ECBCS Annex 49

Low Exergy Systems for High-Performance Buildings and Communities

news

Newsletter No. 7 March 2010

This is the last issue of the LowEx News the biannual newsletter published during the working phase of IEA ECBCS Annex 49. The main results of Annex 49 are described here together with the formats of the final products of the Annex 49.

GUIDEBOOK FOR LOW EXERGY SYSTEMS

The results of Annex 49 are presented in the form of a booklet, which includes the LowEx Guidebook in a CD-ROM format. It contains all the material produced within the project: newsletters, publications, the exergy analysis tools and the full version of the guidebook (also as a printable .pdf version). In addition, the same information can be found in the Annex 49 webpage: www.annex49.com.

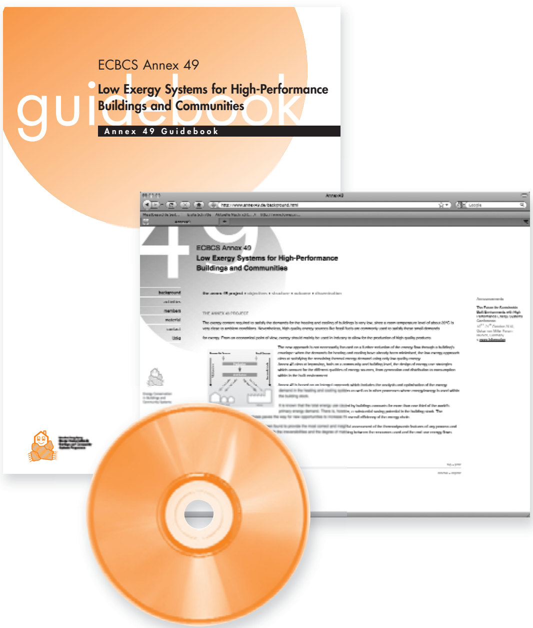

Figure 1: The final products of Annex 49 will be published in many formats.

International Energy Agency
Energy Conservation in Buildings and Community Systems Programme
www.ecbcs.org

Main objectives and layout of the final report
In this context, the main objectives Annex 49 were:

- to develop design guidelines regarding exergy metrics for performance and -sustainability
- to create open-platform exergy software for building design and performance assessment
- to show best practice examples for new and retrofit buildings and communities
- to document benefits of existing and developed demonstration projects
- to set up a framework for future development of policy measures and pre-normative work including the exergy concept

The topics mentioned are treated in detail in the following chapters:

- Following the introduction in Chapter 1 Chapter 2 gives a detailed description of the first unitary methodology for performing dynamic exergy analysis on building systems. Fundamental concepts and the thermodynamic background of the exergy approach are highlighted, as well as detailed equations for the analysis of several building systems.
- In Chapter 3, the tools developed within the work of Annex 49 are presented. A detailed description of the main features, calculation approach and usability of each tool is also given.
- Chapter 4 highlights and summarises main strategies for optimised exergy design of buildings and community systems.
- Chapter 5 presents the main parameters developed or used for characterising exergy performance of any building or community. Based on these parameters, first discussions and bases for setting pre-normative proposals which include the exergy concept are also included.
- Chapters 6 and 7 show the main building and community case studies analysed within the research activities of Annex 49.

Table 1: Details table of contents of the annex 49 guidebook

TOOLS FOR EXERGY ANALYSIS

Tools to facilitate exergy analysis of buildings

In building design, both the energy and exergy performance of the building and its building systems should be taken into account. As a part of the work done in Annex 49, a variety of software tools have been developed to facilitate the use of exergy analysis in building design. These tools have different levels of complexity and can be used in various applications.

They are at the forefront of the use of exergy in the building sector, providing a unique viewpoint that simple analysis based on energy balances alone might overlook. These tools provide designers with a range of options for producing results pertaining to the exergetic performance of a particular design. Table 2 shows an overview of the main features of the tools developed as part of the project.

capabilities of the supply technology. Five technologies were included within the model:

1. a medium efficiency gas fired boiler
2. a high efficiency, condensing gas fired boiler
3. a reciprocating gas fired engine based co-generation system
4. an electrically driven ground source heat pump
5. flat plate solar thermal collectors

SEPE an Excel calculation tool for exergy-based optimisations

SEPE, or "Software for Exergy Performance" is a MS-Excel based software that utilises the iteration features of Excel to perform steady-state exergy evaluations and optimisation of different cooling and heating systems. The tool provides insight on the exergy processes at the component level of building supply systems.

Table 2: Summary of tools for exergy analysis in the built environment developed during the Annex 49 project

Tool	Ideal User	Calc Level	Interface	Programming	Availability	Manual	Repository
Annex 49 pre-design tool	Eng/Arch	Building	Excel	BASIC	Public	Yes	Annex 49
Cascadia	Eng/Planer	Community	Excel	BASIC	Public	No	Annex 49
SEPE	Eng	System	Excel	BASIC	Public	Yes	Annex 49
DPV	Arch/Eng	Building	GUI	C#	Private	Yes (DE)	Keoto
Human Body	Eng	Occupant	GUI	FORTRAN	Public		Annex 49
Decision Tree	Owner/Planer	System/Building	Graphical	--	Public	Yes	Swiss BfE

Excel pre-design tool

The concept and structure of the tool are based on the MS-Excel tool developed within the IEA ECBCS Annex 37 (it can be downloaded at www.lowex.org) and represent a further development of that tool. Main newly implemented features are:

- two different energy sources, or energy supply systems for DHW and space heating demands can be combined, e.g. solar thermal collectors and heat pumps, boilers, etc.
- renewable energy flows are accounted for, both in energy and exergy terms, in the generation and primary energy transformation subsystems
- renewable and fossil energy and exergy flows are regarded separately, allowing good traceability of different energy sources in the energy supply chain

Cascadia tool

A MS-Excel based tool for community analysis, called "Cascadia", has been developed. The model implemented in this tool represents the building as a simple thermal load and emphasises more, the form of the energy supply and its distribution network.

For the evaluation process the district energy supply temperature has been selected, based upon the

Design performance viewer

For the first time, a building exergy calculation has been implemented in a Building Information Modeling (BIM) tool. A new energy and exergy tool called the Design Performance Viewer (DPV) has been developed based on the Excel tool developed in the IEA ECBCS Annex 37, and it is currently being expanded in Annex 49. The tool, which is integrated with Autodesk Revit software, allows planners, designers, and architects to obtain an easy-to-understand graphic display of the energetic and exergetic performance of their buildings.

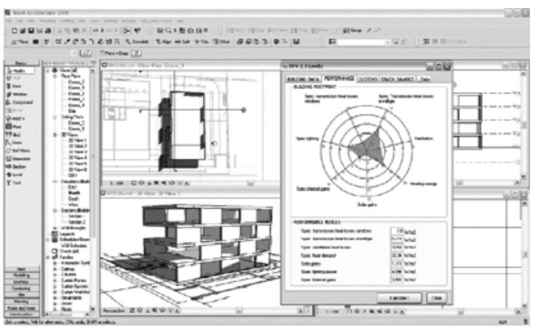

Figure 2: Screenshot from DPV tool with spider graph for comparing the performance of different parts of a building design.

BENCHMARKING FOR COMPONENTS OF BUILDING SYSTEMS AND COMMUNITIES

Including exergy analysis in energy legislation is useful for two reasons: it supports meeting the objective of reducing primary energy consumption, and it supports the design of intelligent energy supply systems based on renewable energy, which will also become important in the future.

The benchmarking proposals from Annex 49 are based on the following parameters:

The exergy expenditure figure is calculated as the ratio between the exergy input (effort) required to supply a given energy demand and the energy demand itself (use). Auxiliary energy for operating the component is also included as input (i.e. effort) in the parameter. Exergy expenditure figures can be used to characterise the performance of components in energy supply systems. This figure can be seen as an enhanced version of the quality factors (exergy to energy ratio), where both the energy and exergy losses in a certain energy conversion unit are depicted

Quality factors are defined as the ratio between the exergy and energy of a given energy system. They indicate the convertibility of an energy flow into mechanical work, i.e. high valued energy with high exergy content. Thereby they characterise and distinguish high exergy sources and demands from low exergy sources and demands. They allow a simple but thermodynamically correct representation of the matching in the quality levels between energy supplied and demanded, and are used for this purpose in the "arrow diagrams" used to depict the performance of community case studies.

Exergy efficiency defined as the ratio between the obtained output and the input required to produce it. Exergy efficiencies help identifying the magnitude and point of exergy destruction within an energy system. Therefore they quantify how well the potential in the energy and exergy inputs to the system are used.

Primary energy ratio (PER) is calculated as the ratio between the useful energy output, i.e. the energy demand to be supplied, and the fossil energy input required for its supply. High PER values indicate that the proportion of fossil energy in the supply is low, thereby meaning that a greater share of renewable energy sources is present in the supply.

Based on the last three parameters two diagrams for depicting the performance of community supply systems have been developed.

Arrow diagrams

The arrow diagram shows the matching between the quality levels of the energy supplied and demanded. The diagram is a qualitative representation of the quality and quantity of energy demands and supply in buildings. Figure 3 shows an arrow diagram as an example.

The position of the arrows on the Y-axis (i.e. "Energy quality, q") represents the quality factor of the energy supplied and demanded and thereby depicts the exergy content of the energy flow. On a scale from zero to one, quality factors for different energy flows are represented.

The thickness of the arrows represents the amount of energy demanded or supplied. In this way, both the quality and quantity of the different regarded energy flows is shown. Thus the matching between the quantity and quality levels of the energy supplied and demanded can be seen.

PER – Exergy efficiency diagram

The (PER)-exergy efficiency diagram characterises the exergy performance and use of renewable energy in the supply of a community. An example of such a diagram can be seen on Figure 7. White dots show both parameters for different supply concepts, characterising the performance of the case study. Dots in the upper right corner indicate good exergy performance and high use of renewable energy sources. Consequently, these supply concepts correspond to "LowEx" community concepts. In turn, dots close to the lower left corner depict case studies with low exergy efficiency and high fossil fuel share on the energy supply.

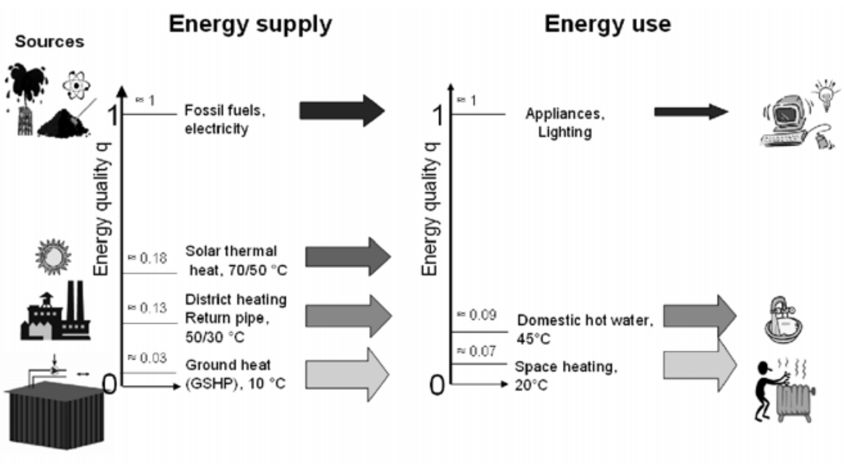

Figure 3: Example of an arrow diagram.

INNOVATIVE BUILDING CASE STUDIES

An overview of the main building components whose performance was analyzed within the research activities of Annex 49.

Exergy recovery from wastewater in small scale integrated systems

Application
- [x] For heating
- [ ] For cooling

State of the art
- [x] Innovative concept
- [x] Prototype
- [ ] Commercially available

In this case study, the recovery of waste energy has a strong influence on the performance of the heat pump, By increasing the source temperature, and consequently the COP, the demand of electricity decreases.

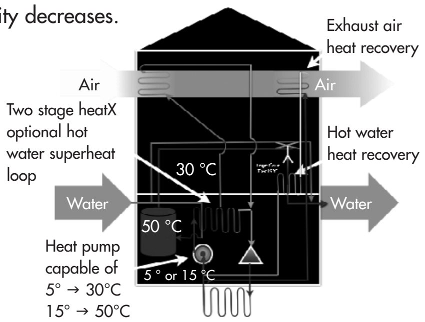

Figure 4: View of the system

Temperature and humidity independent control (THIC) air-conditioning system

Application
- [ ] For heating
- [x] For cooling

State of the art
- [x] Innovative concept
- [x] Prototype
- [ ] Commercially available

This system allows the control of both humidity and temperature by splitting the management of them into two independent systems. Due to the increased temperature for cooling from 7° to 18 °C, much better performances in terms of exergy can be obtained. Referred to an outside reference environment at 25 °C, the exergy content is respectively 6.4% and 2.4% of the produced and delivered heat. Similarly, a chiller ideally working in the same environment would perform almost three times more effectively. Consequently, relevant amounts of exergy can be saved, while still assuring good comfort conditions in the cooled areas

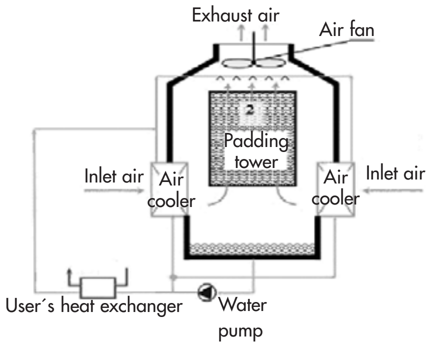

Figure 5: Principle of the chiller

Adjustment of the ventilation rates based on the variation in time of the actual needs

Application
- [x] For heating
- [x] For cooling

State of the art
- [ ] Innovative concept
- [ ] Prototype
- [x] Commercially available

Energy use for air circulation in air unit systems is a relevant part of the overall energy balance. To overcome the pressure drops in air ducts, which implies slight exergy destruction, electricity-driven fans are needed as their exergetic efficiency is very low. This approach limits the electricity consumption for air circulation by making use of the natural pressure differences in the environment that would be otherwise supplied. Furthermore, active systems, such as chillers, can be switched off to maintain IAQ comfort requirements. As a result, in intermediate seasons, it is possible to cut off the electricity consumption, that is exergy, and make use of available environmental sources.

Innovative configuration for cooling purposes: series design for chillers

Application
- [ ] For heating
- [x] For cooling

State of the art
- [x] Innovative concept
- [x] Prototype
- [ ] Commercially available

The industry standard design is to provide a single temperature chilled water supply. Water cooled chillers are normally configured with evaporators in parallel and condensers in parallel. The supply to return temperature differential for both evaporator and condenser water chiller flows is typically between 5.6°C and 6.7°C. The industry large scale chiller plants average approximately 0.267 system kWelectric/kWcooling at 24.2 °C ambient temperature.The improvement potential achievable with an innovative chiller design consisting on a series connection of several chillers is investigated here. Figure 6 shows schematically the conventional design (left) and the innovative configuration proposed here (right). Temperature levels assumed for the performance of both designs are also shown in the diagram. The forecasted electrical energy demand for the chillers is then reduced from the conventional value of 0.267 system kWelectric/kWcooling to 0.135 kWelectric/kWcooling at 24.2°C ambient air temperature. Ideal exergy efficiencies for both configurations amount 8.33 and 12.14 respectively. This represents an improvement of 47%.

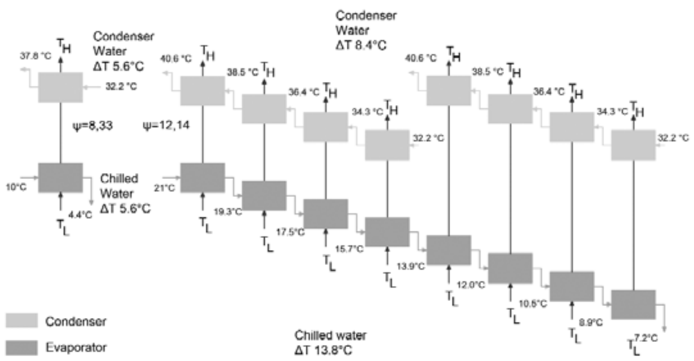

Figure 6: Conventional parallel configuration of chillers for cooling energy supply (left) and innovative series configuration for high efficiency cooling supply (right).

Seasonal heat storage with ground source heat pump system

Application
- [x] For heating
- [x] For cooling

State of the art
- [ ] Innovative concept
- [ ] Prototype
- [x] Commercially available

The main precondition for the exploitation of many renewable sources is the possibility to store energy, due to their inconsistent availability. The exploitation of renewable sources is considered as a low exergy approach. Even though solar radiation has a theoretically great exergy potential, the exergy destruction of the solar radiation would take place anyway, regardless of human exploitation, and its use replaces high-exergy fossil fuels.

Seasonal heat storage has a two-fold positive effect on exergy consumption in buildings: it allows the massive exploitation of solar energy in an efficient way – thus collecting freely available exergy - and it improves the performance of active, electricity-driven systems, such as heat pumps.

INNOVATIVE COMMUNITY CASE STUDIES

Table 3 gives a summary of all community case studies analysed within Annex 49.

In many of the community case studies on the planning phase, the performance of all possible supply options considered at the beginning of the project is analysed. The simple benchmarking diagrams developed within Annex 49 and presented in chapter 5 are used to show, at a glimpse, how suitable the different supply options are. Figure 7 shows, as an example, the PER-exergy efficiency diagram for the case study of Oberzwehren. The great exergy performance of low temperature district heating supply as compared to the other options can be easily seen. Following, this was the supply option chosen for the project.

However, in terms of primary energy the performance of district heating supply could still be improved by using renewable energy fuels to power the CHP units providing waste heat to the district network. This was done for example in the city of Parma. The target was to transform Parma into a renewable city by the year 2050, adopting today's best available technologies. A renewable-fuelled CHP unit was therefore also considered. The improved PER performance of the district heating supply option powered by renewable energy sources can be clearly seen in the PER-exergy efficiency diagram for that case study (see Figure 8).

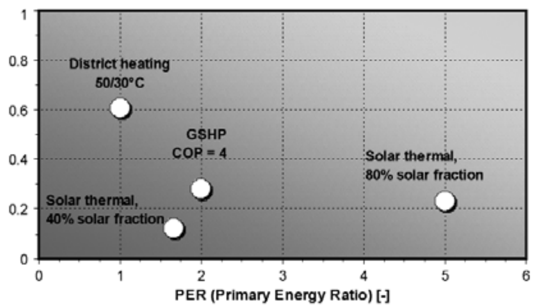

Figure 7: PER ratio vs exergy efficiency diagram for the different energy supply options under consideration for the community of Oberzwerhren,

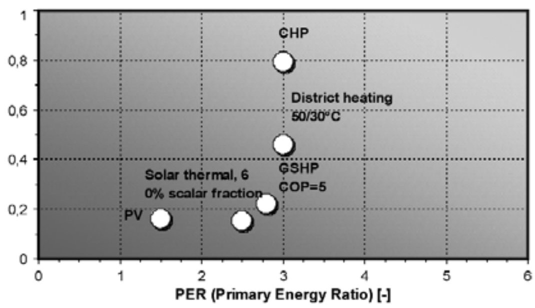

Figure 8: Diagram of exergy efficiency of the systems vs. primary energy ratio [Scenario 2 - Parma 2050].

Table 3: Summary of community cases for exergy analysis in the built environment developed during the Annex 49 project.

community	country	LowEx highlights
Alderney Gate	Canada	Sea water cooling coupled with borehole thermal energy storage
Andermatt	Switzerland	geothermal energy systems
Heerlen	Netherlands	low temperature emission systems, low temperature district heat from old coal mines
Letten	Switzerland	geothermal energy systems
Oberzwehren	Germany	utilisation of a low exergy supply source, i.e. waste heat from CHP
Okotoks	Canada	solar thermal heating systems, coupled with seasonal ground thermal energy storage
Parma	Italy	low temperature heating systems coupled with efficient ventilation systems
Twin cities Minnesota	USA	co-generation and district heating
Ullerød	Denmark	low energy district heating, ground source heat pump (GSHP) and air-to-water heat pump (AWHP)

PUBLICATIONS ANNEX 49

Besides the main Guidebook from Annex 49 presented in this Newsletter, 6 further Newsletter were released biannually. Each newsletter deals in detail with a specific topic on the focus of Annex 49 activities.

Additionally, a mid-term report has also been published. It compiles the main mid-term outcomes of Annex 49 research activities and can be freely downloaded at www.annex49.com.

Another report on the exergy aspects of human body and thermal comfort has also been published within the scope of Annex 49.

On the Annex 49 website we have collected information about Annex 49:
background, activities, members, material, contact and links information on participants, meetings and publications. The website is updated continuously, so the latest information can be found on the website. There you can find:

- Contact information
- Status reports
- Technical presentations
- Annex 49 issues in ECBCS ExCo
- Meetings
- Links to other sites
- Newsletters
- General information

The Annex 49 tools, guidelines, recommendations, best-practice examples, pre-normative proposals and background material developed within the framework of Annex 49 will be oriented and made available to designers, planners and decision makers in the fields of building, energy production and politics.

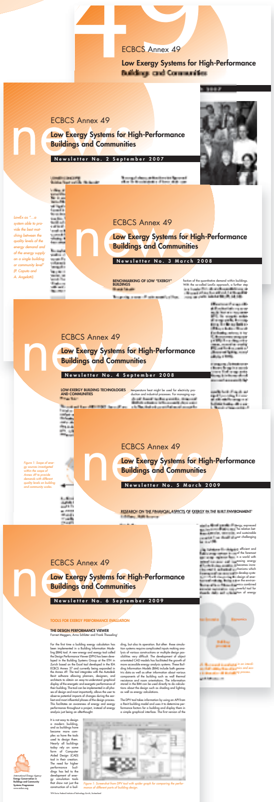

Figure 9: In addition to regular meetings technical reports and conference papers, newsletters were released.

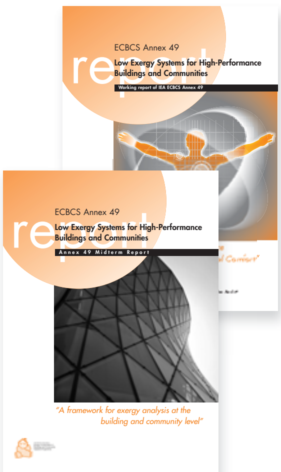

Figure 10: Low Exergy Systems for High-Performanc Buildings and Communites were released in Working Report and Midterm Report.

Figure 11: The annex 49 group at the last meeting in Espoo, Finland, September 2009.

CONFERENCE

The Future for Sustainable Built Environments with High Performance Energy Systems

19th - 21th October 2010
Oskar von Miller Forum
Munich, Germany
www.conference.annex49.com

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.

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.

Annex 49

Low Exergy Systems for High-Performance Buildings and Communities

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ECBCS ANNEX 49

Annex 49 is a task-shared international research project initiated within the framework of the International Energy Agency (IEA) programme on Energy Conservation in Buildings and Community Systems (ECBCS).

Annex 49 is a three year project starting in November 2006, following a preparation phase of one year. 12 countries are participating.

For up-to-date date information see:

www.annex49.com

Announcements

- **The Future for Sustainable Built Environments with High Performance Energy Systems**
  19th - 21th October 2010
  Oskar von Miller Forum
  Munich, Germany
  www.conference.annex49.com

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