efficiencies for several building heating and cooling systems

4.3. Mid-term report

Currently, a mid-term report on the topic “Framework for exergy analysis on community and building level” is being compiled, summarising some of the main results from the research activities within the group.
The report is to include an introduction and discussion on different existing methodologies for applying exergy analysis to the built environment. Benefits and

drawbacks from steady-state and dynamic analysis are to be summarised, as well as discussions on the definition of the reference environment. Particular emphasis is given to the exergy analysis of renewable energy systems for the heating and cooling of buildings. The main outcomes from an extensive literature review on this issue are also to be included.
For characterising the exergy performance of buildings and communicating the concept to a wider audience, several benchmarking criteria have been analysed and concrete benchmarking proposals have been worked out. They are also to be shown, applied to particular case studies, in the report.
Finally, several case studies designed according to the LowEx principles, both at community and building levels are to be presented.
A member of the Executive Committee will be asked to act as external reviewer for this official outcome of Annex 49.

4.4. Building case studies

A number of interesting technologies to achieve heating and cooling of buildings with a low exergy input have been identified. They include:

- Heat pumps for low ΔT
- Waste-water heat recovery
- Novel evaporative chiller
- Fans for low-pressure head loss
- Phase change materials
- Solar collectors

EXAMPLE: waste-water heat recovery

Nowadays, nearly half of the heat demand of most well insulated high performance buildings comes from the production of hot water. In this system, a recovery system is being analysed to maximise the potential of warm wastewater to augment the performance of a heat pump. The heat from showers and other hot water demands is captured at the highest possible temperature and used to reduce the temperature lift needed for the heat pump to produce hot water. Thereby, a low-lift compressor can be used in the production of both low temperature (LowEx) space heating, as well as for hot water production that requires a higher production temperature, but now receives a higher source temperature.

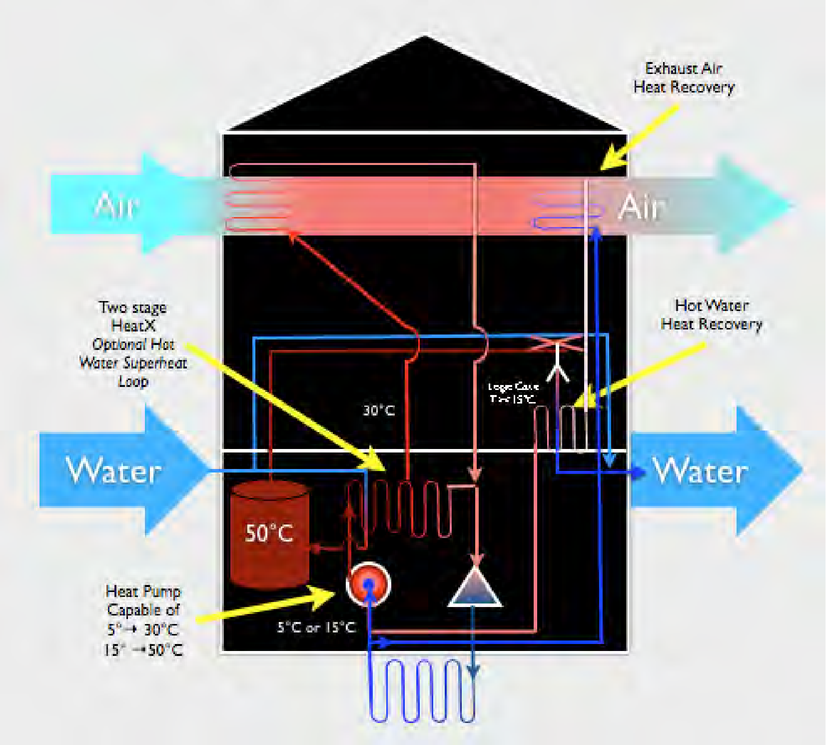


Figure 4: schematic view of the recovery system

4.5. Community case studies

Within Subtask B, working on the community scale, a number of possible case studies has been identified.

- Okotoks, Canada (completed)
- Alderney, Canada (ongoing)
- Darthmouth, Canada (completed)
- Parma, Italy (ongoing)
- Huai-Rou, China (ongoing)
- Toronto, Canada (ongoing)
- St. Paul, USA
- 2 further cases from the Netherlands
- 2 further cases from Germany

EXAMPLE I: Parma, Italy

The city of Parma is located in Northern Italy, in the Emilia-Romagna region, with approximately 178,000 inhabitants and a balanced presence of tertiary, industrial and agricultural sector, a mild climate, and a notable historical building stock and cultural heritage. At the end of the project, there will be an assessment on the futuristic hypothesis of transforming Parma into a 100% renewable city by the year 2050, adopting, as a benchmark today, the best available technology.

EXAMPLE II: Okotoks, Canada

The community of Okotoks, Alberta, Canada lies more than 1,000 m above sea level, but because of its position, has an average summertime temperature that exceeds 20°C. This has allowed for the development of North America's first solar demonstration project that incorporates the principles of low-exergy in its design. Not only does the project include low exergy thermal collection, but it also includes the concepts of short term storage and long term season borehole thermal energy storage (BTES).

The bank of thermal collectors, facing South, at an angle of 45°, are designed to collect up to 1.5MW of thermal energy, enough to supply heat to the buildings at 55°C.

The solar water heating system, which uses 2,293m^2 of commercially available flat plate solar collectors, was designed to provide 90% of the annual space heating and 60% of domestic hot water (DHW) for the 52 individual dwellings located within this North American subdivision. Two 120m^3 un-pressurised epoxy-lined cylindrical steel water tanks, and pumps and controls comprise the SSTS which, through the use of internal baffles, encourage stratified thermal storage that manage the peaks and troughs of daily thermal demand. To extend this capacity and ensure minimal demand for higher exergy fossil fuel consumption, a long-term Borehole Thermal Energy Storage (BTES) has been designed and placed underneath what is now the local park and children's play area.

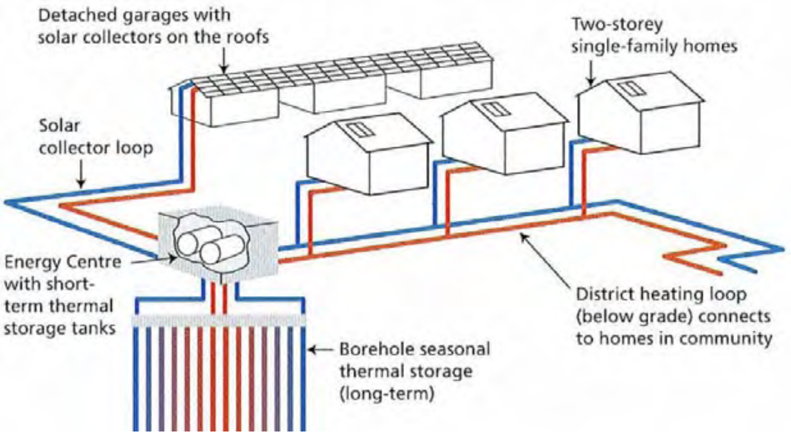


Figure 5: Solar seasonal storage and district heating loop

The plant was designed and built by a consortium of federal and municipal governments and utilities and started operation in June 2007. It is estimated that it will take three years to fully charge the underground storage to the design temperature of 80°C. Performance indications from May 2008 suggest that the solar energy system is performing as designed and that the 90% of the solar fraction will be achieved by year 5.

5. Next meetings and activities

- **Next Annex 49 expert meeting:**

5th Expert meeting: Spring 2009
April 22nd – 23rd, 2009
Location: Maastricht/Heerlen, The Netherlands

- **Further meeting and activity dates:**

    - **Joint Annex 49 – CosteXergy LowEx Conference**, Heerlen, April 21st, 2009, The Netherlands

    - **Final (6th) Annex 49 expert meeting,** Espoo, September 2nd-4th, September 2009, Finland

    - **Final Annex 49 Conference**, Spring 2010, Munich?, Germany

CLOSING REMARKS

The operating agent would like to thank the host institution for the successful and pleasant organisation of the meeting and for allowing the meeting to take place there, as well as the participants for their active commitment and constructive input in Annex 49.

Items to be considered by the ExCo:

- Letters of national participation are still missing from Austria, Denmark, Japan, and Sweden.
- Nominate an ExCo member for mid-term report review
- Guest or possible new participants form China and Turkey declared interest in joining Annex 49. Iceland would also be an interest candidate to collaborate with Annex 49.

APPENDIX I:
WORKSHOP PROGRAMME “DISTRICT ENERGY FUTURES”

An event hosted by the IEA District Heating & Cooling (DHC/CHP) programme in co-operation with Annex 49 of the IEA Energy Conservation in Buildings and Community Systems

Friday, August 29, 2008 Reykjavik
Venue: University Square (Háskólatorg) HT 101 (round room)

08.30-08.45	Registration and coffee/tea	
08.45-08.50	Welcome	Robin Wiltshire
08.50-09.10	Our Geothermal Future	Össur Skarphedinsson (Icelandic Minister of Industry, Energy and Tourism)
09.10-09.30	Future Global Potential Energy Savings with District Heating	Sven Werner
Session I: LOW EXERGY SYSTEMS. Chairman: Gudni Johannesson ECBCS, Annex 49		
09.30-09.55	What is a low exergy system?	Dietrich Schmidt, Annex 49 OA
09.55-10.20	District energy as a low exergy concept	Robin Wiltshire
10.20-10.45	Very low temperature systems for DH	Ken Church Annex 49
10.45-11.00	BREAK	
11.00-11.25	Building systems to suit low ex	Gudni Johannesson Annex 49
11.25-12.00	A low exergy DH case study	Peter Op ‘t Veld Annex 49
12.00-12.30	Discussion and Chairman’s summary	
12.30-13.30	LUNCH	
Session II: DISTRICT ENERGY IN FUTURE BUILDINGS Chairman: Chris Snoek DHC		
13.30-13.55	Buildings energy profiles; primary energy efficiency for future communities	Rolf Ulseth
13.55-14.20	Annex IX, Area 6: District Energy in Future Buildings: Interaction Between District Energy and Future Buildings That Have Storage and Intermittent Surplus Energy	Tom Onno, contractor
14.20-14.45	Annex IX Area 5 Renewable Energy Sources for DES: District Heating for Energy Efficient Building Areas	Kari Sipilä, contractor
14.45-15.00	BREAK	
15.00-15.25	Implementing the UK code for Sustainable homes	Jonathan Williams Antonio Aguilo-Rullan
15.25-15.50	Futuristic current district heating case study(ies): Okotoks	Chris Snoek
15.50-16.30	Discussion and Chairman’s summary	
16.30	CLOSE + COCKTAIL	

APPENDIX II: LIST OF PARTICIPANTS

Austria	Andreas Müller Vienna University of Technology, Institute of Power Systems and Energy Gusshausstraße, 25-29 /373-2 A-1040 Vienna, AUSTRIA	Phone: +43 1 58801 373... Fax: +43 1 58801 37397 E-mail: mueller @eeg.tuwien.ac.at
Canada	Ken Church Sustainable Buildings & Communities/Natural Resources Canada 1Hannel Drive Ontario K1A 1M1, CANADA	Phone: +1 613 947 8952 Fax: +1 613 947 0291 E-mail: kchurch@nrcan.gc.ca
Finland	Mia Ala-Juusela VTT P.O. Box 1000 FIN - 02044, VTT FINLAND	Phone: +358 2 072 26947 Fax: +358 2 072 27027 E-mail: mia.ala-juusela@vtt.fi
Finland	Pekka Tuominen VTT P.O. Box 1000 FIN - 02044, VTT FINLAND	Phone: +358 4073 455 80 Fax: E-mail: pekka.tuominen@vtt.fi
Germany	Andreas Kress Climate Alliance Galvanistr. 28, 60486, Frankfurt, GERMANY	Phone: +49 69 7171 3933 Fax: E-mail: a.Kress @klimabuendnis.org
Germany	Dietrich Schmidt Fraunhofer-Institute for Building Physics Gottschalkstrasse 28a DE - 34127 Kassel, GERMANY	Phone: +49 561 804 1871 Fax: +49 561 804 3187 E-mail: dietrich.schmidt @ibp.fraunhofer.de
Germany	Christina Sager Fraunhofer-Institute for Building Physics Gottschalkstrasse 28a DE - 34127 Kassel, GERMANY	Phone: +49 561 804 1874 Fax: +49 561 804 3187 E-mail: christina.sager @ibp.fraunhofer.de
Germany	Herena Torío Fraunhofer-Institute for Building Physics Gottschalkstrasse 28a DE - 34127 Kassel, GERMANY	Phone: +49 561 804 1871 Fax: +49 561 804 3187 E-mail: herena.torio @ibp.fraunhofer.de

Italy	Michele De Carli Dipartimento di Fisica Tecnica University of Padova Via Venezia 1 I - 35131 Padova, ITALY	Phone: +39 049827 6882 Fax: +39 049827 6896 E-mail: michele.decarli@unipd.it
Japan	Masanori Shukuya Musashi Institute of Technology 1-3-1 Ushikubo-Nishi, Tsuzuki-ku 224-0015 Yokohama, JAPAN	Phone: +81-45-910-2552 Fax: +81-45-910-2553 E-mail: shukuya@yc.musashi-tech.ac.jp
Japan	Itaru Takahashi Tokai University 1117 Kitakaname 259-1292, Hiratsuka, JAPAN	Phone: +81-463-58-1211 (ext.4239) Fax: +81-463-50-2024 E-mail: itaru@keyaki.cc.u-tokai.ac.jp
Poland	Zygmunt Wiercinski University of Warmia and Mazury, Chair of Environmental Engineering Jana Heweliusza, 4 10-724, Olsztyn, POLAND	Phone: +48 89 523 4756 Fax: +48 89 523 4760 E-mail: zygmunt.wiercinski@uwm.edu.pl
Poland	Zbigniew Malolepszy University of Silesia Bedzinska 60 41-200 Sosnowiec, POLAND	Phone: +48 32 2915 865 Fax: E-mail: malol@us.edu.pl
Slovenia	Saso Medved University of Ljubljana Askerceva 6 1000, Ljubljana, SLOVENIA	Phone: +38 641 99 0217 Fax: E-mail: saso.medved@fs.uni-li.si
Sweden	Marco Molinari KTH Building Technology Brinellvägen 34 SE - 10044 Stockholm, SWEDEN	Phone: +46 8 595 3073 Fax: +46 8 411 8432 E-mail: marco.molinari@byv.kth.se
Sweden	Gudni Jóhannesson KTH Building Technology Brinellvägen 34 SE - 10044 Stockholm, SWEDEN	Phone: +46 8 790 8670 Fax: +46 8 411 8432 E-mail: gudni.Jóhannesson@byv.kth.se

Switzerland	Forrest Meggers ETH Zürich, Chair of building systems Wolfgang-Pauli-str. 15 HIL E 15.1 8093, Zürich, SWITZERLAND	Phone: +41-44-633-2860 Fax: E-mail: meggers @hbt.arch.ethz.ch
Switzerland	Petra Karlström Basler & Hofmann, AG Forchstr., 395 CH - 8032 Zürich, SWITZERLAND	Phone: +41 44 387 1338 Fax: +41 44 387 1100 E-mail: petra.karlstroem@bhz.ch
The Netherlands	Peter Op´t Veld Cauberg-Huygen R.I. B.V. PO Box 480 NL - 6200 AL Maastricht, The NETHERLANDS	Phone: +31 43 346 7842 Fax: +31 43 347 6347 E-mail: p.optveld@chri.nl
The Netherlands	Elisa Boelman Delft University of Technology Faculty of Technical Natural Sciences and Architecture, Berlageweg 1, NL – 2600 GA Delft, The NETHERLANDS	Phone: +31-15-278-3386 Fax: +31-15-278-4178 E-mail: e.boelman @tudelft.nl
The Netherlands	Paul Ramsak SenterNovem Energy Research Team P.O. Box 17 6130 AA Sittard, the NETHERLANDS	Phone: +31 46 420 2275 Fax: +31 46 452 8260 E-mail: p.ramsak @senternovem.nl
USA	Dave Solberg HVAC Systems Technology Inc. 5939 Clinton Avenue 55419 Minneapolis, USA	Phone: +1 612 869 6052 Cell: +1 612 770 5405 Fax: + E-mail: dwsolberg @hvacsystemstechnology.com

Anhang F

Protokoll des Meetings in Enschede 2009

Detailed agenda for the meeting in January

13th of January

Outcome: First draft results from each country

08:30-09:00	Welcome by Elisa Boelman and Bram Entrop	Horst T415 (number 20)
09:00-11:00	Presentation of each participant's background	Horst T415 (number 20)
11:00-12:00	Setup for the paper according to Annex 49	Horst T415 (number 20)
12:15-13:00	Lunch (at one's own expense)	Horst canteen (number 20)
13:00-14:00	Literature review	Horst T415 (number 20)
14:00-15:00	Methodology	Horst T415 (number 20)
15:00-16:00	Presentation and discussion of "region specific object of research"	Horst T415 (number 20)
16:00-17:45	Individual working phase	Horst T415 (number 20)
18:00-20:00	COSTeXergy dinner	Restaurant "Faculty club" at campus (number 42)

14th of January

Outcome: First draft results from each country

08:30-10:00	Discussion and substantiating results	Horst T415 (number 20)
10:00-11:00	Comparing results from different regions	Horst T415 (number 20)
11:00-12:15	Deriving draft conclusions	Horst T415 (number 20)
12:15-13:00	Lunch (at one's own expense)	Horst canteen (number 20)
13:00-15:00	Putting results, draft conclusions into the paper structure	Horst T415 (number 20)
15:00-16:30	Describing results and comparison between regions with first draft text elements	Horst T415 (number 20)
16:30-17:00	Transport to brewery	Horst parking lot 2
17:00-19:30	Guided-tour with the department of Construction Management and Engineering (costs €10,- per person)	Brewery of "Grolsch" in Enschede
19:00-21:00	Dinner (at one's own expense)	Restaurant "De Fusting" in Enschede

15th of January

Outcome: First draft of a paper for Annex 49

08:30-10:00	Describing results and conclusions	Horst T415 (number 20)
10:00-12:15	Reflection on the setup for the paper	Horst T415 (number 20)
12:15-13:00	Lunch (at one's own expense)	Horst canteen (number 20)
13:00-15:00	Completing the paper	Horst T415 (number 20)
15:00-16:30	Summary and conclusions	Horst T415 (number 20)
16:30-17:45	Future research activities	Horst T415 (number 20)
18:00-20:00	Dinner (at one's own expense)	Multiple possibilities, like "Mensa", "De Fusting" or "Faculty club"

Coffee and tea will be provided during the day. Room T415 in the Horst Tower is being reserved from 8:00 till 18:00. At 18:00 the building will be officially closed. Internet and beamer are available, but please bring your own laptop with you.

Accommodation

There is a hotel at the campus, building number 44, which offers low priced rooms of a rather good quality. By using http://www.drienerburght.nl/index.php?id=44&L=2 you can make online reservations.

Furthermore, there is a low priced accommodation called Logica (less quality but not poor), building number 65. By using http://www.drienerburght.nl/index.php?id=92&L=2 you can make online reservations.

Anhang G

Protokoll des Meetings in Herleen 2009

Annex 49
Low Exergy Systems for High-Performance
Buildings and Communities

ECBCS Annex 49: *Low Exergy Systems for High-Performance Buildings and Communities*

Internal Minutes of the Fourth Working Phase Meeting
April 22nd and 23rd, 2009
Maastricht, the Netherlands

1. AGENDA OVERVIEW

April 22th

Welcome
Introduction of meeting participants
Objectives and structure of the meeting

Status of the Annex 49

Presentations and discussion of working program for Annex 49 (divided by subtasks)

Workshop: “burning themes”

April 23th

Presentations and discussion of working program for Annex 49 (divided by subtasks)

Discussion in working groups

Plenum

Closing

2. RESUME OF THINGS TO DO FOR NEXT MEETING

Letters of national participation (signature from Participant, KTH, and ExCo meeting	Sweden
Prepare final drafts for chapters of final guidebook	**ALL**

2.1. Résumé of things to do for the deliverables

Deliv. No.	WHAT	WHO	UNTIL WHEN?
D4.1	Input from Uni Heerlen on Exergy training houses – Summary including the use of the exergy approach (in terms of strategy) in the designt of the training houses	Peter	Summary for Newsletter
D2	B3 - Include exergy figures for community case studies in the mid term report - Peter will send around what is necessary for getting simple exergy figures on the case studies included by now on the report	Peter	asap
	C1 -Include exergy figures for building case studies in the mid term report -	Marco	asap
C1.6	Résumé from Hanifs thesis – Paper on TABs for ELCAS + analysis from Padova from existing building	Marco	ELCAS
C1.7	Hanifs thesis – by now document collected	Marco	asap
A5.2	Supply papers from Twente to A49 group	Elisa	OK
B3.3	Review Cascadia tool and might apply it to community case studies	Paola?	Next meeting?
B3.2/B3.3	Detailed exergy analysis for Minewater project from monitoring data	Peter	Next meeting?
C1.1	Ask Dirk Müller for the report (in German)	Herena	Asap
C1.5	Ask Dirk Müller for the report (in German)	Herena	asap
C1.5	Supply dissertation about PCM form KTH to A49	Marco	asap
C1.5	Input from A44 about PCM – finishing now	Peter	asap

3. CONTENTS OF THE FINAL REPORT

CHAPTER	CONTENTS		FROM DELIVERABLES…	WHO
0 Intro	0	Introduction to the new holistic approach of Annex 49: Supply – Demand matching Include comments from Gudni regarding the low exergy approach Refer to exergy of thermal comfort as motivation	B2,	Dietrich
I Analysis	1	Procedures for exergy-based design and performance analysis Fundamentals for performing exergy analysis	*(Input from A4.2, A4.3, B3.1, C4.2)* → **A2.1, A2.2**	Sabine (Adriana)
	2	Mathematical Models for exergy-based design and performance analysis Models and equations for calculating exergy of thermal comfort will be included here	*(Input from A4.2, A4.3, B3.1, C4.2)* → **A3.1, A3.2** A6.1, A6.2, A6.3	Herena (Adriana)

	3	Description/Compendium of tools for exergy-based design and performance analysis	*(Input from A4.2, A4.3, B3.1, C4.2)* → **A4.1**	Forrest (Adriana)
III Examples of analysis of the exergy flow and cost effectiveness in diffrenent systems	4	Examples calculation of thermal comfort: results from Shukuya´s work Results from exergy analysis	A6.1, A6.2, A6.3	Shukuya
	5	Examples of exergy analysis for different systems (PCM, TAB, capilary tubes,RE,…) at building level	C1.1 – C1.7, C2.1	Marco and Gudni
	6	Examples of exergy analysis for different systems (,…) at community level	B1.1, B1.2, B2.1	Peter
	7	Cost-effectiveness of LowEx solutions	A5.1, A5.2	Mia
IV Optimization strategies and Best practice examples	8	(Integral) Optimization possibilities for buildings/ communities, retrofitting and control	*(Input from B3.2, C3.1)* → A1.1	Michele
	9	Collection of best practice examples for new and retrofit technologies for community supply structures and buildings	B3.3, C3.2	Chris
V LowEx categories and pre-normative proposals	10	Categories/Definition LowEx buildings/ communities/ supply structures	A7.1	Mia
	11	Proposals for Regulations on the topic Pre-normative compendium – input from Gudni	*(Input from A7.1)* → **A8**	Sabine

Discussion:

- Final report (Subtask A – chapter I, Analysis) structured as a reference for future work on the exergy analysis on buildings
- Divide subchapters among the participants: **ALL CHAPTERS READY BY end of November 2009 – Drafts by September 2009 (next meeting)**
- Do a table of contents (Mia and Herena): asap
- **AUDIENCE for the guidebook: more oriented to scientific audience** (and to be a reference for future exergy analysis) instead of just a divulgative level for decisions makers
- Final report full version: 300-400 pages
- Printable summary of full version (similar to Annex 37)

- Include in the introduction (in subchapters) the scope and definitions for community scales - (10-20 pages)
- Move the chapter on thermal comfort after the analysis of the energy systems
- Merge Optimization strategies with best practice examples (chapter VI in the updated table above)
- Include a separate section about exergy analysis on the template for technologies (or at least on the case studies description and presentation)

4. Status of the Annex 49 working phase

MID TERM REPORT (to do ASAP):

- Exergy related statements and figures (even if simple) for Community/Building case studies need to be included.
- Try to pinpoint benefits of exergy analysis on a community scale by simple calculations

Discussions:

- Mismatching methodologies – case studies: our own tools and methods are not used in the case studies
- Definition of the objective of the Annex 49: show the benefits of exergy analysis (but limited to exergy analysis without any other footprints)? Or exergy as a concept?
- Difference between LowEx STRATEGY (principles) and ANALYSIS (numeric)
- For the cost analysis the exergy approach does not necessarily need to be calculated in terms of exergy as such

4.1. Status of the Annex 49 by Subtasks

4.1.1. Subtask A: Exergy Analysis Methodologies

(*Mia-Ala Juusela, VTT, Finland*)

Milestones/Tasks		Deliverables			Partici-pants	Man-months	Scheduled/ Ready
A1	System optimisation strategies	A1.1	Integral optimisation strategies (building + supply structure) ------ *Based on B3.2 and C3.1* *B3.2– supply structures (Subtask B)* *C3.1 – building size (Subtask C)*	**IWR**	FI AU IT-P[1] USA ------- SE CA	1	First draft: May 1, 2007 (Padova)
A2	Procedures for design and performance analysis **REVIEWER: F.Meggers**	A2.1	Report of procedures for exergy-based design and performance analysis: **Simplified: Excel-based**	**IWR**	GER-K[2] FI USA	1	Final version on work
		A2.2	Report of procedures for exergy-based design and performance analysis: **Dynamic analysis**	**IWR**	NL (Sabine)[3]		Paper soon
A3	Models for design and performance analysis **REVIEWER: F.Meggers**	A3.1	Report/Compendium of the mathematical models for exergy-based design and performance analysis: **Simplified: Excel-based**	**IWR**	GER-K SE FI USA	1 3	Final version in place
		A3.2	Report/Compendium of the mathematical models for exergy-based design and performance analysis: **Dynamic analysis**	**IWR**	NL (Sabine)		Paper soon

---

[1] P - Padova
[2] K- Kassel
[3] B – Berlin

A4	Tools for design and performance analysis	A4.1	Compendium of the tools for exergy-based design and performance analysis *Including B3.1 and C4.2* *B3.1 – supply structures (Subtask B)* *C4.2 – building size (Subtask C)*	**IWR**	GER-K (Newsletter) (CH)		End of Annex May 31, 2009
		A4.2	Development of simplified Excel-based tool	**TOOL**	GER-K		End of Annex May 31, 2009
			A4.2.1 Community level	**TOOL**	FI AU		
			A4.2.2 Building level	**TOOL**	GER-K		Final version in place
			Manual for the tool	**IWR**			
		A4.3	Development of dynamic analysis tool	**TOOL**	GER-B		End of Annex May 31, 2009
			A4.3.1 Community level	**TOOL**	IT – M[4] (P)		
			A4.3.2 Building level	**TOOL**	GER-B		
			Manual for the tool	**IWR**			
A5	Life cycle economical impacts – Analysis of cost effectiveness of different LowEx systems **REVIEWER: G.Johannesson**	A5.1	Report on cost effective solutions for LowEx systems and life-cycle exergy analysis *Projects:* ***(3TU Project)*** - *Cost effective solutions* - *Financing schemes* ***(Symphony concept)*** *Cost effectiveness*	**IWR** **CP** **both)**	FI © **NL** SE AU (exergy price)	2	**Paper from STSM**
		A5.2	Report on possible financing schemes ***(3TU Project)*** - *Cost effective solutions* - *Financing schemes* ***(Symphony concept)*** *Cost effectiveness*	**IWR**	FI © **NL** SE PL-NO	10	**Paper from STSM**
A6	LowEx systems and thermal comfort	A6.2	Manual or review article on calculation of human body exergy balance	**IWR**	**JP** DK FIN		Done
		A6.3	Report clarifying exergetic conditions for TC on hot humid regions	**JP/**	JP		Done

---

[4] M – Milan: (P) – Paola Caputo
(A) – Adriana Angelotti

A7	(Unambiguous) Definition of LowEx Systems **REVIEWER: M.Molinari/ D.Solberg**	A7.1	Definition (grades/categories) of LowEx system components Definition (grades/categories) of LowEx buildings applied to all building types	**IWR**	**NL-Delft** FI SE GER-B IT USA Kassel (Benchmark)	1 1	Discussed in the "burning themes"
A8	Pre-normative proposals **REVIEWER: Gudni Johannesson**	A8.1	Based on CEN exergy assessment		NL (Sabine) (Input from Herena, Adriana and Zygmunt)		End June 09

A8:
- Dave will submit a report on a proposal for a standard using exergy figures in the USA -> ready for tomorrow
- Define efficiency figures for standards: limit the total exergy input in the building?
- Leave out the embedded energy/exergy
- Proposal should come from the A49 tool
- Check again proposal from Favrat for Geneva canton + tax suggestion from Szargut

PRESENTATIONS:

Sabine Jansen (TU Delft): "Dynamic exergy analysis"
Procedures for dynamic exergy analysis on buildings were introduced, particularly referred to the cooling demand. A new equation module as "add-on" for TRNSYS was presented.

Adriana Angelotti (Politecnico di Milano): "dynamic exergy analysis of an air source heat pump"
Discrepancies between dynamic and steady state exergy analysis had been further investigated.

Masanori Shukuya (Tokyo City University): A6 – "exergy balance of human body - thermal comfort"
The content of the final draft deliverable A6 was briefly presented.

Marcel Schweiker (Tokyo City University): "occupant behaviour within the residential built environment"
Results from analysis of the behaviour of different users on the HVAC systems were presented. A great effect of occupant behaviour on the final exergy consumption with AC units could be identified.

4.1.2. Subtask B: Exergy efficient community supply structures (*Chris Snoek, NRC, Canada; Peter Opt´Veld, CHRI, the Netherlands*)

	Milestones/Tasks	Deliverables			Partici-pants	Man-months	Scheduled/ Ready
B1	Innovative types of technology for LowEx energy supply structures **REVIEWER: P.Opt´Veld**	B1.1	Report on exergy-based optimisation of low temperature DHC	**IWR**	NL SE	1	Soon
		B1.2	Report on exergy-based design and performance of re-mining project Possible demo-project	**IWR**	NL		soon

B2	Innovative types of technology for LowEx energy supply structures – RE based	B2.1	Review article on the use of RE from the exergetic point of view • Solar thermal/PV • Ground heating/ cooling • Use of heat pumps	**IWR**	**JP** IT- P IT- M(A) SE GER-K	1	OK
B3	Advanced system concepts for distribution, generation and storage of energy/ exergy	B3.1	Tool for comparing/ evaluating/choosing different energy supply systems (community level) **REVIEWER: Paola?**	**TOOL**	CA©© IT-M(P)	12-18	Final version in place
			Manual for the tool	**IWR**	CA©		
		B3.2	Report on optimisation possibilities based on exergy analysis of the systems: Development of advanced system concepts **REVIEWER: P.Opt´Veld**	**IWR**	CA© + partners		Final version in place
		B3.3	Collection of best practice examples for new and retrofit forms of technology for community supply structures	**IWR**	NL © SE ALL	1	Asap – include exergy analysis
B4		B4.1	Concepts on community scales		NL+ask Paola!		Asap

B1.1- report on possibilities of low temperature dhc. General guildelines, desing strategies. Addressing the use of low temperature systems in combination with DH networks. Relation to fourth generation of DHC (WS in Reykjavik) – 5-6 pages

B2.1 – article from Sweden (Alberto and Gudni) + Review paper
Sweden: use SEPE Tool for analysing DHC systems

B3 – review of the tool (Paola?) and use it for analysis of community case studies

B3.2 – for the final report: show exergy analysis on case studies

B3.3 - Add to the template a part on the relation of the case study with the exergy approach. Show the relation of the case studies with the exergy approach (Highlights of the case studies) Minneapolis/Wolfhagen/Oberzwehren/
Detailed exergy analysis (e.g. steady state of monitoring data) for the Minewater will be done.

B4 – ask Paola /Chris for possible input to this deliverable. Try to define (even first simplified definition) what a **LowEx community** is. Might be **more a picture than an extensive report**.

The definition of the community itself (rather controversial) does not need to be done in such detail. Write at the beginning of the report (Introduction/Scope) what is it exactly meant here by community (discussed and agreed within the group referring to the work in Annex 43 and 51).

In the presentation from Ronald Rovers on the LowEx Conference (Heerlen) there were good hints on how and what for to use the exergy principles on community projects (Related to ESX).

CASE STUDIES:

- Okotoks, Alberta (CA); complete
- Alderney, Darthmouth (CA); complete
- Toronto, Ontario (CA); ongoing
- St Paul, Minnesota (USA)
- Parma (IT); in planning
- Heerlen (NL); complete - monitoring
- Avantis (NL);

- Oberzwehren (GER); in planning

4.1.3. Subtask C: Exergy efficient building technology (*Gudni Jóhannesson, KTH, Sweden*)

	Milestones/ Tasks	Deliverables			Partici-pants	Man-months	Scheduled/ Ready
C1	Innovative types of technology for low exergy heating and cooling	C1.1	Report on the exergetic performance of capillary tubes	**JP/ CP IWR**	**GER-B** SE		Cases studies have been collected – exergy analysis needs to be included!!! (may one of the tools available be used for that…) asap
		C1.2	Report on the exergetic performance of earth coupled cooling systems/beams	**JP**	**SE** IT-P IT-M(a)	1	
		C1.3	Report on LowEx fans	**IWR**	SE	1	
		C1.4	- Report on hybrid ventilation systems - RESHIVENT	**JP/ CP IWR**	**NL** GER-B??		
		C1.5	Report on exergetic performance of PCM´s	**JP/ CP IWR**	**GER-B** SE NL	1	
		C1.6	Report on exergetic performance of TAB´s	**IWR - JP**	**SE** IT-P	1	
		C1.7	Report on Symphony & Thermodeck projects	**IWR**	**SE**	1	
		C1.8	Recovery from wastewater		Swiss		
		C1.9	Novel evaporative chiller		China		
C2	Innovative control concepts and strategies for a demand controlled exergy supply	C2.1	Report on exergetic analysis of intermittent/continuous operation mode of the systems ▪ Centralised ▪ Decentralised	**JP**	**IT-P** IT-P DK		1. March 09 30 June 08
C3	Advanced system concepts and solutions including exergy storage systems	C3.1	Report on optimisation possibilities based on exergy analysis of the systems: Development of advanced system concepts	**IWR**	SE GER-B	1	1. Dec 08
		C3.2	Collection of best practice examples for new and retrofit technology for building level Demo projects	**IWR**	SE© external organisa-tion ALL		6-7 cases have been collected – report benefits from exergy on them
C4	Advanced system concepts for **retrofitting** energy/exergy	C4.1	Report on exergy analysis of different systems applied to retrofitting of	**IWR**	Input:		30 Sept. 08

	Annex 46 Annex 50 SHC Task 37		buildings		IT-P		
		C4.2	Tool (decision tree) for choosing system configurations (building level)	**TOOL**	CH (Petra)		Tool done – exergy will be included
			Manual for the tool	**IWR**			
C5	Light structures for warm climates	C5.1	Technology transfer between countries Light structures for warm climates	**JP**	JP IT SE		Draft: 01.July.08 30 May 09

- Some technologies will be analysed with one of the tools available (DPV, SEPE…). Results form exergy figures will be given.

- Summary on the technologies and the results from simple analysis for Chapter III-5

PRESENTATIONS:

Forrest Meggers (ETH, Zürich): "Integrated LowEx building components"

RESULTS OF EXERGY OPTIMIZATION OF WASTEWATER HEAT RECOVERY

3 Conference papers on the system and concept have been published. A journal paper with final results will be published, integrated with the heat pump performance analysis.

WATER WALL SYSTEM

The innovative system was investigated in combination with heat pump system: 20% better performance for Zürich climate. A model is available. Results will be published.

DPV

The DPV tool developed at the ETH for architects was presented – final review and corrections in exergy calculation procedure might be required but is almost ready. Schüco is using it. It is an open source, that can be found under: www.keoto.org. A report for the ExCo meeting in June 2009 will be sent to Dietrich.

NON-SUSTAINABILTY DIAGRAMM

A diagram showing possible and necessary development directions for increasing sustainability in the built environment was introduced

Pier Giorgio Cesaratto (University Padova): "C2.1 - Report on exergetic analysis of intermittent/continuous operation mode of centralized building systems"

- Results from analysis: Continuous operation, due to the higher efficiency of the boiler, leads to reducing gas consumption in about 28%.

Petra Benz Karlstöm (Basler & Hofmann, Zürich): "Deliverable C 4.2 - Decision tool for energy efficient cooling for building retrofit"

The tool developed for choosing different cooling systems depending on the building options was presented. An overview of the main cooling systems included on the tool was also give. The tool will be available on the web, for choosing different cooling systems depending on the building options.

Discussion:

- Exergy is not mentioned, even if calculations are planed to be included in combination with SEPE

Marco Molinari (KTH, Stockholm): “Analysis of coupled systems with SEPE”

The new developed Excel-based tool for steady state exergy analysis on a system component level was presented. A Sankey- diagram for the exergy flows will be added.

Petra Benz Karlstöm (Basler & Hofmann, Zürich): “First comparision of cooling systems based on calculations with SEPE”

First results from the evaluation of two different systems with SEPE were shown. The systems analyzed were a groundwater and conventional chiller coupled with chilled ceiling.

WORKSHOP – BURNING THEMES:

A – METHODOLOGIES: DYNAMIC EXERGY ANALYSIS

Definition of the reference environment/temperature -

The main outcomes from the discussion in the workshop on subtask A were:

- Sabine+Forrest+Mia: resume for the end of June on why to take outdoor reference air (dynamic) as temperature
- Relate the definition of the reference temperature to the community scale stating that the focus, even on community level, lies on heating and cooling of buildings

B – COMMUNITIES:

Representation and added value of exergy figures for communities –

The main outcomes from the discussion in the workshop on subtask B were:

- LowEx Highlights
- Matching quality levels supply-demand: arrows approach from Mia for classifying sources and demands (In two columns comparable to each other)
- PER (or renewable energy ratio?)/Exergy efficiency graph from Peter for classifying the different supply options (INPUT FROM PETER IS REQUIRED)

C – BUILDINGS:

- Look for a representation possibilities for exergy results and figures for community systems (INPUT FROM MARCO IS REQUIRED)

4.1.4. Subtask D: Knowledge transfer, dissemination
(*Dietrich Schmidt, Fraunhofer IBP, Germany*)

	Milestones/Tasks	Deliverables			Partici-pants	Man-months	Scheduled/ Ready
D1	Dissemination Activities	D1.1	Industry workshops + Proceedings of workshops	**IWR**	ALL	0.5 per WS	
		D1.2	IEA Future Building Forum “Think Tank”		GER	1	Postponed (end of annex?)
		D1.3	LowExNet workshops				
		D1.4	Website	**Home-page**	GER-K ©	1	updated
		D1.5	Brochure	**IWR**	GER-K ©	0,5	01.03.2007
D2	Mid-term Report	D2.1	State-of the Art Report	**EWR**	NL+deliv.		30.09.08
		D2.2	Newsletters (biannual)	**IWR**	GER-K ©	0.5 per WS	

D3	Design Guidebook	D3.1	Design guide	**EWR**	**GER-K** © Edition ALL	3	
		D3.2	Full version	**IWR**	ALL	4	30.10.2009
		D3.3	Summary	**EWR**	ALL	2	
D4	Training modules (NL)						Draft for mid-term rep. Oct. 08

D4: Peter will provide a draft for the final report.

6th NEWSLETTER: deadline – 1st August (send around nr. Of words for each tool)

- Description of the tools (Annex 49 tool, DPV, SEPE, Cascadia, exergy – for human body exergy calculations – Toshiya, decision tree (from Petra)): **state usability** (when to use which of them).

7th NEWSLETTER:

- Design guidebook and final outcome of the Annex 49

FINAL CONFERENCE ANNEX 49 – Autumn 2010

Place:	Berlin/Munich 2 day conference
Target audience:	Political level / Funding organisations /EU / IEA Industry exhibitions? – Poster project exhibitions – young researchers Workshop (similar to Heerlen) >200 people
Topic:	Annex 49 work Community level New innovative technology (Sugg. From Peter): **“Integrated system approach for the built environment”**
Organisers team:	Dietrich/ Peter/
To be invited:	Dietrich(UAI?)/ Peter (India, / Masanori/ Takao/ Gudni (Algeria)/ Mia (Mali)/ Bjarne (South America)/ Petra (Australia, ERACobuild)

Series of conferences from possible “knowledge centre” but with specific topics dealt with scientific depth
Draft for the ExCo meeting in Maastricht (2009)

- Raise interest in North America and Asia

NEXT MEETINGS

Final Annex 49 “GUIDEBOOK” Meeting	**6th working meeting, Finland** **2-4th September Autumn 2009** Place: Espoo/Helsinki Finland **OBJECTIVE: finalize contents for final GUIDEBOOK**
Annex 49 Final Conference	**Autumn 2010, Munich/Berlin Germany**

4.2. Closing summary

The status of the deliverables related to the final report was checked. The structure and the rough contents of the final guidebook were also discussed.
The operating agent warmly thanked the host institution for the successful and pleasant organisation of the meeting, and for giving it the chance to take place there.

For these meeting minutes:
Herena Torío and Dietrich Schmidt Kassel, Germany, 18th of May 2009.

APPENDIX I: LIST OF PARTICIPANTS

Canada	Chris Snoek Sustainable Buildings & Communities/Natural Resources Canada 1Hannel Drive Ontario K1A 1M1, CANADA	Phone: Fax: E-mail: cwsnoek@sympatico.ca
Finland	Mia Ala-Juusela VTT P.O. Box 1000 FIN - 02044, VTT FINLAND	Phone: +358 2 072 26947 Fax: +358 2 072 27027 E-mail: mia.ala-juusela@vtt.fi
Germany	Dietrich Schmidt Fraunhofer-Institute for Building Physics Gottschalkstrasse 28a DE - 34127 Kassel, GERMANY	Phone: +49 561 804 1871 Fax: +49 561 804 3187 E-mail: dietrich.schmidt@ibp.fraunhofer.de
Germany	Herena Torío Fraunhofer-Institute for Building Physics Gottschalkstrasse 28a DE - 34127 Kassel, GERMANY	Phone: +49 561 804 1834 Fax: +49 561 804 3187 E-mail: herena.torio@ibp.fraunhofer.de
Italy	Pier Giorgio Cesaratto Dipartimento di Fisica Tecnica University of Padova Via Venezia 1 I - 35131 Padova, ITALY	Phone: Fax: E-mail:
Japan	Masanori Shukuya Tokyo City University 1-3-1 Ushikubo-Nishi, Tsuzuki-ku 224-0015 Yokohama, JAPAN	Phone: +81-45-910-2552 Fax: +81-45-910-2553 E-mail: shukuya@yc.musashi-tech.ac.jp
Japan	Hiroyuki Kakoi Nihon Sekkei 6-5-1 Nishi-Shinjuku,Shinjuku-ku 163-1329, Tokyo	Phone: +81-3-5325-7659 Fax: +81-3-5325-8454 E-mail: kakoi-h@nihonsekkei.co.jp
Japan	Marcel Schweiker Tokyo City University 1-3-1 Ushikubo-Nishi, Tsuzuki-ku 224-0015 Yokohama, JAPAN	Phone: Fax: E-mail: marcelschweiker@yahoo.co.jp

Poland	Zygmunt Wiercinski University of Warmia and Mazury, Chair of Environmental Engineering Jana Heweliusza, 4 10-724, Olsztyn, POLAND	Phone: +48 89 523 4756 Fax: +48 89 523 4760 E-mail: zygmunt.wiercinski@uwm.edu.pl
Sweden	Marco Molinari KTH Building Technology Brinellvägen 34 SE - 10044 Stockholm, SWEDEN	Phone: +46 8 595 3073 Fax: +46 8 411 8432 E-mail: marco.molinari@byv.kth.se
Sweden	Gudni Jóhannesson KTH Building Technology Brinellvägen 34 SE - 10044 Stockholm, SWEDEN	Phone: +46 8 790 8670 Fax: +46 8 411 8432 E-mail: gudni.Jóhannesson@byv.kth.se
Switzerland	Forrest Meggers ETH Zürich, Chair of building systems Wolfgang-Pauli-str. 15 HIL E 15.1 8093, Zürich, SWITZERLAND	Phone: +41-44-633-2860 Fax: E-mail: meggers@hbt.arch.ethz.ch
Switzerland	Petra Karlström Basler & Hofmann, AG Forchstr., 395 CH - 8032 Zürich, SWITZERLAND	Phone: +41 44 387 1338 Fax: +41 44 387 1100 E-mail: petra.karlstroem@bhz.ch
The Netherlands	Peter Op´t Veld Cauberg-Huygen R.I. B.V. PO Box 480 NL - 6200 AL Maastricht, The NETHERLANDS	Phone: +31 43 346 7842 Fax: +31 43 347 6347 E-mail: p.optveld@chri.nl
The Netherlands	Sabine Jansen Delft University of Technology Faculty of Technical Natural Sciences and Architecture, Berlageweg 1, NL – 2600 GA Delft, The NETHERLANDS	Phone: + Fax: +31-15-278-4178 E-mail: S.C.Jansen@tudelft.nl
The Netherlands	Paul Ramsak SenterNovem Energy Research Team P.O. Box 17 6130 AA Sittard, the NETHERLANDS	Phone: +31 46 420 2275 Fax: +31 46 452 8260 E-mail: p.ramsak@senternovem.nl

USA

Dave Solberg
HVAC Systems Technology Inc.
5939 Clinton Avenue
55419
Minneapolis, USA

Phone: +1 612 869 6052
Cell: +1 612 770 5405
Fax: +
E-mail: dwsolberg
@hvacsystemstechnology.com

Anhang H

Protokoll des Meetings in Espoo 2009

Annex 49

Low Exergy Systems for High-Performance
Buildings and Communities

ECBCS Annex 49: *Low Exergy Systems for High-Performance Buildings and Communities*

Internal Minutes of the Sixth Working Phase Meeting
September 3rd and 4th, 2009
Espoo, Finland

1. AGENDA OVERVIEW

September 3th	Welcome Introduction of meeting participants Objectives and structure of the meeting Status of the Annex 49 Presentations and discussion of chapters for final guidebook by subtasks Workshop: “research results”
September 4th	Workshop: “burning themes” Final Annex 49 Conference Future projects (Annexes) and activities Closing

2. INTRODUCTION and WELCOME

Mia Ala-Juusela gave a very nice welcoming and introduction on the meeting place and surroundings.
Dietrich after warm welcome mentioned the LowEx Symposium, to be held in October in Kassel. He mentioned that the end of the Annex 49 is November 2009 and it will NOT be applied for an extension to the ExCo.

3. CONTENTS OF THE FINAL REPORT

- Final report (Subtask A – chapter I, Analysis) structured as a reference for future work on the exergy analysis on buildings
- Divide subchapters among the participants: **ALL CHAPTERS READY BY end of November 2009**
- **AUDIENCE for the guidebook: more oriented to scientific audience** (and to be a reference for future exergy analysis) instead of just a divulgative level for decisions makers
- Final report full version: 300-400 pages
- Printable summary of full version (similar to Annex 37)

CONTENTS	FROM DELIVERABLES	WHO
Abstract International energy agency LowEx cooperation Focus / aim of Guidebook Project description Annex 37 and Annex 49		
Acknowledgements Energy conservation in buildings and community systems (ECBCS) Acknowledgements participating countries		
1. Introduction 1.1. About Annex 49 1.2. Energy, exergy and environment 1.3. The LowEx Approach – supply and demand matching 1.4. Exergy concept for comfortable buildings	**Peter: additional value of Annex 49 as compared to Annex 37 should be clearly stated** -> could also provide direction for further projects	Dietrich Schmidt
2. Method and models for exergy analysis 2.1. Fundamentals 2.1.1. The reference environment 2.1.2. Exergy balance 2.1.3. Exergy of state and flow (or energy and matter) 2.1.4. Exergy of cooling processes 2.1.5. Dynamic and steady-state exergy analysis in buildings (input from Zygmunt) 2.1.6. Input-output approach	**Input from** Paper by Sabine Jansen on exergy demand calculation B2. Review paper on exergy analysis in buildings	Sabine Jansen (Adriana Angelotti and Shukuya)

2.2. Mathematical models 2.2.1. Human body exergy consumption – Exergy and thermal comfort (input from Shukuya or Toshiya) 2.2.2. Exergy in building systems Room-air Emission Distribution Storage Generation Boiler Solar thermal system Ventilation units 2.2.3. Add –on TRNSYS equations?? (discuss with Sabine) 2.2.4. Exergy in community systems (equations – Cascadia) Dynamic steady state analysis	**Input from** A4.3 Development of dynamic analysis tool- include as appendix the eqs from TRNSYS and Dymola A6.1 Exergy and human comfort A6.2 Manual or review article on calculation of human body exergy balance A6.3 Report clarifying exergetic conditions for TC on hot humid regions B3.1 mathematical models for exergybased design and performance analysis: Simplified: Excel-based **A3.2** Report/Compendium of the mathematical models for exergybased design and performance analysis: Dynamic analysisTool for comparing/ evaluating/choosing different energy supply systems (community level) **A3.1** Report/Compendium of the Paper by Sabine Jansen on exergy demand calculation	(Adriana Angelotti) + input for thermal comfort from Shukuya or Toshiya

3. Tools for exergy analysis (Intro explaining the advantages/disadvantages/which for what purpose…) 3.1. Excel predesign tool 3.2. Architecture design tool DPV 3.3. Tool for exergy analysis in communities - Cascadia 3.4. Component level Excel tool – SEPE 3.5. Tool for exergy of thermal comfort (Toshiya) 3.6. Decision tree for cooling systems	A4.2 Development of simplified Exce lbased tool Screenshot from TRNSYS B3.1 Tool for comparing/ evaluating/choosing different energy supply systems SEPE- C4.2 Tool (decision tree) for choosing system configurations (building level) DPV Tool for exergy of thermal comfort Decission tree for cooling systems from Petra Text for the tools in the Newsletter: for the summary version	Forrest Meggers (Adriana Angelotti)
4. Optimization strategies 4.1. Exergy optimization in thermodynamics (general references, Ahern, Tsatsaronis…) 4.2. Cost effectiveness? 4.3. Buildings – factors to optimize (and develop strategies) including Cost effectiveness?? 4.4. Communities – factors to optimize (and develop strategies) including cost effectiveness?? 4.5. Best practice examples – theoretical idea (based on the results from case studies above) on how could building or communities in the future look like Dave: report on benefits of the exergy approach on a system level for industries (within 30 days)	**Input from** Graph from Dave (will be provided soon) and Minesotta community A1.1 Integral optimisation strategies (building + supply structure) B 3.2 Optimisation strategies based on exergy analysis of the systems: Development of advanced system concepts C3.1Report on optimisation possibilities based on exergy analysis of the systems: Development of advanced system concepts **A5.1** Report on cost effective solutions for LowEx systems ~~and life-cycle exergy analysis~~ – input available from Twente?? Sabine will ask Bram // Input also from Peter from the REmining project *A5.2 Report on possible financing schemes* **B1.1** Report on exergy-based optimisation of low temperature DHC **B3.3** Collection of best practice examples for new and retrofit forms of technology for community supply structures	Michele de Carli Input from Dave – calculations on the Minnesotta community case

5. LowEx Categories (even a first approach or proposal for clustering them, sort of starting up text) 5.1. Benchmarking parameters 5.2. LowEx buildings 5.3. LowEx communities (PER and arrow-diagrams) 5.4. Pre-normative proposals on building level (PER…too weak yet for a community level)-	A7.1 Definition (grades/categories) of LowEx system components Definition (grades/categories) of LowEx buildings applied to all building types **A8** Pre-normative proposals *State clearly benefits and additional value from exergy approach (in an easy level of detail (steady-state) which could be included besides other current approaches: CO2, primary energy….*	Sabine Jansen + Herena Torio – input also from Dietrich and Dave (Paul Ramsak and Sabine Jansen)
6. Application of the exergy approach to building systems 6.1. Building systems 6.2. PCM, TABs… 6.3. Waste heat recovery 6.4. Solar? 6.1.4 Heat pumps?	**C1.1** Report on the exergetic performance of capillary tubes **C1.7** Report on Symphony & Thermodeck projects **C2.1** Report on exergetic analysis of intermittent/continuous operation mode of the systems **C2.1** Report on exergetic analysis of intermittent/continuous operation mode of the systems **C2.1** Report on exergetic analysis of intermittent/continuous operation mode of the systems **Case study from Dave** –semi-conductor (30 days)	Gudni Johanneson and Marco Molinari
7. Application of the exergy approach to community concepts 7.1. Community systems – definition of community, duration curves, types of technologies,… 7.2. Heerlen 7.3. Okotoks 7.4. Alberta 7.5. Oberzwehren 7.6. Parma 7.7. Minnesotta – St. Paul 7.8. from Finland? 7.9. Denmark – Sven Svendsen? (dhw at T<50°C) 7.10. Waalejingen? (NL) 7.11. Switzerland	**B3.3** Community case studes (with PER and arrow diagrams) Alderney/Okotoks/Parma/Heerlen/Oberzwehren **Input from Dave – Minnesotta**	Peter

8. Conclusions The tool for heating and cooling systems Annex 49 and definition System for the future Next Annexes and future work		
9. References A. Participating countries B. Additional information C. Published articles D. List of presentations in scientific events		

Finished
unfinished
no draft

EVENTUALLY THERE WOULD BE SMALL MEETING IN FRANKFURT?
– TO FIX MISSING ISSUES -

3.1. Status of the Annex 49 by Subtasks

3.1.1. Subtask A: Exergy Analysis Methodologies
(*Mia-Ala Juusela, VTT, Finland*)

CHAPTER 2: is almost ok.

- Input from A7.1 (from Elisa) could be included for the input-output approach here

CHAPTER 3: The part on the tools is only editing needed

- Description of the tools are ready
- Should be included a description on how to use them, audience….

CHAPTER 4: Optimization strategies - topic for **burning themes**

- check from the presentation by Piergiorgio whether there are gaps to be covered there

CHAPTER 5: LowEx Categories - topic for **burning themes**

- input from A7.1 is not valid for here
- Sabine did review on exergy in current standard (Geneva and SIA), implicitly regarded in terms of low-temperature heating systems
- Proposal from Sabine and Herena – feedback from Paul and Dietrich
- Input from C1.7 (from Marco) on Symphony and Thermodeck
- Sabine will ask Elisa for input from Twente
- Input from FhG UMSICHT – labelling on “traffic light” exergy fingerprint (Dietrich will contact Dötsch)
- Include example why primary energy analysis might lead to wrong results (CHP thesis from Daniel Kühler)
- Paul: Try to make a CLEAR STATEMENT ON ADDED VALUE OF EXERGY TO THE PRIMARY ENERGY APPROACH
- Dave input for clustering Figure
- **Adriana:** follow the energy approach and try to limit the allowed presumably consumed exergy (monthly-hourly? quasi steady state energy demand calculations) Give **GUIDELINES** on how to do it on a simple way (steady state, seasonal values for temperature,….)

3.1.2. Subtask B: Exergy efficient community supply structures
(*Peter Opt´Veld, CHRI, the Netherlands*)

CHAPTER 4: Optimization strategies

Input **CHAPTER**

- B1.2 – has been done! - B1.1 – input from Oberzwehren	**For CHAPTER 4**
- B2.1 – It was planned to be on a community level but no references were found on that -> building and methodology level The link between community and building level should be covered here -> topic for **burning themes** Peter: Tools or approaches based on heat load duration curves	**Where it fits?**
- 3.2 // 3.3 –fine but do NOT cover mixed generation systems with different sources - 3.2 -> addresses policy developments (on communities) and mapping exergy in energy efficiency	**For CHAPTER 4**
3.4 – community case studies Okotoks Drake landing Heerlen - LINK BETWEEN COST barriers and cost-effectiveness of such optimized community projects (low valued energy pricing, high infrastructure costs…) - Electricity represents still a high contribution to the supply – develop tools for evaluate sustainable electricity production (bio?-cogeneration, which kind of?, PV?...) Parma Oberzwehren 2x Minnesotta (will be provided by Dave in 30 days) Waalejingen? - Peter Op`t Veld (NL) Finland? - Mia Ala-Juusela (Finnland) Denmark - Sven Svendsen? (dhw at T<50°C) Switzerland - Forrest Meggers (Switzerland)	**For CHAPTER 7**

3.1.3. Subtask C: Exergy efficient building technology (*Gudni Jóhannesson, KTH, Sweden*)

Chapter 6:

- Intro on the "appeal" of the exergy approach and general considerations
- Case studies:
    - Thermal insulation; daylighting; solar gains; comfort; thermal inertia
    - LowEx ventilation (incl. fans)
    - Space heating and cooling exergy loads
    - Heat/Cool "generation" systems: solar, hp, pcm, ground coils,
    - Technologies for electricity generation
    - Storage systems
    - Control strategies

3.1.4. Subtask D: Knowledge transfer, dissemination (*Dietrich Schmidt, Fraunhofer IBP, Germany*)

- **6th NEWSLETTER: ready, printed soon**

- **7th NEWSLETTER**: Spring 2010

Design guidebook and final outcome of the Annex 49

FURTHER ITEMS:

Clima 2010 – LowEx Workshop sp

- About 10 papers (at least) from the LowExgroup to fill a session

FUTURE IEA ECBCS Annex

- Large scale community systems analysis
- Annex focused on a technical (systems) content
- Energy supply structures for islands (as example for small "discretised" systems = communities)
- How to evaluate renewable energy sources?
- Extend (deepen) exergy methodology to energy sources and big supply systems (clustering energy sources by potential or value (exergy) instead of renewability
- Concepts for LowEx communities (definition of communities by Chris Snoek) + connection between community and building levels + integration of renewables (focusing on retrofitting or refurbishing existing communities)

COMMUNITY CONCEPTS (with few case studies and including electricity+heating and cooling): Peter and Gudni offered to contribute to the proposal

Proposal for new IEAnnex “Comfort on low energy buildings”- contact Michele for that

- Kick off meeting (and workshop) in Padova might be around the 24-28 of September 2009

FINAL CONFERENCE ANNEX 49 – Autumn 2010

Place:	Munich 2 day conference - 1 day for communities + 1day for buildings?
Target audience:	Political level / Funding organisations /EU / IEA Industry exhibitions? – Poster project exhibitions – young researchers Workshop (similar to Heerlen) >200 people
Topic:	Annex 49 work Community level New innovative technology (Sugg. From Peter): **“Integrated system approach for the built environment”**
Organisers team:	Dietrich/ Peter/ Annex 49 + COST
To be invited:	Dietrich(UAI?)/ Peter (India, / Masanori/ Takao/ Gudni (Algeria)/ Mia (Mali)/ Bjarne (South America)/ Petra (Australia, ERACobuild) ➔ get contact lists (mailing list) from participants to inform wide public on the conference (send to DS) ➔ Invite industry partners to have small exhibition of their problems?
Problems, barriers:	Discussion with the ExCo and the German Country of Economics needed to secure their support.
Aim:	- getting money for future research projects; Dave provide contact to industries interested

4. WORKSHOP: “LATEST RESEARCH RESULTS”

“Influence of intermittent / continuous operation mode on the primary energy demand in buildings” (Pier Giorgio Cesarotto)

Results from dynamic modelling with TRNSYS on the influence of different operation strategies of floor heating and radiator systems were shown. Great primary energy savings could be found with a continuous (or with night setback) operation of the systems.

“Exergy and economics” (Pekka Touminen, Marco Molinari)

Results on economic analysis of different energy supply options were investigated for four different countries. A strong correlation was found between the cost of different energy carriers and their exergy content. A graph showing desired trends for policies and policy makers in order to promote the use of lowEx systems for lowEx applications in buildings was also presented.

“Calculation tool for human body exergy balance” (Toshiya Iwamatsu)
The calculation tool developed at the Tokyo-City University for calculating exergy balance within human body. The original version of this calculation tool was developed by them as a FORTRAN code. It has been recently implemented on an excel spreadsheet.

“Exergy demand calculation” (Sabine Jansen)

The chapter on fundamentals for exergy analysis in buildings was introduced. Further insight was given on a new detailed calculation method for the exergy demand of a building, considering the exergy for heating up ventilation air as that of a mass flow (or quantity of state).

“Passive house exergy analysis” (Zygmunt Wiercinski)

“Minnesotta – approach for exergy analysis on community level” (Dave Solberg)
The approach is based on an assessment of the “exergy desired outputs” and the exergy available from given boundary conditions (“sources”). This available “sources” would be the ideal way of supplying those demands. Comparing the actual exergy input with the left exergy supply that needs to be fed into the system after the available sources have been used, insight can be gain on the level of “inefficiency” or bad exergy used in the system.

5. WORKSHOP: “BURNING THEMES: HOW TO FILL THE GAPS?”

INNOVATIVE TECHNOLOGIES for COMMUNITIES:

- District heating
- Heat pumps
- Low voltage electricity - no feasible cause of high losses
- Domestic hot water supply outside the house
- Chillers running in series– cascading on the production side

LowEX CATEGORIES (mainly for communities):

- Simple scores depending on the exergy performance – “clusters” : tables with technologies classified by matching level (exergy efficiency?), PER diagram
- Clear added value of the exergy approach
- Easy “clustering” for design level

NEXT MEETINGS

- to check the status of final report
- a meeting within the frame of the costexergy meeting in Milan is planed possibly 15-16 Arpil 2010

Annex 49 Final Conference	**Autumn 2010, Munich Germany** **19-21 October 2010**

5.1. Closing summary

The status of the deliverables related to the final report was checked. The structure and the rough contents of the final guidebook were also discussed.
The operating agent warmly thanked the host institution for the successful and pleasant organisation of the meeting, and for giving it the chance to take place there.

For these meeting minutes:

Herena Torío and Dietrich Schmidt Kassel, Germany, 4th of September 2009.

APPENDIX I: LIST OF PARTICIPANTS

Denmark	Bjarne Olesen International Center for Indoor Environment and Energy Technical University of Denmark, Building 402 DK - 2800 Lyngby, DENMARK	Phone: +45 45 25 41 17 Fax: E-mail: bwo@byg.dtu.dk
Finland	Mia Ala-Juusela VTT Technical Research Centre of Finland P.O. Box 1800 FIN - 02044, VTT FINLAND	Phone: +358 2 072 26947 Fax: +358 2 072 27027 E-mail: mia.ala-juusela@vtt.fi
Germany	Dietrich Schmidt Fraunhofer-Institute for Building Physics Gottschalkstrasse 28a DE - 34127 Kassel, GERMANY	Phone: +49 561 804 1871 Fax: +49 561 804 3187 E-mail: dietrich.schmidt@ibp.fraunhofer.de
Germany	Herena Torío Fraunhofer-Institute for Building Physics Gottschalkstrasse 28a DE - 34127 Kassel, GERMANY	Phone: +49 561 804 1834 Fax: +49 561 804 3187 E-mail: herena.torio@ibp.fraunhofer.de
Italy	Adriana Angelotti Politecnico di Milano, BEST v. Bonardi 3 I – 20133 Milano, Italy	Phone : +39 02 2399 5183 E-mail : adriana.anglotti@polimi.it
Japan	Masanori Shukuya Tokyo City University 1-3-1 Ushikubo-Nishi, Tsuzuki-ku 224-0015 Yokohama, JAPAN	Phone: +81-45-910-2552 Fax: +81-45-910-2553 E-mail: shukuya@tcu.ac.jp
Japan	Toshiya Iwamatsu Tokyo Metropolitan University 1-1 Minami-Osawa, Hachioji-shi 192-0397, Tokyo	Phone: +81-42-677-1111 Fax: +81-42-677-2793 E-mail: kakoi-h@nihonsekkei.co.jp

Poland	Zygmunt Wiercinski University of Warmia and Mazury, Chair of Environmental Engineering Jana Heweliusza, 4 10-724, Olsztyn, POLAND	Phone: +48 89 523 456 Fax: +48 89 523 4760 E-mail: zygmunt.wiercinski @uwm.edu.pl
Sweden	Marco Molinari KTH Building Technology Brinellvägen 34 SE - 10044 Stockholm, SWEDEN	Phone: +46 8 790 8716 Fax: +46 8 411 8432 E-mail: marco.molinari @byv.kth.se
Sweden	Gudni Jóhannesson Icelandic National Energy Authority On behalf of KTH Building Technology Stockholm Grensasvegur 9, 108 Reykjavik, Iceland	Phone: +354 569 6001 / +354 8930390 Fax: +46 8 411 8432 E-mail: gudni.a.Johannesson @os.is
Switzerland	Forrest Meggers ETH Swiss Federal Institute of Technology Zurich Wolfgang-Pauli-Str. 15 8093 Zürich, SWITZERLAND	Phone: +41 44 633 28 60 Fax: E-mail: meggers @hbt.arch.ethz.ch
The Netherlands	Peter Op´t Veld Cauberg-Huygen R.I. B.V. PO Box 480 NL - 6200 AL Maastricht, The NETHERLANDS	Phone: +31 43 346 7842 Fax: +31 43 347 6347 E-mail: p.optveld@chri.nl
The Netherlands	Sabine Jansen Delft University of Technology Faculty of Technical Natural Sciences and Architecture, Berlageweg 1, NL – 2600 GA Delft, The NETHERLANDS	Phone: + +31 15 278 4096 Fax: +31-15-278-4178 E-mail: s.c.jansen@tudelft.nl
The Netherlands	Paul Ramsak SenterNovem Energy Research Team P.O. Box 17 6130 AA Sittard, the NETHERLANDS	Phone: +31 46 420 2275 Fax: +31 46 452 8260 E-mail: p.ramsak @senternovem.nl

USA	Dave Solberg Thermo-Environmental Systems, L.L.C. 1300 E. 66th Street, Ste 200 55423-2684 Richfield, Minneapolis, USA	Phone: +1 612-861-0468 Cell: Fax: E-mail: dwsolberg @hvacsystemstechnology.com

Anhang I

Tagungsprogramm der Abschlusskonferenz Oktober 2010

Conference

Action C24: COSTeXergy

Federal Ministry of Economics and Technology

IEA
Energy Conservation in Buildings & Community Systems Programme
Annex 49

19th - 21st October 2010
Oskar von Miller Forum
Munich, Germany

The Future for Sustainable Built Environments with High Performance Energy Systems

This conference about the future for sustainable built environments and energy systems integrating a maximum amount of renewable energies provides front-edge technologies and solutions for buildings, communities and energy supply. In addition to the presentation of new results and technologies this is an opportunity for personal exchange with participants from politics, research institutions and industry. The conference therefore creates the chance for an open interdisciplinary discussion on how to address the upcoming challenges of energy transition.

Oskar von
Miller Forum,
Munich, Germany

The presenters represent a broad portfolio of competences in integrated energy solutions and give inside information on the state of discussion in the field of buildings, communities and energy supply systems. The conference is the final event of the Annex 49 "Low Exergy Systems for High-Performance Building and Communities" which is part of the Energy Conservation in Buildings and Communities Programme of the International Energy Agency, carried out in close cooperation with the European COSTeXergy project.

During the conference a new approach for the active participation of Master and PhD students is seized to interlink the research and engineering approaches with education and innovative student ideas.

Conference Chair: Dr. Dietrich Schmidt, Fraunhofer Institute for Building Physics - Department Energy Systems, Operating Agent ECBCS (Energy Conservation in Buildings and Community Systems Programme) Annex 49.

www.conference.annex49.de

Conference Programme

18th October 2010

PhD students workshop

19th October 2010

OPENING

Opening of the Conference

Dr. Hans-Christoph Wirth, German Federal Ministry of Economics and Technology (BMWi)

What has been Achieved in Energy Efficiency?

Prof. Gerd Hauser, Director of the Fraunhofer Institute for Building Physics

Towards Energy Efficient Building and Communities

Dr. Morad Atif, Chair of IEA ECBCS (Energy Conservation in Buildings and Community Systems Programm)

KEYNOTE

The Role of Innovation for Energy Transition

Prof. Joachim Warschat, Fraunhofer Institute for Industrial Engineering

CHALLENGES WITHIN THE TRANSITION OF ENERGY SYSTEMS

IEA Policies for Future Energy Systems

Peter Cunz , Chair of IEA CERT (Committee on Energy Research and Technology)

Energy Transition – How to Convert Germany's Energy Supply?

Prof. Jürgen Schmid, Director of the Fraunhofer Institute for Wind Energy and Energy Systems Technology

A New Future for District Energy Systems

Dr. Robin Wiltshire, Chair of IEA DHC (District Heating and Cooling Programme)

A new Role of Utilities within Energy Transition

Peter Flosbach, Vice President Technology, RWE Effizienz GmbH

20th October 2010

METHODS AND DESIGN

Exergy Thinking and Thermal Comfort

Prof. Masanori Shukuya, Tokyo City University (FEIS-TCU), Yokohama, Faculty of Environmental and Information Studies

High Performance Indoor Environments with LowEx Demand

Prof. Bjarne Olesen, Technical University of Denmark, Lyngby, Department of Civil Engineering

Practical Guidelines for LowEx Buildings

Prof. Saso Medved, University of Ljubljana, Faculty of Mechanical Engineering

The LowEx Approach in Real Live Building Projects

Prof. Hansjürg Leibundgut, Swiss Federal Institute of Technology, Zurich

BUILDINGS

Strategies for Integrative Building Design

Prof. Per Heiselberg, Aalborg University of Denmark, Operating Agent IEA ECBCS Annex 44

Limits of Heat Pumps in LowEx Design

Prof. Hermann Halozan, Technical University of Graz, Chair of IEA EUWP (End-Use Working Party)

Advanced Building Systems

Prof. Dirk Müller, E.ON Energy Research Center (E.ON ERC), RWTH Aachen University

Lowex Houses: The Next Step in Energy Efficiency

Prof. Hans Cauberg, Delft University of Tehnology, Faculty of Climate Design and Sustainability

COMMUNITIES I

The Use of Low Valued Cooling Sources - Drakelanding

Ken Church, National Research Council Canada

Exergy based energy stations – Minewater Project

Peter Op't Veld, Cauberg-Huygen R.I., Maastricht

Energy Transition in Parma City

Paola Caputo, Politecnico di Milano, Building and Environment Sciences and Technology (BEST)

COMMUNITIES II

From a Military Property into a Zero Energy Quarter: Bad Aibling

Dr. Ernst Böhm, B&O Wohnungswirtschaft GmbH & Co KG

Wolfhagen – 100% Renewable Energy Supply for a Typical German Town.

Christina Sager, Fraunhofer Institute for Building Physics, Department Energy Systems

Performance of Low Temperature District Heating Systems for Low Energy Houses

Prof. Svend Svendsen, Technical University of Denmark, Department of Civil Engineering

21st October 2010

INTEGRATION AND FUTURE PERSPECTIVES

Integrated Exergy Concepts for Regional and Urban Planning

Prof. Ronald Rovers, Polytechnic University Zuyd, Heerlen, Netherlands, Built Environment

Importance of Education in Energy Transition

Prof. Artūras Kaklakas, Vilnius Gediminas Technical University, Institute of Internet and Intelligent Technologies

Minimisation of Costs and Environmental Impact Using Exergy Based Methods

Prof. George Tsatsaronis, Technical University of Berlin, Institute for Energy Engineering

Students conclusions

Feedback from their Workshop

Anhang J

Artikel
„LowEx Gebäude und Energiesysteme“

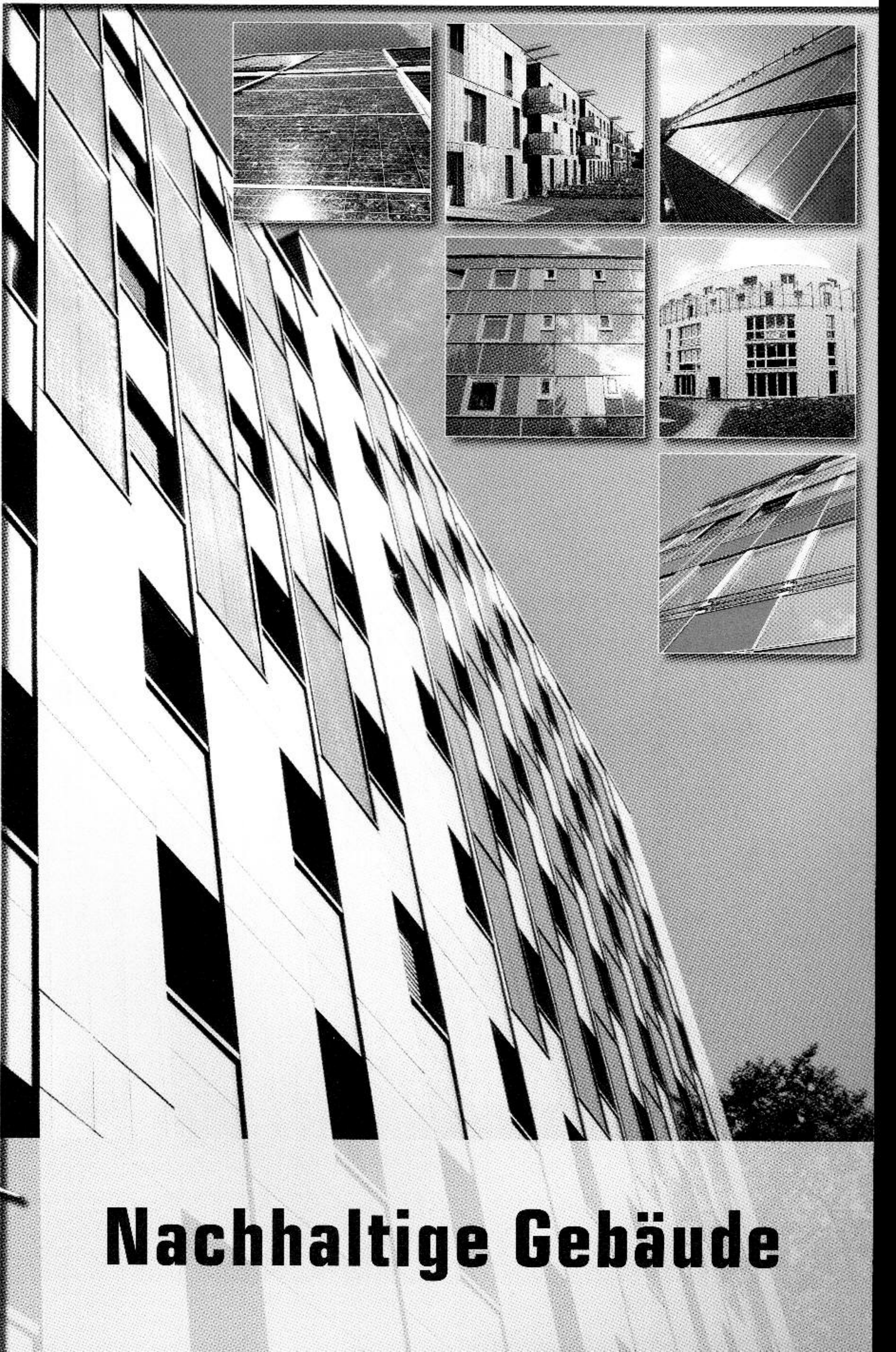
ERNEUERBARE ENERGIE

2008-4

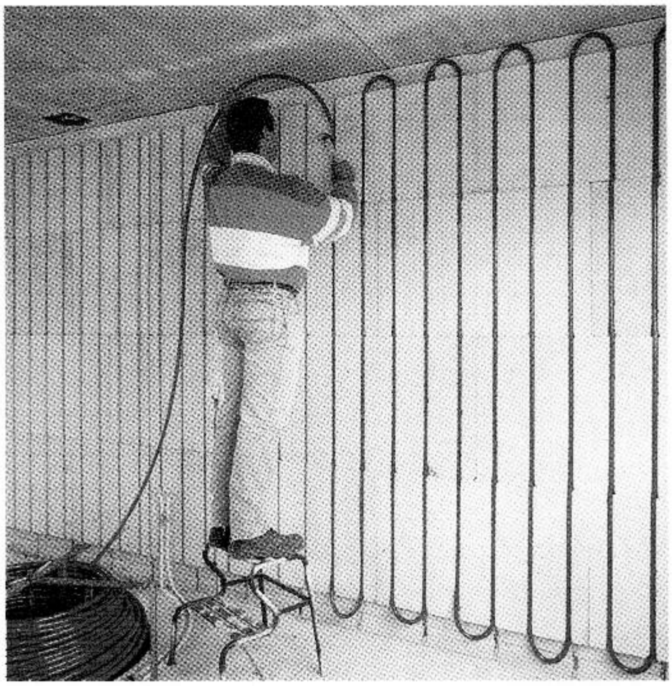
Zeitschrift für eine nachhaltige Energiezukunft

Aus dem Inhalt:

ee ist eine Publikation
der Arbeitsgemeinschaft
ERNEUERBARE ENERGIE



Nachhaltige Gebäude



◀ **Abbildung 1**
Niedertemperatur-Heizsysteme ermöglichen den Einsatz nieder-exergetischer Energieträger
Quelle: Senter Novem

Low-Ex-Gebäude und Energiesysteme

Für jede Anwendung den passenden Energieträger

Von Lukas Kranzl und Andreas Müller *

Werden durchschnittliche Energiekonsumenten darüber befragt, wie hoch sie den Anteil ihres Energieverbrauchs für Raumwärme, Warmwasser, Beleuchtung, Mobilität etc. einschätzen, so werden meist die Wärmeanwendungen unterschätzt und die stromspezifischen Anwendungen überschätzt [1]. Diese „falsche" Einschätzung wird zum Anlass genommen, auf das fehlende Bewusstsein für den Wärmesektor hinzuweisen.

International Energy Agency

Energy Conservation in Buildings and Community Systems Programme

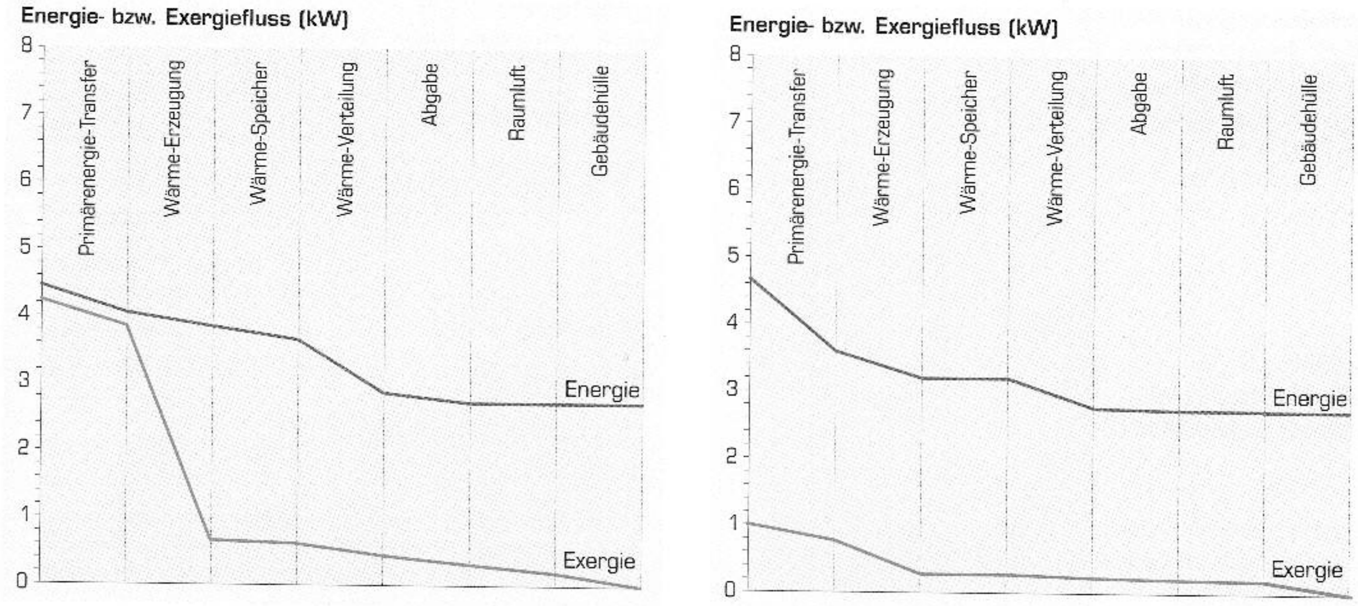
Es ist jedoch auch eine andere Interpretation dieser Umfrageergebnisse möglich. Nämlich die, dass die Befragten bei der Abschätzung des Energieverbrauches das persönliche Gefühl für den qualitativen Wert der eingesetzten Energie implizieren. Das heißt, eventuell wird nicht nur die Menge, sondern auch der „Wert" der Energie beurteilt. Ein Kriterium für diesen „qualitativen Wert" einer bestimmten Energieform stellt zum Beispiel die Differenz des Energieniveaus gegenüber dem Umgebungszustand dar. Der Unterschied in den Energieniveaus bestimmt das Arbeitsvermögen einer bestimmte Energieform, oder vereinfacht ausgedrückt: Es kann die Frage beantwortet werden, wofür eine bestimmte Energieform verwendet werden kann.
Tatsächlich ist unter diesem Gesichtspunkt der qualitative Unterschied zwischen den Energieformen Raumwärme vs. Elektrizität eklatant. Raumwärme besitzt mit lediglich wenigen Grad Celsius Differenz zur Umgebungstemperatur ein äußerst geringes Arbeitsvermögen und kann daher keinem anderen Zweck dienen, als eben ein behagliches Raumklima bereitzustellen. Die Umwandlung in andere Energieformen ist nur in äußerst beschränktem Umfang möglich. Elektrizität hingegen stellt eine hochqualitative Energieform dar, die zur Bereitstellung unterschiedlichster Energiedienstleistungen verfügbar ist, beispielsweise für Beleuchtung, Mobilität oder Kochen.

Exergie

Thermodynamiker nennen den „hochqualitativen" Anteil der Energie, also jenen Anteil, der gegenüber dem Umgebungszustand arbeitsfähig ist, Exergie. Elektrizität weist einen Exergiefaktor von 100% auf. Das heißt, dass der gesamte Energieinhalt

---

* *Dr.* ***Lukas Kranzl*** *und Dipl.-Ing.* ***Andreas Müller*** *sind wissenschaftliche Mitarbeiter der Energy Economics Group, Technische Universität Wien, Lukas.Kranzl@tuwien.ac.at, Andreas.Mueller@tuwien.at, www.eeg.tuwien.ac.at*



▲ **Abbildung 2**
Energie- und Exergiefluss beim Beheizen eines Gebäudes. Links: Hoch-Temperatur-Heizsystem; rechts: Nieder-Temperatur-Heizsystem

einer Kilowattstunde Strom in andere Energieformen, wie Licht, Information, Bewegung übergeführt werden kann. Chemische Energieträger wie Erdöl oder Erdgas weisen mit 75% - 85%[1] ebenfalls sehr hohe Exergieanteile auf. Im Gegensatz dazu liegt dieser Faktor bei Raumwärme bei nur etwa 7%[2].

Wenn wir uns unter diesem Gesichtspunkt die heute dominierenden Heizsysteme ansehen, erkennen wir, dass großteils hochexergetische Energieträger wie Öl oder Gas zur Bereitstellung einer extrem nieder-exergetischen Nutzenergieform, nämlich Raumwärme und Warmwasser verwendet wird. Es wird dadurch der größte Anteil der Exergie dieser Energieträger vernichtet. Das Bewusstsein gegenüber dem Wert hoch qualitativer Energieträger ist also nur in geringem Ausmaß gegeben und führt zu Ressourcenverschwendung, oder anders ausgedrückt: Vernichtung von Exergie.

Raumwärmebereistellung

Abbildung 2 zeigt beispielhaft den Energie- und Exergiefluss vom Energieträger über die Umwandlung in Raumwärme bis zur Gebäudehülle [2]. Das erste Beispiel stellt ein mit Gas beheiztes konventionelles Gebäude mit Hochtemperatur-Heizsystem mit einem Gasbrennwertkessel dar, das zweite Beispiel ein Gebäude, das mit Fernwärme (Abwärmenutzung) und einem Niedertemperatur-Heizsystem beheizt wird. Dabei wird deutlich, dass bei der Umwandlung des fossilen Energieträgers in Niedertemperaturwärme der größte Anteil der Exergie dieses Energieträgers vernichtet wird, was zu einem extrem niedrigen exergetischen Wirkungsgrad führt. Im Gegensatz dazu ist das Exergiegefälle im zweiten Fall deutlich geringer, wenn Abwärme in einem Fernwärmenetz genutzt wird. Analoges gilt für die Nutzung von Solarwärme. Auch hier wird eine niederexergetische Wärmequelle, nämlich Warmwasser aus dem Kollektor bereitgestellt.

„Low-Ex"-Gebäude- und -Energiesysteme

In konventionellen Heiz-, Gebäude- und Energiesystemen werden also ausschließlich hoch-exergetische Energieträger eingesetzt, unabhängig davon, ob letztlich ein hoch- oder ein nieder-exergetischer Bedarf besteht (**Abbildung 3**). Im Gegensatz dazu werden in innovativen, effizienten „low-ex"-Gebäuden für die jeweilige Anwendung Energieträger in der entsprechend passenden Qualität, d. h. mit dem entsprechenden Exergiegehalt (z. B. Solarwärme, Abwärme, Wärmerückgewinnung) bereitgestellt. Was bedeutet das nun für eine optimale, effiziente, nieder-exergetische Gestaltung von Energiesystemen und im Besonderen von Gebäuden?

Konkrete Merkmale von „low-ex"-Gebäuden und -Energiesystemen sind beispielsweise:

- Hocheffiziente Gebäudehüllen
- Passive Nutzung von Solar- und Umgebungswärme
- Niedertemperatur-Heizsysteme (bzw. Hochtemperatur-Kühlsysteme) erlauben den Einsatz von nieder-exergetischen Energieträgern.
- Ersatz von hoch-exergetischen Energieträgern durch nieder-exergetische wie Solarwärme, Abwärme aus Kraft-Wärme-Kopplungen (KWK) und industriellen Prozessen, Nutzung der Rücklaufleitungen bei Fernwärmesystemen
- Anlagen zur Wärmerückgewinnung

---

[1] Bei thermischer Umwandlung der chemischen Energie

[2] Dieser Faktor bestimmt sich bei der Raumheizung aus der absoluten Temperatur der Raumwärme sowie der Außentemperatur (in der Heizperiode). Mit 20°C (293,15 K) Raumwärme und einer Außentemperatur von 0°C (273.15) ergibt sich $1-T_0/T = 1-273{,}15/293{,}15=6.8\%$.

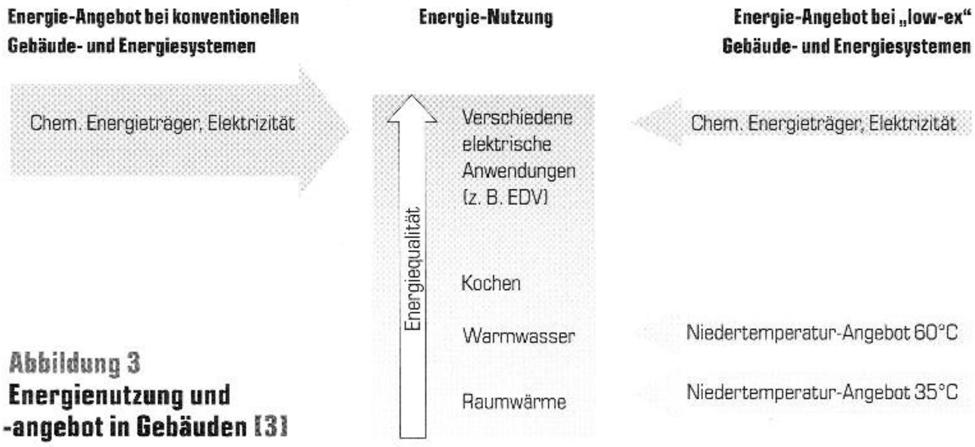


Abbildung 3
Energienutzung und -angebot in Gebäuden [3]

Derartige „low-ex"-Gebäude weisen einen deutlich geringeren Exergie- (und im Gesamtsystem auch Primärenergie-) Verbrauch und geringere CO_2-Emissionen auf. Darüber hinaus führen insbesondere Niedertemperatur-Wärmesysteme auch zu einem hohen Behaglichkeitsniveau. Denn durch den Einsatz von Wand- und Fußbodenheizungen können hohe Temperaturgradienten, Luftzug und ein damit verbundenes unbehagliches Raumklima stark verringert werden.

Was hier auf Gebäudeebene dargestellt wurde, gilt auch für das gesamte Energiesystem in einer Region. Neben den Haushalten weisen auch die Anwendungen in Gewerbe, Landwirtschaft, Dienstleistungsektor und Industrie bestimmte Exergie-Niveaus auf, die in optimaler Weise auf Basis von Energieträgern mit passendem Exergiegehalt bereitgestellt werden. Die Nutzung von industrieller Abwärme in Fernwärmenetzen ist ein Beispiel für den Ausgleich verschiedener Exergieniveaus: Hoch-Temperatur-Anwendungen (z. B. in der Industrie) verlangen nach hochexergetischen Energieträgern, während für Raumwärme die Abwärme aus eben diesen Hoch-Temperatur-Anwendungen ausreichend ist.

Exergetische Analysen

Bei der thermodynamischen Planung und Analyse von Energieanlagen sind exergetische Analysen an der Tagesordnung. Dies ist für energiewirtschaftliche und -systemische Analysen nicht unbedingt der Fall. Die Integration des Exergiekonzeptes in Analysen des Energiesystems kann jedoch zusätzliche Einsichten zur Qualität von Energieträgern und Anwendungen liefern und so neue Optionen zur Verringerung des Bedarfs nach Energieträgern und zur CO_2-Reduktion identifizieren helfen. Exergetische Analysen unterstützen daher die Entwicklung und geeignete Auswahl von Technologien und Konzepten, die zu einer substanziellen Reduktion des Exergie- und Energieverbrauchs in Gebäuden führen können. Die daraus abgeleiteten Strategien können dazu beitragen, den Übergang in ein nachhaltiges, intelligentes und wettbewerbsfähiges Energiesystem zu beschleunigen.

IEA ECBCS Annex 49

Im Rahmen des IEA Implementing Agreements ECBCS (Energy Conservation in Buildings and Community Systems Programme) befasst sich Annex 49 mit „Low Exergy Systems for High-Performance Buildings and Communities" (www.annex49.com). In diesem Projekt werden Konzepte und Methoden zur Reduktion des Exergie-Verbrauchs in Gebäuden sowie Gemeinden und Regionen entwickelt. Während auf Gebäudeebene die Entwicklung von technologischen Konzepten des Heiz- bzw. Kühlsystems, der Wärmeverteilung sowie der Gebäudehülle im Vordergrund stehen, werden auf Gemeinde- und Regionsebene die Erzeugung, Verteilung und Speicherung von Exergie sowie die kaskadische Nutzung behandelt.

Österreichische Beteiligung

Von österreichischer Seite ist die Energy Economics Group an der Technischen Universität Wien an Annex 49 im Auftrag des Bundesministeriums für Verkehr, Innovation und Technologie beteiligt. Diese Beteiligung umfasst die Entwicklung von Methoden und Ansätzen zur Integration des Exergie-Begriffs in energiewirtschaftliche Analysen. Konkret werden Untersuchungen zur ökonomischen Struktur von „low-ex"-Systemen angestellt, langfristige Szenarien zur Entwicklung des Gebäudebestandes und des Raumwärmesektors in Österreich unter exergetischen Gesichtspunkten entwickelt sowie verschiedene Energieketten hinsichtlich ihrer exergetischen Effizienz miteinander verglichen. Annex 49 läuft bis Ende 2009.

Referenzen

[1] Piskernik Ludwig et al. 2007: „Bewusstseinsbildende Maßnahmen zur Förderung des effizienten Umgangs mit Energie – Ergebnisse einer emipirischen Studie" Beitrag zur 5. Internationalen Energiewirtschaftstagung an der TU-Wien.

[2] Schmidt Dietrich: „Calculation tool for an exergy optimised building design" Version 7.7 IEA ECBCS Annex 49.

[3] Sager Christina, Ala-Juusela Mia: „Low-ex concepts" ECBCS Annex 49 Newsletter No. 2 September 2007.

Anhang K

Publikation

Exergy based prices for energy carriers in heating systems – what can we learn from them?

A. Mueller[1], L. Kranzl[1], P. Tuominen[2], E. Boelman[3], M. Molinari[4], A.G. Entrop[5]

July 2010

[1] Vienna University of Technology, Institute of Power Systems and Energy Economics, Energy Economics Group, Gusshausstrasse 25-29/373-2, 1040 Vienna
[2] VTT Technical Research Centre of Finland, Building Services and Indoor Environment, P.O. Box 1000, 02044 VTT
[3] EU Committee of the Regions (in a personal capacity). Formerly with the Delft University of Technology, Climate Design Group
[4] KTH Royal Institute of Technology, School of Architecture and the Built Environment, department of Civil and Architectural Engineering, Brinellvägen 34, 1004 Stockholm, Sweden
[5] University of Twente, Faculty of Engineering Technology, department of Construction Management and Engineering,P.O. Box 217, 7500 AE, Enschede, The Netherlands, tel.: +31 53 489 6860; fax: +31 53 489 2511, a.g.entrop@utwente.nl

1 Introduction

1.1 Background

Considering different heating systems, there is a variety of technological options for converting various energy carriers to useful energy and finally into the energy service of a comfortable room temperature. Historically, during industrialization the mix of fuels changed from biomass towards oil, gas and coal [1]. At the same time, efficiency and emission standards of heating systems as well as comfort levels increased strongly. Besides, modern heating solutions include systems like solar heating, heat-pumps and, in general, an improved energy economy of the building through better insulation, air-tightness and such measures (for examples, see Ala-Juusela et al., 2003 [2]).

The characteristics of these different heating systems lead to different cost structures, regarding capital costs, operating costs and energy costs. The energy costs of energy carriers can differ considerably, as can the quality of energy carriers and energy services. One of the core indicators measuring the quality of an energy carrier is its exergy content. It is reasonable to postulate that, when buying energy, people are interested in the portion of the energy capable of performing work for them, namely exergy, and not unusable forms of energy. Therefore one of our hypotheses is that, in a well-functioning energy market with ample choices, the price of an energy carrier does reflect its exergy content rather than energy content. The term “exergy content” is defined as “ability to perform potentially useful work”.

Thus it can be expect, that low-exergy energy carriers (e.g. low-enthalpy heat) to have a lower price level. However, for a given end use such as heating, the total cost of energy carrier and capital investments necessary to provide the energy service should be about the same for all systems, given that the systems provide a similar comfort level and market distortions are neglectable. This is simply because heating systems that have substantially higher total heat generation costs than the others would soon loose in a free market competition. Based on these premises, one could state the following hypotheses:

- The prices of well-established energy carriers in the marketplace reflect exergy content, and
- The total heat generation costs for widely used systems are generally on an equal level within a country or region regardless of the energy carrier.

In this paper, we will investigate to which extent it is possible to verify these hypotheses.

1.2 Objectives

This paper aims at exploring, for a set of given conditions, to which extent:

- the prices for different energy carriers in fact represent their exergy content, and
- the total heat generation costs of different heating systems represent the exergy content of the used energy carrier (the term “total heat generation costs” will be defined in section 3.)

Our analysis uses data from Austria, Finland, the Netherlands, and Sweden. These countries show large similarities regarding the physical quality of buildings, energy consumption per capita, gross domestic product per capita, and VAT-rates. On the other hand there are differences in climate, heating system traditions and building stock. In view of the above-mentioned objectives, data for these countries can be seen to provide a robust base for a first comparative analysis.

1.3 Approach

For each country (AT, FI, NL, SE) covered in this paper, we:

- Define a characteristic building type along with, several heating systems using different energy carriers to be compared in the analysis;
- Investigate the different cost components of heating systems. These are investment, operation and maintenance costs for different heating systems and their components on the one hand. Variable energy costs on the other hand are represented by the energy price the consumers are paying for a certain fuel or energy carrier;
- Define the exergy factor for each of the energy carriers considered;
- Compare the exergy factor to the energy price (with and without taxes) for each energy carrier;

- Compare the specific exergy content (exergy factor) to the total monetary cost of heat generation for various heating systems. The total monetary cost of heat generation is in this paper defined as the sum of monetary expenses that a residential consumer has to pay for providing and maintaining a comfortable amount and quality of thermal energy to a dwelling. This includes energy prices (excluding taxes), energy taxes and total fixed costs (investment costs, operation and maintenance costs).

We distinguish between the terms “price” and “cost”. Energy prices are the result of supply and demand intersections on energy and resource markets. Thus, they reflect the relation of supply and demand for different energy carriers. Heating related energy costs are the expenses that consumers have to pay for a heating system. This includes fixed costs (investments, operation and maintenance), energy taxes and costs for energy carriers. The latter are represented by energy prices (in a market driven economy) and energy taxes.

Methods and approaches from energy economics and from energy accounting are combined to compare consumer prices and exergy content. To visualize the results, a chart is introduced showing exergy factor (specific exergy content) of an energy carrier on the horizontal axis and the different components of heat generation costs on the vertical axis. We take the slope of the regression line for the different cost components as an indicator of the extent whereby they reflect the exergy content: the steeper the slope, the more the exergy content is reflected in the respective cost components (e.g. the energy price without taxes).

Combining these two approaches, we believe, leads to new and interesting insights into the extent in which current energy market prices take into account the exergy content of energy carriers. In doing so, we considered some critical aspects to this approach, as outlined below:

- The comparison of the analysis in different countries is not straightforward, given the differences in climate, housing stock, adopted technologies and economic conditions. A short overview of these parameters is given in the beginning of each case study description (section 5 to 8).
- Taxes on energy carriers are different in each country and have considerable impact on the outcome of our analysis. Therefore, within the cases prices with and without energy taxes are distinguished.
- Energy prices have shown considerable volatility within the last few years. While price volatility has not been the same for all energy carriers, the level of energy prices strongly affects the ratio of capital to energy costs. We use energy price levels of the year 2005 in all investigated case studies, in order not to reflect the strong price volatility of the years 2007 and 2009. However, we are aware that the reference year for energy prices is of crucial impact as a parameter. Our proposed approach could be applied to energy price time series for the last decades and to energy price scenarios for the next decades.

2 Literature review

The first proposal for using exergy as a criterion for cost allocation was presented in 1932 by Keenan, cited by Lozano and Valero (1993) [3], who suggested that the production costs of a cogeneration plant should be distributed among the products (work and heat) according to their exergy.

Thermoeconomics, originated by Tribus and Evans (1962) [4], combines the second law of thermodynamics with economics by applying the concept of cost to exergy, in order to achieve a better production management with a more cost-effective operation.

Tsatsaronis and Moran (1997) [5] state that thermoeconomics can be considered as exergy-aided cost minimization, and that the objective of a thermoeconomic analysis might be: (a) to calculate separately the cost of each product generated by a system having more than one product; (b) to understand the cost formation process and the flow of costs in the system; (c) to optimize specific variables in a single component; or (d) to optimize the overall system.

Second law analysis methods based on cost accounting are used to determine actual product cost and provide a rational basis for pricing [6]. These methods include e.g. exergetic cost theory [7],[8], average cost approach [9], specific cost exergy costing method [10]. Methods based on optimization techniques are used to find the optimum design or operating conditions. They include e.g. thermoeconomic functional analysis [11][12] and, engineering functional analysis [13].

In a concise note on the evolution of thermoeconomics, Deng et al (2008) [6] recall that the main and more general thermoeconomic methodologies developed include the exergetic cost theory of Lozano and Valero [3], the last in first out method of Lazzaretto and Tsatsaronis [5], the average cost method of Bejan et al. [14], the specific exergy costing method of Tsatsaronis and Pisa [15], the thermoeconomic functional method of Frangopoulos [7],[11] and the engineering functional analysis of Spakovsky and Evans [16].

Deng et al (2008) [6] also note that to a certain extent, multiple methodologies with different theories and nomenclatures cause confusion and impede the development of thermoeconomics. Based on the achievements of predecessors, Valero et al. [8] developed the structural theory of thermoeconomics, which provides a general mathematical formulation using a linear model and encompasses all the thermo- economic methodologies developed up to now, and is considered as standard formalism of thermoeconomics [14],[11].

In the following paragraphs, we review some of the relevant concepts from literature in the areas of exergy accounting, exergetic cost and exergonomics.

Sections 3 and 4 will describe our approaches to using these concepts and how we are taking into account literature described here.

2.1 Exergy accounting

Exergy accounting converts the total amount of resources inflow into their equivalent exergetic form with the help of a table of ‘‘raw exergy data’’ available in the literature. The quantification of each flow on a homogeneous exergetic basis paves the way to the evaluation of the efficiency of each energy and mass transfer between numerous sectors of society and makes it possible to quantify the irreversible losses and identify their sources (Sciubba, Bastianoni and Tiezzi, 2008 [17]).

Sciubba (2001) [18] notes that the word ‘accounting’ has been suggested as a reminder that exergy does not satisfy a balance, in that the unavoidable irreversibilities which characterize every real process irrevocably destroy a portion of the incoming exergy. It is also a reminder that the exergy destruction is the basis for the formulation of a theory of ‘cost’, because it clearly relates to the idea that to produce any output, some resources have to be ‘consumed’.

Gaggioli and Wepfer (1980) [19] state that exergy accounting is concerned with:

- determining the actual cost of products, by determining the cost of the “power” streams which fuel the various unit operations and components of complex processes and systems;
- providing a rational basis for pricing products, by using exergy to properly allocate “energy” costs to the various products of a process;
- providing a means for controlling expenditures during the feasibility studies and design phases, e.g. by optimally selecting each system, component or process unit by properly balancing “fuel” costs with capital and other costs;
- forming a basis for operating decisions and their evaluation, by properly evaluating the tradeoffs between power costs and other operating/capital expenses, so that rational operating decisions can be made regarding maintenance, replacement, revision and operation.

The Extended Exergy Accounting method (EEA) was proposed to exploit the correlation between exergy and economic values by developing a formally complete theory of value based indifferently on an exergetic or on a monetary metric (Sciubba, 2001 [18]). Sciubba defines an ‘extended exergy’ as the sum of the physical exergy and the proper portion of the invested exergy that can be assigned to a stream under consideration, noting that these would share properties of additivity, non-conservation in real processes, etc.

2.2 Exergetic cost

The exergy cost of an energy flow represents the units of external resources used to produce it. Valero (2006) [20] states that the exergetic cost or the cumulative exergy consumption are in fact the same concepts as embodied exergy. He and co-workers focused on the physical roots of cost as well as on providing the concept with a theoretical framework. Within this work, a logical chain of concepts for connecting physics with economics is proposed.

The unit exergetic cost (also called unit exergy consumption, Valero, 2006 [10]) k_p of a product *P* is given by the inverse of the efficiency $\varepsilon_{Pr,chem}$. (Lozano and Valero, 1993 [3], Sciubba, 2001 [18], Valero, 2006 [20]) From this perspective, an improvement in the structure of the system or in the efficiency of its units will always imply lower consumption of resources *F* (also designated as fuel) to obtain a product P (Equation 1).

$$k_p = 1/\varepsilon_{Pr,chem} = F / P \geq 1 \qquad \text{Equation 1}$$

Further elaborating on exergetic costs, Lozano and Valero (1993) [3] note that the physical environment is interrelated to the economic environment, which is characterized by market prices in addition to capital corrosive measures such as depreciation and maintenance.

2.3 Exergoeconomics

Exergoeconomic analyses consider the quality of energy (exergy) in allocating the production costs of a process to the different products it produces. A general methodology for this kind of analysis was presented by Tsatsaronis in 1985 [21], and was later called the exergoeconomic accounting technique (Rivero, 1993 [22]).

The exergoeconomic cost can be regarded as the amount of money consumed to generate an energy flow. Lozano and Valero (1993) [3] define the exergoeconomic cost of a flow as the combination of two contributions: the exergetic cost on the one hand and the capital and maintenance costs associated with achieving the productive process on the other. Tsatsaronis and Winhold (1985) [21] used this procedure for the first time for evaluating the monetary costs of the internal flows and products of complex plants. They defined the exergoeconomic factor as a parameter for measuring the relative weight that investment costs have on the increase of the unit exergoeconomic cost in a plant component. A small exergoeconomic factor shows that, at least theoretically, it will be possible and probably profitable to invest in the unit in order to improve its thermodynamic efficiency (Lozano and Valero 1993 [3])

2.4 Exergy costs and prices

In particular with respect to exergy related literature, it is important to realize that scholars do not always clearly distinguish between processes of cost and price formation and that the terms “cost” and “price” are used in multiple ways in different sources. Valero (2006) [20] notes that the term “cost” is in many cases mistaken as price, and that cost has different meanings for different people and practitioners. He argues that, if physical costs would be strongly related to money prices, then prices would reflect past events, since he defines physical cost as a physical sacrifice of resources already done. He adds that there is no forecasting but accounting of facts already happened.

Valero adds that cost accounting propositions like ‘heat as a by-product’ or ‘work as a by-product’ and so on are needed when we are analyzing the price formation process, but he advocates relating cost to physical measurements like mass flow rates, pressures, temperatures and compositions, as well as to actual irreversibilities occurring in the system, and finally to causes. He argues that this is the only way that we can provide physical roots to the accounting economy, and that from this point, we may use—or not—the values of exergetic costs as a basis for price setting, both external and internal prices.

Sciubba (2001) [18] argues that it is not capital that ought to measure the value of a piece of equipment or of a product by attaching a price tag to it, but exergetic content. He adds that the monetary price ought to reflect this new scale of values, because ‘economic systems are eco-systems that function only because of the energy and material fluxes that sustain human activities.

Sciubba advocates that the monetary ‘price tag’ (expressed in e.g. \$ or $€\cdot \text{unit}^{-1}$) be calculated on the basis of the extended exergetic content (EEC, expressed in $\text{kJ}\cdot\text{unit}^{-1}$) of a good or service, corrected for environmental impact. The conversion factor between the EEC and the price of a product would be the exergetic cost factor, which ought to be the ratio of some measure of the monetary circulation to the global exergetic input. Sciubba notes that for some of the processes the substitution of the equivalent exergetic value for the monetary price will certainly show a discrepancy in the exergy balance, due to the present over- or underestimating of the real extended exergetic content of materials, feed stocks, labor and energy flows. He adds that although it would be desirable that the economic and the exergetic value become locally consistent in the long run, different countries may have different exergetic cost factors, due to their different productive and economic structures and lifestyles.

2.5 Exergy as a rational measure of costs

Lozano and Valero (1993) [3] argue that we need to use exergy to rationally assign costs, because it enables us to compare the equivalence of the flows according to the principles of thermodynamics. They state that the only rigorous way of measuring the physical production cost (not its market value) is the second law, as it provides a unique way to identify, allocate, quantify and attribute a cause to the inefficiencies of real plants which are at the origins of cost and resource consumption.

Valero (2006) [10] adds that thermodynamic cost is only formed where irreversibilities exist, and that in locating and quantifying irreversibilities, we are thus guaranteeing that the costs will be correctly assigned. He notes that exergy connects with intensive properties like pressure, temperature, energy, etc. and its cumulative consumption can be rigorously defined and calculated. He adds that this physical, or more precisely thermodynamic or exergy cost is rigorously bound to the efficiency of the system.

Sciubba (2001) [18] has stated that an invested exergy value can be attached to any product, and specifically to mechanical, thermal and chemical equipment: this invested exergy is equal to the sum of the ‘non-energetic’ externalities (Labor and Capital) used in the construction and operation of a plant in which a product is generated. However he notes that, while exergetic and monetary costs may have the same morphology (they represent the amount of resources that must be ‘consumed’ to produce a certain output), their topology (structure) may be different, leading to the possibility of different optimal design points.

Gaggioli and Wepfer (1980) [19] present a concrete example of a company that was cogenerating substantial amounts of electricity, serving its own needs plus those of the surrounding community, but was unsuccessful at getting a rate increase that was needed to meet its costs. They argue that one factor was that the utilities commission viewed the plant outputs, steam and electricity, as energy and not exergy. Consequently, the allocation of costs to steam was much greater than it should have been, and the price allowed for electricity was less than its true cost. Gaggioli and Wepfer (1980) [19] have calculated energy and exergy (designated here as available energy) costs for this steam.

They note that “the use of energy as the measure for the power flow is an error”, since “there is no logical way to decide at which back-pressures energy costing would be appropriate, and at which pressures it would not be”. They also note that the costing curve derived from exergy (or available energy) shows that “the cost per pound of low-pressure steam goes to zero as its usefulness goes to zero. This is precisely the result that any rational costing scheme should provide”.

3 Average exergy content of energy carriers

After this literature overview our approach for determining the exergy content of different energy carriers is described. We begin with addressing the energy content of standard energy forms that are available to heat the built environment. The forms of energy at the disposal of our economy can be classified according to their exergy content, that is, their ability to perform potentially useful work. One such classification was given by Wall (1977) [23] in his quality indexing of energy forms shown in Table 1.

Table 1. The quality of different forms of energy in terms of exergy as classified by Wall (1977) [23].

Quality	Energy form	"Quality factor" Exergy factor (%)
Extra superior	Potential energy[1]	100
	Kinetic energy[2]	100
	Electrical energy	100
Superior	Nuclear energy[3]	~100
	Sunlight	95
	Chemical energy[4]	95
	Hot steam	60
	District heating	30
Inferior	Waste heat	5
Valueless	Heat background	0

[1] e.g. water reservoirs, [2] e.g. waterfalls, [3] e.g. nuclear fuel, [4] e.g. crude oil

Generally speaking, the energies with high exergy value at the top of Table 1 tend to have the highest economic value for their inherent physical capability of doing work. The ones at the lower end of the table, even if abundant in the environment, tend to be of lowest economic value.

Table 1 indicates the exergy factor of different energy forms, which can be regarded as the ability to be transformed into other forms of energy. Chemical energy is a much-used basis for primary energy conversion, often through combustion. The temperature levels that can be reached in such combustion processes, determine the amount of the chemical exergy that in practice can be converted into thermal exergy. In other words, in combustion processes there is always a certain amount of unavoidable exergy loss due to the maximum achievable temperature levels The exergetic efficiency $\varepsilon_{ex,combustion}$ of an ideal combustion process is determined by the Second law of thermodynamics, and depends basically on the absolute temperature levels of combustion $T_{comb.}$ and of the environment T_0. Thus, the exergetic efficiency of a combustion process indicates the amount of "in practice maximum usable" exergy (i.e. exergy content minus unavoidable exergy losses).

$$\eta_{\mathrm{ex,combustion}} = \frac{e_{\mathrm{heat}}}{e_{\mathrm{fuel}}} = \frac{1 - \frac{T_{\mathrm{ambient}}}{T_{\mathrm{comb.products}}}}{e_{\mathrm{fuel}}} \qquad \textit{Equation 2}$$

A maximum exergy of 85 % can be derived for fully oxidized combustion, assuming $T_{comb} \approx 1700$ K and $T_0 \approx 300$K. On the other hand, the exergy contents in Table 1 indicate that chemical energy could in principle be converted into other forms of energy by up to 95%. The difference then defines the exergy destruction that is unavoidable for thermodynamic reasons and maximum achievable combustion temperatures with current technologies.

For electricity production from natural gas the exergy efficiency is determined by the most efficient available power plants, which today have net power generation efficiency of 58 % and above. Using this approach is reasonable when investigating a specific component or subsystem. Yet when looking at a broader system, such as an energy supply system for district heating (DH), it may overlook the overall efficiency gains of using surplus thermal energy, such as heat supplied from a combined heat and power (CHP) plant to the DH grid.

Comparing secondary energy carriers such as electricity and district heat solely on the basis of their exergy content would lead to some bias, as it would not include exergy destruction upstream the system boundaries. It would also exclude energy carriers which still contain some exergy that cannot be utilized by any means.

Hence, we also consider the thermodynamic losses associated to the temperature limits imposed by current technology for large scale utilization. For natural gas or oil, combined cycle CHP has high exergetic efficiency, depending on the turbine inlet and environmental temperatures, T_0 and T_{inlet}. To be consistent with district heating, we use T_0= 273 K (0 °C) instead of the more common T_0= 293 K (20 °C). Even in most recent gas turbines, the turbine inlet temperature must not exceed a temperature of T $T_{inlet} \approx 1700$ K (ca.1450 °C) as the hot gas would than degrade the turbine blades very quickly. Similarly, for coal-fired CHP (e.g. from metal melting), usual temperatures are in the vicinity of 1400-1500 °C. For biomass combustion, the maximum temperature level on which flue gas can be utilized is mainly determined by impurities. Fluidized bed reactors, nowadays one of the most advanced biomass combustion processes, usually operate at temperature levels not above 800 °C for unconverted, solid biomass.

Based on these assumptions and on Equation 2, we estimate overall values for the exergetic efficiencies of these processes. As described above, we are using these values as “in practice usable” exergy (i.e. exergy content minus unavoidable losses due to temperature limitation). For electricity, however, we neglect upstream energy conversion efficiencies and simply assume an exergy content of 100%.

For district heating, the exergy content is highly sensitive to the ambient temperature. Since we investigate heating systems, the average temperature of the heating season seems to be appropriate. Based on climate data for the case studies, an average temperature of 0 °C for all countries is assumed in this paper. Using a temperature level of 100 °C for the supply line, the exergy content of district heating system is calculated to be 27 %.

Table 2. Exergy content of the energy carriers analyzed in this paper

Energy carrier (temperature level)	Exergy content as used in this paper
Oil, coal, gas (1500 °C)	85%
Biomass (800 °C)	75%
Electricity	100%
District heat (100 °C)	27%

4 System boundaries and monetary costs of heat generation

4.1 System boundaries

The core idea of this paper is to examine the tradeoff between two basic inputs: an energy carrier with its exergy content and the technology for converting it into the required energy service. This trade off is investigated both from an exergetic, physical point of view as well as from an economic perspective.

In order to do so the system boundaries are drawn around the final consumer, namely a typical reference building for each country. The energy, exergy and financial streams passing through the system boundaries will be analyzed.

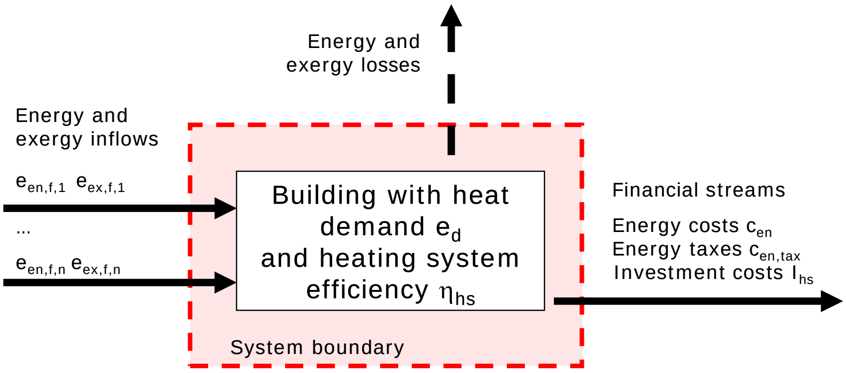


Figure 1. System boundary used in this work

The system boundary has important implications on the following analysis. Firstly, upstream energy losses (e.g. in the electricity grid or during electricity production) are not considered. Secondly, all financial streams and the underlying prices and costs are based on consumer prices. Finally, upstream infrastructure (e.g. electricity or heating grids) and its related cost structure are not analyzed. The costs of the infrastructure are expected to be incorporated in the consumer prices. Thus, the tradeoff between exergy and investment capital is considered from a consumer's point of view (with and without energy taxes).

4.2 Final exergy consumption and overall exergy factor

In our analysis, the annual final energy consumption $e_{en,f}$ for heating is defined by the heat demand of the building $e_{en,d}$ divided by the efficiency of the heating system $\eta_{en,hs}$.

$$e_{en,f} = \frac{e_{en,d}}{\eta_{en,hs}} \left[\frac{\mathrm{MWh}}{\mathrm{year}} \right] \qquad \textit{Equation 3}$$

We then define a lumped parameter $e_{ex,f,i}$ to represent the annual final exergy consumption for heating with energy carrier i, by multiplying $e_{en,f,i}$ with the specific exergy content (exergy factor of energy carrier i) of each relevant energy carrier (as shown in Table 1).

$$e_{ex,f,i} = e_{en,f,DH} \cdot i_{ex,i} \qquad \textit{Equation 4}$$

Subsequently another parameter is defined, namely an overall weighted exergy factor i_{ex}, to represent all incoming energy flows considered in the building and its heating system (e.g. including ambient energy for the case of heat pumps).

$$i_{ex} = \frac{\sum_{i=1}^{n} e_{ex,f,i}}{\sum_{i=1}^{n} e_{en,f,i}} \qquad \textit{Equation 5}$$

4.3 Monetary costs of heat generation

In this paper the term "costs" is related to monetary costs, not exergetic, physical costs (as used e.g. in Valero 2006 [20]). These monetary costs refer to the monetary expenses an energy consumer has to bear for a certain type of heating system. This includes investment costs, operation and maintenance costs and energy costs. The latter ones are depending from the energy price and the efficiency of the heating system. Typically, for grid connected energy carriers a considerable part of the energy price consists of a base price, which is independent of the actual energy consumption. This base price actually can be understood as element to take into account the up-front investments in the district heating grid etc. Due to our system boundary (building envelope) we do not consider this in an explicit manner.

The following financial flows are distinguished:

- variable price for energy carrier c_{en} excluding taxes
- energy related taxes $c_{en,tax}$ based on the energy tax rate $f_{tax,en}$
- total fixed costs (C_{fix}), consist of
  - levelized investment costs of the heating system I_{hs} (€), using the capital recovery factor α. For calculation of the levelized investment costs we used an interest rate (i) of 5% and a depreciation time (T)of 15 years;
  - annual operating and maintenance costs $c_{O\&M}$ (€/yr), including the annual fixed amounts paid to the energy supply company regardless of the actual energy consumption.

$$
\begin{aligned}
&c_{tot} = c_{en} + c_{en,tax} + \frac{C_{fix}}{e_{en,f}} \left[\frac{€}{MWh}\right] \\
&c_{en,tax} = c_{en} \cdot f_{tax,en} \left[\frac{€}{MWh}\right] \\
&C_{fix} = c_{O\&M} + c_{en,fix} + \alpha I_{hs} \left[\frac{€}{yr}\right] \\
&\alpha = \frac{(1+i)^T - 1}{(1+i)^T \cdot i} \left[yr^{-1}\right]
\end{aligned}
\qquad \textit{Equation 6}
$$

Total monetary costs for heat generation (c_{tot}) are calculated from the sum of the energy price charged for a residential consumer (excluding taxes), energy taxes and total fixed costs (e.g. capital costs).

All financial parameters are calculated without value added tax (VAT). As VAT is always placed on top, it only influences the overall price level of a country, yet has no impact on price comparisons within a country. The VAT rates in the analyzed countries (Austria, Finland, the Netherlands, and Sweden) are 20%±1%.

Subsidies and other promotion schemes also have an impact on the competitiveness and total heat generation costs of different heating systems. In our analysis they could have analogous effects to energy taxes. In order to focus on the key issues the impact of subsidies was not taken into account in this research.

4.4 Exergy-Cost-Graphs

In the case studies we use diagrams to visualize the correlation between exergy and costs. As shown in Figure 2, the x-axis represents the overall exergy factor as defined above in Equation 5. The y-axis indicates the costs components defined in Equation 6. Diamond and triangle-shaped data points indicate costs with and without energy related taxes, respectively. The upper triangles (3) represent the economic value of total specific heating costs, without the political intervention of energy taxation. The upper diamonds (4) show the total specific heating costs including taxes.

The lower data points show the specific variable costs of the heating systems, again either excluding (1) or including (2) energy related taxes. The difference between (1) and (3) are the fixed costs. Fixed cost components are mainly related to the installed or supplied thermal power, and can be seen as an indication of the investment capital needs for a given type of heating system.

The following figure shows these values for two generic examples of heating systems (left hand side heating system A, right hand side heating system B). In between, other heating systems or combination of heating systems could be located. In the following case studies we will present the results of a broader variety of heating systems that are typical for each of the considered countries.

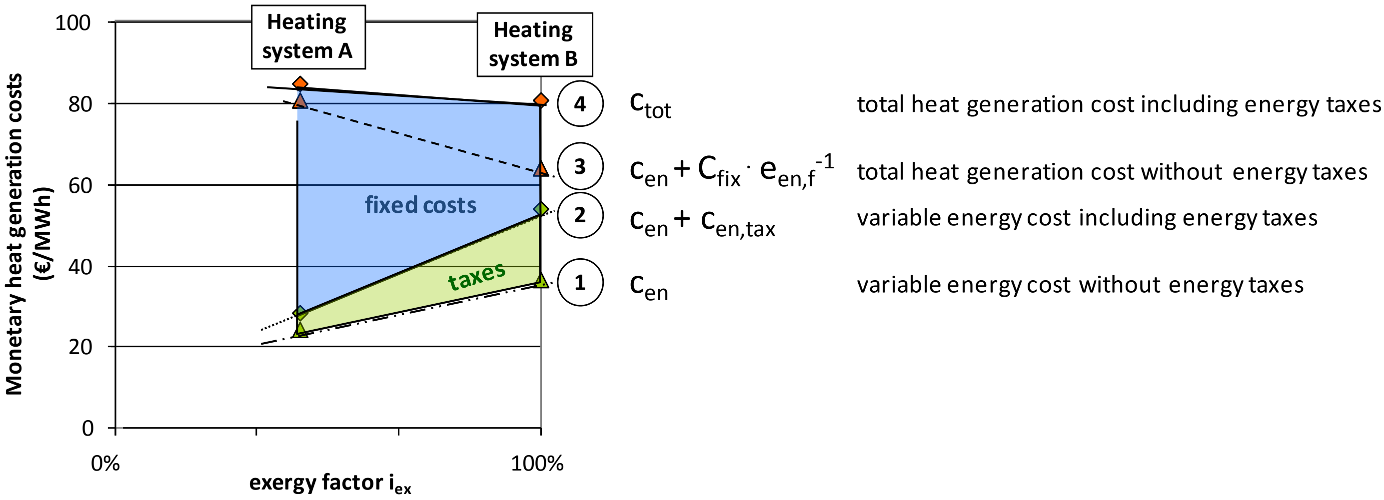


Figure 2. Comparison of cost components of different heating systems

5 Country specific case study 1: Austria

5.1 Local conditions

Due to the topographic conditions, heating degree days (hdd 12/20) in Austria vary considerably. However, the most populated areas show quite comparable values of heating degree days (3200 – 3400 Kd/yr). The mountainous regions with higher values (up to 4300 Kd/yr) have much lower population density. Average heating degree days in Austria are in the range of about 3500 Kd/yr.

5.2 Description of the chosen building

In the last few decades, the quality of thermal insulation of residences in Austria has improved significantly. The annual heating demand of single-family houses which were built before 1981 range from about 160 to more than

300 kWh/m² and those of multi-family houses from about 110 to 150 kWh/m². By contrast, the annual heating loads of houses from the period 2002 to 2007 are about 50 kWh/m².

According to Amann 2005 [24], the following annual rates of thermal renovation were achieved in the nineties: Less than 1 % in the field of privately owned houses and homestead apartments and about 2 % in the field of municipal tenements. On average, the rates of thermal renovation were 1 %. Current rates are estimated to be slightly higher (1 % and between 2 % and 3 %, respectively).

However, from 1990 to 2006, the effect of decreasing average heating loads was compensated by an increase of the average floor space. In total, the final energy consumption for space heating and cooling has stayed relatively constant throughout this period.

For our analysis we selected a conventional single family house with an annual heating energy demand of 20 MWh. With a typical size of 150 m² this leads to a specific energy consumption of 133 kWh/m²yr. This corresponds more or less the case of the single family house of the construction period 1981-1991 or an older building after related thermal renovation measures.

5.3 Description of the selected heating systems

Figure 3 provides insight into the structure of the current stock of principal residences in Austria and the installed heating systems. About 50 % of the total stock has central heating systems installed and about one fifth is equipped with access to district heating systems. Concerning the age-structure, it is clear to see that in residences in older buildings the share of single stoves, gas and self-contained central heating systems is significantly higher than in newer buildings. Among residential buildings which were constructed after 1970, about 60 % have central heating systems installed and 22 % have access to district heating.

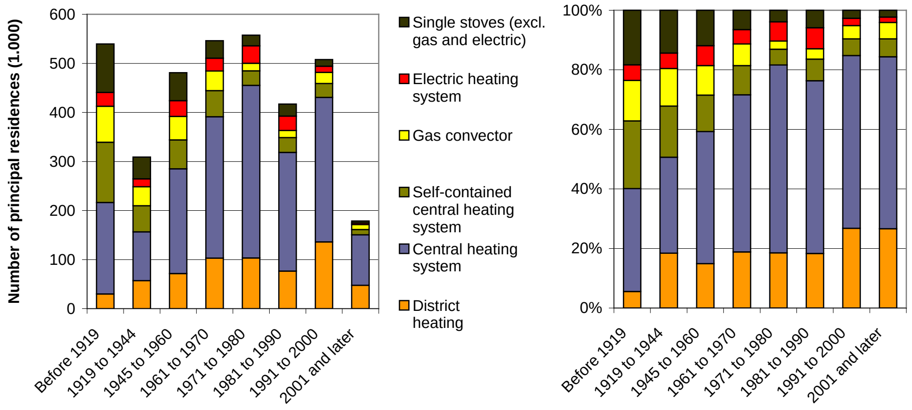


Figure 3. *Structure of principal residences in Austria broken down by age-structure of the building and heating systems in 2007(Statistik Austria, 2009 [25])*

The following heating systems were selected for the Austrian case study:

- District heating: assumed to operate by waste heat either from a CHP plant or from industrial processes.
- Heat pumps (air/water; brine/water)
- Biomass central heating systems (based on wood log, wood chips, wood pellets)
- Fossil based central heating systems (gas, oil)
- Direct electric heating
- Combination of solar collectors with natural gas central heating; a solar ratio of 1/3 is assumed.

5.4 Consumer prices and cost structure for thermal energy

Table 3 lists the input data that have been used for the heating systems investigated in the Austrian case study.

Table 3 Energy costs, consumer prices and technology data for the heating systems considered in Austria

		Wood log boiler	Wood pellets boiler	Gas boiler	Oil boiler	District heat Vienna	Heat pump air/water	Heat pump brine/water surface	Electrical convection type heater	Electrical night storage heater
Variable energy price	€/MWh	23	29	40	40	31	83	83	83	73
Energy taxes	€/MWh	0	0	5	11	0	17	17	17	17
Investment costs	€	10.728	13.645	10.915	10.298	11.085	11.417	16.417	2.565	3.794
Levelized investment costs	€/a	1.034	1.315	1.052	992	1.068	1.100	1.582	247	366
Operation and maintenance costs	€/a	297	352	202	270	443	233	194	21	30
Total fixed costs	€/MWh	67	83	66	63	98	70	93	17	24
Total heat generation costs with taxes	€/MWh	97	121	113	112	131	104	113	100	97
Total heat generation costs without energy taxes	€/MWh	97	121	120	125	131	110	118	117	114

Cost data: own calculations based on data taken from Müller et al. (2009) [26], RES (2009) [27], Reichl et al. (2010) [28]

5.5 Energy cost and consumer price analysis based on exergy factors of used energy carriers

The following graph (Figure 4) shows the cost components of heat generation costs vs. the exergy factor of various heating systems and the respective energy carriers. We distinguish between the costs for the energy carrier (depending on the energy price and the efficiency of the heating system) with and without taxes and the total heat generation costs with and without taxes. The slope of the corresponding regression lines can be understood as a rough indicator to what extent these components of the heat generation costs are based on the exergy content of the energy carriers.

The graph shows that on the level of the energy carriers (with and without taxes), there is a clearly positive gradient. At the level of the total generation costs we see that there is no positive or even a negative gradient. We can see this under two points of view: First from the market point of view: The economic decision of consumers for a heating system is based on the total generation costs (as far as the decision is based on an economic basis at all). The market for a specific type of building thus leads to comparable total heat generation costs for multiple heating systems.

Second, from the exergetic-economic point of view: Obviously there is a tradeoff between capital expenses and fuel expenses. For making use of low-exergy energy carriers' additional effort for corresponding technologies and thus capital expenditures is required.

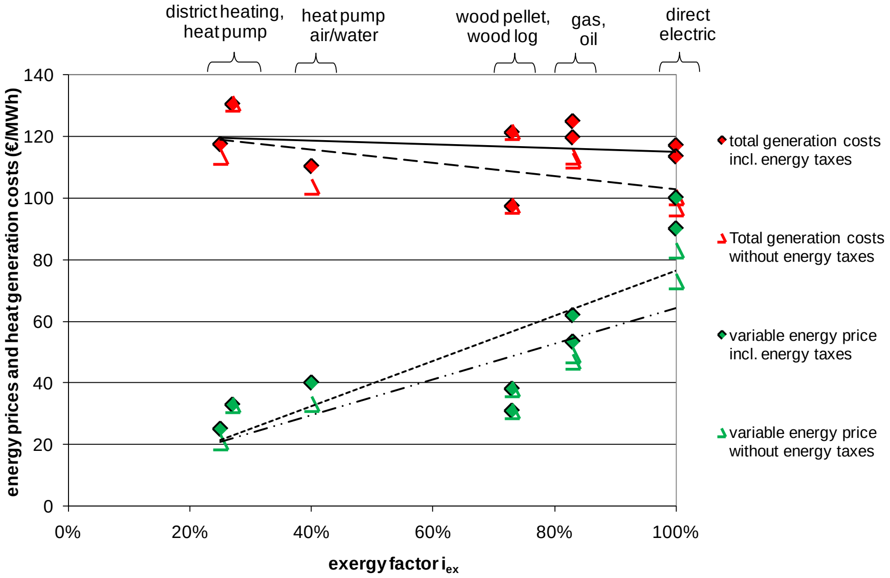


Figure 4. Components of heat generation costs vs. exergy factor for various heating systems for the Austria case study. From left: District heating (based on waste heat), heat pump, various biomass systems (wood log and wood pellets), fossil based systems (natural gas and oil), direct electric heating.

5.6 Conclusions

Having a more detailed look on the graph, we can observe that the most important points that do not fit well to the regression line are biomass systems. To our mind, the reason for that lies in the fact that solid fuels require more expensive boilers than liquid or gaseous fuels in order to guarantee a high efficiency and low emissions. This is an aspect which is not related to the exergy content of the energy carrier but lies in this specific nature of solid fuels.

The following conclusions can be drawn from the Austrian case study:

- The deviation from mean heat generation costs is both with and without energy taxes below 25%. The only major exemption here is wood log (see above). This fact can clearly be explained by the general lower comfort level of a manually fed biomass heating system compared to an automatic one.

- The deviation from the regression line for the energy prices is also in the range of about 25% (for biomass higher, see above). Again, the biomass fuels show the highest deviation from the regression line. Here, this can be explained by the fact that the energy carriers electricity, oil, gas and biomass do not only differ with respect to their exergy content. Rather, there are also principal differences with respect to their suitability for well controlled combustion processes. Biomass needs a more capital intensive system in order to achieve high efficiencies and low emissions.
- This supports both hypotheses of our paper (see section 1).

6 Country specific case study 2: Finland

6.1 Local Conditions

Finland differs from most industrialized countries in that many of its energy needs stem from the Nordic conditions. Finland is located between 60 and 70 degrees northern latitude and a quarter of its area lies north of the Arctic Circle. In fact, one third of all people living north of the 60th parallel are Finns. The annual mean temperature in the south of the country is around 5 ºC and 0 ºC in the north. The population-weighted average number of heating degree days for Finland is 5000 Kd, considerably more than in Sweden and Norway (4000 Kd). Thus, the Finnish climate is the coldest in the EU and, consequently, a large share of the energy (22 %) is used for the heating of buildings. Hence, the economical use of heating energy is of especially great importance in the Finnish conditions. (Alakangas 2002 [29]).

6.2 Description of the chosen building

According to Statistics Finland (2009) [30] the Finnish residential building stock is 270 million m^2 of which 55 % are single-family houses, 33 % apartment buildings and 12 % row houses. The calculations for the Finnish example building are based on the norm house as it is defined by the Finnish government energy efficiency promotion corporation Motiva in its heating energy calculator software. The building represents a typical contemporary Finnish single-family house. The gross built area of the building is 147 m^2 and its volume is 455 m^3. A typical Finnish family of two adults and two children is assumed to dwell in the house. The U-values of the envelope components are as follows: walls 0.21 W/m^2K, roof 0.15 W/m^2K, floor 0.20 W/m^2K, windows 1.50 W/m^2K and doors 1.50 W/m^2K. More details are available from Motiva (2007) [31].

6.3 Description of the selected heating systems

District heating is the most commonplace heating source in Finland with a share of 43 % of all heated area. It is most common in cities and towns and larger buildings. Small buildings and rural areas are usually covered with other heat sources. In all of the building stock, oil and electric heating share the second place with 22 % each. Solid fuels such as wood and peat are used in 8 % of buildings and the remaining 5 % use other heating sources such as ground heat pumps.

Heat pumps encounter in the Finnish conditions the difficulty that very low outside temperatures lower their efficiency just when heat is needed most. Usually they have to be supplemented with firewood or direct electric heating, which lowers the overall efficiency of heating. Nevertheless heat pumps are a viable heating form in Finland and enable significant reductions in heating energy consumption.

In single-family houses direct electric radiator heating has the largest share, 44 %. Oil heating has a share of 25 % and solid fuels 21 %. District heating is used in 6 % of the stock and 4 % use other heating sources. (Statistics Finland 2007 [32])

In newly constructed houses, however, the shares are quite different. In 2004 the share of direct electric heating had risen to 56 % and district heat and ground heat pumps to 14 % each for new houses. Oil heating was installed to 9 % of the new houses and solid fuel heating only to 6 %. (Heljo 2005 [33])

Overall, district heating, oil and electricity are the most important heating sources in Finland – together they cover 87 % of space heating in the country. Moreover, in single-family houses firewood heating has a major role. They are, therefore, the heating sources that have been chosen for the analysis presented here.

Firewood is also used in other forms than wood pellet, especially as a secondary source of heat. Here pellet heating was chosen because pellets have a market on a national level and as a boiler-based system it is best suited to be a primary heating system in a new house.

The following heating systems were selected for the Finnish case study:

- Wood pellets boiler
- Oil boiler
- District heating
- Heat pumps (air/water, ground/water)
- Direct electric heating
- Partially storing electric heating

6.4 Consumer prices and cost structure for thermal energy

Table 4 shows data for various cost components of heat generation costs, and sources thereof, used for this analysis. Prices are averages for 2005, except for wood pellets, where prices provided by Motiva (2007) [31] are used. For district heating, an annual base tariff is charged based on the water flow from the system, which averages around 20 % of annual heating costs, excluding investment costs (Turku Energia 2009 [34]). Additionally, a fee is charged for the energy consumed. The initial investment cost is rather high and includes a charge for connecting to the district heating system.

Oil heating has lower investment costs but the energy price tends to be higher than for the low-exergy district heating. Taxes include – if charged –fuel taxes, yet exclude VAT. Direct electric heating has lowest investment costs, but the energy cost is the highest. In addition to variable energy price, a monthly fee is collected, but this is not included in the calculation, as it is assumed that households would have a grid connection in any case. About 28 % of the electricity price is different taxes, including VAT and an electricity tax. These are also paid by the users of heat pumps, but since a significant amount of heating energy is pumped from the air exhaust or the surroundings, the effective energy price is similarly lower.

Table 4. Energy costs, consumer prices and technology data for the heating systems considered in Finland

		Wood pellets boiler	Oil boiler	District Heat	Heat pump exhaust	Heat pump ground	Direct electric heating	Partially storing electric heating	
Variable energy price	€/MWh	34	33	31	53	53	53	48	(1)
Energy taxes	€/MWh	0	14	2	9	9	9	8	(T)
Investment costs	€	12.780	10.584	10.112	7.762	13.650	2.989	4.034	(2)
Levelized investment costs	€/a	1.231	1.020	974	748	1.315	288	389	(c)
Operation and maintenance costs	€/a	124	96	43	92	126	64	76	(1)
Total fixed costs	€/MWh	68	56	62	42	72	18	23	(c)
Total heat generation costs with taxes	€/MWh	110	96	95	69	92	71	72	(c)
Total heat generation costs without energy taxes	€/MWh	110	112	98	73	95	80	80	(c)

* Excluding taxes. (1) For district heating, see (Finnish Energy Industries 2006 [35]), oil and electricity (Statistics Finland 2009 [36]), wood (Motiva 2007 [31]). Heat pumps cut energy costs for heating energy with the same share as heat can be derived from costless sources. (2) See (Motiva 2007 [31]), also source for annual energy consumption. (C) Indicates calculation from other figures, (T) indicates calculation of taxes according to national tax code.

6.5 Energy cost and consumer price analysis based on exergy content

Figure 5 shows the relation between the different components of heat generation costs of various heating systems using specific energy carriers and the exergy content of the said carriers. The results show that in the Finnish case the postulated correlation can be seen: indeed the lower the exergy content, the lower the price of energy and thus the variable costs of its use.

When fixed costs are included, the total heat generation cost differences are leveled off somewhat, although not entirely. However, the lower exergy alternatives are not systematically cheaper now. For example, district heating appears to be somewhat more expensive than the higher exergy alternative, heat pump. The leveling of heat generation cost differences would appear to confirm the hypothesis of the exchangeability of capital and exergy, since higher capital investment seems to allow the use of lower exergy energy.

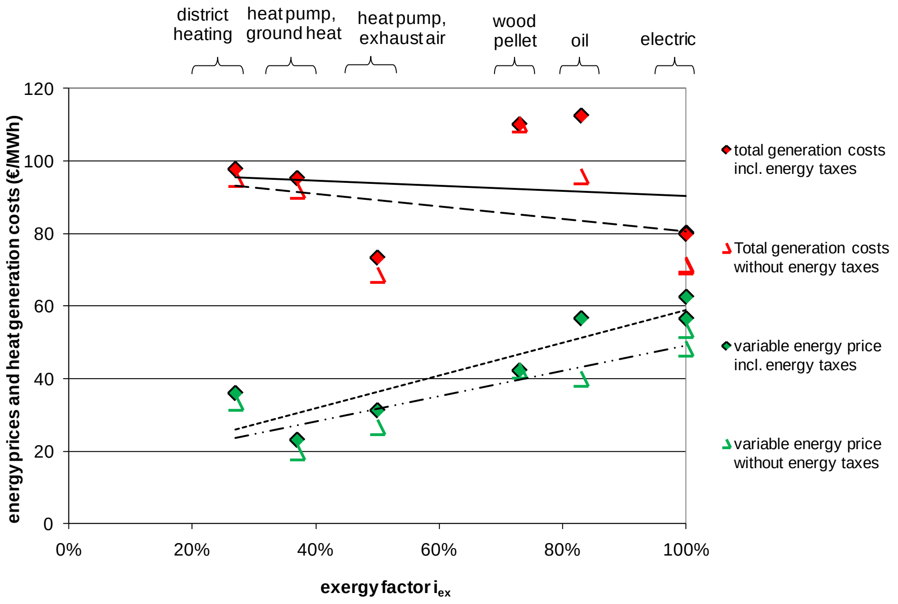


Figure 5. Components of heat generation costs vs. exergy factor for various heating systems in Finland. From left: District heating (based on waste heat), heat pump ground heat, heat pump exhaust air, wood pellet, oil, direct electric heating.

6.6 Conclusions

The Finnish case shows a positive correlation with exergy factor and the price of an energy carrier, as is shown by the two lowest trend lines in Figure 5. However, the when capital costs associated with the use of the energy carriers is factored in, the difference in total heat generation costs is leveled out. This is shown by the two uppermost trend lines that represent the total generation costs.

These findings are in agreement with the hypothesis that exergy, rather than energy, would be the basis for energy pricing. This makes sense considering that exergy represents the useful, applicable portion of energy and is, therefore, of economic interest to users. It is also expected that including capital costs should even out the price differences: should one form of heating have a higher total cost than the others, its demand would diminish and prices would fall. It seems therefore that, in this sense, capital and exergy are at least partly interchangeable in the Finnish market for heating energy.

A typically Finnish finding is the advantageous competitive position of electrical heating systems. This is can be attributed to the relatively low price of electricity in Finland. Also the Finnish conditions require a rather large investment in hardware, which brings an advantage to the less capital intensive electrical heating systems.

7 Country specific case study 3: the Netherlands

7.1 Local Conditions

The Netherlands have a population of 16.5 million people and are located in the western part of Europe along the North Sea. This location offers a maritime climate with an average temperature of 9.8 °C (KNMI, 2009 [37]). The rainfall is notorious, but statistics from 1971-2000 show that it is only around 770 mm per year. The incoming solar radiation is 1313 to 2881 MJ/m^{2}y (364.7 to 800.3 kWh/m^{2}yr) depending on the orientation of the surface. These weather conditions and heating degree days of about 2750 Kd/yr a year (using 18 °C as reference) make it necessary to heat most dwellings during six or seven months per year.

7.2 Description of the chosen building

There are approximately seven million dwellings in the Netherlands. Every year 80,000 to 100,000 dwellings are added to this stock. The national agency of the Ministry of Economic Affairs for innovation and sustainable development, named AgentschapNL (formely known as SenterNovem), has specified multiple reference dwellings, which enables them to estimate the energy consumption. The reference dwellings are divided in two main categories: 27 different types of existing dwellings and 6 types of new dwellings. The most common type of dwelling is the row house. Row houses built between 1946-1965 form an important majority in the building stock, that originally did not incorporate any energy efficiency measures at all (SenterNovem, 2007 [38]).

Between 1980 and 1988 another common type of row houses was built, that already showed some basic insulation. This group nowadays consists of approximately 469,000 houses. These houses will form in this research our example. The houses have in general a surface area of 98.1 m^2. The U-value of the ground floor is 1.1 W/m^{2}K with a surface of 44.7 m^2. The U-value of the roof is 0.68 W/m^{2}K and has a surface of 58.4 m^2. The walls have a thermal surface of only 35.8 m^2 and a thermal resistance of 0.65 W/m^{2}K. The windows on the ground floor have double glazing (10.4 m^2 and 3.1 W m^{2}K). The windows on the first floor were originally single glazed (3.4 m^2 and 5.1 W/ m^{2}K) [38]. It has been calculated that these houses have a gas consumption of

1417 m³/year and a building related electric energy use of 222 kWh/yr for ventilation and as auxiliary energy for the gas boiler system.

On average a household used in 2006, according to Milieucentraal (2008) [39], 3402 kWh electric energy and 1652 m³ natural gas. CBS (2008) [40] speaks of 1470 m³ natural gas per household in 2006 and of 1375 m³ in 2007. In 2006 the electric energy use was, according to them, 3618 kWh. Based on the weather conditions and system efficiency, a natural gas consumption of 1401 m^3/year complies with 34.74 GJ/year. When electric heating systems would be used, the system efficiency within the building shell is at a maximum. Nevertheless, within the power plant the efficiency is approximately 39 %.

7.3 Description of the selected heating systems

In the fifties one the largest natural gas supplies in the world was found in the Netherlands. Since the sixties it is therefore common to heat water, living space and work space by burning natural gas. There are also quite some dwellings, namely more than 250.000, connected to district heating. New houses are in general equipped with highly efficient (HR107) boilers (sometimes assisted by a solar collector) or heat pumps. New houses should comply with a so called Energy Performance Coefficient of 0.8. This coefficient is computed by an equation that relates forecasted and permissible energy use. The forecasted energy use is based on the efficiency of the installed equipment, heat demand, warm tap water use, lighting, etc. The permissible energy use is mainly based on the size of the object (Entrop et al, 2010 [41]).

During the last decade the average gas consumption per dwelling is decreasing, but the electric energy use is increasing. Electric energy is rarely being used to heat houses. Nevertheless, the increasing amount of electric equipment and the broad availability of air conditioning systems explain the increasing demand for electric energy. Most electric energy is being generated in power plants that use natural gas. The waste heat of these power plants is sometimes used to provide district heating. Due to the fact that heat pumps are very rare, they were not considered in the Dutch case study. The following heating systems were selected for the Dutch case study:

- district heating
- Natrual gas boiler
- Electric heating

7.4 Consumer prices and cost structure for thermal energy

The Dutch energy pricing system consists of several components. First of all, the costs of the energy and the costs of the infrastructure to provide the specific form of energy are charged separately. Secondly, many Dutch households receive an energy bill based on double tariffs. In that case two different fares are being used for electric energy: a low fare for during the night and a high fare for during daytime. When a household consumes more electric energy during daytime than during the night, it is often cheaper just to use a single tariff. Depending on the region you live in, you will have 88 till 98 hours per week in which the low fares are being charged.

A Dutch energy bill will in general address the following items:

- Providing electric energy: the electric energy can be paid for by a price per kWh in the form of single tariff or double tariffs with low and high fares. On average the electric energy price was 0.179 €/kWh in 2005 (CBS, 2009 [40]);
- Providing natural gas: providing the natural gas resulted in a price of 0.503 €/m^3 in 2005 [40];
- Infrastructure electric energy: two components of costs can be distinguished; providing the electric energy resulting in a price per kWh (single tariff or double tariff with low and high fares) and fixed costs resulting in a price per year. In 2005 a 3 x 25 A connection did cost 48.30 €/year and 0.0328 €/(kWh·yr) (Energiekamer, 2005 [42]);
- Infrastructure natural gas: two components of costs are distinguished, which vary per region; providing the natural gas resulting in a price of 0.012642 €/m^3yr per gas consumed and fixed costs resulting in a price of 51.85 €/yr [42]. Since 2009 there is only a fixed rate that does not depend of the amount of gas consumed;
- Meter costs: again two components of costs addressing the meter for electric energy use and natural gas consumption. These fees are approximately 25 €/year.
- Energy tax: three components of costs can be addressed here:
  - Taxes per kWh for electric energy use of 0.0699 €/kWh in 2005;
  - Taxes per m^3 for natural gas consumption of 0.1494 €/kWh in 2005;
  - A discount on the taxes per household of 194 € in 2005
- Administration costs: additional costs of 25 to 50 €/yr to be billed by the energy company.

Table 5. Energy costs, consumer prices and technology data for the heating systems considered in the Netherlands

		Natural gas	District Heating	Electric Heating
Variable energy price	€/MWh	38	50	125
Energy taxes	€/MWh	16	23	42
Investment costs	€	11,931	10,592	3,462
Levelized investment costs	€/a	1,149	1,020	334
Operation and maintenance costs	€/a	81	50	13
Total fixed costs	€/MWh	87	87	60
Total heat generation costs with taxes	€/MWh	134	140	184
Total heat generation costs without energy taxes	€/MWh	154	164	226

7.5 Energy cost and consumer price analysis based on exergy content

Natural gas is a relatively cheap energy carrier regarding exergy content compared to electric energy. The principle of price leveling ensures that district heating is relatively expensive compared to natural gas, because of the low exergy factor of the heated water used in district heating networks. For the Dutch case, we decided not to draw the regression lines in a similar way as we did it for the other regions, because we think that the result of the three heating system data points does not allow for a too rigorous interpretation.

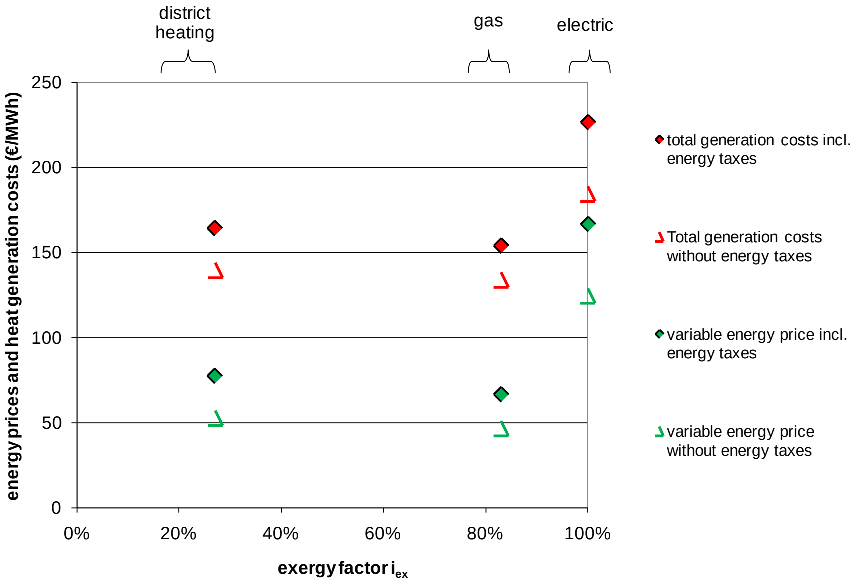


Figure 6. Components of heat generation costs vs. exergy factor for various heating systems in The Netherlands.

7.6 Conclusions

The Netherlands have regulations regarding the maximum consumer price of district heating, stating that the fares should not be higher than when the house would be connected to the natural gas network. The energy bills of comparable houses and households connected to the gas grid or district heating grid should therefore be the same. Nevertheless, when we regard the exergy factor the price of district heating is relatively high compared to natural gas. One of the reasons could be that this price includes some part of the up-front investment costs for the district heating grid costs (which we did not take into account due to our system boundaries.) The large supply of natural gas and the extended Dutch network for its distribution in a dense area result in a relatively low energy price. The investment costs for district heating systems (i.e. cogeneration systems producing electric energy and heat and their grid of insulated tubes) are assigned to consumers by means of a relatively high variable price per gigajoule. The direct investment costs for the consumer (i.e. a heat exchanger) are relatively low compared to the gas boiler for example.

When regarding electric energy as an option to heat houses, it is clear that the investment costs are relatively low. However, the variable costs are significantly higher than in the case of district heating or natural gas. Some new neighborhoods are now being developed without connections to the natural gas grid or without district heating. In those cases consumer investments in other heating systems could have a shorter return on investment period than for houses that are connected to natural gas or district heating grids.

In all situations the taxation has a significant impact on the heat generation costs levels. Especially the prices of electric energy are strongly influenced.

8 Country specific case study 4: Sweden

8.1 Local conditions

The distribution of the population in Sweden has great influence on its energy use for building heating: the total population accounts for about 9.2 million inhabitants on an overall surface area of circa 450 km^2, thus resulting in an average population density of 20 persons per km^2, with a much higher figure in the southern areas of Sweden. Most of the population lives in urban areas, fact that contributed to the large diffusion of the district heating suitable in the last decades.

Climate conditions in the country vary dramatically according to the latitude: the number of degree days referred to an inside temperature of 17 °C ranges from 3000 in the south to 7000 in the north, with an average value of about 5200 (Eurostat 2007 [43]). Accordingly, design day for district heating accounts for an outside temperature of -14 °C in the south and -36 °C in the north [44].

8.2 Description of the chosen building

According to Statistiska centralbyrån ([45][46][47]), the Swedish government agency for statistics, the number of multi-dwelling buildings in the country is about 2,400,000 for a total heated area of 163 million m^2 and almost two millions for one- or two-dwellings buildings, totalizing 263 million m^2.

Characteristics of the building stock vary a lot depending on the construction year, the type of building and the building place. However, a standard house built in the nineties would feature an insulation of 200 mm in the external walls, 350 mm in the roof and 100 mm in the ground floor with a U-value for the windows of 1.5 W/m^2K; infiltration would be typically 0.6 l/s m^2 at 50 Pa.

8.3 Description of the selected heating systems

The yearly energy use for heat in Sweden in 2006 (IEA, 2008 [48]) was 50.4 GWh; about 90 % of the heat produced is used in the building sector, with 60 % in residential sector and 30 % in commercial and service sector, while the remaining part is used in the industry.

The DH market share for the heat supply in Sweden has been saturated for the multi-family houses and the services buildings, also due to legislation constraints aiming at the spread of this supply mean for large buildings. In 2006, district heating represented 76 % of the total energy supply for heat in multi-dwelling buildings and heat pumps accounted for 10 % of the heat supply, the remaining quota being oil (2 %), direct electricity heating (3 %) and other sources (around 9 %) [45].

A completely different situation regards small houses –grouping one- and two-dwelling buildings: heat is provided mostly by means of heat pumps (32 %) and direct electric heating (31 %), while district heating, which still represents a minor presence, is set to 10 %. The rest is covered by other sources, mainly wood, chip and pellets for a total amount of 10.4 TWh [46].

Residential and commercial buildings in Sweden make use of respectively about 31% and 21 % of the total electricity produced, which comes almost entirely from nuclear power (46.7 %) and hydropower (43 %) (IEA [48]).

Heat is produced mainly by biomasses (53 %), waste (12.8 %) and coal (11.5 %).Small quantities of oil (6.2 %) and gas (3.6 %) are also used for this purpose [49].

The following heating systems have been selected for the Swedish case study:

- District heating
- Oil boiler

- Gas boiler
- Direct electric heating
- Heat pumps

8.4 Consumer prices and cost structure for thermal energy

Six types of heat supply technologies have been considered in this study case: wood pellets boiler, district heating, electric resistance radiators and heat pumps, oil and gas boilers. According to the above described energy distribution in the buildings, district heating has been referred to a multi-dwelling building, where it represents the absolute majority of the cases, while electricity and natural gas have been related to small households. As previously stressed, there is a very small presence of oil and gas for heating purposes; even though, they are here considered to maintain a similitude with the other study cases in this paper.

The prices for the different energy carriers vary very much according to the energy use: for electricity, five residential standard consumers are considered, from 600 kWh to 20,000 kWh, equal to about a subscribed demand of 9 kW.

For natural gas, as well, five standard consumption bands are provided, ranging from around 2400 kWh for a solely oven gas to 290 MWh for a central heating supplying at least ten dwellings. The first two bands, that are not regarding heating, have not been considered here.

In Table 6 the components of heat generation costs for the different energy carriers are gathered. Data are given in Euro even if the official currency in Sweden is the Krona to allow simpler comparisons with the other countries: however, since the Euro-Krona exchange ratio[1] has changed dramatically in the last two years, direct comparisons should be made with caution. Once again it should be stressed that the most relevant information is found in the comparison of the sources within a country more than between costs of the same sources among different nations.

---

[1] In this paper an exchange rate of 9,28 SEK/€ has been used.

Table 6. Energy costs, consumer prices and technology data for the heating systems considered in the Sweden

		Wood pellets boiler	Oil boiler	District Heat	Heat pump ground	Direct electric heating	Gas
Variable energy price	€/MWh	34	38	36	65	65	42
Energy taxes	€/MWh	0	32	0	24	24	21
Investment costs	€	12396	10672	19810	15844	8517	10241
Levelized investment costs	€/a	1194	1028	1909	1526	821	987
Operation and maintenance costs	€/a	323	215	120	161	0	215
Total fixed costs	€/MWh	65	53	83	72	35	51
Total heat generation costs without taxes	€/MWh	107	100	124	96	100	94
Total heat generation costs including energy taxes	€/MWh	107	139	124	105	124	115

Investment costs of central heating systems include boiler costs and the heat distribution costs inside the building (5500 €)

8.5 Energy cost and consumer price analysis based on exergy content

Figure 7 shows the investigated correlation between components of the heat generation costs and exergy factors of the energy carrier for Sweden, the lower line representing the variable costs for energy excluding taxes and the upper one representing the total energy costs.

Here as well a certain direct correlation between cost and quality of the energy delivered is found but it appears that there is less compensation via taxation, the way the legislator has to compensate the energy use of the different sources, than in other countries.

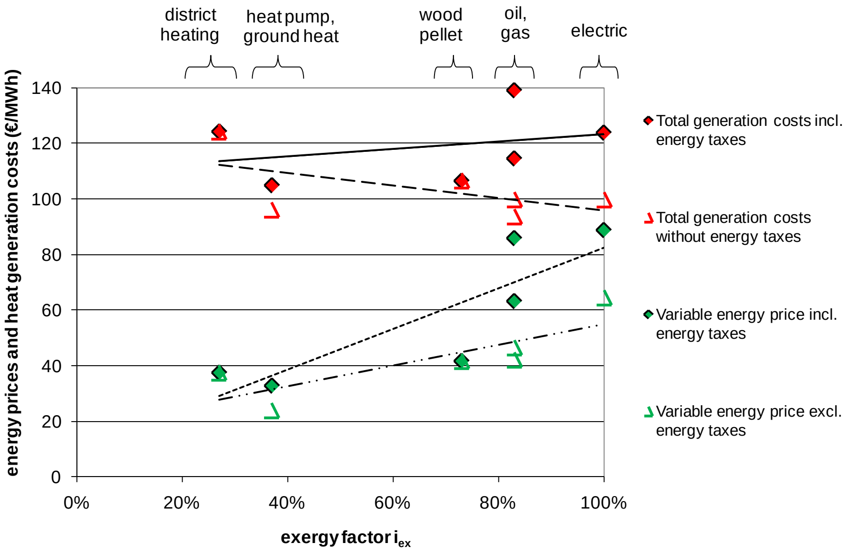


Figure 7. Components of heat generation costs vs. exergy factor for various heating systems in Sweden. From left: District heating (based on waste heat), heat pump ground heat, wood pellets, fossil based systems (natural gas and oil), direct electric heating.

9 Synthesis

In the previous sections we compared different components of heat generation costs, in particular energy prices and total heat generation costs depending on their exergy content for different selected European countries. As a next step we are carrying out a synthesis of these results by comparing all considered heating systems in those countries. For this purpose, we are calculating the share of variable energy costs on the total heat generation costs for each technology and country (each including energy taxes). A low share of variable energy costs means indicates that a relatively high share of the total heat generation costs is due to investment costs. A high share indicates that only a relatively low amount of investments is necessary to provide useful heat with this heating system.

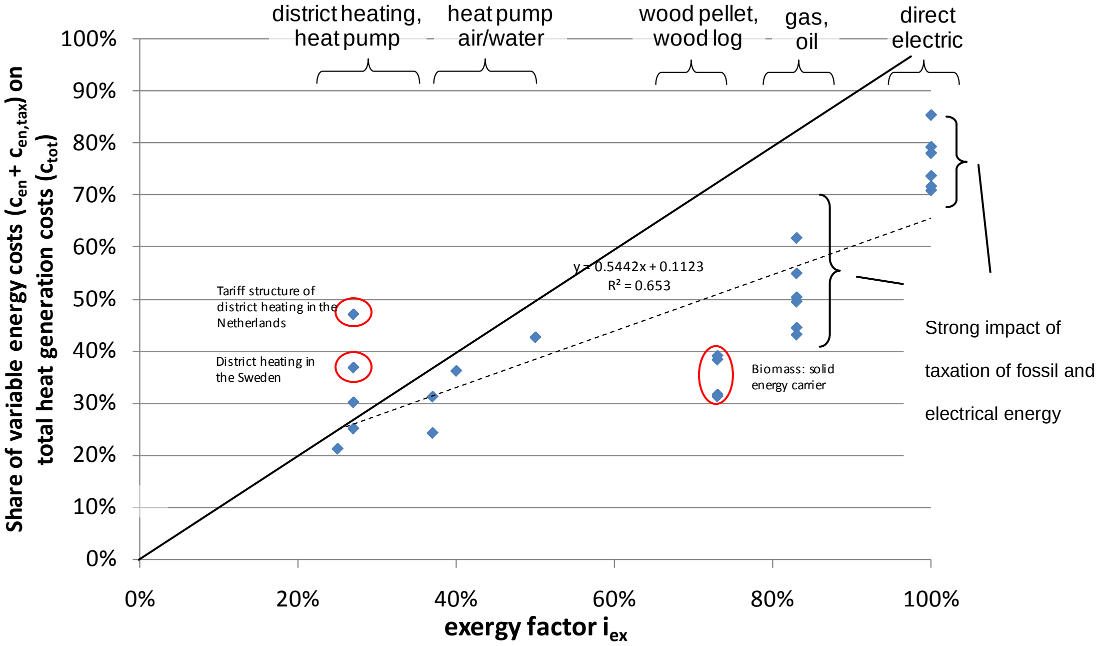


Figure 8. Share of variable energy costs on total heat generation costs for all technologies and case studies

Figure 8 shows a rather strong relation between the share of variable energy costs (mainly influenced by energy prices, taxation of energy carriers and the efficiency of the heating system) on the total heat generation costs and the exergy factor of the used energy carriers for many data points. This shows that the lower the exergy factor, the higher the investment and capital needs for making use of this low-exergy energy source. Major outliers can be explained by taking the drawn system boundaries into account. Since we used the price structure of retail consumers, at least some part of the upfront investments do account for variable energy costs. This is particular evident for the tariff structure of district heating in Sweden and the Netherlands. Biomass technologies considered in this study are using a raw energy carrier compared to the other technologies, which again means, that all the necessary purification and other comparable processes, which take place upfront for the other technologies, have to be done within the chosen system boundaries.

9.1 Conclusions

The case studies showed that, even though the exergy content of energy carriers is reflected to some extent in the variable costs, this is not the case for the total heat generation costs. The reason is that additional capital expenses are required for making use of these low-exergy resources. Thus, capital costs level out the lower variable costs of low-exergy energy carriers.

This can also be formulated in terms of the possibility to substitute exergy with capital and hence reduce the consumption of high-exergy resources by additional capital input[2]. This supports, for the cases studied here, the proposition that exergy and capital can be substituted for each other to some extent. As detailed in the literature review, exergy experts have been proposing metrics (e.g. exergoeconomic factor, exergetic cost factor) to define and quantify the relationship between monetary and exergetic costs (though in the literature this is mainly done for CHP and large scale industrial applications).

In our analysis, we bear in mind that using low exergy energy carriers usually requires the installation of more equipment, which explains the higher capital cost but also entails more opportunities for technological improvement. Taking the case of Austria, if advances in technology would lead the capital cost to drop by 20 % for a low exergy heating alternative, e.g. heat pumps, this could potentially lead to a drop in total cost of about 20 €/MWh according to Figure 4. For a high exergy heating alternative, e.g. direct electric heating in Austria, the share of capital cost is much smaller. Even if advances in technology did lower capital costs by 20%, again reading from Figure 4, that would only lead to a drop of about 5 €/MWh in total costs. Therefore the prospects of technological improvement appear in general more promising for low exergy alternatives when considering the sheer volume of physical capital alone.

Several open questions are left for further research. In particular they refer to the following issues:

- extending the sources of energy carriers and systems (e.g. solar thermal systems),
- extend the system barrier (e.g. including the capital costs for gas or district heating grids),

---

[2] The question, to which extent the material consumption for this additional capital input again implies exergy consumption, is left for further research (Valero et al. 2010 [50])

- extending the exergy concept to the exergy needed for an investment (e.g. boiler, district heating grid etc)

The results of this analysis and the proposed approach, as well as further research on this topic, could be used to provide policy recommendations on how to adjust energy carrier taxation as well as other policy instruments so as to stimulate the use of low-exergy carriers to meet low-exergy demands in buildings.

10 Acknowledgement

This publication was enabled by action C24 (*www.costexergy.eu*) of COST, a European framework enabling international cooperation between scientists conducting nationally funded research (*www.cost.esf.org*) as well as IEA ECBCS Annex 49 (www.annex49.com).

11 References

[1] IEA, “30 years of energy use in IEA countries, 30 years of energy use in IEA countries,” 2004.

[2] M. Ala-Juusela and A. Rautakivi, “Annex 37: Low Exergy Systems for Heating and Cooling of Buildings,” *Heating and Cooling with Focus on Increased Energy Efficiency and Improved Comfort Guidebook to IEA ECBCS Annex 37 Low Exergy Systems for Heating and Cooling of Buildings*, 2003.

[3] M. Lozano and A. Valero, “Theory of the exergetic cost,” *Energy*, vol. 18, Sep. 1993, pp. 939-960.

[4] M. Tribus and R.B. Evans, *A Contribution to the Theory of Thermoeconomics*, UCLA, Dpt. of Engineering. Report No. 62–63, Los Angeles, USA, 1962.

[5] A. Lazzaretto and G. Tsatsaronis, “On the quest for objective equations in exergy costing,” *Proceedings of the ASME advanced energy systems division, AES*, New York: ASME, 1997.

[6] J. Deng, R. Wang, J. Wu, G. Han, D. Wu, and S. Li, “Exergy cost analysis of a micro-trigeneration system based on the structural theory of thermoeconomics,” *Energy*, vol. 33, Sep. 2008, pp. 1417-1426.

[7] C.A. Frangopoulos, “Thermoeconomic functional analysis :
a method for optimal design or improvement of complex thermal systems,” Dissertation, Georgia Institute of Technology, 1983.

[8] A. Valero, L. Serra, and M. Lozano, “Structural theory of thermoeconomics,” New Orleans: Richter HJ., editor. International symposium on thermodynamics and the design, analysis and improvement of energy systems, ASME Winter Annual Meeting, ASME book no. H00874, 1993, pp. p. 189–98.

[9] B. Erlach, L. Serra, and A. Valero, “Structural theory as standard for thermoeconomics,” *Energy Conversion and Management*, vol. 40, Oct. 1999, pp. 1627-1649.

[10] A. Valero, L. Serra, and J. Uche, “Fundamentals of Exergy Cost Accounting and Thermoeconomics. Part I: Theory,” *Journal of Energy Resources Technology*, vol. 128, Mar. 2006, pp. 1-8.

[11] C.A. Frangopoulos, “Thermo-economic functional analysis and optimization,” *Energy*, vol. 12, Jul. 1987, pp. 563-571.

[12] C.A. Frangopoulos, “Application of the thermoeconomic functional approach to the CGAM problem,” *Energy*, vol. 19, Mar. 1994, pp. 323-342.

[13] M.R. von Spakovsky, “Application of engineering functional analysis to the analysis and optimization of the CGAM problem,” *Energy*, vol. 19, Mar. 1994, pp. 343-364.

[14] A. Bejan, G. Tsatsaronis, and M.J. Moran, *Thermal design and optimization*, Wiley-IEEE, 1996.

[15] G. Tsatsaronis and J. Pisa, “Exergoeconomic evaluation and optimization of energy systems -- application to the CGAM problem,” *Energy*, vol. 19, Mar. 1994, pp. 287-321.

[16] M.R. von Spakovsky and R.B. Evans, “Engineering Functional Analysis---Part I,” *Journal of Energy Resources Technology*, vol. 115, Jun. 1993, pp. 86-92.

[17] E. Sciubba, S. Bastianoni, and E. Tiezzi, “Exergy and extended exergy accounting of very large complex systems with an application to the province of Siena, Italy,” *Journal of Environmental Management*, vol. 86, Jan. 2008, pp. 372-382.

[18] E. Sciubba, “Beyond thermoeconomics? The concept of Extended Exergy Accounting and its application to the analysis and design of thermal systems,” *Exergy, An International Journal*, vol. 1, 2001, pp. 68-84.

[19] R.A. Gaggioli and W.J. Wepfer, “Exergy economics: I. Cost accounting applications,” *Energy*, vol. 5, Aug. 1980, pp. 823-837.

[20] A. Valero, “Exergy accounting: Capabilities and drawbacks,” *Energy*, vol. 31, Jan. 2006, pp. 164-180.

[21] G. Tsatsaronis and M. Winhold, “Exergoeconomic analysis and evaluation of energy-conversion plants--I. A new general methodology,” *Energy*, vol. 10, Jan. 1985, pp. 69-80.

[22] R.L. Rivero, “L’Analyse d’Exergie: Application a` la Distillation Diabatique et aux Pompes a` Chaleur a` Absorption,” Thèse Doctorale. Institut National Polytechnique de Lorraine, Nancy, 1993.

[23] G. Wall, *Exergy a useful concept within resource accounting*, Göteborg, Sweden: Institute of Theoretical Physics, Chalmers University of Technology, 1977.

[24] W. Amann, *Spartenbezogene Entwicklung des Bauwesens / Sanierung, Marktstudie*, Vienna: IIBW, im Auftrag des Zentralverbands Industrieller Bauprodukte Hersteller, 2005.

[25] W. Janik, *Wohnen 2008, Ergebnisse der Wohnungserhebung im Mikrozensus Jahresdurchschnitt 2008*, Statitik Austria, 2009.

[26] A. Müller, L. Kranzl, and R. Haas, *Energieszenarien bis 2020: Wärmebedarf der Kleinverbraucher. Projektendbericht im Rahmen der Erstellung von energiewirtschaftlichen Inputparametern und Szenarien zur Erfüllung der Berichtspflichten des Monitoring Mechanisms.*, Vienna, Austria: Energy Economics Group, Vienna University of Technology, 2009.

[27] RES, “Kostenvergleich für Privathaushalte, Stand KW37, 2009,” 2009.

[28] J. Reichl, A. Kollman, N. Pakhomova, S. Moser, S. Görs, J. Lindorfer, E. Greibl, K. Fazeni, A. Müller, M. Kloess, and N. Sagbauer, “Analyse der Wirkungsmechanismen von Endenergieeffizienz- Maßnahmen und Entwicklung geeigneter Strategien für die Selektion ökonomisch-effizienter Maßnahmenpakete,” 2010.

[29] E. Alakangas, *OPET Report 9*, Jyväskylä, Finland: 2002.

[30] Statistics Finland, “Buildings and free-time residences, statistics,” 2009.

[31] Motiva, *Pientalon Lämmitysjärjestelmä*, Motiva, 2007.

[32] Statistics Finland, “Rakennuskanta, Statistical databases,” 2007.

[33] J. Heljo, E. Nippala, and H. Nuuttila, *Rakennusten energiankulutus ja CO2-ekv päästöt Suomessa*, Institute of Construction Economics, Tampere University of Technology, 2005.

[34] Turku Energia, “Hinnastot,” 2009.

[35] Finnish Energy Industries, “Energiavuosi 2005 Kaukolämpö,,” 2006.

[36] “Energy supply, consumption and prices, statistics,” 2009.

[37] KNMI, “Klimatologie; Jaar 2008: twaalfde warme jaar op rij,” 2009.

[38] SenterNovem, “Voorbeeldwoningen bestaande bouw 2007,” 2007.

[39] Milieucentraal, “Energie en energie besparen,” 2008.

[40] CBS, “Statistics Netherlands,” 2009.

[41] A. Entrop, H. Brouwers, and A. Reinders, “Evaluation of energy performance indicators and financial aspects of energy saving techniques in residential real estate,” *Energy and Buildings*, vol. 42, May. 2010, pp. 618-629.

[42] Energiekamer, “Besluiten transporttarieven gas en elektriciteit,” 2005.

[43] Eurostat, “Panorama on Energy, 2007,” 2007.

[44] S. Werner, “District Heating in Sweden 1948-1990,” 1991.

[45] Statistiska centralbyrån, *Energistatistik för flerbostadshus 2006 (Energy statistics for multi-dwelling buildings in 2006)*, Statistiska centralbyrån, 2007.

[46] Statistiska centralbyrån, *Energi statistik för småhus 2006 (Energy statistics for one- and two-dwelling buildings 2006)*, Statistiska centralbyrån, 2007.

[47] Statistiska centralbyrån, *Energi statistik för småhus, flerbostadhus och lokaler 2006 (Energy statistics for dwelling and non-residential premises for 2001-2006)*, Statistiska centralbyrån, 2007.

[48] IEA, “2007 Energy Balance for Sweden,” 2007.

[49] SEA, *Energy in Sweden 2008*, Swedish Energy Agency, 2009.

[50] A. Valero and A. Valero, “A prediction of the exergy loss of the world's mineral reserves in the 21st century,” *Energy*, vol. In Press, Corrected Proof.

12 Nomenclature

c_F	market prices
c_P	unit economic cost of a product
F	the resources (fuel) consumed to produce a product
K_P	unit exergetic cost of a product

P	the desired product of a process
Z	depreciation and maintenance cost (non-energetic production factors)
η_{b}	thermodynamic efficiency
ε	*exergetic efficiency*
E_{D}	exergy destruction
AV	avoidable
UN,Therm	unavoidable for thermodynamic reasons
UN,Tech	unavoidable for technical reasons
$\eta_{ex,combustion}$	exergetic efficiency of an ideal combustion process
$T_{comb.products}$	temperature of combustion products
$T_{ambient.}$	temperature of the ambient environment
i_{ex}	exergy factor
$e_{ex,f}$	specific exergy content of energy carriers
c_{en}	variable price for energy carrier excluding taxes
$c_{en,tax}$	energy related taxes
$f_{tax,en}$	specific energy tax rate
I_{hs}	investment cost
α	capital recovery factor
$c_{O\&M}$	operation and maintenance costs
C_{fix}	Annual fixed costs (Independent of actual energy consumption)

Anhang L

Publikation
„ Scenarios for exergy consumption in the Austrian building sector
up to 2050”

Scenarios of exergy consumption in the Austrian building sector

Lukas Kranzl, Andreas Müller
Vienna University of Technology, Energy Economics Group

1. Introduction

1.1. Background

This paper deals with the exergy consumption for space heating and hot water production in Austria. Space heating and hot water consumption holds a big part of total energy consumption. In the EU-27 countries the share of final energy demand for heating and cooling in the residential, service and agricultural sector since 1990 holds more or less a constant share of about 33% (Capros 2007). In Austria, the share of final energy demand for heating and hot water on decreased from about 38% in 1970 to about 33% in 2008 (Statistik Austria 2009). A basic characteristic of space heating is the low exergy content of the provided useful energy (Ala-Juusela 2005). However, still high exergetic energy carriers are used for providing this type of energy service. Low-exergy systems for providing space heating and hot water are available (see e.g. (Dietrich Schmidt & Torio 2009), (Ala-Juusela 2005)). But their share in the consumption is still clearly below their potential. By the means of scenarios up to 2050 we will show different paths of how the exergy input in this sector could be decreased.

1.2. Objective

The core objective of this paper is (1) to determine the amount of exergy input in the building related heating sector of Austria starting with the year 1970 up to 2008, (2) identify paths for reducing exergy input up to the year 2050 and (3) derive recommendations for policy making.

1.3. Approach

In order to achieve this objective, we are carrying out the following steps:

- As a first step we are determining the exergy content of different energy carriers. The literature provides various approaches and values for the exergy content of different energy forms. The main differences are due to different system boundaries and methodological approaches, each of which is suitable for certain types of application. We are choosing a methodology which allows comparing the different energy forms based on their maximum practically – and given existing technologies – useable exergy content. (section 2)
- The second step includes a description of the current structure of energy consumption of the Austrian space heating and hot water production. This is done based on official statistics and literature.
- The third step is the scenario development for the Austrian space heating and hot water sector until 2050. We are doing these calculations by the model Invert/EE-Lab (for a more detailed description see chapter 3). The model is based on a detailed

disaggregated description of the Austrian building stock and its heating and hot water systems. The simulation algorithm is a myopic, multinominal-logit approach with a coupled logistic growth model. We present three scenarios: a fossil-based reference scenario, a business-as-usual scenario and a scenarios based primarily on renewable heat (RES-H-based scenario) which are presented in section 4.
- As the next step we are calculating the exergy consumption in this sector by applying the exergy content described in step 1 on the energy carrier mix in each of the scenarios. Moreover, the resulting mean exergy content of energy consumption in the heating sector as well as the overall exergetic efficiency development of the sector is investigated. (section 5)
- Finally, we derive conclusions for possible measures of how to achieve low-exergy scenarios in the Austrian space heating and hot water sector. (section 6)

1.4. System boundaries

We investigate the whole Austrian building stock which includes residential as well as non-residential buildings and the corresponding building related heat consumption. This term „building related heat“ includes both space heating and hot water production in these buildings. We explicitly do not deal with industrial and other high temperature heat applications (e.g. cooking). We included all relevant types of heating systems and energy carriers. In particular, we consider single stoves and central heating systems using natural gas, heating oil, coal, electricity, wood log, wood chips, wood pellets, solar thermal and ambient energy.

1.5. Structure of this paper

After this introduction we will describe the approach we have selected for determining exergy content of energy carriers (section 2). Then we will describe the model Invert/EE-Lab and the basic underlying data sources (section 3). Subsequently the scenarios of space heating and hot water in Austria up to 2050 will be presented (section 4). Section 5 includes the basic results of this paper with respect to the exergy consumption of the Austrian building related heating sector. We are closing with the conclusions in section 6.

2. Exergy content of energy carriers

The core idea of this paper is to determine the exergy consumption of the Austrian space heating and hot water sector. One of the basic starting points for this purpose is the exergy content of various energy carriers.

For different forms of energy different approaches exist for calculating their exergy content (see e.g. (Szargut et al. 1988), (Kotas 1985), (Bejan 1988)). Energy related to work transfer is equivalent to exergy transfer since exergy is defined as the maximum work potential. The exergy content of heat transfer is calculated by taking into account the Carnot-Factor ($1-T_0/T$) where T_0 is the ambient temperature and T the heat source temperature. Physical or thermomechanical exergy basically depends on temperature and pressure. The concept for determining chemical exergy is based on the idea that the pure component is brought in the chemical equilibrium with the environment. It can be calculated based on the specific molar chemical exergy of a reference component in the environment and the molar fraction of this component in the chemical substance. The exergy related to a stream flow in a steady state is determined by the kinetic exergy, the potential exergy, the thermomechanical exergy and the chemical exergy of the components in the stream. (A good overview is given e.g.in (Shukuya & Hammache 2002) or (Torío et al. 2009).)

Based on these approaches the literature provides standard values of exergy content for different type of energy carriers. These values can vary subject to the assumptions and the detailed methodological approach. In particular, the reference state is one of the most crucial parameters (Torío et al. 2009). One such quantification of exergy content was given by (Wall 1977) in his quality indexing of energy forms shown in Table 1.

Table 1. The quality of different forms of energy in terms of exergy as classified by (Wall 1977).

Quality	Energy form	Exergy content (%)
Extra superior	Potential energy[1]	100
	Kinetic energy[2]	100
	Electrical energy	100
Superior	Nuclear energy[3]	~100
	Sunlight	95
	Chemical energy[4]	95
	Hot steam	60
	District heating	30
Inferior	Waste heat	5
Valueless	Heat background	0

[1] e.g. water reservoirs, [2] e.g. waterfalls, [3] e.g. nuclear fuel, [4] e.g. crude oil

For the analysis in this paper only some of these energy forms are relevant. In particular these are (1) electrical energy, (2) sunlight, (3) chemical energy (in the form of heating fuels biomass, coal, natural gas and oil) and (4) district heating and waste heat. The approach for determining exergy content should consider the purpose of this paper. For this paper we concentrate on the definition of exergy content of an energy form as the share of energy that can be converted to work. For the purpose of this paper the share that could in practice due to maximum achievable temperature levels in thermodynamic processes be converted to work, is of particular relevance. Having this concept in mind, it becomes clear that the theoretical exergy values based on the approaches described above in practice cannot be realized with – from a thermodynamic point of view – possible technologies. In the following, we will describe for each of the energy forms relevant for this paper the approach of determining exergy content.

2.1. Electrical energy

Electricity is pure exergy, i.e. the exergy content of electricity is 100%.

2.2. Sunlight

Results from literature (e.g. (Wall 1977)) usually point out the high exergy content of sunlight. (Torío et al. 2009) lists a considerable range of corresponding literature. This literature analyses are all based on a system boundary including the solar collector transforming solar radiation into hot water. This on the one hand results in low exergetic efficiency of the overall solar thermal system and on the other hand in high exergetic value of sunlight itself. With our presumption to consider the amount of exergy that can be exploited from a practical point of view, we have decided to use an approach which considers the typical average output of efficient solar thermal collectors under Austrian climate conditions. Thus, we are selecting the outflow of hot water as our system boundary to the heating or hot water system and not the solar collector[1]. This is similar to the approach of (Torío et al. 2009) and (Sandnes 2003). In particular, (Torío et al. 2009) point out that "this method might be of interest when the analysis and optimisation of the solar collector as a single component is not of interest, but in turn its efficient integration into an energy system is the main pursued aim." This meets exactly the concept of this paper.
Thus, the exergy content (ex_{sol}) of solar thermal energy (i.e. the output of solar collectors) can be calculated based on the ambient temperature (T_0) and the output temperature of the collector (T):

$$ex_{Sol} = \left(1 - \frac{T_0}{T}\right) \qquad \textit{Equation 1)}$$

However, this static approach does not take into account dynamic fluctuations of the reference temperature as well as the output temperature of the collector during the year. The dynamic approach (equation 2) allows for a more detailed consideration of these dynamic aspects.

$$ex_{Sol} = \frac{\sum_t Q_{Sol,t} \cdot \left(1 - \frac{T_{0,t}}{T_t}\right)}{\sum_t Q_{sol,t}} \qquad \textit{Equation 2)}$$

For the analysis in this paper we assumed an efficient collector under Austrian climate conditions giving a solar yield of about 400 kWh/m²/a and calculated the exergy content on a daily basis. Of course, output-temperature depends on the integration of the collector in the whole system and so only average values have been assumed starting from 30°C output in January up to an average of 90°C output temperature in July. With the standard daily outdoor temperature for mean Austrian conditions this leads to an average exergy content of solar thermal energy of 16%. Depending on the size of the system, the overall system integration into the building, the relation of supply and demand, size of heat storage etc can lead to corresponding variations of the output temperature of the collector.[2]

---

[1] Another argument for this system boundary is that basically all chemical energy carriers originally also are based on solar energy. Thus, one would have to take into account the conversion of solar energy via photosynthesis for biomass and for fossil fuels in addition the required pressure, temperature and time for converting biomass into fossil fuels. (Torío et al. 2009)

[2] Assuming 20% higher output temperature (i.e. starting with 36°C in January and going up to 118°C in July) would lead to nearly 19% exergy content. However, we leave this question and possible sensitivity analyses of this value to further research.

Given the fact that there is no real “competition” for solar energy (besides the competition for roof area[3] which currently is not yet the most restricting factor) not the potential maximum exergetic output that could be gained from solar energy (i.e. sunlight) with best possible systems should be the reference but the real exergy yields which result from current solar thermal systems. If we follow this approach for a more detailed analysis one would need the specific details of the design of operation of all (or typical average) systems. Currently, this information is not available for Austria. Therefore, we take an exergy content of 16% for solar thermal energy in Austria as a starting point for the analysis. However, we hope that future research will lead to a more profound basis of this value, which might improve the level of accuracy.

2.3. Chemical energy

Chemical energy is a much-used basis for primary energy conversion, often through combustion. The temperature levels that can be reached in such combustion processes, determine the amount of the chemical exergy that in practice can be converted into thermal exergy. In other words, in combustion processes there is always a certain amount of unavoidable exergy loss due to the maximum achievable or utilizable temperature levels The exergetic efficiency ($\eta_{ex,combustion}$) of an ideal combustion process is determined by the Second law of thermodynamics, and depends basically on the absolute temperature levels of combustion $T_{comb.}$ and of the environment $T_{ambient}$. Thus, the exergetic efficiency of a combustion process indicates the amount of “in practice maximum usable” exergy (i.e. exergy content minus unavoidable exergy losses).

$$\eta_{ex,combustion} = \frac{e_{heat}}{e_{fuel}} = \frac{1 - \frac{T_{ambient}}{T_{comb.products}}}{e_{fuel}} \qquad \textit{Equation 3}$$

A maximum exergy of 85 % can be derived for fully oxidized combustion, assuming a utilizable combustion temperature (with available materials) $T_{comb} \approx 1700K$ and $T_{ambient} \approx 300K$. On the other hand, the exergy contents in Table 1 indicate that chemical energy could in principle be converted into other forms of energy by up to 95%. The difference then defines the exergy destruction that is unavoidable for thermodynamic reasons and maximum utilizable combustion temperatures with current technologies.

For electricity production from natural gas the exergy efficiency is determined by the most efficient available power plants, which today have net power generation efficiency of 58 % and above. Using this approach is reasonable when investigating a specific component or subsystem. Yet when looking at a broader system, such as an energy supply system for district heating (DH), it may overlook the overall efficiency gains of using surplus thermal energy, such as heat supplied from a combined heat and power (CHP) plant to the DH grid.

---

[3] The basic competition for roof area is basically between solar thermal and PV systems. PV systems currently have an energetic efficiency of about 15%-20%. With an exergy content of sunlight of 95% according to (Wall 1977) this results in an exergetic efficiency of about 16%-21%. This means that PV currently is able to make use of about 16%-21% of the sunlight’s exergy content. The value that we are using for solar thermal systems is within this range, though in the lower part.

Comparing secondary energy carriers such as electricity and district heat solely on the basis of their exergy content would lead to some bias, as it would not include exergy destruction upstream the system boundaries. It would also exclude energy carriers which still contain some exergy that cannot be utilized by any means.

Hence, we also consider the thermodynamic losses associated to the temperature limits imposed by current technology for large scale utilisation. For natural gas or oil, combined cycle CHP has high exergetic efficiency, depending on the turbine inlet and environmental temperatures, T_0 and T_{inlet}. To be consistent with district heating, we use T_0= 273K (0 °C) instead of the more common T_0= 293K (20°C). Even in most recent gas turbines, the turbine inlet temperature must not exceed a temperature of $T_{inlet} \approx 1700K$ (ca.1450°C) as the hot gas would than degrade the turbine blades very quickly. Similarly, for coal-fired CHP (e.g. from metal melting), usual temperatures are in the vicinity of 1400-1500 °C. For biomass combustion, the maximum temperature level on which flue gas can be utilized is mainly determined by impurities. Fluidized bed reactors, nowadays one of the most advanced biomass combustion processes, usually operate at temperature levels not above 800 °C for unconverted, solid biomass. The conversion of biomass can allow higher combustion temperature but leads to some efficiency losses during the conversion steps.

Based on those assumptions and on Equation 3, we estimate overall values for the exergetic efficiencies of these processes. As described above, we are using these values as “in practice usable” exergy (i.e. exergy content minus unavoidable losses due to temperature limitation). For electricity, however, we neglect upstream energy conversion efficiencies and simply assume an exergy content of 100%.

2.4. District heating and waste heat

The exergetic content of district heating can either be considered within the system boundary of the building or within a system boundary taking also into account the heat production and distribution. In the first case the exergy content is determined by the supply temperature of the district heating grid (and of course the reference temperature). For the purpose of this paper we choose the second case because we want to determine the exergy input to the whole space heating and hot water sector which includes also the heat plants of district heating systems (or waste heat that is used). Of course, the exergy content of district heating in this case depends on the way of heat generation.

Therefore, in the following part of the paper we will investigate the historic development of district heating in Austria and the exergy consumption in this sector. Based on data from (Statistik Austria 2009) we calculated the exergy input to the district heating systems in Austria for the period from 1970-2008. For those plants which are pure thermal district heating plants the approach is straightforward by multiplying the energy consumption ($Q^{in}_{heatplants}$) of each energy carrier by its exergy content (ex) (Equation 4).

$$EX^{in}_{heatplants} = \sum_i Q^{in}_{heatplants,i} \cdot ex_i \qquad \text{Equation 4}$$

Q	Energy
EX	Exergy
ex	exergy content of energy carriers

i	energy carriers

For CHP plants, there are various methods for assigning a share of the fuel input to the heat generation. We decided to use an exergy based weighting of the outputs heat and electricity (Equation 5). Thus, the fuel input that is assigned to the heat production of a CHP plant is determined by the exergy content of the heat output compared to the exergy content of the overall output of the plant.

$$EX_{CHP}^{in} = \sum_{i} Q_{CHP,i}^{in} \cdot ex_i \cdot \frac{ex_{th} \cdot Q_{th,i}^{out}}{ex_{th} \cdot Q_{th,i}^{out} + ex_{el} \cdot Q_{el,i}^{out}} \qquad \text{Equation 5}$$

Q	Energy
th	thermal
el	electrical
EX	Exergy
ex	exergy content of energy carriers
i	energy carriers

Figure 1to Figure 3 show the historical development of district heating in Austria in terms of the energy output, the energy consumption, the exergy consumption and the energy carrier mix. Each of the figure distinguishes between pure heat plants and CHP plants[4]. The share of waste heat from CHP on total district heat generation increased remained quite stable in the 1970s with about 48% and increased from the late 1970s until 2007 to nearly 70%. During this period, the whole district heating sector increased strongly with an average annual growth rate of 7%. In the early 1970s the sector was mainly dominated by oil heating plants and coal CHP. Since the early 1980s natural gas started to play a more and more important role, both for pure heat plants and for CHP. In the same time municipal solid waste incineration started to become more significant. Oil heat plants and CHP experienced a peak around the mid 1990s. The first biomass heat plants in Austria were built in the mid 1980s. However, it took another 10 years until a significant share of the district heat generation was provided by biomass. During the 20 year period from 1988 to 2008 an average annual growth rate of 14% could be achieved. Moreover, feed-in-tariffs for biomass CHP in the period from 2002 to 2006 provided a strong incentive also for waste heat utilization from biomass CHP in district heating grids[5]. This led to a share of the common heat output of biomass heat and CHP plants on the total district heat generation of 38% in 2008.

Assuming an inlet temperature level of 150°C in the district heating grids, we calculated the overall exergetic efficiency for this period. It increased from 38% in 1970 to about 53% in 2008. This increase in particular is due to the increased share of CHP and biomass in the Austrian district heating sector

---

[4] (Statistik Austria 2009) does not list waste heat from industrial processes as source of district heating.

[5] Since 2006 a minimum overall efficiency of 60% was required for receiving support. This is only possible with a certain share of heat utilization from CHP.

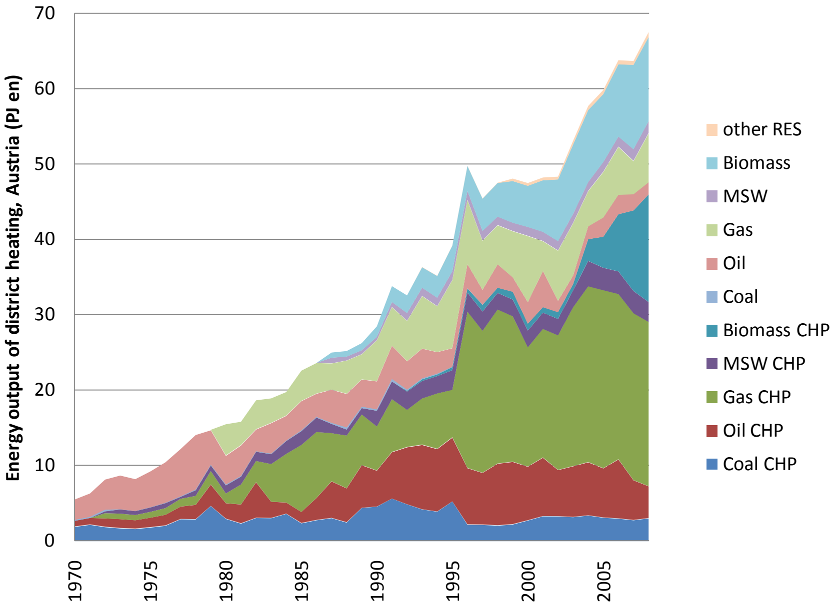


Figure 1: Energy output of district heating plants, Austria

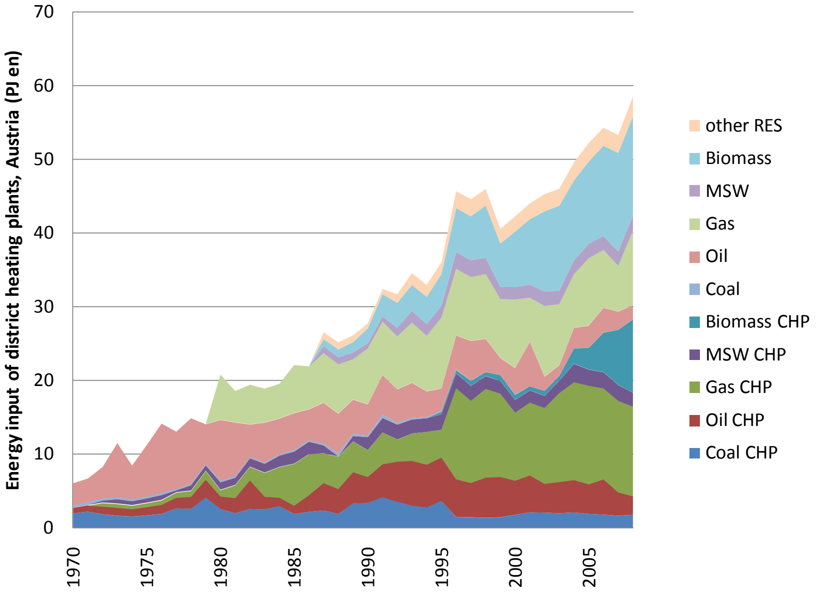


Figure 2: Energy input in district heating plants, Austria

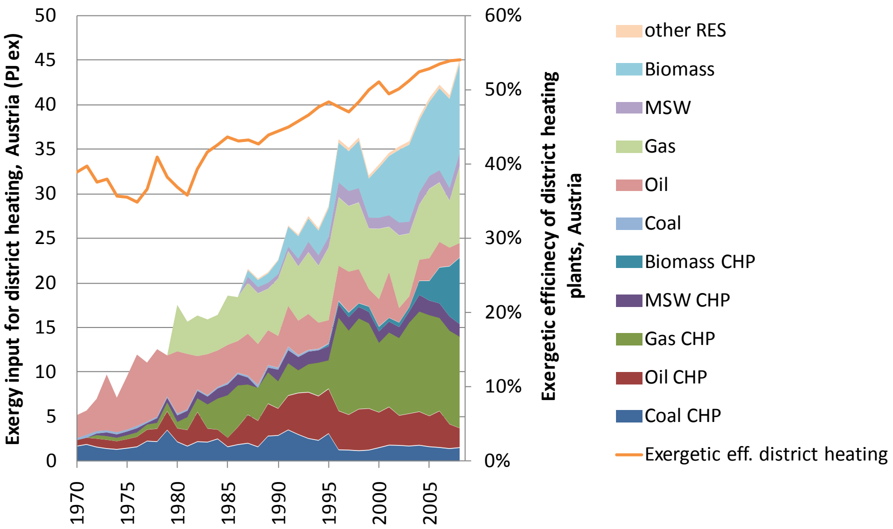


Figure 3: Exergy input in district heating plants in Austria and resulting exergetic efficiency of district heating

The core target of this section is to derive a factor that converts the output of the model Invert/EE-Lab to exergy consumption. The building stock model Invert/EE-Lab results in the output (i.e. the demand) of district heating plants. This result according to our approach is converted to exergy input to the district heating plants. Thus, we need the factor exergy input per heat output (ex_{dh}). We calculate it based on historical data from (Statistik Austria 2009) and presume typical values for efficiencies for these plants.

$$ex_{dh} = \frac{EX_{heatplants}^{in} + EX_{CHP}^{in}}{Q_{th}^{out}} \qquad \text{Equation 6}$$

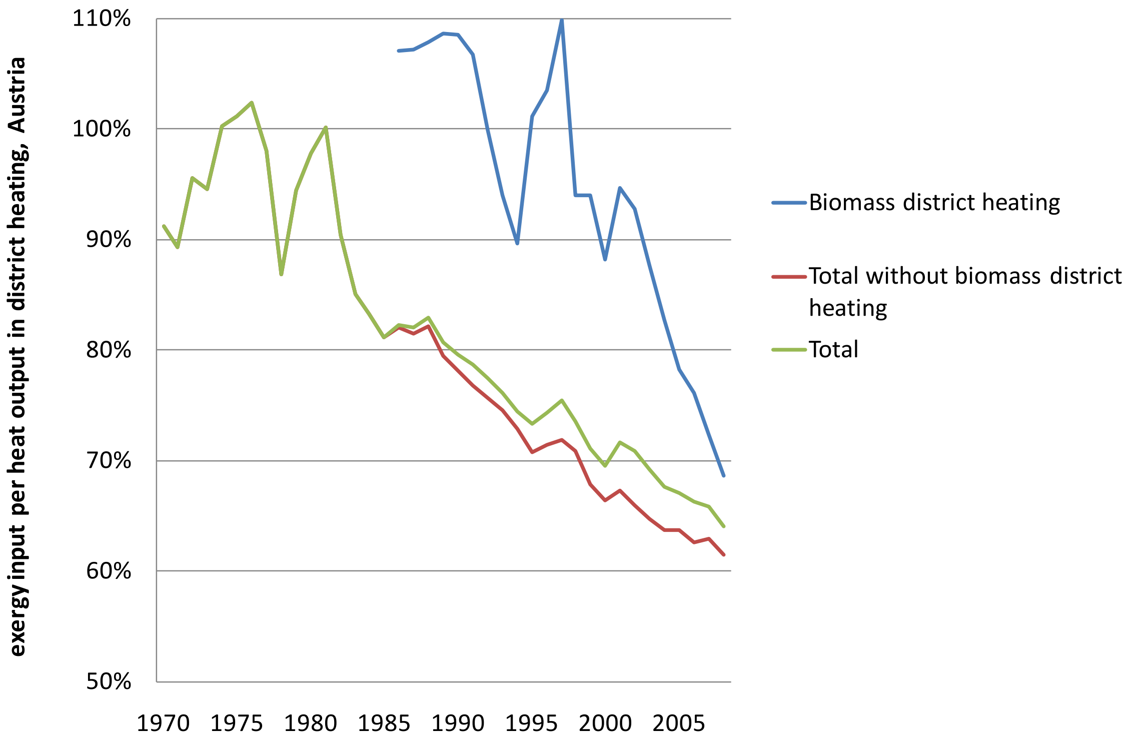


Figure 4: Exergy input per heat output in district heating plants, Austria

The resulting exergy input required per energy unit of heat output is shown in Figure 4. We are taking this result as a starting point for estimating the future development of this indicator. This estimation implies a certain share of CHP in the district heating plant mix and a certain energy carrier mix. Since the building model Invert/EE-Lab (chapter 3) delivers results for district heating separated for biomass district heating and other district heating plants, we are estimating these factors for these two sectors. For the purpose of the paper we postulate that there will be a further increase in the share of CHP on district heating and there will be an increase in the use of “other renewable energy carriers” which is basically solar and geothermal energy. We imply a smooth increase of MSW incineration. These presumptions lead to an exergy input factor per heat output of 57% for biomass district heating and 44% for “other district heating systems” in the year 2050 (counting other renewable energy carriers to the second group).

Table 2. Energy input in district heating plants in Austria and resulting exergy content factor

	1970	1980	1990	2000	2010	2020	2030	2040	2050
Share of energy consumption (%)									
Coal CHP	33%	12%	12%	4%	3%	3%	2%	1%	0%
Oil CHP	12%	8%	13%	11%	5%	4%	3%	1%	0%
Gas CHP	0%	4%	13%	22%	23%	25%	26%	27%	29%
MSW CHP	0%	5%	6%	4%	4%	5%	5%	6%	8%
Biomass CHP	0%	0%	0%	2%	20%	23%	27%	31%	37%
Coal	5%	1%	1%	0%	0%	0%	0%	0%	0%
Oil	50%	40%	15%	8%	3%	3%	2%	1%	0%
Gas	0%	30%	27%	22%	13%	11%	8%	4%	0%
MSW	0%	0%	2%	4%	3%	3%	2%	1%	0%
Biomass	0%	0%	7%	18%	23%	21%	18%	15%	12%
other RES	0%	0%	2%	5%	2%	4%	7%	11%	15%
total energy in (PJ en) (*)	6.0	20.7	27.7	42.2					
Share of exergy consumption (%)									
Coal CHP	33%	12%	13%	5%	4%	3%	2%	1%	0%
Oil CHP	12%	8%	13%	12%	5%	4%	3%	2%	0%
Gas CHP	0%	4%	14%	23%	25%	27%	29%	32%	36%
MSW CHP	0%	4%	6%	4%	4%	4%	5%	7%	8%
Biomass CHP	0%	0%	0%	2%	19%	22%	27%	33%	40%
Coal	5%	1%	1%	0%	0%	0%	0%	0%	0%
Oil	50%	40%	16%	9%	4%	3%	2%	1%	0%
Gas	0%	30%	28%	24%	14%	12%	9%	5%	0%
MSW	0%	0%	2%	4%	3%	3%	2%	1%	0%
Biomass	0%	0%	7%	17%	22%	21%	19%	16%	13%
other RES	0%	0%	0%	1%	0%	1%	2%	2%	3%
total exergy in (PJ en) (*)	5.1	17.5	22.6	33.3					
total heat out (PJ en) (*)	5.5	15.4	28.4	47.5					
total exergy out (PJ ex) (*)	2.0	5.5	10.1	16.8					
Exergetic efficiency (%)	38%	31%	45%	51%	58%	61%	64%	67%	71%
Exergy content of input per heat output (%)									
district heating total	91%	98%	80%	70%	61%	58%	56%	53%	50%
district heating biomass (**)			109%	88%	65%	64%	62%	59%	57%
district heating without biomass	91%	98%	78%	66%	58%	55%	52%	48%	44%

(*) Energy and exergy consumption as well as heat output of district heating differs from scenario to scenario (see section 4)

(**) The Austrian energy statistics ((Statistik Austria 2009) do not indicate biomass district heating before 1988. The value for 1990 is based only on relatively few plants and thus is not reliable.

Sources: 1970 to 2008 is based on historical data from official Austrian energy statistics (Statistik Austria 2009) and own calculations; 2009-2050 is based on own scenario presumptions.

2.5. Synthesis

The following table gives a summary of the exergy content values applied in this paper.

Table 3. Exergy content of the energy carriers analysed in this paper

Energy carrier (temperature level)	Temperature level	Reference temperature level	Exergy content as used in this paper
Oil, coal, gas	1500 °C	0°C	85%
Biomass	800°C	0°C	75%
Waste	800°C	0°C	75%
Electricity	-	-	100%
District heat biomass	(**)	(**)	69% (2008) - 57% (2050) (*)
District heat other energy carriers	(**)	(**)	62% (2008) – 44% (2050
Solar thermal	(***)	(***)	16%
District heat inlet flow (150°C)	150°C	0°C	35%
Space heating (20°C)	20°C	0°C	7%
Hot water	60°C	20°C	12%

(*) Development of district heating generation mix see chapter 2.4.
(**) See chapter 2.4
(***) See chapter 2.2

3. Modelling of building related heat energy consumption

One of the core approaches of this paper is the application of the model Invert /EE-Lab. Invert/EE-Lab is a dynamic bottom-up simulation tool that evaluates the effects of different promotion schemes (in particular different settings of economic and regulatory incentives) on the energy carrier mix, CO2 reductions and costs for society promoting certain strategies in the building related energy demand sector (spa ce heating and hot water). Furthermore, Invert/EE-Lab is designed to simulate different scenarios (price scenarios, insulation scenarios, different consumer behaviours, etc.) and their respective impact on future trends of renewable as well as conventional energy sources on a national and regional level.

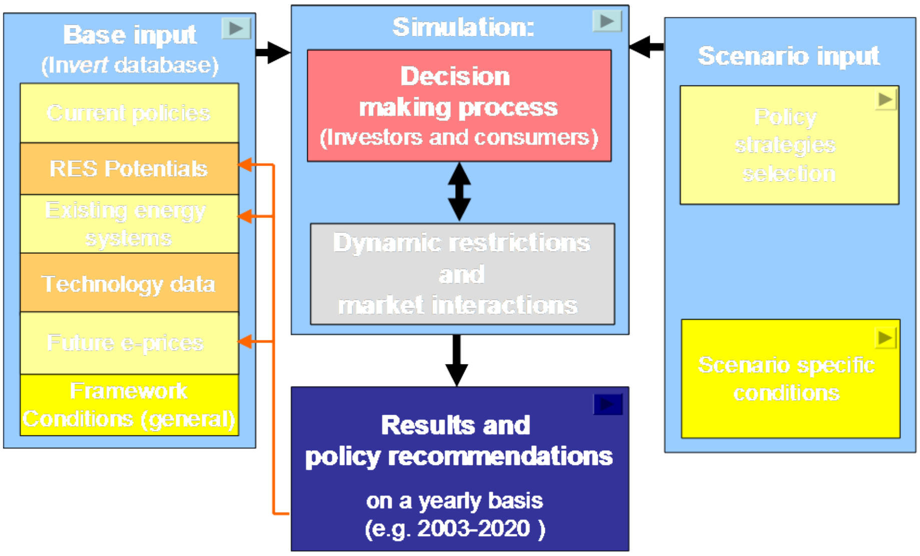


Figure 5: Overview structure of Invert-Simulation-Tool

Invert simulation tool originally has been developed by Vienna University of Technology/EEG in the frame of the Altener project Invert (Investing in RES&RUE technologies: models for saving public money). During several projects and studies the model has been extended and applied to different regions within Europe, see e.g. (L. Kranzl et al. 2006), (M. Stadler et al. 2007), (Schriefl 2007), (Lukas Kranzl et al. 2007), (Biermayr et al. 2007), (Nast et al. 2006), (Reinhard Haas et al. 2009). The last modification of the model in the year 2010 included a re-programming process and accommodation of the tool, in particular taking into account the inhomogenous structure of decision makers in the building sector and corresponding distributions (Müller 2010), (www.invert.at). The current state of the model relies on this new calculation-core (called EE-Lab) leading to the current version of the model Invert/EE-Lab506 which has been used in this paper.

The core of the tool is a myopical, multinominal logit approach, which optimizes objectives of “agents” under imperfect information conditions and by that represents the decisions maker concerning building related decisions. Invert/EE-Lab models the stock of buildings in a highly disaggregated manner. Therefore the simulation tool reflects some characteristics of an agent based simulation.

The model allows for a flexible choice of the simulation time frame. The scenarios presented in this paper are calculated for the period 2006-2050.

3.1. The basic decision algorithm

The basic decision/selection process works on an annual basis and is defined as follows:

For each year of the simulation period INVERT decides for each building segment if the system (regarding building shell and heating / dom. hot water system) remains as it is or if a new heating technology respectively a measure to improve the building shell has been chosen. The share of buildings applying changes is calculated based on the age of the considered building element (including heating and hot water systems) using a Weibull distribution. The share on the actual installation of available types is calculated based on adjusted heat generation costs using the multinominal logit approach. This incorporates, that low-cost options (based on adjusted heat generation costs) get the largest market share, but more expansive options hold some share too. The necessary distribution parameters are calibrated in order to meet historic development

In order to put the basic model represented by the basic decision algorithm in a realistic frame work the model is extended with the consideration of three different categories of restrictions:

restrictions concerning resource potentials (e.g. maximum amount of biomass used for heating)

restrictions concerning technology penetration rates (defining the maximum share of a technology, especially relevant for new / unconventional technologies, technologies where low acceptance can be expected)

restrictions concerning replacement rates (maximum number of buildings per year where a certain measure may be carried out, e.g. windows may be changed in only x% of all buildings for one year)

After the calculation of replacement rates for the current year of the simulation period for each building segment where a change occurs according to the basic algorithm it is decided if all the buildings of this building segment are subjected to this change or if it has to be split up in two parts (one part containing the changed buildings, the other part containing the unchanged buildings). Restrictions are exogenously defined for each year of the simulation period.

The following variables are defined via distribution rather than single values.

Resource availability for each building segment

Technical life time for equipment

Investment, operation & maintenance costs and final energy costs for different measures

3.2. Modeling the energy demand

Energy demand is modeled depending on service demand and efficiency. The two energy services under investigation are space heating and water heating. Behavioral aspects in the case of space heating (such as level of indoor temperature, ventilation habits) are considered through the service factor. This parameter describes the relation between actual and theoretically calculated energy consumption for space heating. The model calculates the service factor as a function of thermal quality (specific heat load) of the building and degree of automation of the heating system (central heating system vs. single stove heating system) as well as the specific size per occupant. Final energy demand for space heating is computed based on the specific heat load of a building (W/m²K) and the average outdoor temperature using a monthly balance approach.

Final energy demand for water heating is modeled as dependent on the number of people living in the dwelling under consideration and the service demand for domestic hot water (volume of hot water with 50° C) per person and day, or the average hot water demand per square meter when it comes to non residential buildings, and annual efficiency of the water heating system.

3.3. Database of the buildings stock

The currently implemented buildings represent a detailed, disaggregated image of the building stock. Residential buildings are classified distinguished by their size (number of dwellings per building) and construction period as well as type of location (urban or rural). This holds for non residential buildings as well. Yet, since less information about these types of buildings is available, the distinction is less detailed. The building stock is described according to its thermal quality (e.g. based on (Reinhard Haas et al. 1998) and further developed in (Schriefl 2007), (Müller 2010) and (Lukas Kranzl et al. 2007)), the number of buildings and heating systems basically relies on official statistics of buildings and energy ((Statistik Austria 2004), (Statistik Austria 2004), (Statistik Austria 2006), (Statistik Austria 2009).

With respect to the heating systems, the following types are taken into account:

Single stoves: Oil single, Gas single, Coal single, Wood log single, Pellets single, Electrical converter single, Electrical night storage single

Central heating systems: Oil central, Oil condensing central, Gas one floor, Gas central, Gas condensing central, Coal central, Wood log central, Wood chips central, Wood pellets central, Heat pump air/water, Heat pump water/water, Heat pump brine/water shallow, Heat pump brine/water deep, District heating biomass, district heating (without biomass)

Solar thermal systems: hot water only, combined hot water and space heating

3.4. Economic input data

Energy price scenarios are an important input factor for the development of solar thermal systems. We are using Eurostat price relations for 2007-2009 and take into account a medium energy price scenario according to Capros (2009). The scenarios available up to 2030 are extrapolated until 2050. The applied energy prices are documented in Table 3.

Table 4. Applied energy prices in the BAU and the RES-H scenario[6]

€/MWh	2010	2020	2030	2040	2050
Gas	72.5	84.4	95.4	107.6	118.6
Oil	74.7	87.0	98.3	110.9	122.3
Coal	57.9	69.7	80.9	92.8	101.5
Wood log	34.2	38.0	41.3	44.9	47.9
Wood chips	27.1	30.1	32.8	35.6	38.0
Pellets	49.1	54.6	59.4	64.5	68.9
Electricity	168.1	190.0	209.7	231.5	251.6
District heat	46.4	51.9	56.8	62.1	66.7
District heat biomass	69.2	76.9	83.7	90.8	97.1

Energy prices documented in this table do only include variable price components. In addition to these prices fixed cost components are added to the economic analysis in the model Invert/EE-Lab. These components include capital costs and operation and maintenance costs of heating systems.

The cost data for heating systems have been taken from literature, data collection from producers and associations of RES-H systems and other heating systems. We have assumed a moderated amount of technological learning. More details with respect to cost data, economic comparison of heating systems and sources are given in (Lukas Kranzl et al. 2010).

3.5. Investigated policies

Support policies for heating systems (e.g. renewable fuels or efficient boilers) change the comparative advantage between different heating systems. The model Invert/EE-Lab takes simulates the impact of economic instruments by taking into account e.g. the amount of an investment subsidy in the economic comparison among the different heating system options. Also the effect of regulative instruments can be simulated. An example for such regulative instruments are RES-H obligations. Such schemes oblige building owners to use a minimum amount of RES-H in their buildings. The European directive for the support of renewable energy (European Parliament and the Council 2009) asks member states to implement such schemes “where appropriate”. In (Veit Bürger et al. 2008) these and other support schemes are described more detailed.

For the scenarios presented in this paper investment subsidies (in the business as usual scenario) and RES-H obligations (in the RES-H scenario) have been selected.

4. Scenarios of space heating and hot water in Austria up to 2050

Based on the method described above we present three scenarios for the energy carrier mix in the Austrian space heating and hot water sector. In each of these scenarios we imply measures for stimulating thermal renovation of buildings. The rate of building renovation in all scenarios increases from currently 0.4% to a maximum of 1.3% per year. This leads to a corresponding decrease of heating energy demand. For this paper, we take this decrease more or less as exogenously given, i.e. it is the same for the three scenarios. However, the

---

[6] In the fossil based scenario, energy prices were fixed on the level of 2002 (see also 4)

energy carrier mix differs strongly due to the different energy price scenarios and policy settings. In particular, we will show the following three scenarios:

- Fossil based scenario:
  This scenario should mainly act as a theoretical reference scenario preserving roughly the status quo of the year 2000 and the developments around that time period. We are assuming very low energy prices (level of 2002 remains until the year 2050) and no technological change (even the technological change that took place in the years from 2000-2010 does not occur, i.e. there are no innovative biomass boilers, solar collectors and heat pumps available.)
- Business as usual:
  The BAU scenario presents a development that is based on moderately increasing energy prices and moderate policies supporting RES-H systems. This leads to a slow decrease of the fossil energy. However, no strong incentives are in place for an ambitious transition towards sustainability in the heating sector.
- RES-H based scenario:
  The RES-H based scenario shows an ambitious-realistic development of the Austrian space heating and hot water sector. Moderately increasing energy prices and ambitious policy instruments (RES-H obligations) lead to a corresponding growth of RES-H technologies.

The following figures show the historic development of the Austrian space heating and hot water sector and the results for the three simulation runs. The data of the historical development from 1970-2007 is based on Austrian energy statistics (Statistik Austria 2009). The energy consumption has been adjusted by the deviation of heating degree days. The model Invert/EE-Lab is calibrated to the official energy statistics. However, it is a bottom-up model and basically relies on data of buildings, heating systems etc. Therefore, there is a slight jump at the transition from historical data to the results of the simulation runs. This in particular is the case for ambient energy. (Statistik Austria 2009) reports relatively high values for ambient energy in the service sector. The number of heat pumps currently installed according to (Biermayr et al. 2010) does not support this high value. Thus, it might include the use of waste heat, maybe also for process applications. For the simulations in the model Invert/EE-Lab we used the data included in (Biermayr et al. 2010) which results in a slight discontinuity around the year 2008.

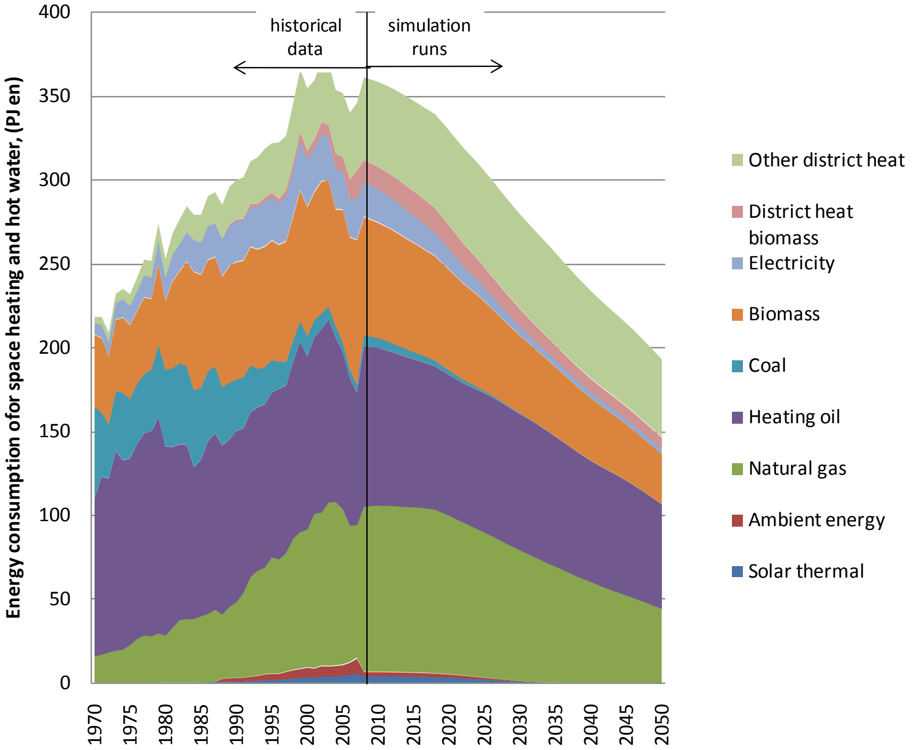


Figure 6: Energy carrier mix for space heating and hot water in Austria, fossil based scenario

Sources: (Statistik Austria 2009), (Biermayr et al. 2010), *own calculations*

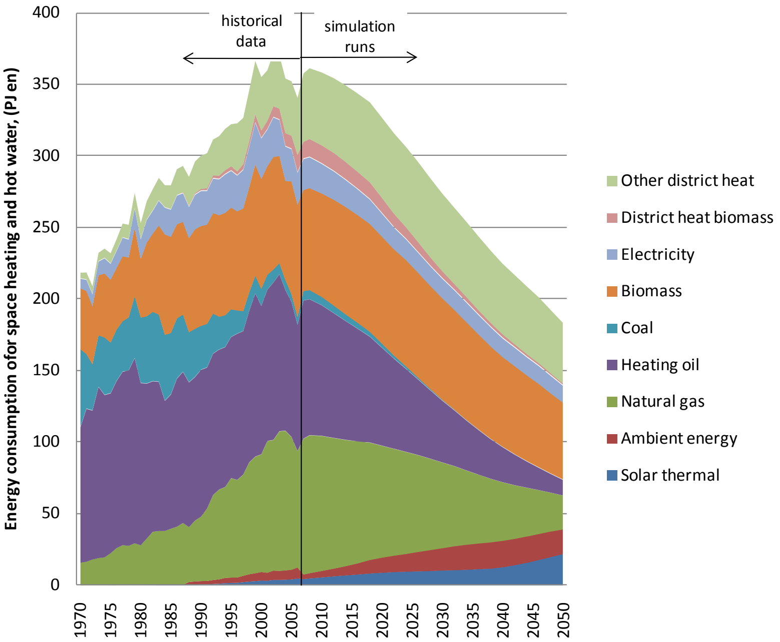


Figure 7: Energy carrier mix for space heating and hot water in Austria, business as usual scenario

Sources: (Statistik Austria 2009), (Biermayr et al. 2010), *own calculations*

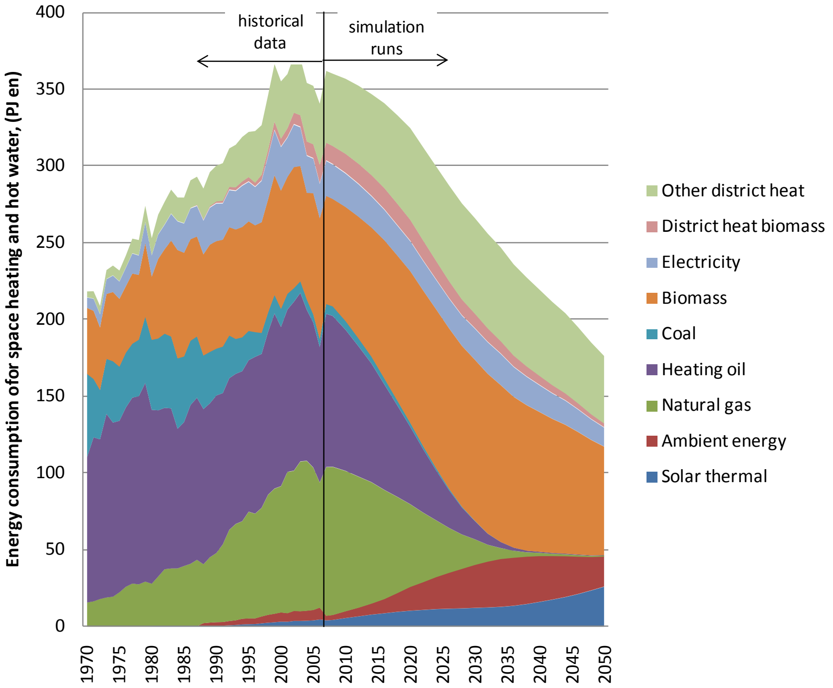


Figure 8: Energy carrier mix for space heating and hot water in Austria, RES-H based scenario

Sources: (Statistik Austria 2009), (Biermayr et al. 2010), *own calculations*

Figure 6 to Figure 8 show the results of the three scenarios. In the fossil based scenario the heating oil and natural gas remain the dominant energy sources of this sector. Biomass, ambient energy and solar thermal energy continuously lose market share.

The business-as-usual scenario results in a steady decrease of oil and gas. Their share in the total energy consumption in 2050 is less than 20%. The absolute amount of biomass and district heating is slowly decreasing. However, due to the reduced energy demand their market share increase (30% biomass and 24% district heating in 2050). Solar thermal energy and ambient energy can strongly increase in absolute and relative terms. In 2050 solar and ambient energy reach a share of 12% and 10%, respectively.

The RES-H based scenario shows that a phase out of fossil energy until about 2035 is possible. In this scenario the highest share is covered by biomass which increases strongly in absolute and relative terms and peaks around 2027 (about 115 PJ energy consumption for biomass and biomass district heating). However, in 2050 the absolute energy demand for biomass in the heating sector is lower than in 2010. Ambient energy shows high growth rates and peaks around 2035. After this point of time solar thermal energy increases strongly.

We want to stress that neither the development of demand nor the development of RES-H in the RES-H based scenario should be considered as maximum achievable scenarios. Given ambitious policies and/or high energy prices even faster transition processes could be feasible. However, this is not subject of this paper.

5. Scenarios of exergy consumption for space heating and hot water

According to the methodology described above in this section we are analyzing the exergy consumption in the Austrian space heating and hot water sector for each of the three scenarios presented in section 4.

The results show that the increasing utilization of RES-H technologies leads to a relatively steep decline in exergy consumption. On the one hand this is due to the thermal renovation measures and reduction of energy demand. On the other hand this is also due to the decrease in exergy content. The slight decrease in exergy content that took place in the past decades is strongly accelerated in the second and third scenario.

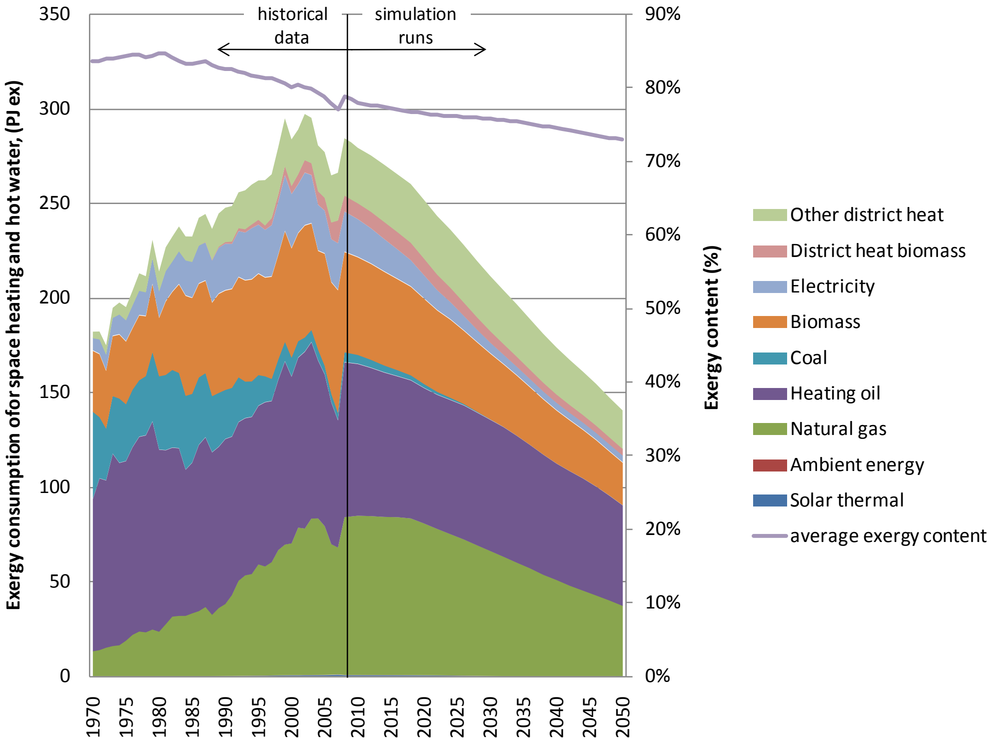


Figure 9: Exergy consumption for space heating and hot water in Austria (HDD adjusted), fossil based scenario

Sources: (Statistik Austria 2009), (Biermayr et al. 2010), *own calculations*

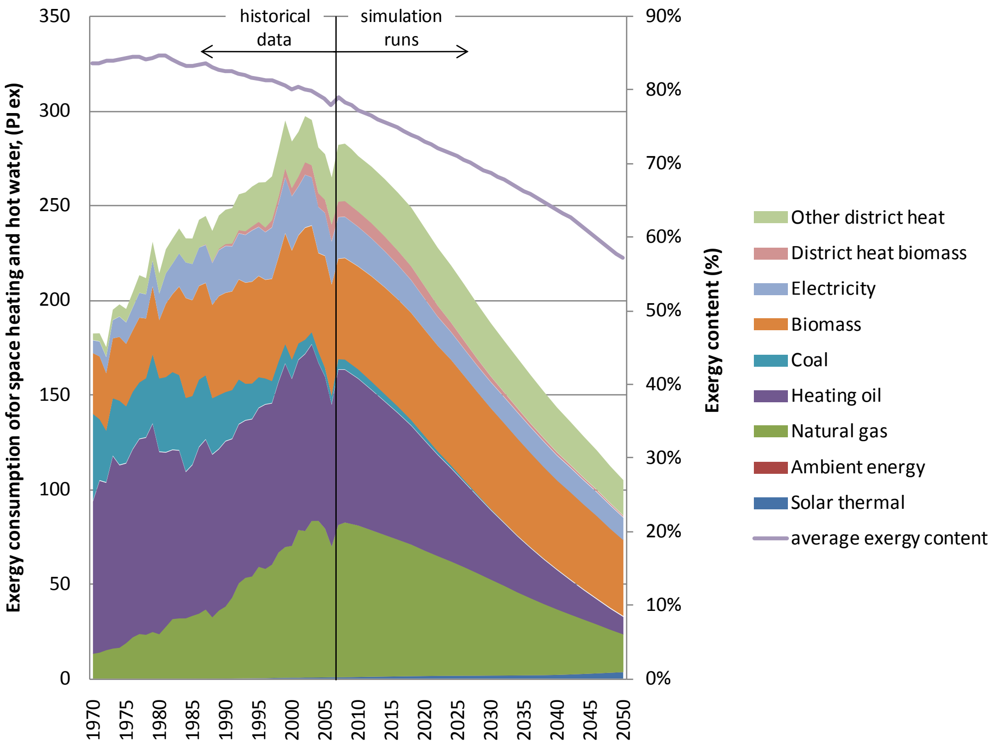


Figure 10: Exergy consumption for space heating and hot water in Austria (HDD adjusted), business as usual scenario

Sources: (Statistik Austria 2009), (Biermayr et al. 2010), *own calculations*

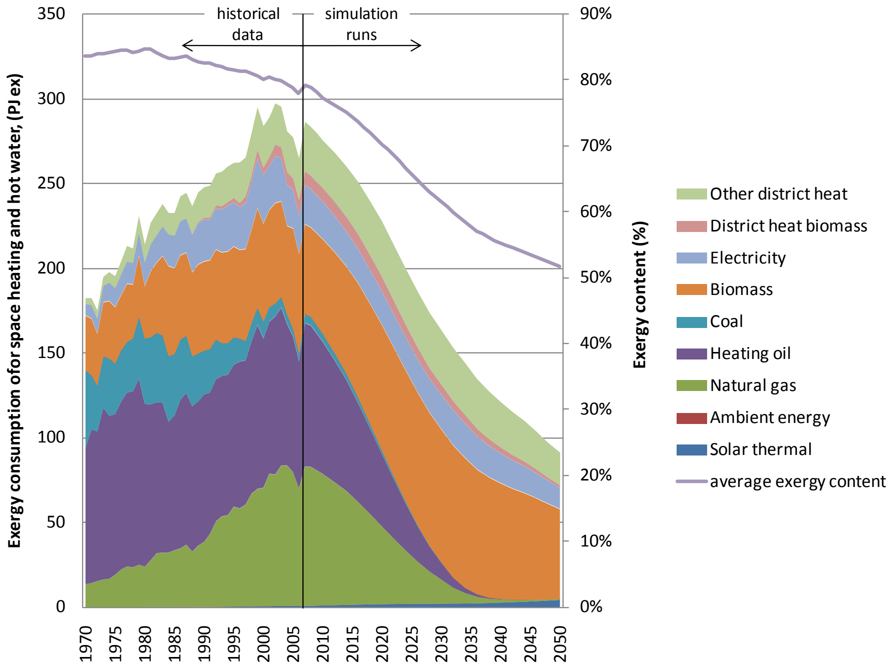


Figure 11: Exergy consumption for space heating and hot water in Austria (HDD adjusted), RES-H based scenario

Sources: (Statistik Austria 2009), (Biermayr et al. 2010), *own calculations*

Figure 12 compares the exergetic efficiency in the three investigated scenarios. For this calculation the following steps were carried out: (1) Calculation of useful heat energy (by taking into accoung time series of typical energy efficiency values for different heating systems, (2) calculation of exergy content of useful heat energy by taking into account the share of space heating and hot water in the investigated period and (3) dividing exergy content of useful heat energy by the exergy consumption. Due to energy efficiency improvements as well as a change in the mix of heating systems the exergetic efficiency in the Austrian space heating and hot water consumption increased from 1970 to 2008 from about 5% to more than 9%. The jump from the historical data (based on (Statistik Austria 2009)) to the results of the bottom-up simulations are due to data inconsistencies and methodological different approaches between the historical data collection and the calculation in the model (e.g. with respect to the level of ambient energy as discussed in section 4). Due to the different energy carrier mix and in particular due to the different share of solar thermal and ambient energy, the range of the overall exergetic efficiency in 2050 is between less than 12% (in the fossil based scenario) up to more than 18% in the RES-H based scenario.

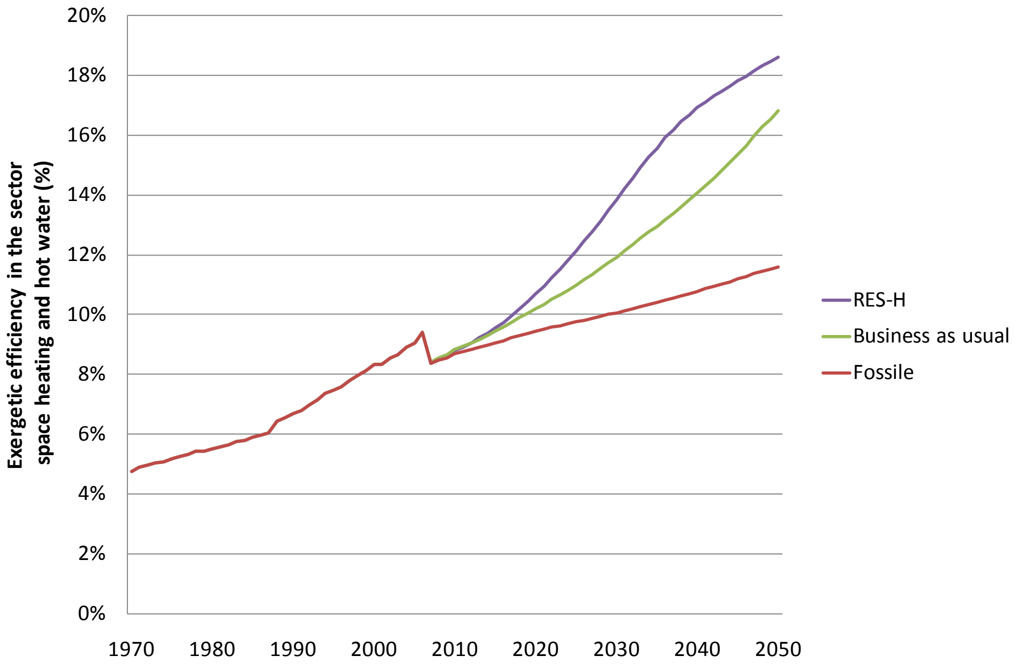


Figure 12: Comparison of exergetic efficiency in the sector space heating and hot water from 1970-2050 in the three investigated scenarios, Austria

6. Synthesis and conclusions

The results of this analysis show that there is a high potential of increasing exergetic efficiency in the Austrian space heating and hot water sector. Some part of this potential already has been exploited in the period between 1970 and 2008: in this period the exergetic efficiency increased by about 4% due to a higher energetic efficiency of heating systems and a moderate reduction of energy content of applied energy carriers. However, the high growth of energy consumption (also triggered by a growth in living space and comfort level, (Unander 2004)) resulted in a significant incline in exergy consumption. The scenarios up to the year 2050 show that a much stronger increase of the exergetic efficiency would be feasible: in the most ambitious scenarios presented in this paper the exergetic efficiency could increase by more than 11%. In the same time the exergy content of energy consumption in this sector could reduce by almost 30%. Together with thermal renovation measures this could lead to a decline of exergy consumption from 2008 to 2050 by two thirds.

However, the comparison of the scenarios also shows that this development only happens with the corresponding conditions: The fossil based scenario shows an increase of just 4% of exergetic efficiency until 2050. One of these conditions which are required is a corresponding level of energy prices (either due to market mechanisms and resource shortages or due to taxation of high exergetic energy forms). Another prerequisite is support policies for thermal renovation and low-exergy heating systems, in particular renewable low-exergy systems.

The scenarios show that a transition to low-exergy systems is possible. And they also illustrate that diffusion constraints have to be taken into account. Time constants in the building stock and heating system stock are relatively high and it takes correspondingly high effort to achieve a faster rate of change in heating systems etc.

Several aspects could not be discussed in detail in this paper. In particular the following questions remain for further research:

- What is the future potential of further district heat and CHP in the light of lower heat loads of buildings? How would this affect exergy consumption and exergetic efficiency in this sector?
- What is the impact of different scenarios of thermal building renovation on exergy consumption and exergetic efficiency
- What is the impact of an increased amount of waste heat from industrial processes for district heating?

The analysis of energy systems under the light of exergy consumption and exergetic efficiency leads to another type of insight in these systems and helps to identify possible exergy and energy – and finally greenhouse gas – saving potentials. Particularly the space heating sector due to its low-exergy useful heat energy characteristics provides a large field of related activities and measures.

7. Acknowledgment

This publication was financed by the Austrian Ministry of transport, innovation and technology in the frame of IEA implementing agreement ECBCS (Energy conservation in building and community systems) Annex 49 (Low Exergy Systems for High-Performance Buildings and Communities, www.annex49.com).

8. References

Ala-Juusela, M., 2005. *Heating and Cooling with Focus on Increased Energy Efficiency and Improved Comfort. Guidebook to IEA ECBCS Annex 37 Low Exergy Systems for Heating and Cooling of Buildings.*,

Bejan, A., 1988. *Advanced Engineering Thermodynamics*, A Wiley - Interscience Publication, John Wiley & Sons.

Biermayr, P. et al., 2007. *Bestimmung der Potenziale und Ausarbeitung von Strategien zur verstärkten Nutzung von erneuerbaren Energien in Luxemburg. Endbericht im Auftrag des Ministeriums für Energie.*,

Biermayr, P. et al., 2010. *Innovative Energietechnologien in Österreich. Marktentwicklung 2009. Biomasse, Photovoltaik, Solarthermie und Wärmepumpen*, Wien: Bundesministerium für Verkehr, Innvoation und Technologie.

Bürger, V. et al., 2008. Policies to support renewable energies in the heat market. *Energy Policy*, 36(8), 3150-3159.

Capros, P., 2007. *Primes - Baseline Scenario for EU-27*, European Parliament and the Council, 2009. *Directive on the promotion of the use of energy from renewable sources and amending and subsequently repealing Directives 2001/77/EC and 2003/30/EC,*

Haas, R., Auer, H. & Biermayr, P., 1998. The impact of consumer behavior on residential energy demand for space heating. *Energy and Buildings,* 27(2), 195-205.

Haas, R., Müller, A. & Kranzl, L., 2009. *Energieszenarien bis 2020: Wärmebedarf der Kleinverbraucher. Ein Projekt im Rahmen der Erstellung von energiewirtschaftlichen Input-parametern und Szenarien zur Erfüllung der Berichtspflichten des Monitoring Mechanisms. Im Auftrag der Umweltbundesamt GmbH,* Wien.

Kotas, T.J., 1985. *The Exergy Method of Thermal Plant Analysis,* Butterworths: Anchor Brendon Ltd.

Kranzl, L. et al., 2006. Deriving efficient policy portfolios promoting sustainable energy systems–Case studies applying Invert simulation tool. *Renewable energy,* 31(15), 2393–2410.

Kranzl, L. et al., 2007. Integrating policies for renewables and energy efficiency: Comparing results from Germany, Luxembourg and Northern Ireland. In eceee 2007 summer study. La colle sur Loup, France.

Kranzl, L. et al., 2010. *Assessment of the effectiveness and economic efficiency of selected support options for Austria. A Working Document prepared as part of the IEE project "Policy development for improving RES-H/C penetration in European Member States (RES-H Policy)".,* Vienna. Available at: www.res-h-policy.eu.

Müller, A., 2010. Hat Heizen zukunft? Eine langfristige Betrachtung für Österreich. In Symposium Energieinnovation. Graz.

Nast, M. et al., 2006. *Eckpunkte für die Entwicklung und Einführung budgetunabhängiger zur Marktdurchdringung erneuerbarer Energien im Wärmemarkt“ Endbericht. Im Auftrag des deutschen Bundesministeriums für Umwelt, Naturschutz und Reaktorsicherheit.,*

Sandnes, B., 2003. *Energy efficient production, storage and distribution of solar energy. PhD Thesis.* Oslo: University of Oslo, Norway.

Schmidt, D. & Torio, H., 2009. *Low Exergy Systems for High Performance Buildngs and Community Systems. Annex 49 Midterm Report,* Stuttgart.

Schriefl, E., 2007. *Modellierung der Entwicklung von Treibhausgasemissionen und Energieverbrauch für Raumwärme und Warmwasser im Österreichischen Wohngebäudebestand unter Annahme verschiedener Optimierungsziele.* Wien: Technische Universität Wien.

Shukuya, M. & Hammache, A., 2002. *Introduction to the Concept of Exergy - for a better Understanding of Low-Temperatrue-Heating and High-Temperature-Cooling Systems,* Espoo.

Stadler, M. et al., 2007. Policy strategies and paths to promote sustainable energy systems–The dynamic Invert simulation tool. *Energy policy*, 35(1), 597–608.

Statistik Austria, 2004. *Arbeitsstättenzählung 2001,* Wien.

Statistik Austria, 2009. *Energiestatistik: Energiebilanzen Österreich 1970 bis 2008.*, Statistik Austria. Available at: www.statistik.at [Accessed July 30, 2010].

Statistik Austria, 2004. *Gebäude- und Wohnungszählung 2001*, Wien.

Statistik Austria, 2006. *Wohnungen 2005*, Wien.

Szargut, J., Morris, D.R. & Stewart, F.R., 1988. *Exergy Analysis of Thermal, Chemical and Metallurgical Processes,* Hemispheric Publishing Corporation.

Torío, H., Angelotti, A. & Schmidt, D., 2009. Exergy analysis of renewable energy-based climatisation systems for buildings: A critical view. *Energy and buildings*, 41(3), 248–271.

Unander, F., 2004. *30 years of energy use in IEA countries*, International Energy Agency.

Wall, G., 1977. *Exergy - a useful concept within resource accounting*, Göteborg: Institute of Theoretical Physics. Available at: http://www.exergy.se/ftp/paper1.pdf.

Anhang M

Publikation
Niedrigexergetische Gebäudesysteme – Identifikation von Best-Practice Beispiele in Österreich

Niedrigexergetische Gebäudesysteme

Identifikation von Best-Practice-Beispielen in Österreich

Julian Matzenberger, Lukas Kranzl

Vienna University of Technology, Institute of Power Systems and Energy Economics,
Energy Economics Group, Gusshausstrasse 25-29/E373-2, A-1040 Vienna, Austria,
Tel: +43-1-58801-37351, Fax: +43-1-58801-37397,
E-mail: kranzl@eeg.tuwien.ac.at, Web: http://eeg.tuwien.ac.at

Arbeitspapier erstellt im Rahmen der österreichischen Beteiligung an IEA ECBCS Annex 49
"Low Exergy Systems for High-Performance Buildings and Communities"

1 Einleitung

Innerhalb des letzten Jahrzehnts hat in der internationalen wissenschaftlichen Community eine breite Diskussion um die Integration des Exergie-Konzepts in energiewirtschaftlichen Analysen eingesetzt. Dieser Exergie-basierte Ansatz vermittelt ein besseres Verständnis über die Qualität verschiedener Energie-Formen und kann dadurch zu effektiveren Maßnahmen zur Einsparung von Energieträgern und für den Klimaschutz beitragen. Beispielsweise ist der Exergiegehalt, der zur Beheizung bzw. Kühlung eines Gebäudes benötigt wird, sehr gering. Dennoch werden weltweit fossile Energieträger mit hohem Exergiegehalt zur Befriedigung dieses geringen Exergie-Bedarfs verwendet.

Systeme, die Energie mit geringem Exergie-Aufwand bereitstellen, werden als LowEx-Systeme bezeichnet. Diese Systeme können zum sparsameren Einsatz von Energieträgern beitragen und stellen damit wesentliche Elemente nachhaltiger Energiesysteme dar.

Annex 49 ist ein internationales Forschungsprojekt, das im Rahmen des Programmes „Energieeinsparung in Gebäuden und Gemeinden (ECBCS)" der International Energy Agency (IEA) initiiert wurde.

Ziel von Annex 49 ist die Entwicklung von Konzepten zur Reduktion des Exergie-Bedarfs in Gebäuden, um so die CO2-Emissionen des Gebäude-Bestands zu reduzieren und Strukturen für nachhaltige und zuverlässige Energiesysteme im Gebäude-Sektor zu unterstützen.

2 Fragestellung

Das Ziel dieses Arbeitspapiers ist es, aufbauend auf den Richtlinien, die im Zuge der Annex 49 Arbeitsgruppe für Niedrigexergie-Systeme [Schmidt 2009] und der Annex 37 Arbeitsgruppe für Niedrigexergie-Systeme in Gebäuden [Ala-Juusela 2003] beschrieben wurden, in Österreich eingesetzte Systeme zu identifizieren und deren Eignung als Best-Practice-Beispiele zu evaluieren. Ausgewählte Best-Practice Beispiele werden detaillierter beschrieben.

3 Methodik

Im Rahmen dieser Arbeit wurde gezielt nach dem Vorhandensein von innovativen LowEx Komponenten in Österreich gesucht, die als Best-Practice-Beispiele angesehen werden können. Konkret besteht die Methodik, die in diesem Arbeitspapiers angewendet wurde, aus den folgenden Schritten:

- Identifikation von „low-ex"-Komponenten.
  In diesem Schritt wird dargestellt, welche Komponenten in Energiesystemen als „low-ex" Komponenten gelten, also Technologien oder (Teil-) Systeme, die nieder-exergetische Energiequellen nützen, oder zu nützen in der Lage sind. Dabei wurden im Wesentlichen Ergebnisse aus der Literatur, in erster Linie auf Basis der Arbeiten in IEA ECBCS Annex 37 und Annex 49 zurückgegriffen. Es wird dabei in diesem Schritt kein Anspruch auf Vollständigkeit gelegt.
- Darstellung der methodischen Ansätze zur Bewertung der exergetischen Effizienz dieser Komponenten
- Sichtung aktueller Forschungs-, Pilot- und Demonstrationsprojekte
  In diesem Schritt werden aktuelle Projekte, insbesondere aus der Programmlinie „Nachhaltig Wirtschaften" gesichtet und auf das Vorhandensein von Low-ex-Komponenten bewertet. Auf Basis dieser Analyse werden, so weit möglich, Best-Practice-Beispiele identifiziert.
- Darstellung ausgewählter Best-Practice-Beispiele

Die Sichtung von in Frage kommenden Best-Practice-Beispielen umfasst die Endberichte der letzen fünf Jahre (ab 2006) aus den Programmlinien „Haus der Zukunft", „Fabrik der Zukunft", „Energiesysteme der Zukunft", „Energie der Zukunft", die Teil des Nachhaltig Wirtschaften Programms sind.

Über das Impulsprogramms Nachhaltig Wirtschaften, welches 1999 als mehrjähriges Forschungs- und Technologieprogramm vom Bundesministerium für Verkehr, Innovation und Technologie gestartet wurde, wurden eine Vielzahl innovativer Projekte gefördert. Im „Haus der Zukunft" Programm sind zahlreiche Studien über Passivhäuser erfasst. Gebäude, die dem Passivhausstandard genügen, verfügen zumeist über Luftwärmetauscher und sind durch ihre Gebäudearchitektur auf eine optimale Ausnutzung der solaren Strahlung ausgelegt. Da in diesem Arbeitspapier auf besonders innovative Nutzung von LowEx-Systemen Wert gelegt werden soll, wurden Gebäude bzw. Projekte, die keine zusätzlichen LowEx-Komponenten aufweisen konnten, nicht weiter berücksichtigt.

Als Best-Practice-Beispiele werden insbesondere Projekte gesehen, die eine innovative Verknüpfung mehrerer LowEx Komponenten aufweisen.

4 Beschreibung ausgewählter LowEx Komponenten

4.1 Identifikation von Low-Ex-Komponenten

Der wesentliche Punkt dieses Papers ist die Identifikation von Komponenten, die bereits im Rahmen der Annex 49 und Annex 37 Arbeitsgruppe eingehend beschrieben und als LowEx-Systeme hervorgehoben wurden, in aktuellen österreichischen Forschungs- und Demonstrationsprojekten. Der erste Schritt bestand daher in der Definition und Identifikation derartiger Komponenten.

Tabelle 1 zeigt eine Auflistung der definierten Komponenten, wie sie in Annex 37 erarbeitet wurden [Ala-Juusela 2003]. Diese Tabelle enthält eine umfassende Liste von zum Teil recht disaggregierten Sub-Systemen und Technologien. Für den Zweck in diesem Arbeitspapier ist es nötig, diese stärker zusammenzufassen. Diese Zusammenfassung richtet sich also danach, die so identifizierten Komponenten praktikabel zur Sichtung der Forschungsprojekte verwenden zu können.

What	Suitable for	State of the art	Costs	Cooling temp. [°C]	Heating temp. [°C]
Surface heating and cooling					
Floor heating					
Embedded coils in slabs	Non-Residential	Commerical		10-15	25-30
Coils in surface layers	Residential and non-res.	Commerical		16-20	28-35
Hollow core slabs	Non-Residential	Commerical	+ -	15-18	25-30
Suspended floors	Residential and non-res.	Commerical	+ -	16-20	30-40
Phase Change in floor heating	Non-Residential	Experimental	++	-	25-50
Wall heating and cooling					
Pipes in surface layers (wet/half wet,mounted)	Residential and non-res.	Commerical		10-15	25-50
Pipes in surface layers (half-dry embedded)	Residential and non-res.	Commerical		10-15	25-50
Pipes in surface layers (wet, embedded)	Residential and non-res.	Commerical		10-15	25-50
Pipes in surface layers (dry systems)	Residential and non-res.	Commerical		10-15	25-50
Double walls	Residential and non-res.	Experimental	++	15-18	25-35
Dynamic Insulation	Residential	Experimental	+ -		25-30
Capillary tubes	Residential and non-res.	Commerical	+ -	10-15	25-30
Ceiling cooling and heating					
Radiative panel	Non-Residential	Commerical	+ -	10-15	25-50
Cooling beams	Non-Residential	Commerical	+ -	10-15	25-50
Ceiling integrated system	Residential and non-res.	Commerical		10-15	25-50
Evaporative roof surfaces	Non-Residential	Commerical		15-20	-
Ceiling panel cooling by double-roofing with	Residential	Experimental			
Local heaters					
Low temperature radiators/convectors	Residential and non-res.	Commerical	+ -	-	30-50
Radiators integrated in the interior design			+ -		
High Temperature Radiators	Residential and non-res.	Commerical		10-20	20-40
Base board heaters	Residential and non-res.	Commerical		-	80-130
Transparent insulation	Residential and non-res.	Commerical	++	-	40-95
Air heating and cooling					
Air to air heat exchanger					
Sensible Only Heat Exchangers /	Residential and non-res.	Commerical	+ -		40-95
Counter flow air to air heat exchanger/	Residential and non-res.	Commerical	+ -	10-15	20-50
Total (Latent) Heat Exchangers / Regenerator	Non-Residential	Commerical	++		25-50
Altering Heat Exchangers	Residential	Commerical	+ -		40-95
Water to air heat exchanger					
Supply air conditioning	Non-Residential	Commerical	++	-	40-90
Fan coil units				10-15	25-30
Steam / vapour to air heat exchanger					
Supply air conditioning	Non-Residential	Commerical	++		100-120
Other heat exchanger					
Supply air façade	Non-Residential	Commerical	+ -	-	20-100
Evaporative cooling					-
Passive system					
Atria	Non-Residential	Commerical	+ -		
Solar chimneys	Non-Residential	Innovative	++		
Generation / conversion of cold and heat					
Boilers					
Condensing boilers	Residential and non-res.	Commerical	+ -	-	
Pulsating gas boiler	Residential	Commerical	+ -	-	50-80
Ground heat					
Ground coils	Residential and non-res.	Commerical		8-18	-
Bore hole	Residential and non-res.	Commerical	+ -	8-18	18-22
Slab on ground	Non-Residential	Commerical	+ -	14-22	16-22
Heat pumps					
Compressor heat pumps	Residential and non-res.	Commerical	+ -	10-15	25-50
Absorption heat pumps	Non-Residential	Commerical	+ -	10-15	-
Solar collectors					
Flat plate collectors	Residential and non-res.	Commerical	+ -	-	20-80
Evacuated tube collector	Residential and non-res.	Commerical	++	-	20-120
Unglazed flat-plate collector	Residential	Commerical		-	20-80
Combined heat and power generation					
Cogeneration units with gas motor	Residential and non-res.	Commerical	+ -	-	80-90
Cogeneration units with microturbines	Non-Residential	Experimental	++	-	
Cogeneration units with stirling motor	Non-Residential	Experimental	++	-	
Fuel cells					
Fuel cells	Non-Residential	Experimental		-	
Biological systems / Metabolic					
Bacteria	Non-Residential	Innovative	+ -	-	20-60
Animals	Residential and non-res.	Innovative	++	-	20-35
Plants	Residential and non-res.	Experimental	++	20-25	-

Tabelle 1 Auswahl von Low-Ex-Komponenten nach IEA ECBCS Annex 37 [Ala-Juusela 2003]

Die Zusammenfassung der Komponenten mit niedrigem Exergie-Bedarf, die als zukunftsweisende Best-Practice Systeme genannt werden können, ergibt die folgenden Cluster:

- Kontrollierte Wohnraumlüftung
  Der meiste Energieverbrauch fällt bei Gebäuden für die Regulierung des Raumklimas an. Der Exergiegehalt von Raumluft ist allerdings gering (Bei einem Temperaturunterschied zwischen Innenraumtemperatur und Außenluft liegt er bei 7%). Niedrig-Exergetische Raumwärmebereitstellung wird durch Wärmerückgewinnung mittels Wärmetauscher zwischen Zu- und Abluft realisiert.

- Feuchterückgewinnung
  Die in der Luftfeuchtigkeit der Raumluft enthaltene Wärmemenge kann durch Luftfeuchtetauscher zurückgewonnen werden und so einen Beitrag zu Niedrig-exergetischer Raumklimatisierung stellen. Feuchterückgewinnung stellt somit eine Erweiterung der kontrollierten Wohnraumlüftung dar. Eingesetzt werden in der Regel Membranen oder Sorptionsmittel.

- Heizen und Kühlen mit Grundwasser und Erdwärme
  Die Temperatur in oberflächennahen Bodenschichten liegt im Sommer unter und im Winter über den Außentemperaturen. Diese Temperaturunterschiede können zur Wohnraumbeheizung bzw. –kühlung genutzt werden. Die Verwendung von Grundwasser bietet prinzipiell den Vorteil, dass aufgrund der höheren Wärmeübertragungskapazität von Wasser bessere Jahresarbeitszahlen (und somit bessere Exergieeffizienz) der Wärmepumpe erzielt werden können, ist aber abhängig von der Verfügbarkeit bzw. vom Grundwasserstand.

- Solare Kühlung
  Von solarer Kühlung spricht man allgemein, wenn Sonnenenergie zum Antrieb eines Kühlprozesses eingesetzt wird. Wird ein Sonnenkollektor nur für Brauchwasserbereitung und Heizung eingesetzt, so kann es im Sommer zu nicht nutzbaren Überschüssen kommen. Der Einsatz von solarer Kühlung hat den Vorteil, dass hohe Solarstrahlung und Kühllast gleichzeitig auftreten. Die exergetische Beschreibung von Systemen zur Raumkühlung hat in der Annex 49 Arbeitsgruppe große Aufmerksamkeit erhalten. Eingesetzt werden bisher vor allem Absorptionskältemaschinen und solarunterstützte Kühlung mit Sorptionsmitteln.

- LowEx-Gebäudearchitektur
  Die Gebäudearchitektur, wie sie bei Passivhäusern des Öfteren zum Einsatz kommt, ist auf eine optimale Anpassung an den Verlauf des Sonnenstandes angepasst. Dadurch kann zusätzlich niedrigexergetische solare Wärmestrahlung bei niedrigem Sonnenstand bzw. im Winter eingebracht werden und der Einfall der solaren Strahlung bei hohem Sonnenstand bzw. im Sommer minimiert werden. Es wird darauf abgezielt, die Wärmeübertragung (der solaren Strahlung) im Sommer zu verringern und im Winter zu erhöhen.

- Bauteilaktivierung
  Voraussetzung für eine niedrigexergetische Bereitstellung von Raumwärme ist bei

der zumeist geringen Temperaturdifferenz eine hinreichend große Fläche zur Wärmeübertragung. Eine Auflistung der möglichen Bauteile findet sich in Tabelle 1. Typische Bauteile bestehen aus Betonelementen eingebetteten Kunststoffrohren, die in Wänden und Böden (Fußbodenheizung) verbaut werden.Sie können zur Beheizung ab einer Mindesttemperatur von 23°C bzw. zur Kühlung ab 19°C eingesetzt werden.

4.2 Beurteilungsmethodik und Abschätzung des Exergiebedarfs ausgewählter Komponenten

Energieträger

Exergieeffizienz ist eine gute Basis um Raumheizung- und Raumkühlung zu vergleichen, da sie in Systemen mit dem selben Exergieoutput helfen kann jene mit dem geringsten Verlust an Exergie zu identifizieren.

Die exergetische Analyse folgt prinzipiell den Überlegungen in im Annex 49 Zwischenbericht [Schmidt 2009] dargelegt wurden sowie Arbeiten die im Rahmen der Arbeitsgruppe erstellt wurden [Torio et al. 2009; vgl. Kranzl et al. 2010]

Prinzipiell gilt, dass in einem reversiblen Prozess nur der mit dem Carnot-Faktor $1 – (T_u/T)$ multiplizierte Anteil der zugeführten Wärme (dQ) in Arbeit umwandelbar ist. Der Anteil der Anergie kann nicht als Arbeit gewonnen werden. Aus der obigen Gleichung ist auch zu erkennen, dass Wärme (T) die bei Umgebungstemperatur (T_u) zur Verfügung steht nicht in Exergie umgewandelt werden kann. Für die Exergie gilt im Gegensatz zur Energie kein Erhaltungssatz. [Dubbel 2007]

Die thermische Exergie, die bei der Verbrennung eines Energieträgers frei wird, kann über das nutzbare Temperaturverhältnis bestimmt werden.

Zur Beschreibung der in Ofenräumen ablaufenden Verbrennungsprozesse ist die kalorische von der theoretischen Verbrennungstemperatur zu unterscheiden. Wird ein Brennstoff mit Luft (in einer adiabaten Brennkammer) verbrannt, so stellt sich in dem entstandenen Heizgas die kalorische Verbrennungstemperatur ein, nachdem alle brennbaren Bestandteile in ihre höchste Oxidationsstufe (in der Regel H_2O und CO_2) umgesetzt wurden. Die kalorische Temperatur wird jedoch selbst bei adiabater Verbrennung nie erreicht, da diese aufgrund chemischer Gleichgewichtsbedingungen nicht vollständig abläuft (dies insofern, als CO_2 und H_2O dissoziieren) [Spur and Stöferle 1998]. Die exakte theoretische Verbrennungstemperatur muss aufgrund der unterschiedlichen molaren Wärmekapazitäten der einzelnen Rauchgase iterativ ermittelt werden.

Als vereinfachte Abschätzung der Verbrennungstemperatur, die für den Vergleich der exergetischen Effizienz an dieser Stelle als hinreichend genau herangezogen wird, kann auf die Arbeit von Kranzl et al. [2010] zurückgegriffen werden.

Unit	ambient temperature °C	(usable, possible) temperature °C	exergy content %
Electricity			100%
mechanical energy (engine)			100%
space heat	0	20	7%
process heat	0	300	52%
Woody biomass	0	800	75%
FT-Diesel	0	1500	85%
Maize silage / Manure mix	0	800	75%
biogas crude	0	800	75%
biogas fed into gas grid	0	1800	87%

Tabelle 2 Exergiegehalt ausgewählter Energieträger [Kranzl et al. 2010]

Der Exergiegehalt der Raumwärme wird analog berechnet. In dieser Arbeit wird, falls nicht anders angemerkt, von einer Temperaturdifferenz von 20°C ausgegangen. Dies resultiert in einem Exergiegehalt von rund 7%.

Umgebungswärme / Wärmepumpen

Bei jenen Formen der Bereitstellung von Raumwärme, die schwer nutzbare Nieder-Exergetische Wärmequellen mittels Wärmepumpen heranzieht, wurde die Jahresarbeitszahl zur Bestimmung des Exergieanteils ($Ex_{\%}$) am bereitgestellten Wärmestrom herangezogen.

$$Ex_{\%} = \frac{1}{JAZ} * 100\%$$

Die Jahresarbeitszahl (JAZ) ist der Maßstab für die Effizienz einer Wärmepumpenanlage. Sie sagt aus welcher Heizungswärmestrom ($\dot{Q}_{therm}$) im Verhältnis zum eingesetzten Strom (P_{el}) von der Wärmepumpe im Laufe eines ganzen Jahres im betreffenden Haus erzeugt wurde. Dieser Berechnungsmethodik liegt die Annahme zugrunde, dass Umgebungswärme als Anergie - also mit einem Exergiegehalt von 0 – vorliegt. Strom hat einen Exergiegehalt von 100%.

$$JAZ = \frac{\dot{Q}_{therm}}{P_{el}}$$

Der exergetische Wirkungsgrad (η_{Ex}) ist definiert als:

$$\eta_{Ex} = \frac{Ex_{out}}{Ex_{in}}$$

Bei den Jahresarbeitszahlen von Wärmepumpen konnten in den letzen Jahren erhebliche Verbesserungen festgestellt werden [Faninger 2007]. Für Luft/Luft Wärmepumpen können üblicherweise zumindest JAZ von 3, bei Luft/Wasser Wärmepumpen zumindest JAZ von 4 erreicht werden. Dabei ist allerdings zu berücksichtigen, dass die tatsächliche JAZ in hohem Maße nicht nur von der Wärmequelle sondern auch von der Vorlauftemperatur und damit dem Wärmeverteilsystem und der thermischen Qualität eines Gebäudes abhängt.

Eine JAZ von 3 entspricht einem Exergiegehalt des bereitgestellten Wärmestroms von etwa 33% bzw. entspricht eine JAZ von 4 einem Exergiegehalt von etwa 25%. Wird am Beispiel der Raumwärmeaufbringung eine Temperaturdifferenz von 20°C unterstellt, ergibt sich somit ein exergetischer Wirkungsgrad von 21% bzw. 28%. Im Vergleich dazu liegt der exergetische Wirkungsgrad bei einer Beheizung mit Strom (100% Exergiegehalt) etwa bei 7%.

		Wärmetauscher Luft/Luft	Wärmetauscher Luft/Wasser	Elektische Beheizung	Heizöl
Jahresarbeitszahl	JAZ	3	4	(1)	
Exergiegehalt	Ex_{out}	33%	25%	100%	88%
exergetischer Wirkungsgrad der Raumwärmeaufbringung	η_{Ex}	21%	28%	7%	8%
Exergieeffizienz-Steigerung gegenüber einer Beheizung mit Heizöl		264%	352%	-12%	

Tabelle 3 Exergetische Wirkungsgrade von Wärmepumpen

Die kontrollierte Wohnraumbelüftung folgt dem Prinzip eines Luft/Luft Wärmetauschers – der exergetische Wirkungsgrad liegt bei einer Jahresarbeitszahl von 3 bei 21%.

Raumfeuchtetauscher

Das Innenraumklima unterscheidet sich vom Referenz-Außenklima nicht nur durch einen Temperaturunterschied sondern auch durch die Luftfeuchtigkeit, die einen bestimmten Enthalpiegehalt aufweist.

Die physikalische Exergie feuchter Luft berechnet sich wie folgt:

$$Ex_{phys,Luft,Feucht} = (c_{p,trocken} + \omega * c_{p,Dampf}) * \left[(T - T_0) - T_0 * \ln\frac{T}{T_0}\right] + (1+\omega) R_a T_0 \ln\frac{p}{p_0}$$

Da bei Raumklimatisierung Atmosphärendruck herrscht, ist üblicherweise kein mechanisches Exergiepotential vorhanden. Es wird im folgenden angenommen, dass es keine Druckdifferenz zwischen Innenraum Umgebung herrscht.

Die spezifische Wärmekapazität von trockener Luft ($c_{p,trocken}$) beträgt 1,003 kJ/kgK, jene von Wasserdampf ($c_{p,Dampf}$) 1,872 kJ/kgK. Bei einer Temperatur von 20°C liegt das maximale Massenverhältnis von Wasserdampf zu Luft ($\omega = m_v/m_a$) - entsprechend 100% Luftfeuchtigkeit - bei 0.0147 kg/kg.

Chemische Exergie, die etwa durch Kondensation freigesetzt wird, ist in dieser Berechnung vernachlässigt.

Die optimale Luftfeuchtigkeit für ein behagliches Raumklima liegt zwischen 40% und 65%. Eine 65%ige Luftfeuchtigkeit entspricht einem Massenverhältnis von 0.0087 kg/kg.

Die maximale Exergieeinsparung entspricht einer vollständigen Anreicherung der Zuluft mit der Luftfeuchtigkeit der Abluft. Tatsächlich können etwa 80% der Luftfeuchte getauscht werden. Eingesetzt werden in der Regel Membranen (z.B. ausgeführt als wasserdurchlässige Folien in rekuperativen Systemen) oder Sorptionsmittel in Regeneratoren (Rotationswärmetauscher).

Für die die Berechnung wird eine Außentemperatur von 0°C und eine Innentemperatur von 20°C angenommen.

rel. Luftfeuchtigkeit	%	0	20	40	60	80	100
m_{Wasser}/m_{Luft}	kg/kg	0,000	0,003	0,006	0,006	0,012	0,015
$Ex_{Raumluft}$	kJ/kg	0,700	0,704	0,708	0,708	0,716	0,720
max. Exergieeinsparung	%	0,00%	0,54%	1,08%	1,08%	2,18%	2,74%
$c_{pLuft,trocken}$	1,003						
$c_{p,Wasserdampf}$	1,872						
T_0	273,15						
T	293,15						

Tabelle 4 Maximal erreichbare Exergieeinsparung durch Luftfeuchtetauscher

Solare Kühlung

Verdunstungskühlung

Torio [et al. 2009] präsentiert eine exergie-basierte Analyse von Klimatisierungssystemen.

Da die Exergieanalyse kein normiertes Berechnungsschema ist, sind unterschiedliche Rechenwege, mit teils unterschiedlichen Ergebnissen möglich.

Ein Weg um Verdunstungskühlung exergetisch zu erfassen ist die Exergie der Luft in chemische, thermische und mechanische Komponenten zu unterteilen. Verdunstungskühlung wird durch Verlust der chemischen Exergie im primären und sekundären Luftkreislauf erreicht um die thermische Exergie der Primärluft zu erhöhen.

Wepfer [nach Torio et al 2009] findet unter den Annahmen einer Außentemperatur TA=35°C, Umgebungsdruck = 1 atm und eines Wasser zu Luft Massenverhältnisses von 0.01406 kg/kg für Verdunstungskühlung eine Exergieeffizienz von 38%

Sorptionskühlung

Die Exergieeffizienz für Sorptionskühlung mit Solarthermie wird ähnlich der von konventionellen Kältemaschienen deffiniert, beinhaltet aber den Exergieoutput der Solarthermieanlage als Input für das Gesamtsystem.

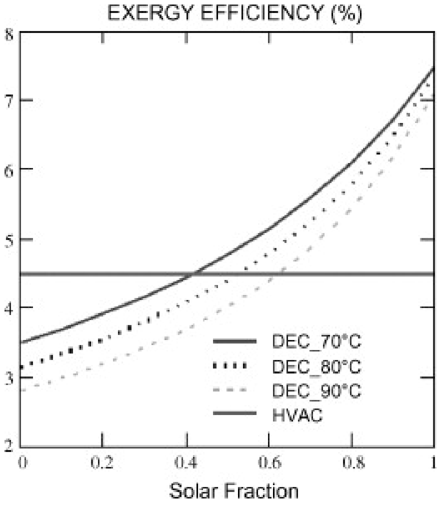


Tabelle 5 Exergieeffizienz für eine konventionelle Kältemaschine und Solare Kühlung mit verschiedenen Zulufttemperaturen und Anteile der Solarenergie [Torio et al. 2009]

Bemerkenswert ist, dass trotz der höheren JAZ im Sommer die Exergieeffizienz für die Gebäudekühlung signifikant geringer ist als für die Beheizung. Das resultiert aus dem geringen Temperaturunterschied zwischen Innenraum- und Außentemperatur, der zu einem sehr geringen Exergiebedarf zur Raumkühlung führt [Torio 2009]. Daher ist der Gebäudekühlung eine niedrige Exergieeffizient immanent und folglich aus exergetischen Gesichtspunkten möglichst zu vermeiden bzw. passiv zu realisieren. Der Einsatz von solarer Kühlung hat den Vorteil, dass die im Sommer oft überschüssige Wärmeenergie aus Solarkollektoren eingesetzt werden kann.

5 Ergebniss-Cluster

5.1 Haus der Zukunft

Die meisten Best-Practice-Beispiele, die Niedrigexergie-Komponenten aufweisen können, wurden erwartungsgemäß im Programm Haus der Zukunft gefunden. Es konnten sieben erfolgreich eingesetzte Technologien identifiziert werden. Niedrigexergetische Aufbringung von Raumwärme wird in allen untersuchten Beispielen zumindest über einen Luftwärmetauscher realisiert. Weit verbreitet ist auch der zusätzliche Einsatz von Solarthermieanlagen.

Aus der umfangreichen Liste an Projekten wurden jene ausgewählt, die aus unserer Sicht in besonderem Ausmaß low-ex-Komponenten integrieren. Wir weisen allerdings darauf hin, dass eine derartige Auswahl nur schwer nach eindeutigen Kriterien zu treffen ist und viele andere Objekte ebenfalls in der einen oder anderen Weise low-ex-Technologien anwenden.

Projekt	Programmlinie	RaumluftWT	RaumfeuchteWT	ErdWT	GrundwasserWT	Solarthermie	solare Kühlung	LowEx-Gebäudearchitektur	(Photovoltaik)	Referenz
Lehm Bürogebäude Tattendorf	HdZ	X	X		X	X		X		*[Wagner et al. 2009a]*
Passivhaus Roschégasse 20	HdZ	X		X				X		*[Wagner et al. 2009b]*
Sunny Energy Building	HdZ	X	X		X	X	X	X	X	*[Rauhs et al. 2009]*
Holz-Passivhaus Mühlweg	HdZ	X				X				*[Kogler 2008]*
Einfamilienpassivhaus Pettenbach	HdZ	X		X				X	X	*[Lang et al. 2007]*
Ökologischer Freihof Sulz	HdZ	X				X				*[Sonderegger et al. 2007]*
alpines Passivhaus Schiestlhaus Hochschwab	HdZ	X				X			X	*[Wolfert et al. 2006]*
S-House	HdZ	X			X	X				*[Wimmer et al. 2006]*

Tabelle 6 Best-Practice Beispiele für Low-Ex-Systeme aus der Programmlinie Haus der Zukunft

Das Projekt Lehm –Passivhaus Tattendorf [Wagner et al. 2009a] zeichnet sich durch die gezielte Auswahl der Baumaterialien nach bauökologischen Gesichtspunkten aus. Hinsichtlich Niedrig-Exergetischer Komponenten ist insbesondere die Verwendung von großflächigen Lehm-Heizelementen in Verbindung einer Solarthermie-Anlage (Nachheizung mittels E-Heizstab) zu nennen. Zur Kühlung der Räume kann aus einem Brunnen kaltes Wasser gefördert werden, das über einen Wärmetauscher Kühlenergie an den Heizkreis abgibt. Ein zusätzlicher positiver Effekt auf den Feuchtigkeitshaushalt wird durch den Lehm-Verbundwerkstoff erreicht, der aufgrund seiner materialspezifischen Eigenschaften als Feuchtepuffer wirkt. Zur Nachheizung der Zuluft ist ein Bio-Ethanol Brenner vorhanden.

Die Anlage Roschégasse in Wien ist mit 114 Wohneinheiten die derzeit größte Passivhaus-Wohnanlage Österreichs [Wagner et al. 2009b]. Durch die großen, kompakt gehaltenen Baukörper ergibt sich ein sehr niedriger Energiebedarf. Die Vorwärmung oder Vorkühlung der Außenluft über erfolgt über einen Luft/Sole - Wärmetauscher. Der Erdwärmekreis arbeitet mit 11 Tiefensonden á 100 m und wird mittels Ringleitungen mit den Heiz- und Kühlregistern über Dach verbunden. Für jedes Stiegenhaus gibt es einen eigenen Ansaugturm. Am Beispiel Roschégasse kann gezeigt werden, dass eine Niedrig-Exergetische Raumwärmeaufbringung auch in großen Wohneinheiten realisiert werden kann.

Das Sunny Energy Building [Rauhs et al. 2009] in Wien hat den Anspruch durch die Kombination von verschiedenen Maßnahmen eine größtmögliche Energieeinsparung zu erreichen. Die Planung wurde im Zuge eines integralen Prozesses von einem Team von mehr als 10 verschiedenen Planern und Konsulenten gemeinsam erarbeitet.

Gemäß der Zielsetzung wird eine Reihe an Niedrig-Energie-Komponenten eingesetzt, die auch LowEx-Charakter aufweisen. Herauszuheben ist eine großflächige Bauteilaktivierung, die die Nutzung von geringen Temperaturpotentialen ermöglicht sowie die solare, sorptionsgestützte Klimatisierung, eine innovative Form der Gebäudeklimatisierung, die im

ENERGYbase erstmals in Österreich in diesem Ausmaß zum Einsatz gekommen ist [Rauhs et al. 2009].

Am Holz-Passivhaus Mühlweg [Kogler 2008] wurde der Versuch unternommen ein Demonstrationsprojekt zu realisieren, das sich in weiterer Folge auch im frei finanzierten Wohnbau etablieren kann. Dazu wurde industrielle Vorfertigung der tragenden Holzstruktur inklusive Fassade forciert. Aus Kostengründen wurde vom verstärkten Einsatz von LowEx-Komponenten in der Ausführung Abstand genommen. Durch den verstärkten Einsatz einer Solarthermie-Anlage können jedoch bereits 2/3 des Wärmebedarfs gedeckt werden.

Am Einfamilienhaus Pettenbach [Lang et al. 2007] wurde der erste Umbau eines Altbaus auf Passivhausstandard demonstriert. Als Best-Practice nach Niedrig-Exergetischen Gesichtspunkten ist besonders die Nutzung der Abwärme der Senkgrube zur Luftvorerwärmung anzumerken.

Der ökologische Freihof Sulz [Sonderegger et al. 2007] ist ein denkmalgeschütztes Objekt und wurde als öffentlich-gewerbliches Gebäude unter ökologischer und energetischen Kriterien saniert. Die erforderliche Raumwärme wird kombiniert durch eine Biomasse-Contracting-Heizung, eine Solaranlage und die Nutzung der Abwärme aus der gewerblichen Tätigkeit bereitgestellt.

Das Passivhaus Schiestlhaus am Hochschwab [Wolfert and Rezac 2006] wurde als Prototyp eines ökologischen alpinen Schutzhauses mit Passivhaustechnologie konzipiert. Warmwasser wird mit niedrigem Exergieeinsatz über eine Solarthermie-Anlage sowie über einen Wärmetauscher im Feststoffbrennherd gewonnen. Zur Spitzenlastabdeckung wird ein Pflanzenölbetriebenes BHKW eingesetzt. Die Raumwärmeaufbringung wird aus Wärmerückgewinnung aus Abwässern durch Absetzbecken im Haus und Wärmetauschern in der Dunstabzugshaube sowie in der Abluft unterstützt. Prinzipiell werden Verbraucher mit geringem Exergiebedarf eingesetzt. Das Haus wurde auf eine optimale Ausnutzung der Sonneneinstrahlung hin positioniert.

Das S-House [Wimmer et al. 2006] demonstriert die Verbindung nachwachsender Baustoffe mit denen der Passivhaustechnologie. Dadurch wurde der Ressourcen- und Energieverbrauch, ohne die Baukosten zu erhöhen, um den Faktor zehn verringert werden.

Der Heizenergiebedarf wird mit einem eigens entwickelten Holz befeuerten Speicherofen, der seine Energie an den Abluftstrang des Lüftungssystems abgibt, abgedeckt. Die Wärme wird über Wärmetauscher an die Zuluft übertragen und im Gebäude verteilt. Das Lüftungssystem verfügt außerdem über einen Erdwärmetauscher, durch den die Außenluft vorgewärmt oder vorgekühlt werden kann. Eine Solarthermie-Anlage liefert Energie für die Brauchwarmwasserbereitung in einen Pufferspeicher.

5.2 Fabrik der Zukunft

Im Fabrik der Zukunft Programm konnten keine erfolgreichen Projekte identifiziert werden, die explizit den Einsatz von LowEx-Systemen zum Gegenstand gehabt haben. Herauszuheben wäre ein Projekt, das sich mit Solarkollektoren für Prozesswärme über 100°C befasst hat. Prozesswärme bis zu einem Temperaturniveau von etwa 100°C kann problemlos mit am Markt erhältlichen Sonnenkollektoren (Flachkollektoren bzw. Vakuumröhrenkollektoren) erzeugt werden. Ein großer Anteil der benötigten Prozesswärme liegt aber auch im Temperaturbereich zwischen 100°C und 200°C. Solche Temperaturniveaus können jedoch nur noch mit konzentrierenden Systemen erreicht werden, da bei herkömmlichen Kollektoren die Wärmeverluste bei diesen Temperaturen zu hoch werden und damit der Wirkungsgrad stark abnimmt.

Die Ergebnisse des Projektes lassen allerdings in Österreich nicht auf eine überdurchschnittliche weitere Verbreitung des betrachteten Produkts schließen. [Jähnig et al. 2006]

„Die Nutzung von solarer Wärme in Produktionsprozessen steht erst am Anfang und erfordert noch einen beträchtlichen Aufwand zur Umsetzung und eine Weiterentwicklung der Entwurfsmethoden." [vgl. Schnitzer et al. 2007]. Ein Nachfolgeprojekt zur Entwicklung von Parabolrinnenkollektoren zur Kälteerzeugung läuft derzeit. [Jähnig 2010]

5.3 Energiesysteme der Zukunft

Projekt		Relevanz für LowEx-Systeme	Referenz
Dezentrale Energieerzeugung für Fernwärme	EdZ	LowEx-Prozesswärme	*[Bucar et al. 2006]*
Bioenergie Kraft-Wärme-Kälte-Kopplung	EdZ	Prozesswärme zur (Fern-)Kühlung	*[Krotil und Ragossnig 2009]*
Regenerative Energieversorgung einer Industrieregion	EdZ	Best-Practice Regionen	*[Tragner et al. 2007]*

Tabelle 7 Best-Practice-Beispiele für LowEx-Systeme aus der Programmlinie Energiesysteme der Zukunft

Im Rahmen der Energiesysteme der Zukunft untersuchen insbesondere die beiden Studien „Dezentrale erneuerbare Energie für bestehende Fernwärmenetze" [Bucar et al. 2006] und „Bioenergie-Kraft-Wärme-Kälte-Kopplung-Versorgung" [Krotil and Ragossnig 2009] Technologien und Projektbeispiele die für eine niedrigexergetische Aufbringung von Wärmeenergie für Gebäude und Gemeinden in Betracht kommen.

Eine detaillierte Beschreibung der Projekte findet sich in Anschit 6.

Als Modellregionen, die sich im „Sinne der Programmlinie" entwickelt haben werden von Tragner [et al. 2007] die Gemeinde Güssing und das Auenland Carnuntum angeführt. Entscheidendes Auswahlkriterium war das Ziel, eine vollständige Deckung der Energieversorgung mit erneuerbaren Ressourcen zu erreichen.

Exergetische Betrachtung zur Raumwärmeaufbringung ausgewählter Modellregionen

Im Auenland Carnuntum wird lt. Angaben des Vereins Energiepark der Endenergieverbrauch an Strom zu über 100% aus erneuerbaren Quellen gedeckt. Der Anteil der erneuerbaren Energieträger am Endenergieverbrauch der Wärme beträgt lediglich 13,6% (Gesamtanteil erneuerbarer Energieträger am Endenergieverbrauch 34,85%.) Eine genaue Aufschlüsselung der Energieträger ist für die Region in Tragner [2007] nicht gegeben, es muss daher an dieser Stelle auf eine weitere Berechnung der Exergieeffizienz der Gemeinde verzichtet werden. Prinzipiell lässt sich jedoch sagen, dass fossile Energieträger gerade im Bereich der der Raumwärmebereitstellung eine vergleichsweise schlechte Exergieeffizienz aufweisen.

Da im Bereich Raumwärme derzeit das größte Exergieeinsparungspotential gesehen wird und der überwiegende Anteil des Endenergieverbrauchs der Region im Bereich Wärme anfällt, kann von der Region Auenland Carnuntum in exergetischer Hinsicht noch nicht von einer Best-Practice-Region gesprochen werden.

Die Gemeinde Güssing deckt ihren Endenergiebedarf an Wärme lt. Daten im Bericht derzeit zu 49% aus erneuerbaren Ressourcen. (Der Eigenversorgungsgrad der Stadt Güssing mit Wärme liegt bei 94%).

Die Berechnung des Exergiegehalts der Energieträger erfolgt wie in 4.2 beschrieben. Für die Berechnung des exergetischen Wirkungsgrades wurde eine Raumtemperatur von 20°C (entsprechend etwa 7% Exergiegehalt) angenommen. Daten der Raumwärmeaufbringung nach Energieträgern wurden für die Region Güssing nach Koch [et al. 2006] bzw. für Österreich nach Müller [2010] angenommen.

Im Folgenden wurde der exergetische Wirkungsgrad der Raumwärmebereitstellung nach den anteilig eingesetzten Primärenergieträgern in der Region Güssing mit 12,8% ermittelt. Im Vergleich dazu liegt der exergetische Wirkungsgrad der Raumwärmebereitstellung österreichweit bei 12,2%.

				Primärenergieträger Raumwärmeaufbringung				exergetischer Wirkungsgrad der Raumwärmeaufbingung	
	Nutztemperatur	Exergie-gehalt	exergetischer Wirkungsgrad	Region Güssing	Österreich	Region Güssing	Österreich	Region Güssing	Österreich
	[°C]	[%]	[%]	[MWh]	[GWh]	[%]	[%]		
Fernwärme	70	20%	33%	31200	14848	17,6%	15%	5,9%	5,0%
Heizöl	2000	88%	7,754%	54317	29407	30,6%	30%	2,4%	2,3%
Holz	800	75%	9%	63110	15989	35,6%	16%	3,3%	1,5%
Kohle	2200	89%	8%	1870	1882	1,1%	2%	0,1%	0,1%
Strom	-	100%	7%	17938	5803	10,1%	6%	0,7%	0,4%
Gas	1800	87%	8%	7804	25816	4,4%	26%	0,3%	2,0%
Wärmepumpe / Solar	Annahme: JAZ* 4	25%	27%	786	2044	0,4%	2%	0,1%	0,6%
Pellets, Stroh, Hackgut	800	75%	9%	352	3473	0,2%	3%	0,0%	0,3%
Insgesamt [MWh]				177377	99262	100,0%	100%	**12,8%**	**12,2%**
Quelle der Primärenergieträger: [nach Koch 2006 S.70, Müller 2010]									
Region Güssing Sonstige (0,4%) wurden vernachlässigt									
Daten Österreich für 2007									
*) Jahresarbeitszahl									
T_{aussen} (0°C)	273,15	K							
Temperaturdifferenz	20	K							

Tabelle 8 Vergleich des exergetischen Wirkungsgrades der Raumwärmeaufbringung

Es zeigt sich, dass der exergetische Wirkungsgrad der Region Güssing nicht wesentlich über jenem für gesamt Österreich liegt. Das ist insbesondere auf eine Konzentrierung von Fernwärme in städtischen Gebieten zurückzuführen, die für Österreich einen ähnlichen Anteil aufweist wie für die Region Güssing.

6 Detaillierte Beschreibung ausgewählter Best-Practice-Beispiele

6.1 Sunny Energy Building

Ein gut dokumentiertes Beispiel für den Einsatz innovativer, nachhaltiger Energiesysteme ist das Sunny Energy Building (ENERGYbase – Bürohaus der Zukunft), das im Rahmen der „Haus der Zukunft“ Programmlinie (www.hausderzukunft.at) realisiert wurde.

Zur Abschätzung des Betriebsverhaltens der innovativen Komponenten wurden vorab Detailanalysen und thermische Simulationsrechnung durchgeführt. Zu nennen sind insbesondere Detailuntersuchungen zum Betriebsverhalten der thermisch aktivierten Bauteiltemperierung und zur solaren Klimatisierung sowie thermisch-hygrische Simulationen für Pflanzenpuffereinbindung. Aus den Simulationen können Daten zur Auslegung und Dimensionierung der Bauteile getroffen werden. Eine derartige Planung für das Zusammenwirken der verschieden eingesetzen LowEx Komponenten leistet einen wesentlichen Beitrag zur Optimierung des Energie und Exergiebedarf.

Komponenten, die LowEx-Charakter aufweisen und als zukunftsweisende Best-Practice Beispiele identifiziert wurden, stellen sich wie folgt dar [vgl. auch Rauhs et al. 2009]:

- Temperierung mit thermisch aktivierten Bauteilsystemen
  Eine Grundtemperierung der Büroeinheiten wird über thermisch aktivierte Bauteilsysteme (Flächenkühlsystem unter Nutzung von thermisch aktivierter

Baukörpermasse) bewerkstelligt. Die Wärmezufuhr bzw. -abfuhr wird von von der Lüftungsfunktion entkoppelt und nutzt die thermische Speicherfähigkeit von geeigneten Bauteilen des Gebäudes. Dieses System arbeitet thermisch träge und zeichnet sich durch die Begrenzung der thermischen Leistung aus.

- Heizen und Kühlen mit Grundwasser
  Die günstigen geologischen Bedingungen des Standortes lassen eine Nutzung von Grundwasser durch eine gekoppelte Wärmepumpe zur winterlichen Beheizung des Gebäudes zu. Eine direkte Nutzung des Kühlpotenzials vom Grundwasser erfolgt im Sommer. Über einen Wärmetauscher zwischen den beiden hydraulischen Kreisen werden zur Kühlung geeignete Temperaturen bereitgestellt. Wasser/Luft Wärmetauscher sine eine erprobte Technologie, die einen Beitrag zur niedrig-exergetischen Raumklimatisierung leisten kann.

- Solare Klimatisierung
  Eine solare Gebäudeklimatisierung übernimmt die technische Aufgabe der Zuluftkonditionierung. Die solare Klimatisierung wurde mittels Sorptionskühlung, Desiccant Evaproative Cooling (DEC), umgesetzt. Dieses exergieeffiziente Klimatisierungsverfahren nutzt im Wesentlichen drei Prozessschritte der Luftbehandlung:
  1.) Lufttrocknung - mit einem so genannten Sorptionsrotor,
  2.) Wärmerückgewinnung und
  3.) adiabate Verdunstungskühlung.
  Die Regeneration des beladenen Trocknungsrotors erfolgt unter Verwendung von Solarenergie. Die solare, sorptionsgestützte Klimatisierung ist eine innovative Form der Gebäudeklimatisierung, die im ENERGYbase erstmals in Österreich in diesem Ausmaß zum Einsatz gekommen ist.
  Die exergetische Beschreibung von Systemen zur evaporativen Kühlung hat in der Annex 49 Arbeitsgruppe große Aufmerksamkeit erhalten.

- Pflanzenpuffereinbindung
  Es wurden Pflanzenpufferräumen zur ökologischen Luftbefeuchtung im Gebäude integriert. Pufferräume, in denen 500 Pflanzen einer speziell für die Luftbefeuchtung gezüchteten Art im Winter und in der Übergangszeit die Luft befeuchten, sind eine absolute Neuheit, weil sie als abgeschlossene Feuchtegeneratoren arbeiten und regelbar, präzise steuerbar, und damit erstmals als berechenbare Größe in ein haustechnisches System integrierbar sind.

- LowEx-Gebäudearchitektur
  Die Gebäudearchitektur, wie sie bei Passivhäusern des Öfteren zum Einsatz kommt, ist auf eine optimale Anpassung an den Verlauf des Sonnenstandes angepasst. Dadurch kann zusätzlich niedrigexergetische solare Wärmestrahlung bei niedrigem Sonnenstand bzw. im Winter eingebracht werden und der Einfall der solaren Strahlung bei hohem Sonnenstand bzw. im Sommer minimiert werden.

6.2 Dezentrale Energieerzeugung für Fernwärme

Fernwärme ist eine verbreitete Technologie zur Nutzung niedrigexergetischer Abwärme.

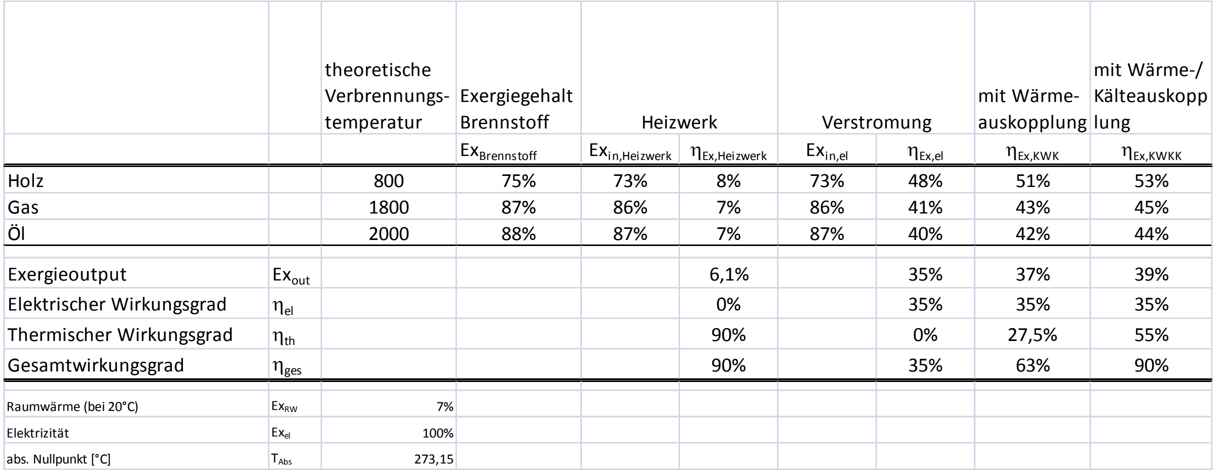
Der österreichische Fernwärmebedarf wird vorwiegend durch kommunale oder kommunalnahe Versorgungsunternehmen gedeckt. Schwerpunkte der Fernwärmeversorgung sind Wien, Graz, Linz, Salzburg, Klagenfurt, St. Pölten und Wels. Aber auch in kleineren Gemeinden wird immer stärker auf die Versorgung mit Fernwärme gesetzt.

In der Studie [Bucar et al. 2006] wird die Einspeisung in ein lokales Fernwärmenetz aus Geothermie, Biomasse KW-Kopplung und Solarthermie behandelt. Es werden zahlreiche Beispiele beleuchtet und verglichen. Als innovatives Projektbeispiel der Einspeisung von solarthermischer Wärmeenergie wird die UPC-Arena (ehem. Arnold Schwarzenegger Stadion) hervorgehoben. Ein Hemmnis für den weiteren Ausbau ist der mangelnde Absatz für Wärme im Sommer.

6.2.1 Bioenergie Kraft-Wärme-Kälte-Kopplung

Aufgrund des Nachteils der fehlenden Wärmeabnahme bioenergiebetriebener Anlagen im Sommer (Hitzeperiode) wird versucht anhand von drei konkreten KWK-Anlagen aufzuzeigen, wie dieser wirtschaftliche Nachteil bei KWK-Systemen durch eine Anlagenerweiterung abgefedert werden könnte.

Das Verwaltungsgebäude des Umweltdienstes Burgenland und das Landeskrankenhaus Oberpullendorf sind bereits mit einer Absorptionskälteanlage in Verbindung mit dem KWK - System Oberpullendorf ausgestattet.



		theoretische Verbrennungs-temperatur	Exergiegehalt Brennstoff	Heizwerk		Verstromung		mit Wärme-auskopplung	mit Wärme-/Kälteauskopplung
			$Ex_{Brennstoff}$	$Ex_{in,Heizwerk}$	$\eta_{Ex,Heizwerk}$	$Ex_{in,el}$	$\eta_{Ex,el}$	$\eta_{Ex,KWK}$	$\eta_{Ex,KWKK}$
Holz		800	75%	73%	8%	73%	48%	51%	53%
Gas		1800	87%	86%	7%	86%	41%	43%	45%
Öl		2000	88%	87%	7%	87%	40%	42%	44%
Exergieoutput	Ex_{out}				6,1%		35%	37%	39%
Elektrischer Wirkungsgrad	η_{el}				0%		35%	35%	35%
Thermischer Wirkungsgrad	η_{th}				90%		0%	27,5%	55%
Gesamtwirkungsgrad	η_{ges}				90%		35%	63%	90%
Raumwärme (bei 20°C)	Ex_{RW}	7%							
Elektrizität	Ex_{el}	100%							
abs. Nullpunkt [°C]	T_{Abs}	273,15							

Tabelle 9 Vergleich der Exergieeffizienz verschiedener Kraft-Wärme-Kopplungs-Varianten

Der niedrige Exergetische „Wert“ von Raumwärme resultiert in einer schlechten Exergieeffizienz von Heizwerken (8% für Holz bzw. 7% für Öl und Gas) und zu einer nur geringfügig verbesserten Exergieeffizienz von KWK und KWKK Anlagen gegenüber reiner Verstromung.

Dennoch kann durch die Nutzung von KWKK Anlagen ein beträchtliches Exergieeinsparungspotential gegenüber elektrischer Raumkühlung realisiert werden.

Im Bereich der Klimatisierung von Gebäuden ist noch wenig Literatur hinsichtlich spezifischer Kennzahlen (Kühllast, Kältebedarf) zu finden. In dieser Richtung zeigt sich ein klarer Bedarf an weiterführender Forschung, da der Energiebedarf für die Klimatisierung zusehends an Bedeutung gewinnt. [Krotil und Ragossnig 2009]

7 Zusammenfassung

Es konnten wie folgt sechs in Österreich eingesetzte Low-Ex Systeme für Gebäude identifiziert werden:

- Kontrollierte Wohnraumlüftung
- Feuchterückgewinnung
- Heizen und Kühlen mit Grundwasser und Erdwärme
- Solare Kühlung
- LowEx-Gebäudearchitektur
- Bauteilaktivierung

Ein gut dokumentiertes Beispiel für den Einsatz von LowEx-Systemen ist das Sunny Energy Building (ENERGYbase – Bürohaus der Zukunft), das im Rahmen der „Haus der Zukunft“ Programmlinie (www.hausderzukunft.at) realisiert wurde. Komponenten mit niedrigem Exergie-Bedarf, die als zukunftsweisende Best-Practice Beispiele zur Anwendung kommen, sind: Wärme- und Feuchterückgewinnung, Heizen und Kühlen mit Grundwasser, Solare Kühlung und gebäudearchitektonische Maßnahmen die sich positiv auf den Exergiebedarf auswirken.

Hervorzuheben ist insbesondere der Einsatz von solarer Kühlung, die den Vorteil hat, dass hohe Solarstrahlung bzw. geringer Wärmebedarf und Kühllast gleichzeitig auftreten. Die exergetische Beschreibung von Systemen zur Raumkühlung hat in der Annex 49 Arbeitsgruppe große Aufmerksamkeit erhalten.

Es ist davon auszugehen, dass der Kühlbedarf in Zukunft weiter steigen wird. Da aufgrund der geringen Temperaturdifferenzen der Gebäudekühlung eine relativ geringe Exergieeffizienz immanent ist, können insbesondere in diesem Bereich verfügbare Technologien zu einer exergetischen Optimierung einen Beitrag leisten.

Auf Gemeindeebene kann die Einspeisung in lokale Fernwärmenetze aus verschiedenen Quelle wie industrieller Abwärme, Geothermie, Solarthermie oder Wärme aus Biomasse KWK und sonstigen KWK einen wesentlichen Beitrag zur Bedarfsdeckung an niedrigexergetischer Wärmeenergie zur Raumklimatisierung und Warmwasserbereitstellung leisten.

Ein Hemmnis für den Ausbau von Fernwärme ist grundsätzlich der mangelnde Absatz für Wärme im Sommer. In Kombination mit Verfahren die (Ab-)Wärme zur Kälteproduktion (z.B. Absorptions-Kälte-Anlagen) verwenden ist hier ein großes Einsparungspotential zu verorten.

Das Verwaltungsgebäude des Umweltdienstes Burgenland und das Landeskrankenhaus Oberpullendorf sind bereits mit einer Absorptionskälteanlage in Verbindung mit dem KWK-System Oberpullendorf ausgestattet, das es ermöglicht die Fernwärme aus dem KWK-System zur Kühlung des Gebäudes zu Nutzen.

Prinzipiell ist das Konzept der exergetischen Bewertung derzeit nicht weit verbreitet, daher hat sich noch keine einheitliche Auswertung unter exergetischen Gesichtspunkten etabliert. Eine stärkere Einbeziehung in die Analyse von Gebäuden könnte einen wertvollen Beitrag leisten um Einsparungspotentiale aufzuzeigen.

8 Referenzen

Ala-Juusela M. 2003. Heating and cooling with focus on increased energy efficiency and improved comfort: guidebook to iea ecbcs annex 37, low exergy systems for heating and cooling of buildings. Espoo, finland: vtt technical research centre of finland.

Bucar et al. 2006. Einbindung von dezentraler energie aus erneuerbaren energieträgern in bestehende fernwärmenetze. http://www.energiesystemederzukunft.at/results.html/id3464.

Dubbel H. 2007. Dubbel. taschenbuch für den maschinenbau 22. ed. Springer, Berlin.

Faninger G. 2007. Der wärmepumpenmarkt in Österreich 2006. Berichte aus energie-und umweltforschung 11c/2007.

Jähnig et al. 2006. Entwicklung und optimierung eines parabolrinnenkollektorsystems zur erzeugung von prozesswärme für industrielle produktionsprozesse. http://www.fabrikderzukunft.at/results.html/id2962.

Jähnig D. 2010. Solarthermische kälteerzeugung mit parabolrinnenkollektorsystem und dampfstrahlkältemaschine. http://www.fabrikderzukunft.at/results.html/id5030.

Koch et al. 2006. Energieautarker bezirk güssing. http://www.energiesystemederzukunft.at/results.html/id3680.

Kogler G. 2008. Sozialer wohnbau, holz-passivhaus am mühlweg, 1210 wien. http://www.hausderzukunft.at/results.html/id3875.

Kranzl L, Müller A, Kalt G. 2010. The trade-off between exergy output and capital costs: the example of bioenergy utilization paths.

Krotil R, Ragossnig A. 2009. Energiesysteme der zukunft - publikationen. http://www.energiesystemederzukunft.at/publikationen/view.html/id769.

Lang G, Lang M, Krauß B. 2007. Erstes einfamilien-passivhaus im altbau - umsetzung des passivhausstandards und -komforts in der altbausanierung von einfamilienhäusern am beispiel efh pettenbach. http://www.hausderzukunft.at/results.html/id3868.

Müller A. 2010. Hat heizen zukunft? eine langfristige betrachtung für Österreich. In: . 10-12.2.2010, Graz, 2010.

Rauhs G, Schneider U, Preisler A. 2009. Sunny energy building: energybase - bürohaus der zukunft. http://www.hausderzukunft.at/results.html/id4800.

Schmidt D. 2009. Low exergy systems for high-performance buildings and communities. Energy and buildings 41:331-336.

Sonderegger A, Nadler-Kopf B, Bertsch G. 2007. Sanierung ökologischer freihof sulz. http://www.hausderzukunft.at/results.html/id3870.

Spur G, Stöferle T. 1998. Handbuch der fertigungstechnik: 6 bände. Hanser Fachbuch.

Torio H, Angelotti A, Schmidt D. 2009. Exergy analysis of renewable energy-based climatisation systems for buildings: a critical view. Energy and buildings 41:248-271.

Tragner et al. 2007. Energiesystem - industrieregion. http://www.energiesystemederzukunft.at/results.html/id4347.

Wagner W, Jähnig D, Prein A. 2009a. Lehm - passiv bürohaus tattendorf. http://www.hausderzukunft.at/results.html/id2758.

Wagner W, Prein A, Mauthner F. 2009b. Energietechnische, baubiologische und nutzerspezifische begleituntersuchung zu innovativen baukonzepten, der im rahmen haus der zukunft umgesetzten projekte. http://www.hausderzukunft.at/results.html/id2775.

Wimmer R, Hohensinner H, Drack M. 2006. S-house - phase errichtung: planen und bauen für die zukunft. http://www.hausderzukunft.at/results.html/id3133.

Wolfert C, Rezac M. 2006. Alpiner stützpunkt - schiestlhaus am hochschwab - phase errichtung. http://www.hausderzukunft.at/results.html/id2765.

Anhang N

Publikation
„The trade-off between exergy-output and capital costs: the example of bioenergy utilization paths“

The trade-off between exergy-output and capital costs: the example of bioenergy utilization paths

Lukas Kranzl, Andreas Müller, Gerald Kalt

Vienna University of Technology, Institute of Power Systems and Energy Economics,
Energy Economics Group, Gusshausstrasse 25-29/E373-2, A-1040 Vienna, Austria,
Tel: +43-1-58801-37351, Fax: +43-1-58801-37397,
E-mail: kranzl@eeg.tuwien.ac.at, Web: http://eeg.tuwien.ac.at

Abstract:

Exergy analyses are able to provide insight to energy systems that may not be gained with purely energetic approaches. Due to the high variety of possible bioenergy utilization paths this question in particular is relevant for the analysis of bioenergy systems. Thus, in this paper we are investigating to which extent higher investment costs are required for achieving higher exergy outputs. We have selected bionergy chains based on two different resources (woody biomass and biogas) producing thermal energy, electricity and mechanical energy (transport). A special focus is on the transport sector where we are comparing combustion engines fuelled with liquid and gaseous biofuels on the one hand with electric cars with bio-based electricity on the other hand. The results show that there are high differences with respect to exergetic efficiencies. For some sub-sectors we can observe a very clear (almost) linear trade-off between exergetic efficiency and capital costs. According to the data we used for woody biomass it turns out that bioenergy based electric mobility is more than 3-4 times more exergy efficient than comparable 2nd generation biofuels. At the same time the electric mobility path shows lower costs, though higher investments. Moreover, conclusions are derived for a possible long-term vision for efficient bioenergy utilization.

Keywords: Exergy, Bioenergy, Biomass

1 Introduction

1.1 Motivation

One of the key characteristics of bioenergy is the multitude of technology paths. This variety results on the one hand from the numerous types of biomass resources which can be processed by different conversion technologies. On the other hand there are the different outputs of bioenergy technologies. All these energy forms on the input and on the output are characterized by different qualities, e.g. with respect to their ability to provide work. This aspect in particular is relevant for the investigation of plants with various products (polygeneration). The exergetic assessment of these products is a methodology that considers these different qualities. While the output “space heating” (i.e. Energy on a low temperature level) shows low exergy content, that of CHP (electricity + low temperature heat) is clearly higher.

Not only the exergy output, also the costs (and possible revenues) of these biomass utilization paths are quite different. For other energy systems, [1] shows that the use of high exergy sources can be substituted by a higher capital input. Now, we can ask whether this is also true with respect to the exergy output (i.e. the exergy efficiency) of a certain bioenergy technology. Thus, the question arises: How high are the additional costs for gaining a higher exergetic value from biomass resources?

1.2 Objective of this paper

The core target of this paper consists of the following two aspects:

- Analyse and compare the costs and exergetic efficiencies of selected bioenergy paths.
- Investigate the tradeoff between exergy output and (capital) costs of these selected bioenergy systems.

1.3 Approach

The approach of this paper consists out of the following steps:

- Description of bioenergy pahts. In particular, we have selected technologies out of the following categories:
    - Heating boilers
    - CHP plants
    - Liquid fuels for transport
    - Gaseous fuels for transport
    - Electric vehicles (using electricity generated from bioenergy plants) as a comparison to the combustion engine based vehicles using liquid or gaseous biogenous fuels.
- Analysis of the exergetic efficiency of these bioenergy paths
- Analysis of the generation costs of these bioenergy pahts (distinction between capital and variable costs)
- Identification of the trade off between (capital) costs and exergy output

More detailed aspects of the methodological approach are described below.

The main part of this work is related to the concept of exergy assessments. The idea behind this is to quantify the ability to work of a certain energy type. The analysis of the chemical exergy content only partly is related to this idea, because neither with best available technologies nor under perfect thermodynamic conditions it is possible to 100% make use of fuel’s exergy content.

This aspect has already been discussed in the literature [1], [2]. We are following here a definition of the exergy content that considers the potential technical realization.

The work presented in this paper has been carried out in the course of the Austrian participation in IEA implementing agreement ECBCS (Energy conersvation in building and community systems), Annex 49 (Low Exergy Systems for High Performance Buildings and Communities). The objective of Annex 49 is to disseminate the exergy concept, investigate and provide low-exergy solutions and thus support the further penetration and utilization of high efficient low-exergy systems, in particular in the heating sector.

2 Methodology

Several aspects are crucial for determining exergetic efficiencies of (bio-) energy systems. The following sub-sections are dealing with those that are most relevant for our paper: (1) how to determine the exergy content of different energy forms, (2) how we are defining and calculating the tradeoff between capital costs and exergy efficiency and (3) how we defined the system boundaries of this analysis.

2.1 Determining the exergy content of energy forms

$$Ex = 1 - \frac{T_0}{T_1}$$

Table 1. Exergy content of energy forms relevant for this paper

Unit	ambient temperature °C	(usable, possible) temperature °C	exergy content %
Electricity			100%
mechanical energy (engine)			100%
space heat	0	20	7%
process heat	0	300	52%
Woody biomass	0	800	75%
FT-Diesel	0	1500	85%
Maize silage / Manure mix	0	800	75%
biogas crude	0	800	75%
biogas fed into gas grid	0	1800	87%

2.2 Calculating the trade off between capital costs and exergy efficiency

The economic and exergetic results are calculated based on the following formulars:

$$C_{tot} = \frac{IC \cdot \alpha}{T_{FL}} + \frac{O\&M}{T_{FL}} + \frac{p_{fuel}}{\eta_{el}} - \frac{p_{heat}}{\eta_{th}}$$

C_{tot}	Total energy generation costs (€/MWh main output)
IC	Investment costs (€/kW main ouput)
α	annuity factor
T_{FL}	Full load hours (h/yr)
O&M	Operation and maintenance costs (€/kW main output/yr)
p_{fuel}	Energy price (€/MWh)
p_{heat}	Heat price (only for CHP) (€/MWh)
η_{el}	electric efficiency
η_{th}	thermal efficiency

$$\varepsilon = \frac{EX_{out}}{EX_{in}}$$

ε	Exergy efficiency
EX_{out}	Exergy content output
EX_{in}	Exergy content input

The exergy content of energy input and output is calculated as a weighted average of exergy contents of the single energy streams:

$$EX_{out} = \sum_i ex_i \cdot \beta_i$$

$$EX_{in} = \sum_j ex_j \cdot \gamma_j$$

2.3 System boundaries

An important aspect is the choice of system boundaries. We have made the following assumptions:

- For thermal output the system boundary on the input part is the biomass resource and on the output part the provided space heating temperature level.
- For CHP the system boundary on the input part is the biomass resource and on the output part the produced electricity and the provided space heating temperature level.
- For mobility applications the system boundary on the input part is the biomass resource and on the output part the produced mechanical energy on the drive (and the thermal energy from the CHP plants for providing space heating).
- In this paper, we are assuming for all considered bioenergy chains a homogenous biomass resource. In particular for biogas generation (using e.g. biowaste or manure) this assumptions is not valid. This should be discussed in further investigations.
- We are not considering the non-energetic use of biomass. A possible interpretation of this assumptions is that in the considered utilization paths only such biomass resources are used for energetic purposes that are either on the end of a cascadic utilization path or which are not in competition to non-energetic purposes.

Extending these system boundaries will be subject to further analysis in future research work.

3 Bioenergy chains: exergetic efficiency and costs

3.1 Selected bioenergy systems

We selected the following bioenergy chains:

- Woody biomass
    - Large scale wood chips heating plant (not including costs for heat distribution in the district heating grid) producing thermal energy for space heating.
    - Large scale wood chips CHP with steam turbine (not including costs for heat distribution in the district heating grid) producing electricity and thermal energy for space heating.
    - Large scale wood chips fluidized bed gasification with IGCC (not including costs for heat distribution in the district heating grid) producing electricity and thermal energy for space heating
    - Large scale wood chips fluidized bed gasification with gas turbine (not including costs for heat distribution in the district heating grid) producing electricity and thermal energy for space heating

    - Using electricity from each of the mentioned CHP plants in electric vehicles, producing thermal energy (from the CHP) for space heating and mechanical energy on the drive chain of an electric car.
    - Second generation FT Diesel based on wood chips producing mechanical energy on the drive chain of a conventional combustion engine car.
    - Second generation ligno-cellulose ethanol based on wood chips producing mechanical energy on the drive chain of a conventional combustion engine car.
- Biogas
    - Biogas (based on maize/manure mix) CHP with local gas engine producing thermal energy for space heating and electricity
    - Biogas (based on maize/manure mix) electricity generation with local gas engine producing electricity without making use of heat output
    - Cleaning and upgrading of biogas (based on maize/manure mix) and feed-in into the natural gas grid. Using biogas in decentral small scale gas heating boilers producing thermal energy for space heating.
    - Cleaning and upgrading of biogas (based on maize/manure mix) and feed-in into the natural gas grid. Using biogas in small scale decentral gas engines producing thermal energy for space heating and electricity.
    - Cleaning and upgrading of biogas (based on maize/manure mix) and feed-in into the natural gas grid. Using biogas in large scale gas turbines producing electricity and thermal energy for space heating and electricity.
    - Cleaning and upgrading of biogas (based on maize/manure mix) and feed-in into the natural gas grid. Using biogas in large scale IGCC producing electricity and thermal energy for space heating and electricity.
    - Cleaning and upgrading of biogas (based on maize/manure mix) and feed-in into the natural gas grid. Using biogas in combustion engine cars producing mechanical energy on the drive chain.
    - Using electricity from each of the mentioned biogas CHP plants in electric vehicles, producing thermal energy (from the CHP) for space heating and mechanical energy on the drive chain of an electric car.

The following tables show the main technology data (efficiency, cost data) for woody biomass, biogas and vehicles.

Table 2. Main technology data woody biomass

	Woody biomass			
	Thermal	CHP		
	heating plant	steam turbine	SNG, IGCC	SNG, gas turbine
full load hours (h/yr)	5000	7000	7500	7500
eta 1	75%	28%	41%	29%
eta 2	0%	52%	22%	34%
eta 3	0%	0%	0%	0%
eta total	75%	80%	62%	62%
investment costs (€/kW)	420	2000	2778	2228
O&M costs (€/kW/a)	13	27	153	253
Fuel price (€/MWh)	24	24	24	24

(*) depending on bioenergy generation costs + distribution costs (electricity, biogas or liquid fuels)

Table 3. Main technology data biogas

	Biogas						
	Biogas feed-in	Thermal	CHP				
	fermentation, cleaning, upgrading	decentral heating boilers	local CHP	local ele (w/o heat utilization)	(decentral) gas engines	(central) gas turbine	(central) IGCC
full load hours (h/yr)	7500	1500	3500	4500	2000	7000	7000
eta 1	64%	90%	29%	30%	30%	36%	54%
eta 2	0%	0%	29%	0%	57%	42%	27%
eta 3	0%	0%	0%	0%	0%	0%	0%
eta total	64%	90%	58%	30%	87%	78%	81%
investment costs (€/kW)	1350	250	2500	2500	1400	700	1700
O&M costs (€/kW/a)	73	58	150	150	42	180	80
Fuel price (€/MWh)	18	(*)	18	18	(*)	(*)	(*)

(*) depending on bioenergy generation costs + distribution costs (electricity, biogas or liquid fuels)

Table 4. Main technology data electric vs. conventional vehicles

	Mobility	
	electric vehicle (additional costs only)	conventional vehicle
full load hours (h/yr)	250	250
eta 1	75%	20%
eta 2	0%	0%
eta 3	0%	0%
eta total	75%	20%
investment costs (€/kW)	235	0
O&M costs (€/kW/a)	0	0
Fuel price (€/MWh)	(*)	(*)

(*) depending on bioenergy generation costs + distribution costs (electricity, biogas or liquid fuels)

3.2 Exergetic comparison

Making use of the approach for exergy efficiency calclulation described above results in values for the exergy efficiency which are shown in the next two figures.

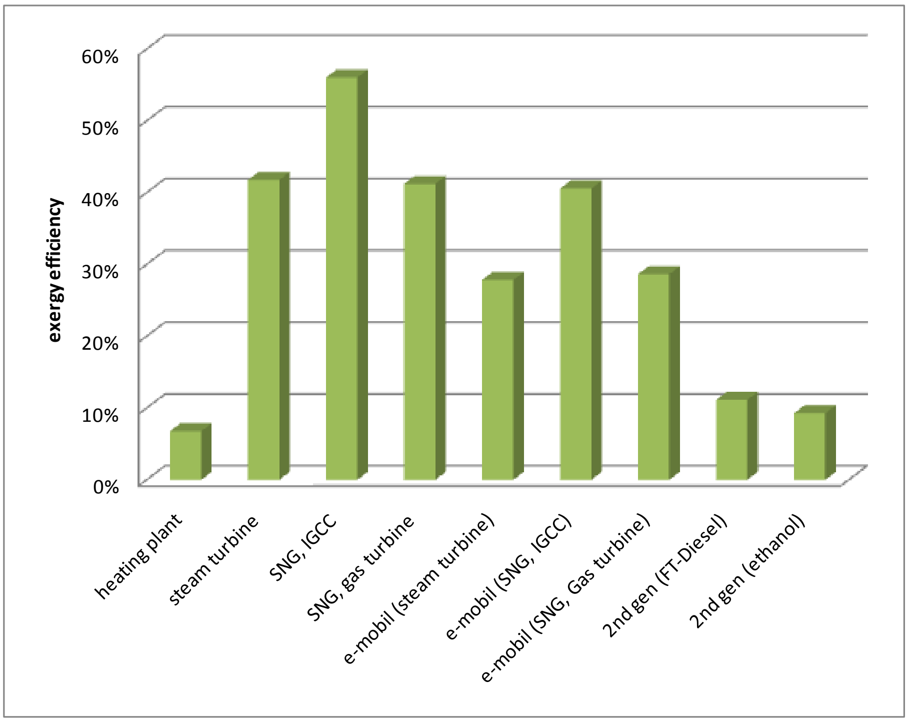


Figure 1. Exergy efficiency of selected woody biomass chains

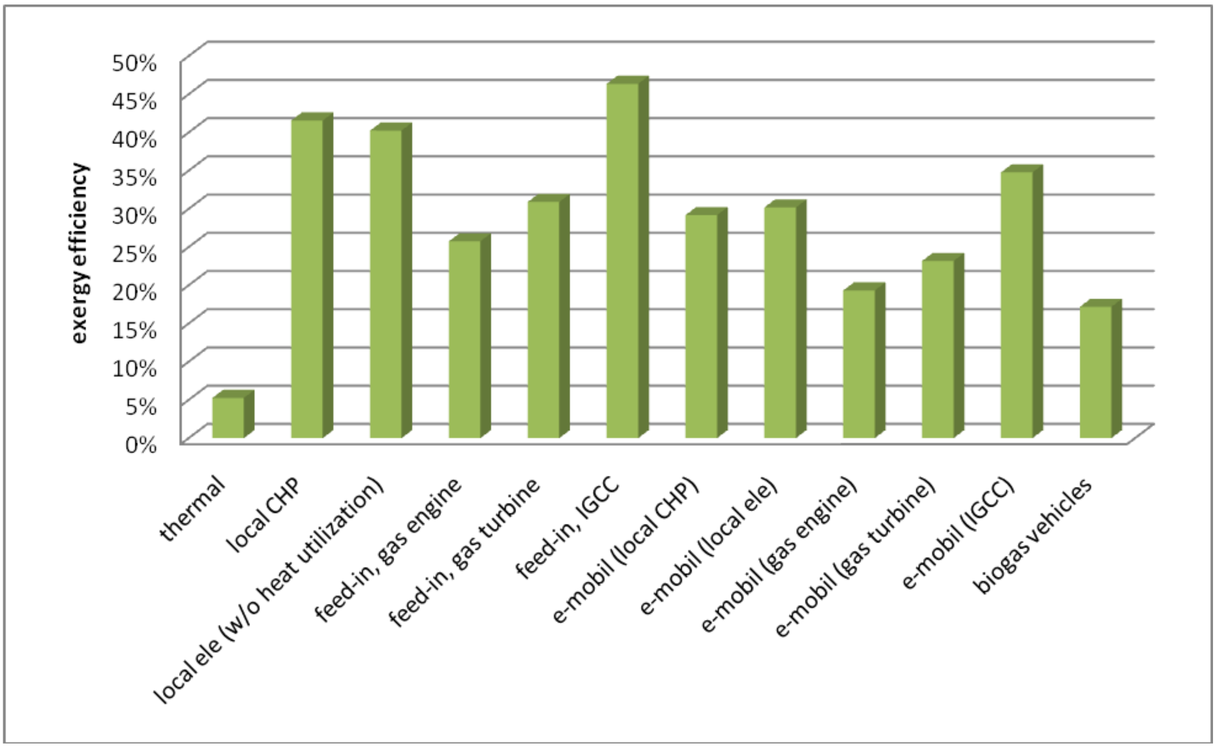


Figure 2. Exergy efficiency of selected biogas chains

Of course, due to the low temperature level of space heating applications, these systems show very low exergetic efficiencies (about 5%). Depending on the electric efficiencies and pre-treatment of resources (e.g. losses of exergy during biogas up-grading and cleaning) the exergetic efficiency is clearly higher for CHP. Due to the low efficiency of combustion engines, the exergetic efficiency of these bioenergy chains is in the range of 10%-15%. The related biobased e-mobility chains show exergy efficiencies up to 35%-40%.

3.3 Economic comparison

The following figures show a comparison of energy generation costs for the selected bioenergy technology chains. As described above, we are calculating energy generation costs for the following energy forms: thermal, electric and mechanical energy. Due to this approach the low efficiency of combustion engines in conventional vehicles, combined with relatively high biofuel production costs leads to very high energy generation costs. For electric vehicles, capital costs are the dominant component. Thus, the results are sensitive to full load hours, interest rate and depreciation time.

The bars for variable costs include O&M costs as well as fuel costs minus heat revenues in case of CHP. This explains the very low values for the "steam turbine" case where thermal efficiencies are relatively high compared to total costs.

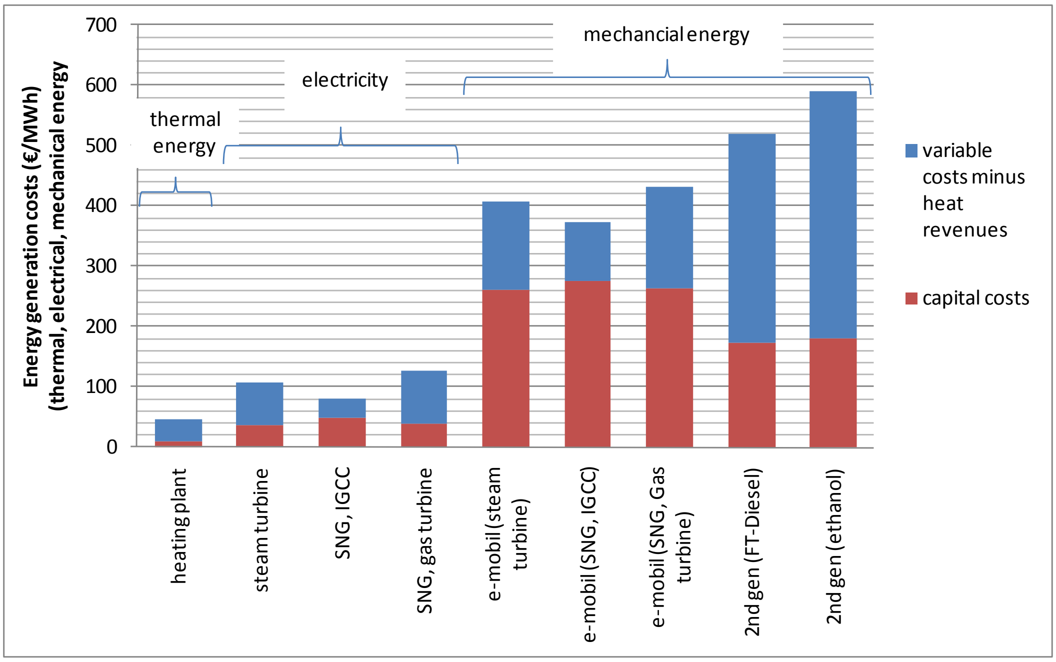


Figure 3. Comparison of different energy generation costs (thermal, electrical and mechanical energy), woody biomass

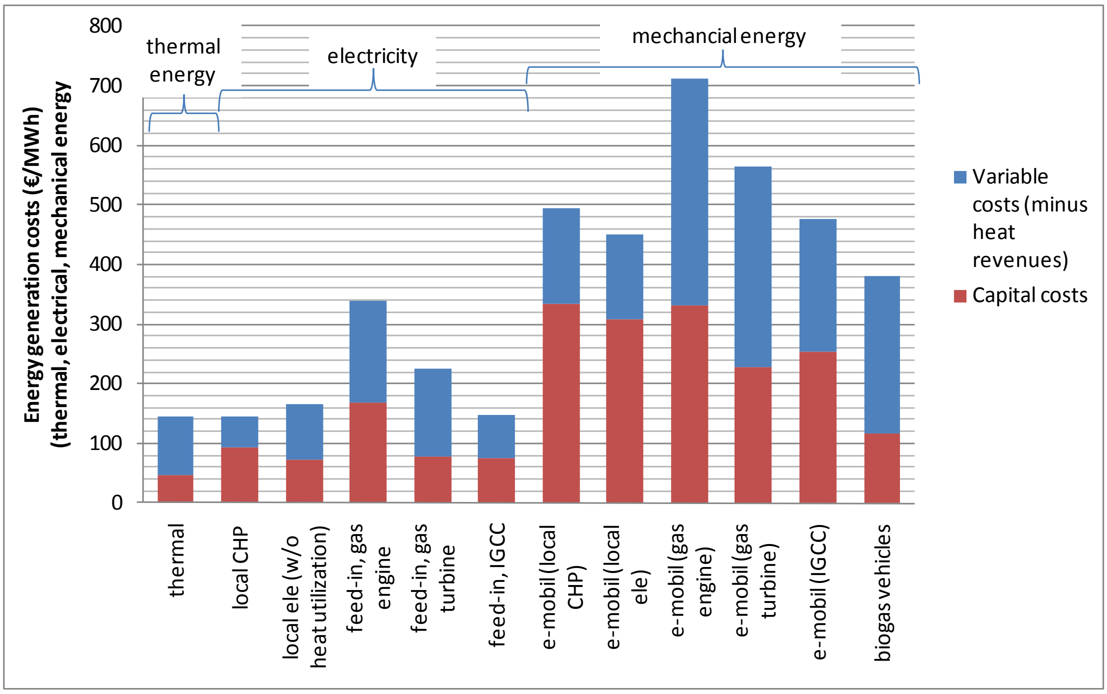


Figure 4. Comparison of different energy generation costs (thermal, electrical and mechanical energy), biogas

Several conclusions may be drawn from this comparison:

- Of course all mobility applications show clearly higher costs than CHP or pure heating plants (on the one hand due to high capital costs and on the other hand due to low efficiency).
- However, if we are comparing just the mobility systems, we can learn that the 2nd generation liquid biofuels are more expensive than the related bio-based e-mobility systems. Of course this conclusion is sensitive to the related technology data. Assuming a relatively cheap polygeneration plant which can make use of by-products (heat, electricity) this could lead to lower costs, too. This in particular holds for SNG based on woody biomass in the transport sector which we did not include in our analysis.
- The same result does not hold for the biogas related systems: Vehicles driven with biogas are cheaper than the related biogas based e-mobility systems. Again, this result is highly sensitive to some input parameters, in particular to the capital costs of electric vehicles which could come done essentially assuming higher full load hours (e.g. by car sharing systems).
- Feed-in of biogas leads to relatively high costs for the case of heating appliances and those CHP plants with relatively low electric efficiencies. For mobility applications, this might be an economically reasonable path compared to other biobased mobility applications.

3.4 The trade-off between exergy efficiency and (capital) costs

The following figures are combining the exergy efficiency and the capital costs of the investigated systems. If we are separating the areas (1) thermal plants and CHP and (2) mobility (because the latter shows clearly additional costs for different reasons) we can observe that there is a clear tradeoff between exergy output (efficiency) and capital costs (for the selected woody biomass chains this is an almost linear relation, for the selected biogas chains the situation is not that clear). This shows that there are clearly higher investments necessary in order to make use of the full exergetic potential of biomass resources.

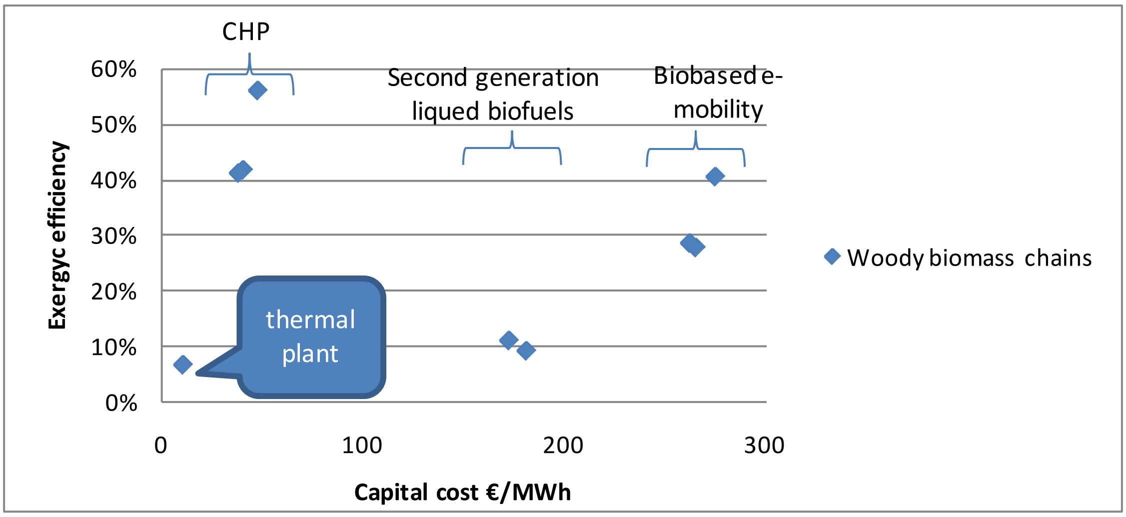


Figure 5. Exergy efficiency and capital costs (woody biomass)

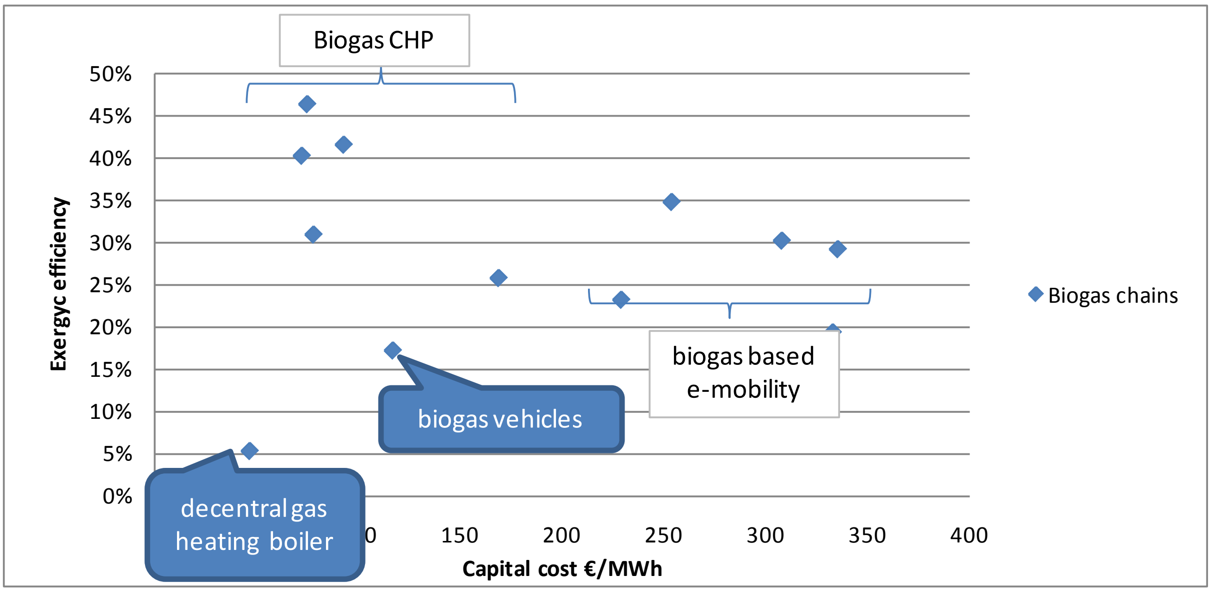


Figure 5. Exergy efficiency and capital costs (biogas)

If we would follow the objective to gain a highest possible exergetic use of biomass resources with a minimum of capital cost, we would have to draw an envelope line in these figures connecting those points situated on the left hand and top side of each graph. This would lead to the conclusion, that biomass for transport purposes in any case is not efficient, both from an exergetic and from a investment costs point of view. Moreover, for biogas plants feeding biogas into the gas grid and generation electricity and heat in large scale IGCC plants (top point in figure 5) could be an efficient option (not taking into account grid constraints!).

However, if we are considering that currently there is a high demand for individual transport systems, the least exergy losses would be achieved with biobased e-mobility schemes compared to combustion engines. This would require clearly higher investment costs (which are partly offset, at least for the case of 2^{nd} generation liquid biofuels by lower running costs).

4 Conclusions

The exergy losses in the (bio-) energy system are very high. There is the potential to reduce these exergy losses substantially by making use of more exergy efficient bioenergy paths. These paths are on the one hand CHP plants with high electric efficiencies and on the other hand bio-based e-mobility. However, the analysis shows that there are higher capital costs required for making use of this high exergy potential of biomass. This has to be considered as a major barrier.

On the other hand, if we are considering that currently not only biomass is wasted from an exergetic point of view for producing space heating, but also (and in fact first of all) fossil energy, the replacement of these fossil energy by biomass is a cheap and effective way of reducing CO_2-emissions.

Thus, the concept of exergetic analysis (and combining it with economic analysis) can give us a hint of how an “optimum” long-term future of biomass utilization could look like: Since space heating will be supplied by a large share of highly efficient technologies (low and passive houses) and solar thermal energy, it will be possible to allocate biomass to higher exergetic purposes: Producing electricity (of course besides non-energetic purposes like construction material etc) in large scale CHP plants, using the waste heat for industrial processes and using electricity partly in electric vehicles could be such a vision.

Many aspects and questions remained open in this paper. This includes the question of system boundaries, bioenergy chains to select (e.g. SNG in the transport sector), assessment of different biomass resources (in particular cascadic use of biomass). We are leaving this to future research work.

5 References

[1] Müller A. et al (2010), Exergy based prices for energy carriers in heating systems – what can we learn from them?, Arbeitspapier im Rahmen von IEA ECBCS Annex 49

[2] Gutschi C., Bachhiesl U., Stigler H. (2008), Exergieflussbild Österreichs 1956 und 2005. Beitrag zum 10. Symposium Energieinnovation, Graz 2008.

[3] Kalt G, et al., Long-term strategies for an efficient use of domestic biomass resources in Austria, Biomass and Bioenergy (2010), doi:10.1016/j.biombioe.2009.12.009

[4] De Vries S. (1999), Thermodynamic and economic principles and the assessment of bioenergy. PhD Thesis, TU-Delft.

[5] König A. (2009), Ganzheitliche Analyse und Bewertung konkurrierender energetischer Nutzungspfade für Biomasse im Energiesystem Deutschland bis zum Jahr 2030. Dissertation an der Universität Stuttgart.

Acknowledgement

The work presented in this paper has been carried out in the course of the Austrian participation in IEA implementing agreement ECBCS (Energy conersvation in building and community systems), Annex 49 (Low Exergy Systems for High Performance Buildings and Communities).

Anhang O

„Energie Effiziente Gemeinden“
IEA ECBCS Annex 51

IEA ECBCS Annex 51:

Results of Annex preparation phase and actualized draft proposal for the ExCo meeting in June 2008

1. Background

Based on the outcome of the FBF Think Tank on “Future Sustainable Buildings and Communities” held in March 2007 in Espoo/Finland and on a workshop held in October 2007 in Berlin, with participants from Finland, Denmark, Italy, France, The Netherlands and Germany, a proposal on a new Annex *“Energy Efficient Communities”* was presented by Germany at the ExCo meeting in November 2007 in Brügge/Belgium. To achieve the objectives of the Annex, it was proposed to carry out 4 subtasks:

Subtask A: Methods and Design Tools for Energy Efficient Communities

Overview of the state-of-the art in integrated local energy planning (existing methods, models and practical experiences with them) and R&D needs.

Subtask B: Case studies on Energy Efficient and Low Carbon City Quarters, Neighborhoods and Settlements

Evaluation of completed and running “green settlement” projects, good-practice examples on technical concepts, weaknesses, and lessons learned

Subtask C: Integrated Energy Planning for Cities and Implementation Strategies

Application of Advanced Local Energy Planning (“ALEP”) methods for cities or towns and approach to achieve long-term energy targets

Subtask D: Knowledge Transfer and Dissemination

Exchange of experiences, preparation of a Community Energy Concept Adviser and provision of a guidebook on energy efficient communities.

This proposal was discussed at length at the ExCo, resulting in a decision to launch the Annex preparation phase. Germany was asked to prepare a detailed Annex proposal in close contact with interested parties by organizing an experts workshop. R. Jank was designated by Germany as Operating Agent.

2. ExCo recommendations, November 2007

During the ExCo discussion in Brügge, there was concern from some ExCo members that the scope of Annex 51 was spanned too wide and the focus on the outcome of the Annex that would be of immediate use would thus be lost. Therefore, a concentration on neighborhoods rather than whole cities was recommended, as well as a focus on simplified planning tools to be used on the level of decision makers rather than on comprehensive tools of high complexity that need skilled planners working on detailed design issues. In particular, easy-to-use energy/CO_2 balancing tools for the considered units would be of interest for local decision makers. Furthermore, the product to be delivered by the Annex should be defined after a coordinative process with the participants and the Annex title should reflect this objective.

In addition to the demand and supply of heating energy, considerations should also embrace electricity and cooling demand. The “zero-energy buildings” approach, as treated in the SH&C Implementing

Agreement, should be extended to “zero-energy communities” in an appropriate way to take into account the transition in energy structures which will be necessary for sustainable cities of the future.

The influence of the local / national legal framework on the planning approach and results was mentioned by the ExCo as one point of specific interest in an international project with mutual learning by the participants. To ensure feed-back from practice, a participation of decision makers from communities was described as important, both within the case studies of Annex 51 and its workshops.

3. Annex Preparation Experts Meeting, Eindhoven, 10th – 11th April 2008 - Results

To coordinate the objectives of Annex 51 with the future participants, the Operating Agent together with P. Heijnen from SenterNovem invited the ECBCS members to an experts workshop to be held in Eindhoven, NL in April 2008. Experts from France, Canada, The Netherlands and Germany convened at this workshop and presented an overview of the ongoing activities in these countries concerning urban energy issues. Japan could not attend, but Prof. Sadohara from the University of Yokohama sent a presentation explaining Japan’s view on the objectives of Annex 51.

Summary of the presentations on national activities

The Netherlands

A number of projects on sustainable urban development or on urban climate change action plans have been initiated during recent years in The Netherlands, focused on (CO_2-neutral) estates and neighborhoods. The far-reaching energy transition that is necessary in the long term requires extending the efforts to communities, and in this field the Dutch participants seek for exchange of international experiences. Preparing the Dutch participation in Annex 51, a program has been designed under the name TRANSEP (“Transition in Energy and Process for Sustainable Community Development”), where research institutes and universities shall co-operate with planners and communities.

The present Dutch situation is characterized by the willingness of a growing number of communities to move towards sustainable urban development. In particular, the idea of a “CO_2-neutral community” as a long-term target of urban policy is announced in many Dutch cities. Even though the technologies are there to pursue this target, it is very difficult to initialize the necessary changes in local urban development because

- the design of a long-term energy plan to achieve ambitious energy targets in an optimized way is a complex task which requires knowledge generally not available in the urban administration
- there are insufficient instruments available to enable or enforce the implementation of such an energy plan
- there is a fragmentation in the local decision processes which makes it very difficult to establish and maintain a consistent strategy involving all decision makers.

As a consequence, a multidisciplinary approach will be necessary which merges social, managerial, legal and political issues with urban planning and energy optimization. To initiate this approach, SenterNovem is going to organize the above mentioned program TRANSEP within the major framework of EOS LT (“Energie Onderzoek Subsidie - Long Term”), a Dutch energy research program managed by SenterNovem. TRANSEP will contain four main work packages:

WP 1:	Process and Policy
WP 2:	Instruments
WP 3:	Technical Concepts
WP 4:	Pilot Projects and Implementation Strategies.

A number of organizations have been contacted for participation, such as housing and estate developers, research centres (TNO, ECN), Universities (Delft, Rotterdam, Amsterdam), The Hogeschool

Zuyd (Maastricht), planners and consultants. Four pilot communities have been selected (Almere, Apeldoorn, Nijmegen, Tilburg) which shall develop and implement a long-term urban plan to achieve “CO_2-neutrality” and serve as case studies within Annex 51. Further communities will accompany the work to include their experiences based primarily on sustainable neighborhood planning, such as Heerlen, Venlo, Heerhugoward and The Hague, some of them already networking with other European cities in the framework of the CONCERTO program of the EU.

France:

EiFER (“European Institute for Energy Research”, a joint research institute of Electricitè de France and the University of Karlsruhe) has presented an overview of the current climate change policy in France and the resulting consequences for communities. The main influences come from the so called “Le Grenelle Environnement” process - a round table on national level - that has treated issues of “urbanism” in the context of future climate change policy requirements. One important outcome of this process is the “eco-quartier” approach in the framework of the French “ville durable” program which focuses on the rehabilitation of urban quarters. A number of recent urban projects in France have created experiences on approaches, instruments and also planning models for urban refurbishment, which shall be applied in the broad dissemination program which is now in the preparation phase in France.

The headline of the present energy / climate change policy in France is the “factor 4” target, which aims at a reduction of either CO_2-emissions or (fossil) primary energy consumption by 75 % until 2050, compared to 1990. To implement this, substantial changes of frame conditions are being prepared at present, triggered by the “Le Grenelle” process. Enhanced building standards for new and existing buildings, new legislation on energy taxation and rents and new principles for urban planning, focusing on sustainability issues, will emerge from this political change. This will be accompanied by new research and support programs, such as a revitalization program for city quarters and a research program on “eco-quartier” – pilot projects dealing with innovations in energy, architecture, urban planning and urban sociology. These pilot projects will be selected on the basis of a call for tenders in 2008. They shall deliver exemplary cases of long-term planning, urban energy concepts and implementation strategies.

Canada:

Ken Church gave an overview on the present situation in Canada. Like in France, the dependency on diminishing fossil energy sources and recently confirmed national climate change targets are of increasing concern for decision makers. While municipalities are relatively weak compared to European cities, activities towards urban sustainability development come from developers as land owners on the neighborhood scale (bottom-up) and from the federal government asking for long-term community plans (top-down).

The federal climate change policy aims at a reduction of fossil energy consumption by 50 % until 2030. In this context there are federal support programs available for communities which plan to increase their urban development efforts but funding will in general depend on the existence of a long-term energy autarky plan or an “integrated community sustainability plan”. This move is still in its infancy in Canada but will become more important in the future to deliver positive results in the national climate change policy. Therefore, Canada will be interested in participating in international co-operation in the community sector.

There is large interest on issues of “urban systems of tomorrow” and the necessary change management to achieve them. Concrete Canadian case studies at neighborhood scale involving developers, municipalities and utilities may be accessible for Annex 51, but will need time for definition. On the city scale, Toronto was mentioned as a “G 40” metropolitan city, a group of big global cities (including cities like New York, London, Berlin, and many others worldwide) which currently make enhanced efforts to meet climate change policy requirements.

Germany:

As in The Netherlands, there have been launched new federal programs for communities in 2007 and 2008 in Germany as well. The aim is to enable communities to make their due contributions to the very ambitious national targets to

- increase energy efficiency by 20 % until 2020,
- increase the contribution of renewables to total electricity generation to 30 % (today's contribution is 12 %)
- increase renewables use for low-temperature heating to 12 % (today 6 %) and to
- reduce CO_2-emissions by 40 % until 2020 compared to 1990.

The first of the two programs mentioned, provided by the Ministry of Economics, is directed to urban quarters and neighborhoods, where recent technical innovations shall be demonstrated and evaluated in case studies. The second program, managed by the Ministry of Research and Education, has just begun in 2008 and is focused on holistic approaches to towns and cities as awhole. The main purpose of both programs is to close the gap between technical potentials and their actual implementation rate in communities which is observed in reality. The underlying rationale is that without significant progress in communities it will be impossible to achieve the demanding climate change policy targets.

In both programs, exemplary municipal pilot and demonstration projects shall be planned and carried out, accompanied by external scientific support. After evaluating these projects, the experiences made and lessons learned shall be made public.

The general approach is the

(1) Analysis of the current state; definition of a reference scenario ("business-as-usual")

(2) Study of the technical options locally available and their cost structures and potentials; definition of local energy policy targets

(3) Definition of a municipal (or local) long-term master plan ("climate change action plan")

(4) Detailed design of measures for energy conservation and use of renewables, waste heat etc. (and feed-back to the master plan in an iterative process, if necessary)

(5) Implementation strategy (priorities, responsibilities, support programs, instruments, monitoring)

(6) Continuous evaluation and feed-back.

In principle, this approach is applicable for both neighborhood and city planning. The difference between both is caused by the degree of complexity, the number and role of the decision makers and the planning tools that have to be used. Based on the experiences made with local energy planning projects since the 80's, existing methods and tools will be applied and further developed due to new technologies and new means of calculation and modeling. One tool which is to be developed is the "Community Energy Adviser", an expert system for local decision makers which is based on the experiences with the "Energy Concept Adviser" developed in Annex 36.

Another related activity has been going on in Germany for about 5 years, based on the Swiss *"Energiestadt"* approach. This management approach was developed to provide an instrument to introduce and maintain a process towards energy efficiency and sustainability within urban administrations. This approach is supported by state programs in some of the German federal states. It is called *"European Energy Award"* in Germany. Cities which have achieved specific "good governance targets" and proved that they have continuously maintained or further improved them receive an Energy Award. Some 100 German cities are so far participating in this program as well as some 100 cities in Switzerland and Austria. It can provide a sound first step into a comprehensive municipal climate action strategy. At present, a new planning tool is in its testing phase which provides an easy means to create an urban energy and CO_2-balance, merging available local data on energy consumption with statistical data bases from state or local statistics authorities. This tool, called “ECO_2Regio”, was developed by ETH Zürich and ECO Speed, a Swiss software provider.

Several German neighborhood projects have been presented at the experts meeting that could be carried out in the framework of the new program, such as districts in Freiburg, Karlsruhe and Kassel. The denomination of projects as case studies for Annex 51 will depend on actual applications of communities to be included in the two federal programs and the timeframe of Annex 51.

Japan:

Prof. Sadohara of the University of Yokohama announced that Japan will participate in Annex 51. To organize the Japanese contributions, a working group has been set up with Prof. Sadohara as the chair of the group. He is responsible for providing Japanese ideas concerning the Annex work plan and later for managing the contributions of Japan to the Annex.

Since he was not able to attend the experts meeting, he sent a paper to Eindhoven explaining the issues which are of specific interest to Japan. According to this, there is a focus on an integrated energy management approach on a “block level” (business districts or neighborhoods consisting of high-rise dwelling buildings). Integrating energy conservation measures for individual buildings with an area-wide energy supply system (heating, cooling, electricity) and also including emergency prevention measures could yield a much improved efficiency in terms of energy as well as cost within Japanese cities. In addition, improved planning principles towards higher density, better urban mixture and improved transportation systems would further contribute to urban sustainability in Japan (and everywhere else). Prof. Sadohara is interested in case studies on block scale in cities, developing and testing planning tools and investigating technical concepts and implementation strategies. By the national energy plan of Japan passed in 2007, a transition to decentralized supply is considered desirable to achieve the national targets of climate policy, the necessary decrease of energy import dependency, and emergency precaution at the same time. Japan is therefore highly interested in sharing experiences and know how on these topics with other countries by participating in Annex 51.

Conclusions

It was pointed out by all speakers that a strong increase of interest in sustainability issues is observed in community administrations as a result of pressure both from national and urban politics. As a result, ambitious targets are set – such as a decrease of CO_2-emissions by 50 % within the next 20 years – but with limited understanding of the consequences. The difficulties in achieving such targets are not caused by a lack of technologies, but by insufficient know-how on strategic planning, management abilities during the implementation process and availability of tools and instruments for decision making, planning and monitoring. The work plan of Annex 51 should reflect this situation and - as its main objective - provide a *practical guide for urban decision makers* on how to achieve ambitious energy and CO_2-targets on a local and urban scale.

The structure of the Annex as proposed to the ExCo in November 2007 should be maintained, but the objectives of the four subtasks should be changed in some respect, as explained below. The Annex title should also reflect this objective adequately. Concluding, the following title was decided:

“Towards Zero-Energy Communities:

Case Studies and Strategic Guidance for Urban Decision Makers”

Compared to technology oriented Annexes, the emphasis of the Annex is on management, communication and even sociology issues rather than technical questions. Contrary to discussions within the ExCo meeting of November 2007, the experts meeting came to the conclusion that both neighborhoods (or blocks or quarters) and municipalities should be the objectives of Annex 51, thus reflecting the present national policies at least in NL, F and D. There was strong agreement with the Exco to keep the perspective of a “zero-energy” or “CO_2-neutral” community as a long-term aspiration for urban development, including heating, cooling and electricity consumption.

While “benchmarking” of neighborhoods or communities was – in agreement with the ExCo – considered to be not very useful in an international context, a sound balancing of energy/CO_2-flows and their variation over time due to the results of implementing the energy plan would be very important. Comparable methods and tools should be used for that purpose in the different case studies. Also, the interaction between legal framework, planning and implementation strategy has to be a main emphasis of the work, in agreement with the requirements of the ExCo.

4. Revised Annex 51 proposal

While the fabric of the Annex as proposed in November 2007 shall be maintained, containing

- a subtask intended to review and evaluate existing knowledge and experiences within the participating countries
- two subtasks with case studies either on neighborhood and on community scale
- a subtask for information dissemination and preparation of the final product of the Annex,

the contents and aspirations of the subtasks should be transformed in some aspects. The following subtask objectives resulted from the experts meeting:

Subtask A: Existing Organizational Models, Implementation Instruments and Planning Tools for Local Administrations and Developers

In this subtask, a review on planning methods and existing tools and models for urban or local energy planning, which are presently available for local administrations and developers in the participating countries, shall be provided.

Main work items:

- describe examples for successful community energy planning projects within the participating countries with focus on methods and planning principles and implementation strategies
- review the state-of-the-art of urban or local energy system modeling and its combination with conventional planning tools
- review data acquisition methods and tools for monitoring municipal energy and GHG balances
- evaluate work on sustainability evaluation (usually focused on buildings) carried out so far in IEA Annexes / Tasks and its potential extension to communities
- compare approaches in participating countries
- provide conclusions for local decision makers.

Remark:
Compared to the proposal provided in November 2007, it is not planners but local decision makers that are addressed by this subtask. As a consequence, the question of available planning tools for planners plays a minor role in the revised proposal. Instead, the legal frameworks and different approaches found within the participating countries shall be discussed according to their suitability to satisfy increased requirements “towards zero-energy communities”.

Subtask B: Case Studies on Energy Planning and Implementation Strategies for Neighborhoods, Quarters and Municipal Areas

Remark:
This subtask is taken without changes from the Annex proposal of November 2007.

Objectives

Due to the fact that a city is a complex unit and it can only be compared to other cities to a limited extent, it will be useful to divide cities in “typical areas” which can be found in every city (residential areas dating back to typical construction periods, as well as urban industrial and commercial areas). To a certain extent, case study results, providing practical examples for favorable technical concepts on neighborhood scale, can be transferred to similar neighborhoods or quarters in other municipalities. Subtask B case studies should primarily address

(1) planning of energy efficient quarters by ***refurbishment of the existing building stock***, supply of “LowEx” energy, local implementation of renewable energy sources and use of waste heat

(2) planning and construction of ***new “green” settlements***.

For the involved buildings in the first case, the objectives should be met by a combination of retrofit measures to reduce energy demand with an optimized exergetic energy supply and/or the use of renewables. In the second case, due to more degrees of freedom for the planner, a “total” optimization of the whole system shall be aspired.

Case studies of Subtask B can either be planning projects including their first steps of implementation or projects that are already in some stage of implementation (or just finished) and can serve as examples for successful project planning and development which can then be used as input for Subtask A. In general, it is expected that the case studies are part of a comprehensive urban sustainability effort on the part of the involved local administration.

The minimum target for the case studies is a reduction by at least 50 % of the primary energy consumption compared to a defined standard situation in the regarded city.

Main work items:

- Case studies and pilot projects to implement the planning results
- Evaluation of market potentials (and market barriers) for innovative energy conservation or supply technologies: generalization of the results found in the case studies
- “marketing approaches” to implement the energy plan
- Practical results on costs and efficiencies: Feed back to Community ECA (Subtask D)

The key issues in Subtask B are the planning and implementation of innovative local energy (efficiency, conservation, renewables) projects and an evaluation of the experiences made thereby, concerning objectives, results, methods used, technical and non-technical framework and lessons learned for further activities. An important aspect will also be the evaluation of “marketing approaches” used within the case studies in order to achieve the necessary acceptance and to ensure the implementation of the energy plans by the affected decision makers.

This evaluation is to be made in close co-operation with all participants of the Annex and will deliver a main input for the “Urban Energy Efficiency Guidebook” (Subtask D).

Subtask C: Case Studies on Integrated Energy and CO_2-Planning Towards "Zero-Energy Communities" by Urban Planners and Stakeholders

One conclusion of the experts meeting in Eindhoven was that the largest deficits on know-how, practical experiences and usable instruments are on the city scale. The most urgent needs have been identified concerning

- usable methods for a realistic estimate of the energy demand and consumption of towns/cities
- tools for a continuous recording of energy and CO_2 balances on the city scale
- methods and instruments usable to support urban decision makers in choosing long-term energy strategies for the community.

Using the example of one (?) case study per participating country, the approach to develop a municipal "zero-energy" masterplan, define an implementation strategy and secure its realization shall be demonstrated, using results and experiences from subtasks A and B.

Main work items, as applicable to individual subtask C case studies:

- Analysis of the existing state of the local energy system and its performance
- Exploration of appropriate and cost-efficient data acquisition methods
- Application of suited methods and planning tools to develop a comprehensive energy master plan as an urban planning support for local decision makers
- Development of communication and learning processes for local stakeholders / decision makers
- Evaluation of an implementation strategy
- Definition of a monitoring system.

Deliverables:

- Municipal energy masterplans
- Exchange of experiences with other involved communities and planners.
- Input to Subtask D (Energy Efficient Communities Guidebook)

Remark:
Contrary to the Annex proposal from November 2007, only a limited number of case studies are proposed (one per participating country). The emphasis is on decision support. Energy system models may be used, if applicable, but conventional planning means may also be employed.

Subtask D: Evaluation of Case Study Experiences and Practical Guidebook for Urban Decision Makers

Remark:
This subtask is overtaken with slight changes from the Annex proposal of November 2007.

Objectives

Subtask D is focused on an evaluation of the experiences from the case studies with respect to

- management, communication and marketing approach for urban energy planning projects, taking into account top-down as well as bottom-up oriented actions

- comparison of legal conditions on the local and national level and of effects of existing or planned EU-directives that may influence local planning decisions
- means for performance assessment.

Main work items:

- Evaluation of subtask experiences (approach, methods, legal conditions, lessons learned)
- Documentation of best practice examples
- Conclusions and recommendations for planners
- Input from the participating parties is used to generate *the "Urban Energy Efficiency Guidebook":* How to establish and implement an Energy Efficiency Strategy in Communities
- Development of a Community Energy Concept Adviser for decision makers in communities (FhG-IBP, Stuttgart)
- Dissemination: Newsletters, a website and seminars / workshops within participating countries.

Deliverables:

(1) Dissemination platform

The results of Subtasks A, B and C will be used as input to the joint activity in Subtask D. All the information collected as well as task-related results will be published using the different channels mentioned above. A web-based information platform, open seminars (on a national basis) and scientific publications will be used for the dissemination of information. The addressed target group will be the decision makers in communities: city administration, housing companies, utilities, planners. A link to the CONCERTO program of the European Union shall be established to increase the audiences.

(2) The Community Energy Concept Adviser

This tool is based on the experiences from Annexes 36, "Energy Concept Adviser for Educational Buildings", and Annex 46, "IT-Toolkit for the Energy Efficient Retrofit of Government Buildings". The "Community Energy Concept Adviser" shall support the conception of energy-efficiency and conservation technologies and the optimization of supply structures to ensure a low fossil-energy consumption of a typical neighborhood/quarter. It is a new approach that needs to prove that it will deliver a tool that will be usable in practice. Based on the experiences fromAnnexes 36 and 46 it is expected that this will be achieved.

(3) "Energy Efficient Communities: A Practical Guidebook for Urban Decision Makers"

While the ALEP guidebook of Annex 33 describes theoretical considerations and experiences made with the application of comprehensive energy system models for LEP, this Annex is focused on practical approaches and methods and their use in concrete urban planning projects based on the evaluated case studies of Subtasks B and C and the lessons to be learned from them.

Other results

- Design guidelines based on criteria for performance and sustainability, distinguishing between newly built areas and urban retrofit projects. This will include a possible classification of energy supply technologies in communities in terms of performance and improvement potential.
- Catalogue of verified open-platform and commercial software for the design of "LowExergy" (in collaboration with Annex 49, "Low Exergy Systems for High Performance Buildings and Communities") as well as for conventional energy supply structures and energy conservation measures in communities in order to determine energy use performance.

- Recommendations for policy measures - local and national - within participating countries.

5. Further information and actions

During the experts meeting in Eindhoven, the question of lead countries and subtask leaders was discussed. It was proposed that **Prof. Jacques Kimman** from Hogeschool Zuyd (Maastricht, The Netherlands) would take the role as subtask leader for subtask B. **Jacques Ghisgant** from EiFER / France would be willing to take the lead of subtask A, under the prerequisite that France will participate in Annex 51, which is still in question.

Since more countries have declared interest in Annex 51 than have participated in the experts meeting in April, a decision concerning the lead countries of subtasks C and D should be postponed until the question of participating countries is settled. Further clarification is expected from the ExCo meeting of June 2008 in Graz.

Assuming that a clarification of the participants (participating countries, national participants) will be achieved in June 2008, it was proposed in Eindhoven to organize a kick-off meeting on September 8th, 2008. At this meeting, the organization of the Annex, the role of the participants and the detailed work plan including estimates of the necessary manpower shall be approved. On this basis, the final Annex description can be presented to the ExCo's autumn meeting. After adoption, the Annex could then be launched in January 2009.

Anhang P

Abschlussworkshop Wien März 2010

Low-exergy systems for high-performance buildings and communities.

Österreichische Beteiligung an IEA ECBCS Annex 49

Lukas Kranzl, Andreas Müller

Workshop „Zukunft der Raumwärme-Bereitstellung
und nieder-exergetische Energiesysteme“
TU-Wien, 24.3.2010

IEA Annex 49 „Low-exergy systems“ zu ECBCS

- IEA Implementing agreement ECBCS (Energy Conservation in Building and Community Systems)
- Annex 49 Low Exergy Systems for High Performance Buildings and Communities

- www.annex49.org
- www.ecbcs.org

IEA Energy Conservation in Buildings & Community Systems

Annex 49
Low Exergy Systems for High-Performance Buildings and Communities

IEA – ECBCS

IEA Energy Conservation in Buildings & Community Systems

- ECBCS - Energy Conservation in Buildings and Community Systems.
- Hauptaufgabe und Zielsetzung von ECBCS:
  - Forschung an Gebäude-Energie-Effizienz in einem internationalen Fokus.
  - Organisation der Arbeiten durch eine Reihe von “Annexes”.
  - Ergebnisse formulieren, die national und international in politische Maßnahmen und Standards für Energieeffizienz einfließen.

TECHNISCHE UNIVERSITÄT WIEN Vienna University of Technology

Energy Economics Group

ECBCS – Strategische Ausrichtung

Trends	Focus Areas	R&D Goals
Changes in lifestyles, work and business environment	Dissemination	To develop and improve information mechanisms, methods and tools in order to create powerful, environmentally aware end-users and to create basis for attractive environment of new business models
Towards iterative and interactive processes	Decision-making	To develop methodologies, methods and validated tools for the life cycle decision-making enabling advanced processes to produce high-performance building and community solutions on demand
From components to integral systems and solutions	Building products and systems	To develop and demonstrate highly resource-efficient new and retrofit/ refurbishment building and community solutions, and advanced operating systems for the use and control of them

TECHNISCHE UNIVERSITÄT WIEN Vienna University of Technology

Energy Economics Group

ECBCS Annexes

IEA Energy Conservation in Buildings & Community Systems

- Ongoing Annexes
  - 55 Reliability of Energy Efficient Building Retrofitting - Probability Assessment of Performance & Cost (RAP-RETRO)
  - 54 Analysis of Micro-Generation & Related Energy Technologies in Buildings
  - 53 Total Energy Use in Buildings: Analysis & Evaluation Methods
  - 52 Towards Net Zero Energy Solar Buildings
  - 51 Energy Efficient Communities
  - 50 Prefabricated Systems for Low Energy Renovation of Residential Buildings
  - **49 Low Exergy Systems for High Performance Buildings and Communities (2006-2010)**
  - 48 Heat Pumping and Reversible Air Conditioning
  - 47 Cost Effective Commissioning of Existing and Low Energy Buildings
  - 46 Holistic Assessment Tool-kit on Energy Efficient Retrofit Measures for Government Buildings (EnERGo)
  - 45 Energy-Efficient Future Electric Lighting for Buildings
  - 44 Integrating Environmentally Responsive Elements in Buildings
  - 5 Air Infiltration and Ventilation Centre
- Completed annexes
  - 37 Low Exergy Systems for Heating and Cooling
  - …

Annex 49

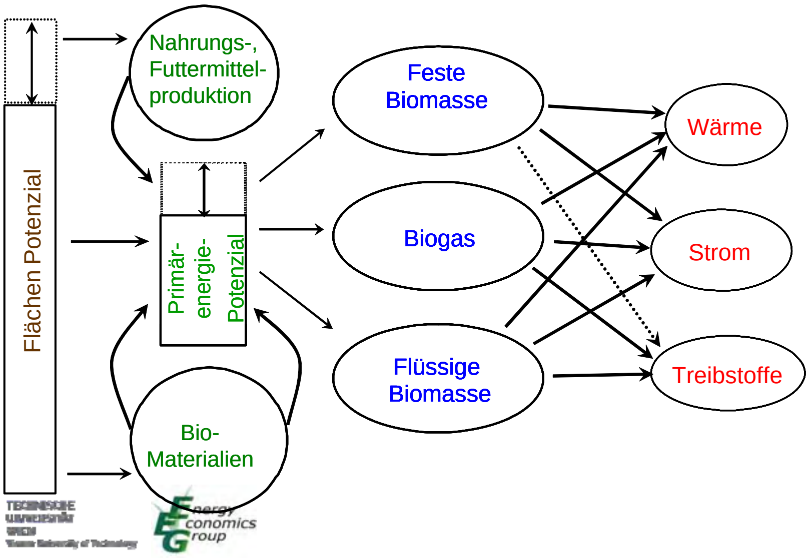
Annex 49
Low Exergy Systems for High-Performance Buildings and Communities

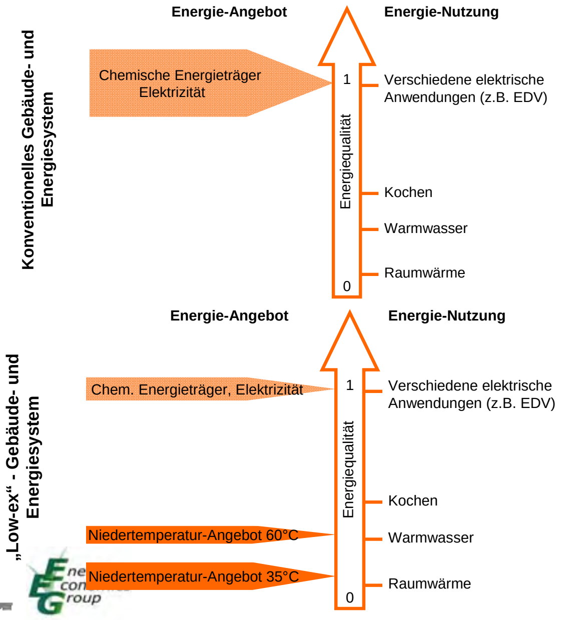
- Low Exergy Systems for High Performance Buildings and Communities
- Zielsetzung ist, mittels der Analyse, Förderung und Informationsverbreitung zu nieder-exergetischen Systemen einen Beitrag zu Energie- und Treibhausgaseinsparungen zu liefern.
- Teilnehmende Länder:
  Austria, Canada, Denmark, Finland, Germany, Italy, Japan, Poland, Sweden, Switzerland, The Netherlands, USA
- 2010 wird Guidebook „low-exergy system“ fertig gestellt.

Österreichische Beteiligung

- Beteiligung an dem Annex seit Mitte 2008
- Fokus: Integration des Exergie-Konzepts in energiewirtschaftliche Analysen und Fragestellungen
  - z.B. Heizsysteme
  - z.B. Bioenergie-Systeme
  - z.B. Szenarien des österreichischen Raumwärmesektors

Ausgangspunkt, Motivation





Konventionelles Gebäude- und Energiesystem

Energie-Angebot

Energie-Nutzung

Chemische Energieträger Elektrizität

Energiequalität

1

0

Verschiedene elektrische Anwendungen (z.B. EDV)

Kochen

Warmwasser

Raumwärme

„Low-ex“ - Gebäude- und Energiesystem

Energie-Angebot

Energie-Nutzung

Chem. Energieträger, Elektrizität

Niedertemperatur-Angebot 60°C

Niedertemperatur-Angebot 35°C

Energiequalität

1

0

Verschiedene elektrische Anwendungen (z.B. EDV)

Kochen

Warmwasser

Raumwärme

Fragestellung und Ziel dieses Beitrags

- Analyse und Gegenüberstellung der Kosten und exergetischen Wirkungsgrade ausgewählter Biomasse-Nutzungspfade
- Welcher Trade-Off besteht zwischen Exergie-Output und (Kapital-) Kosten ausgewählter Biomasse-Nutzungspfade?

Methodik (1): Exergiegehalt

- Bei thermischen Energieformen: $Ex = 1 - \frac{T_0}{T_1}$
- Bei chemischen Energieformen
  - Exergiegehalt der chemischen Energie
  - ODER: technisch maximal realisierbaren exergetischen Wirkungsgrad

Unit	ambient temperature °C	(usable, possible) temperature °C	exergy content %
Electricity			100%
mechanical energy (engine)			100%
space heat	0	20	7%
process heat	0	300	52%
Woody biomass	0	800	75%
FT-Diesel	0	1500	85%
Maize silage / Manure mix	0	800	75%
biogas crude	0	800	75%
biogas fed into gas grid	0	1800	87%

Methodik (2): ausgewählte Biomasse-Pfade

- Holzartige Biomasse:
  - Heizwerk
  - KWK (Dampfturbine)
  - Wirbelschichtvergasung, GuD
  - Wirbelschichtvergasung, Gasturbine
  - Elektrizität aus den KWK-Systemen zum Einsatz in Elektrofahrzeugen
  - FT-Diesel
  - Ligno-Zellulose Ethanol
- Biogas:
  - KWK mit lokalem Gas-Motor (mit und ohne Wärmenutzung)
  - Einspeisung von Biogas mit ...
    - Einsatz in dezentralen Heizkesseln
    - Einsatz in dezentralen Gasmotoren
    - Einsatz in zentralen Gasturbinen
    - Einsatz in zentralen GuD-Anlagen
    - Einsatz in Fahrzeugen
  - Elektrizität aus Biogas-Anlagen zum Einsatz in Elektrofahrzeugen

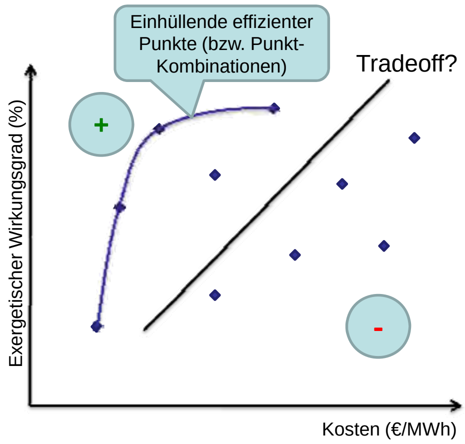
Methodik (3): Systemgrenzen

- Thermische Energie: Wärme auf Raumtemperaturniveau
(Kosten ohne Berücksichtigung der Wärmenetze)

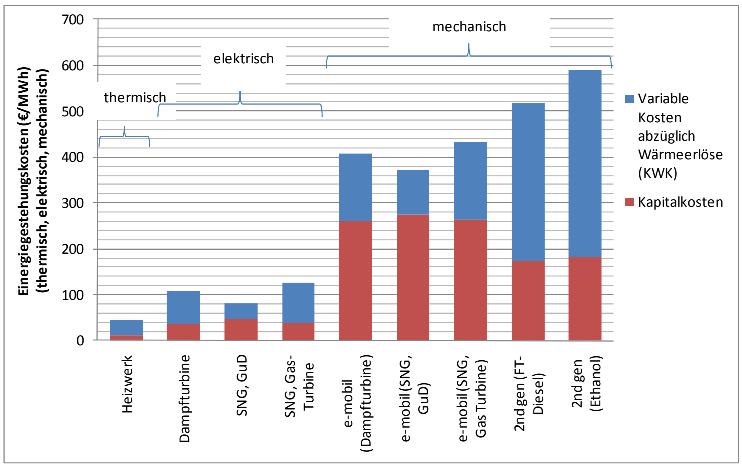
- Strom: ab Kraftwerk

- Mobilität: mechanische Energie am Antriebstrang des Verbrennungs- oder Elektromotors
(Kosten der Elektrofahrzeuge als Zusatzkosten zum konventionellen Fahrzeug)

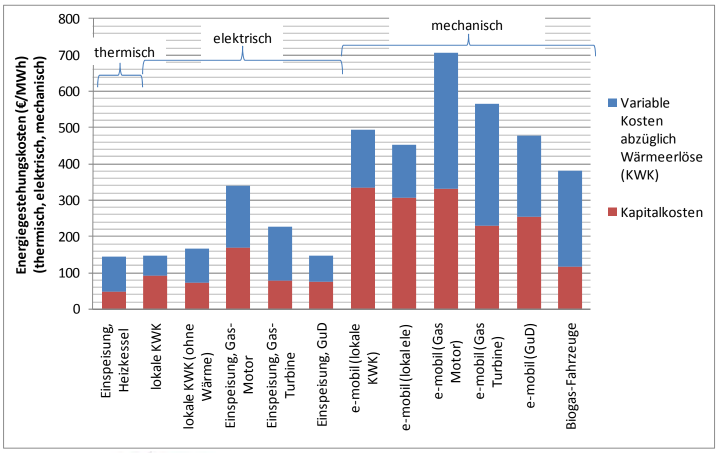
Methodik (4): Grundidee des Ansatzes



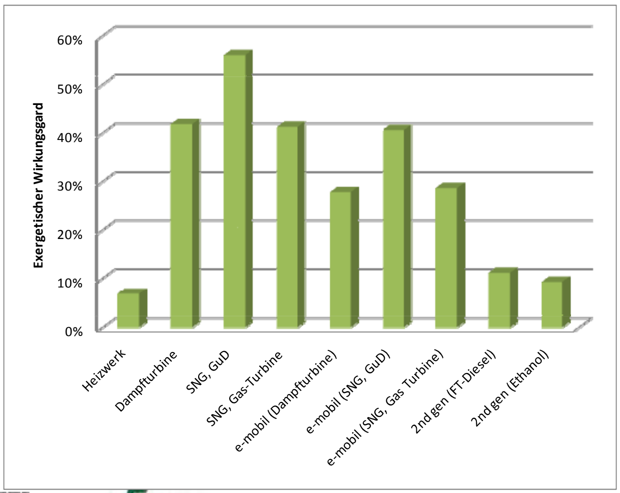
Kosten ausgewählter Biomasse-Pfade (Holz)



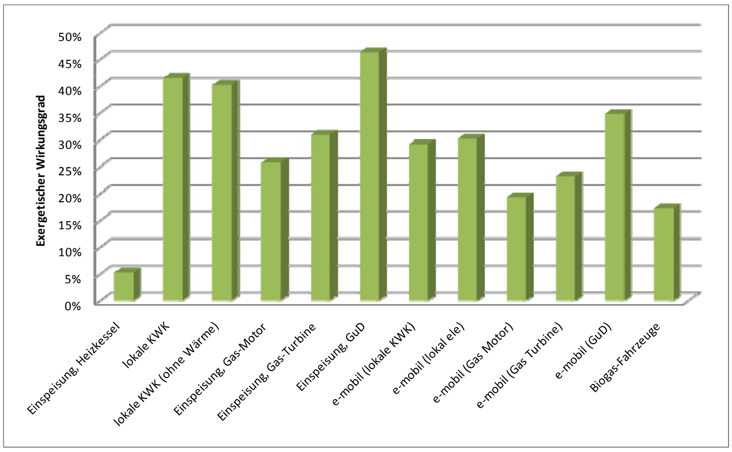
Kosten ausgewählter Biomasse-Pfade (Biogas)



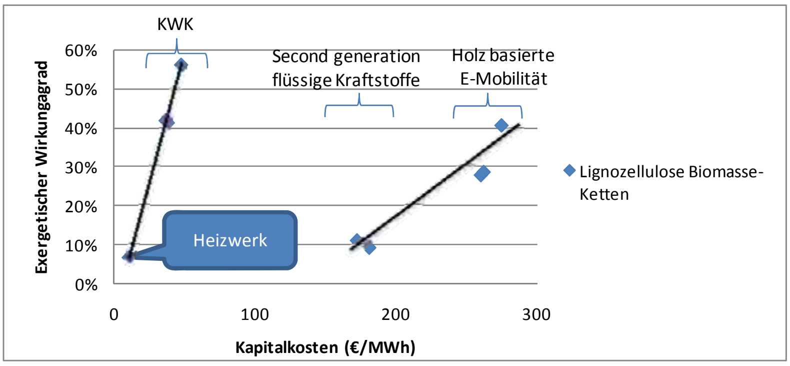
Exergetische Wirkungsgrade (Holz)



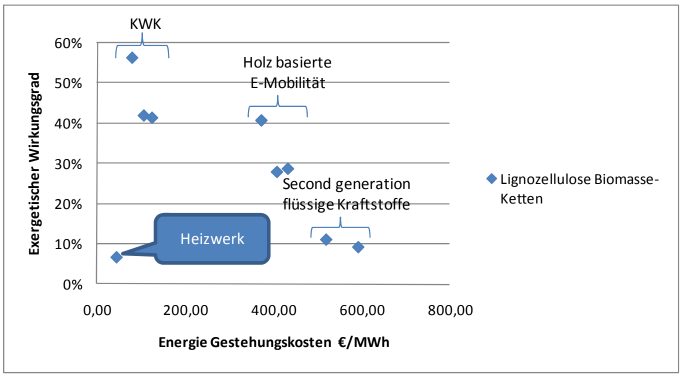
Exergetische Wirkungsgrade (Biogas)



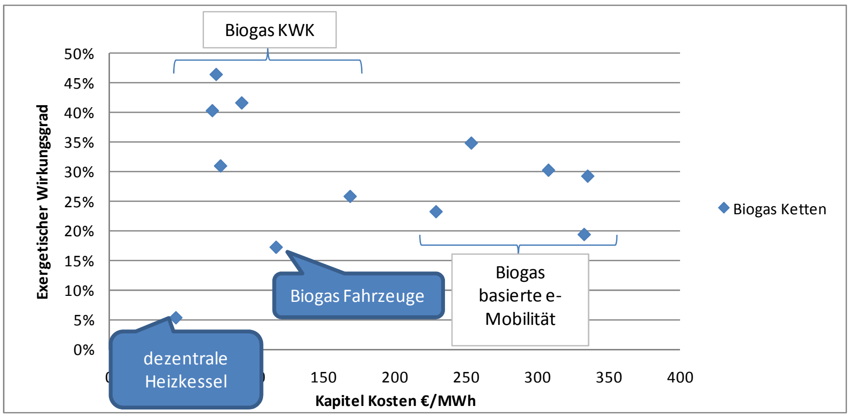
Exergetischer Wirkungsgrad und Kapitalkosten (Holz)



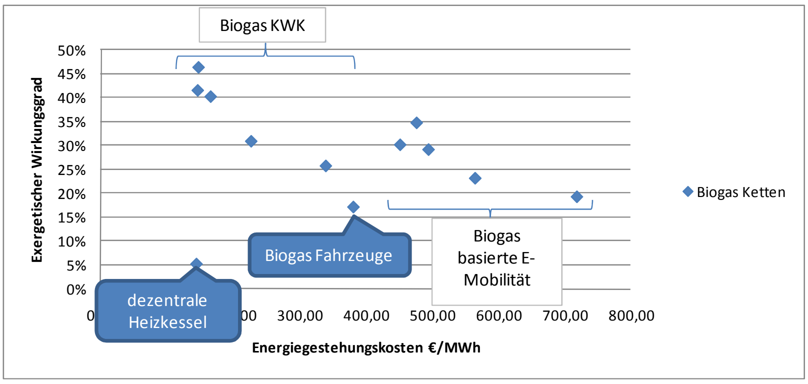
Exergetischer Wirkungsgrad und Kosten (Holz)

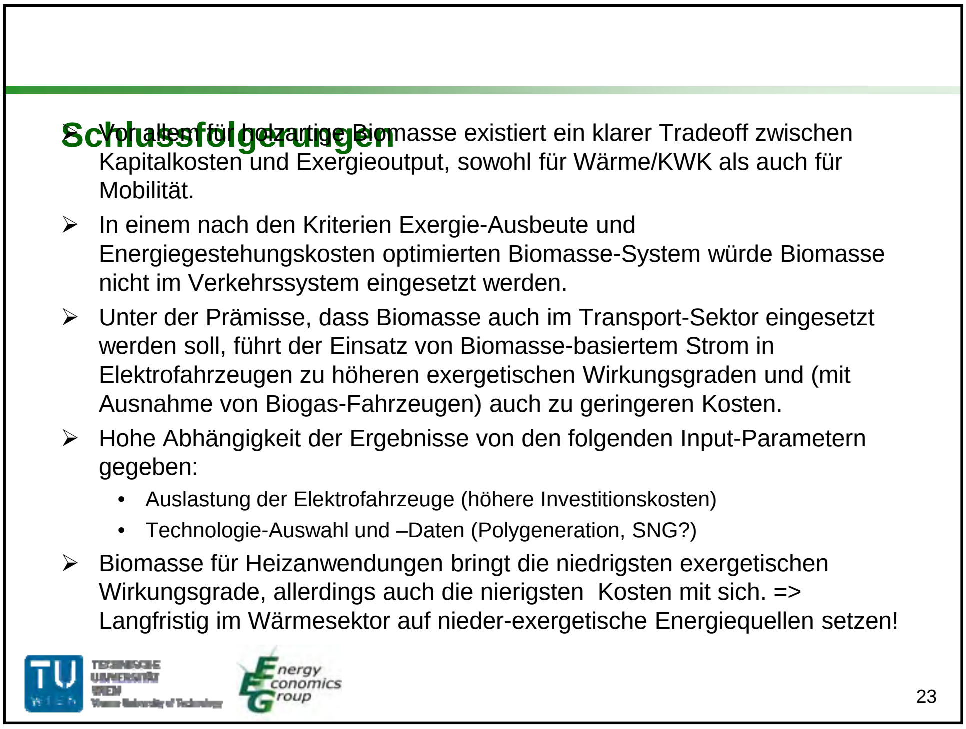


Exergetischer Wirkungsgrad und Kapitalkosten (Biogas)



Exergetischer Wirkgungsgrad und Kosten (Biogas)





Schlussfolgerungen

- ➢ Vor allem für holzartige Biomasse existiert ein klarer Tradeoff zwischen Kapitalkosten und Exergieoutput, sowohl für Wärme/KWK als auch für Mobilität.
- ➢ In einem nach den Kriterien Exergie-Ausbeute und Energiegestehungskosten optimierten Biomasse-System würde Biomasse nicht im Verkehrssystem eingesetzt werden.
- ➢ Unter der Prämisse, dass Biomasse auch im Transport-Sektor eingesetzt werden soll, führt der Einsatz von Biomasse-basiertem Strom in Elektrofahrzeugen zu höheren exergetischen Wirkungsgraden und (mit Ausnahme von Biogas-Fahrzeugen) auch zu geringeren Kosten.
- ➢ Hohe Abhängigkeit der Ergebnisse von den folgenden Input-Parametern gegeben:
  - Auslastung der Elektrofahrzeuge (höhere Investitionskosten)
  - Technologie-Auswahl und –Daten (Polygeneration, SNG?)
- ➢ Biomasse für Heizanwendungen bringt die niedrigsten exergetischen Wirkungsgrade, allerdings auch die nierigsten Kosten mit sich. => Langfristig im Wärmesektor auf nieder-exergetische Energiequellen setzen!