NEW COST ACTION PROPOSAL – DRAFT

Netherlands National Cost Coordinator: Mr. Dick Schoorel

This proposal is being prepared by Elisa C. Boelman, TU Delft-NL,
in close collaboration with the experts listed in Annex 2

Analysis and Design of Innovative Systems for Low-EXergy in the Built Environment

COSTeXergy

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ABSTRACT

In buildings, high-grade energy is often used in heating, cooling and ventilation systems to meet low-grade heat demands, resulting in a mismatch between the quality levels of energy supply and end-use**.** Exergy is a thermodynamic concept which is useful for quantifying the mismatch between the low quality of heat required in buildings, and the high quality level of electricity and fossil fuels often used in heat supply systems. Application of exergy analysis to the built environment is likely to favour systems supplying and utilising low-grade thermal energy, and hence to support thermally neutral buildings. Exergy also provides a thermodynamic basis for developing sustainability indicators for construction, considering materials and energy through the entire life cycle of buildings.

This Action addresses demand and supply aspects of the exergy chain in the built environment, including renewable energy supply and human thermal comfort. The main objective is to broadly disseminate new knowledge and practical design-support instruments that can facilitate practical application of the exergy concept to the built environment. In addition to a dissemination plan, the action has three Work Packages, each related to one of the following working objectives:

O1. definition of the practical applicability of exergy analysis to the built environment, particularly in support of wider RES[1] deployment, and increase in the awareness and commitment of industrial players to the exergy concept;

O2. use of insights from exergy analysis to identify and develop innovative concepts and assess their potential to contribute to a substantially more effective energy resource utilisation in the built environment, including a wider RES deployment;

O3. generation of innovative insights into the interaction between human body and indoor environment.

A. The target audience includes researchers, educators and students, industry (manufacturers and service providers), standards bodies, planners and policy makers. Background

Context

Buildings account for ca. 40% of final energy use in the European Union, as of 1997. Energy for heating and cooling purposes amounts to more than 50% of the yearly

[1] RES stands for Renewable Energy Sources

energy demand of buildings in the operational phase. A (gradual) transition to affordable, reliable and clean energy sources in the built environment can significantly contribute to the broader EU objectives of reducing CO_2 emissions, stimulating the deployment of renewable energy, and reducing the dependence on fossil fuels. The need for energy efficiency improvement in the building sector has been addressed in the recently issued European Directive on the Energy Performance of Buildings. While high in terms of energy units, the heating needs of buildings can in principle be met by low-grade heat sources, since the required temperatures are often below 100 ºC. However, high-temperature processes (e.g. fossil fuel combustion) are often used to deliver the low-grade heat required by end-users in buildings. Also, the temperature of heat delivery to indoor spaces (e.g. by radiating panels) is often higher than what would be required in terms of human thermal comfort and the rational use of renewable energy and passive strategies.

Nowadays, energy systems in buildings are designed based solely on the energy conservation principle. However, this principle alone does not provide a full understanding of important aspects of energy use in buildings, e.g. matching the quality levels of energy supply and end-use; describing how the human body experiences temperature differences between indoor air and surfaces (e.g. wall, ceilings, etc.); fully expressing the advantages of using passive (e.g. thermal insulation, window design) and ambient energy (e.g. heat pumps) in buildings. From this viewpoint, exergy analysis is an important link in understanding and designing energy flows in buildings.

The exergy analysis method is well known for optimisation of energy conversion in large industrial and power plants. It is also applied to quantify material flows (e.g. plastics, metals) involved in the manufacturing and recycling of industrial products (e.g. cars). However, it is not popular in the building sector, and needs to be adapted to the needs of the building profession.

Outline of the Exergy concept

Exergy is a thermodynamic concept which enables us to articulate what is consumed by all working systems (e.g. man-made systems like thermo-chemical engines and heat pumps, or biological systems including the human body) when energy and/or materials are transformed for human use. Exergy analysis can give insight into e.g. the

- extent to which the quality levels of energy supply (e.g. high-temperature combustion) and demand (e.g. low-temperature heat) are matched;
- location and magnitude of energy degradation spots, resulting from e.g. heat transfer (temperature drop) or energy conversion (e.g. electricity or solar radiation into low-grade heat);
- environmental impact of producing, reusing and recycling building materials;
- limitations (e.g. maximum thermodynamic efficiencies) and breakthrough needs (e.g. technology substitution) of complex systems.

Recently, pioneering research has also been started on the exergy of the human body, aimed at articulating why low temperature systems are essential for creating a rational and comfortable built environment. These insights can assist a designer, researcher or educator/student in selecting proper technologies (or combinations thereof) most likely to minimise energy resource depletion in a given context.

Exergy analysis also has a potential for stimulating innovation and improving energy and material resource utilisation, but the exergy concept is still often regarded as complex and hard to understand by non-specialists.

Basics of the Exergy concept

The effective use of energy is determined with both the first and second laws of thermodynamics. The first law of thermodynamics states that energy is conserved and cannot be destroyed. The second law of thermodynamics introduces the useful concept of exergy, which is a measure of the quality of energy. Exergy can be destroyed when energy is transferred or converted.

The classical exergy analysis enables to pinpoint the location, to understand the cause, and to establish the true magnitude of waste and loss. Exergy analysis is therefore an important tool for the design of systems since it provides the designer with answers to two important questions of where and why the losses occur. The designer can then proceed forward and work on how to improve the system.

The quality of energy represents its capacity to cause change. The fact that there is an energy quality is evident from our experience in everyday life, as illustrated in Figure 1. It is obvious that 100 kJ of electricity stored in a 12 V and 2.3 Ah car battery is more useful (i.e., easier to transform into something useful) than the same amount of energy stored in 1 kg water at a temperature of 43 °C, if the ambient temperature is 20 °C. The first energy form is good for running a machine (e.g., a computer), or for operating a 40 W light bulb for 42 min or at least for warming 1 kg of water by 23 °C. The energy in the second example is only useful to wash our hands or a few dishes.

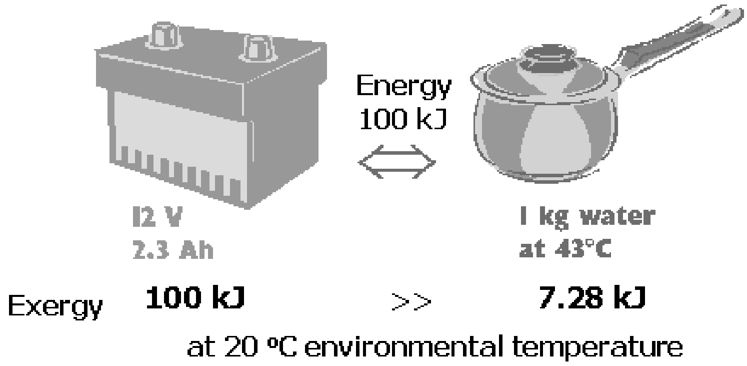

Figure 1 example of high-quality electricity and low-quality heat

A more general thermodynamic statement can be made by modelling this amount of water as a so-called thermal energy reservoir with a uniform temperature distribution. The exergy transfer rate connected with the heat transfer rate can then be calculated by the formula shown in Figure 2.

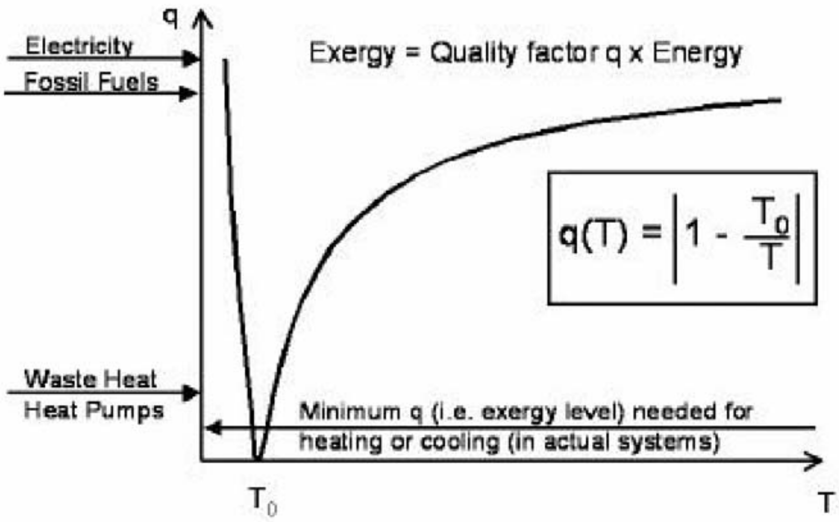

Figure 2 Exergy as a function of temperature

The quality factor (*q*), also known as the exergy factor, gives a quantitative indication of the quality (or exergy) level of the heat contained in the water in the reservoir. The closer the temperature (*T*) of this water is to the ambient temperature (T_0), the smaller its quality factor. In the example of water at 43 °C in a surrounding environment 20 °C (sketched in Figure 1), the quality factor *q* is ca. 0.07. Exergy expressed as the quality factor is useful for quantifying the mismatch between the low quality of heat required in buildings, and the high quality level of electricity (*q*=1) and fossil fuels (*q* ca. 0.98) often used in heat supply systems.

Summary of previous research and state of the art in the area

Different authors have advocated using the exergy concept as a sustainability indicator (Dewulf, 2000-Belgium, Rosen, 2001-USA; Wall, 2001-Sweden) while others have inspired their building designs on exergy (Kristinsson, 1999-Netherlands; Wall, 1998-Sweden). In the field of building research, pioneer work is ongoing in Japan (Shukuya, 1994, 2002-Japan) towards applying the exergy concept to the built environment. His pioneering research was awarded a prize by the Architectural Institute of Japan (2001) and has been recognized by the international community. Prof. Shukuya is the chairman of the LowExNet International Society for Low Exergy Systems in Buildings, and has expressed interest in joining the COSTeXergy Action. The International Energy Agency has also supported an annex on low-exergy systems for heating and cooling of buildings (IEA Annex 37, 2004). This annex was successfully concluded in 2004.

Relevant links and complementarities with EU research programmes

The field of buildings and energy is currently dealt with mainly in programmes managed by DG-TREN: Intelligent Energy Europe – EIE (mainly SAVE and ALTENER) and FP6 (chiefly Concerto). EIE focuses mainly on non-technical barriers for the implementation of energy conservation and renewable energy, including but not limited to buildings. The COST Action has a potential to generate

interest in planners, policy-makers and standards bodies. Such interest could form a basis for preparing a research proposal for EIE or for Concerto.
Furthermore, there is interest in enhancing the ongoing exchange of PhD and post-doctoral researchers among the proposers. A COST Action greatly facilitates the preparation of joint research projects, which could result e.g. in Marie Curie projects.

Why COST

A COST Action provides a wide setting for exergy researchers to interact with building professionals and with wider segments of society (e.g. planners, policy makers, standards bodies). Such interaction, in turn, enhances the possibilities of achieving significant energy savings by applying the exergy concept to the built environment.

B. Objective, Scope and Benefits

Main objective

The main objective of this Action is to broadly disseminate new knowledge and practical design-support instruments that can facilitate practical application of the exergy concept to the built environment.

Scope

In order to achieve this objective, the Action relies on research activities carried out by its members, which focus on investigating and demonstrating how exergy analysis can:

- be used in the development of innovative insights and concepts and;
- support a wider deployment of low-valued heat and other renewable energy sources.

The Action has a strong technical focus – particularly on thermal energy in the built environment, for which there is a larger body of exergy-related knowledge available. With regard to the scale, the Action focuses mainly on the building and building component level.
On the other hand, the Action also acknowledges the importance of considering a broader context. Since it has a future-oriented character, it leaves room for emergent areas such as low-exergy building material cycles. It also leaves room for expanding the scale to the district level, since low-exergy systems for the supply of energy may require a larger scale to be effective. Furthermore, the Action acknowledges the importance of addressing not only technical issues, but also of considering interactions among different actors (e.g. industrial players, building owners, regulators).

Working objectives

The Action focuses on the following working objectives:

O4. definition of the practical applicability of exergy analysis to the built environment, particularly in support of wider RES[2] deployment, and increase in the awareness and commitment of industrial players to the exergy concept;

O5. use of insights from exergy analysis to identify and develop innovative concepts and assess their potential to contribute to a substantially more effective energy

[2] RES stands for Renewable Energy Sources

resource utilisation in the built environment, including a wider deployment of renewable energy sources;

O6. generation of innovative insights into the interaction between human body and indoor environment.

Benefits for end-users

The transition to affordable, reliable and clean energy sources in the built environment is expected to benefit from innovative systems integrating different aspects such as supply and demand, diverse technical components and other sectors (e.g. urban planning, transportation). On the building level, the transition is expected to benefit from thermally neutral[3] buildings using mainly electricity from renewable sources.

Application of exergy analysis to the built environment is expected to support thermally neutral buildings, in that it is likely to favour systems supplying and utilising low-grade thermal energy (e.g. from heat pumps, waste-heat and solar boilers, depending on end-use requirements). This is in line with the broader EU objectives (www.managenergy.net/indexes/I372.htm) of encouraging:

- greater use of RES in a wide range of building types as well as in district heating and cooling schemes;
- greater share of heat to be produced from RES;
- exploitation of geothermal heat sources via heat pump technologies.

In additional to its relevance to energy technology, Exergy is also of potential interest as an environmental performance indicator concerning other aspects of eco-buildings. For example, exergy provides a thermodynamic basis for developing sustainability indicators for construction, considering materials and energy through the entire life cycle of buildings. This approach has a potential to minimise the environmental impact of producing, reusing and recycling building materials.

European added value

The main European added values include:

- exchange and training of European researchers and practitioners on energy and eco-buildings;
- input of results to CEN working groups for preparing standards and;
- contribution to the Energy Performance of Buildings Directive.

C. Scientific programme

The work plan consists of three work packages (WP), in line with the corresponding workingobjectives mentioned in item B. This item outlines the WPs in relation to the objectives, highlights the new knowledge relative to state-of-art, and describes the WPs in terms of tasks and expected results.

Work plan outline in relation to objectives

The three working objectives outlined in item B are reflected in three work packages (WP 1 to 3).

[3] Thermally neutral buildings are buildings with a neutral thermal balance relative to their environment, averaged over one year. Thermal neutrality can be achieved by reducing the thermal demand (e.g. by better thermal insulation, ventilation with heat recovery), but also by seasonal heat storage.

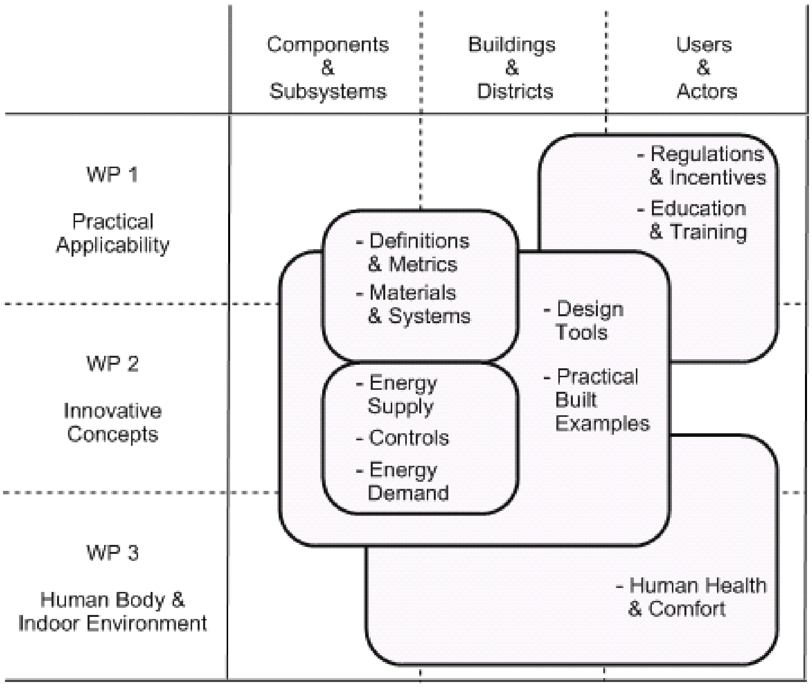

Figure 3 Contextual framework.

Figure 3 provides a contextual framework for the scientific programme. Each work package (WP) is shown as a row in the figure. The columns correspond to targeted and potentially targeted systems, and the round-edged boxes indicate the main themes covered by the Action. While most themes are chiefly related to one WP and/or system, there are also significant overlaps. Hence, the Action organisation structure foresees interaction among WPs, asoutlined in item D, Figure 4.

New knowledge and innovation relative to state-of-the-art

One important novelty of this Action is the broad exergy-based approach to heating and cooling systems in the built environment. The Action addresses a wide spectrum of the exergy chain in the built environment, including demand as well as supply aspects. It includes renewable energy supply on the one side of the spectrum and human thermal comfort on the other side.

The emerging field of human exergy demand for thermal comfort can help generate new insights into the interaction between human body, building envelope and building services. So far, little is known about this interaction in terms of exergy. If the quality levels of energy supplied to buildings can be matched to exergy requirements for human comfort, a significant potential for energy savings may emerge. On the supply side of the spectrum, exergy analysis has a potential to clearly quantify the advantages of using renewable energy sources in buildings, particularly for applications requiring low-grade energy (e.g. low temperature heating and ground free cooling). Because exergy lends itself well to quantifying and comparing energy flows across different carriers and quality levels, it is well suited for overall analyses integrating demand and supply. Furthermore, the emerging field of exergy analysis applied to building materials allows this analysis to be extended one step further, by including insights into the exergy content of materials as well.

This action contributes to innovation[4] by investigating and demonstrating how exergy analysis can be used to develop novel insights and concepts relevant to eco-buildings, and to support a wider deployment of low-valued heat and other renewable energy sources in the built environment.

Contents of the work packages

Work packages 1 to 3 are described below, each consisting of several tasks to be allocated during the technical annex preparation. Essentially, the tasks and expected results reflect the research activities carried out by the participants. The dissemination plan is described in item G.

WP1. definition of the practical applicability of exergy analysis to the built environment, particularly in support of wider RES deployment, and increase of industrial players' awareness and commitment to the exergy concept.

Tasks

- critical analysis of exergy-related definitions and metrics, in order to understand the possibilities and limitations of applying them to conditions in the built environment[5];
- generation of ideas for pre-normative work, including technical issues and actor-related factors;
- assessment of the viability of using exergy as an environmental performance indicator for building materials[6], (including the development of exergy-based sustainability indicators);
- demonstration of possibilities for applying the exergy concept in support of a wider deployment of renewable energy sources in the built environment;
- facilitation of exergy analysis application to the integrated design of buildings and building services (e.g. exergy analysis tools, education and training of building design professionals);
- education of the general public (e.g. industry, service providers, building owners) about exergy analysis and low-exergy systems.

Expected results

- definitions of exergy-based metrics applicable to the built environment (e.g. exergy consumption, exergy efficiency, reference conditions); quantification of savings potential by means of combined exergy/energy analysis.
- exergy-based case-studies, benchmarked against similar studies based on the EPBD[7] and on national codes, for use in support of pre-normative work; recommendations for implementing the exergy concept into the new German building energy performance calculation method (DIN 18599).
- exergy-based sustainability indicators for construction, considering materials and energy through the entire life cycle of dwellings; this includes quantification by exergy analysis of the impact of sustainable construction methods, application of the developed exergy indicators to case-studies and guidelines for sustainability assessment of building materials.

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[4] For the purposes of this Action, a concise working definition of innovation is: "*the renewal and enlargement of the range of products and services and associated markets (…)*" (COM (1995) 688).

[5] Exergy-related definitions and metrics often have their origin in other disciplines, e.g. mechanical and chemical engineering.

[6] Exergy analysis for material cycles is an emerging field. One application has been in studies on metal recycling for the automobile industry.

[7] EPBD stands for the EU Energy Performance of Buildings Directive

- office and residential buildings running with TABS[8], ground source heat pumps and ground free cooling; exergy analysis results for buildings using ambient heat sources (e.g. ground source heat pumps, solar collectors) and ground free cooling.
- simplified software-based exergy/energy analysis tool for use in the design of buildings and their associated energy supply systems; review paper from Japan on the use of RES from the exergetic viewpoint, targeted at architects and building engineers; exergy courses targeted at graduate students and building professionals;

WP2. use of insights from exergy analysis to identify and develop innovative concepts and assess their potential to substantially contribute to more effective energy resource utilisation in the built environment, including a wider deployment of renewable energy sources.

Tasks

- identification and dissemination of buildings within the European Community that can serve as low-exergy building examples (also related to WP1)
- identification and assessment of low-exergy cooling systems (also related to WP1 and WP3);
- assessment of the utilisation potential of renewables and near-ambient heat and cold, in buildings as well as in district heating and cooling systems;
- development of low-exergy concepts for energy supply to buildings, including the integration of renewable energy sources;
- design and development of building and HVAC[9] components in cooperation with industrial partners;
- development of innovative control strategies for HVAC systems (also related to WP3).

Expected results

- guidelines for the identification of exergy analysis needs for new concepts and for the selection of exergy analysis tools.
- technical paper from Japan on the radiant-exergy evaluation method for indoor thermal environment in relation to human thermal comfort, particularly under hot and humid summer conditions.
- prefabricated deck systems with integrated low exergy and natural cooling, including technical performance demonstration.
- presentation of a method for implementing second-law thermodynamic analysis into a cogeneration (district heating) plant, including calculation examples on interactions between plant, buildings and occupants.
- exergy analysis of heating and ventilation systems based on dynamic simulations.
- development and analysis of new heat storage systems with phase change materials
- measurements of low temperature difference heat exchangers (capillary tubes)
- recommendations on technical and environmental issues (including possible side effects) to be considered in low exergy solutions.

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[8] TABS stands for Thermally Active Building Systems
[9] HVAC stands for Heating, Ventilation and Air Conditioning.

- thermodynamic insights on the significance of new concepts on a system level.

WP3. generation of innovative insights into the interaction between human body and indoor environment.

Tasks

- generation of new insights on the relationship between human productivity, comfort and health;
- use of exergy analysis on human thermoregulation;
- generation of new insights on comfort effects of temperature drift in buildings, and on how temperature drift may benefit the use of low exergy systems;
- evaluation of heating, ventilation & cooling systems and components concerning the achievement of thermal comfort in buildings;
- assessment of low-exergy ventilation concepts integrating natural ventilation and low-exergy sources of energy, including renewables (also related to WP2).

Expected results

- review paper on the human thermal exergy balance model developed in Japan.
- diagrams showing the relation between comfort (temperature and air quality) and the performance of people.
- guidelines for including human adaptability in indoor environment design, considering existing comfort criteria and exergy analysis of the human heat balance; model for adaptive comfort in Italian climate conditions.
- recommended design criteria for dynamic temperature conditions in buildings;
- analysis results concerning exergy and entropy generation by humans in buildings, leading to new thermodynamic insights into what is behind thermal comfort criteria.
- insight into comfort and environmental aspects of low exergy systems; guidelines for the applicability of different HVAC strategies related to human comfort goals.

WP4. dissemination;
Dissemination is to be carried out within each WP. The dissemination WP will provide a common framework for facilitating communication and diffusion, and for avoiding work duplication. Details of this framework are presented below in item G, Dissemination plan.

D. Organisation

Relationship between work packages

Figure 4 outlines the basic structure of the Action and its Working Groups (WG). The working groups correspond to the work packages (WP) outlined in item C.

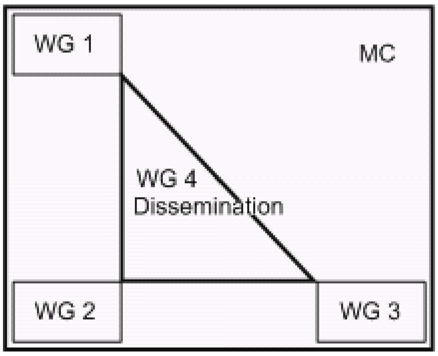

Figure 4 Basic organisational structure

WG2 is concerned with the most tangible aspects of the Action, namely the assessment, design and development of concrete technologies with a foreseeable application potential.WG 2 receives insight on fundamental issues from WG 1 and WG 3, and in return provides them with feedback on how to integrate these insights into the development of tangible components and systems.

WG1 is concerned with the feasibility of applying exergy to the built environment. Its fundamental part is concerned with exergy metrics and analysis tools, while its practical part is concerned with evaluating and enhancing the application potential of exergy analysis to the built environment.

WG3 explores aspects related to the emerging field of exergy and the human body, and has a mainly fundamental character.

Dissemination activities are to take place within each working group, facilitated by a common framework provided by WG 4.

Joint activities with other COST actions

The (proposed) coordinators of "Sustainability of Constructions", "COSTeXergy" and C23 have contacted each other in order to reach agreement on possible means for coordinating the cooperation of complementary activities, avoiding overlaps and fostering synergies.

- Information exchange and possible synergies development will be promoted through regular communication between the leadership of these actions, via e-mail and telephone.
- Depending on budget availability, personal exchanges will also be stimulated.
- The dates of public activities will be informed to representatives of other COST Actions, who will be offered the opportunity to attend. The possibility of organising one joint cross-cutting event among different Actions may also be explored.

E. Timetable

Total duration

The Action will last for four years.

Interim milestones

The Action will consist of internal and public activities, to be carried out as outlined in Table 1. Public activities will consist of two plenary meetings (in the second and fourth years) as well as workshops and PhD meetings in the framework of international conferences. These workshops and PhD meetings will be smaller and more specialised than the plenary meetings. The working groups and PhD researchers will be encouraged to contact the organisers of international conferences relevant to

their specific activities in order to arrange these events. Budget availability will determine to what extent travel and accommodation costs will be covered by the Action or by the participants themselves. If necessary, the management committee will give practical advice on planning and organisation.
Internal activities will consist of management committee (MC) meetings, to be carried out twice a year, and working group (WG) meetings. WG meetings will take place once or twice a year, depending on budget availability.
The once-a-year, mandatory schedule of internal meetings is indicated by a darker shade of grey in Table 1. The lighter shades of grey are used in the Table to indicate low-budget, self-organised events that will be stimulated but not mandatory. In particular, PhD researchers will be encouraged to organise their own networking events in the context of international conferences.

Table 1 Overall timetable for the COSTeXergy action

	public or internal		year 1		year 2		year 3		year 4	
Conference workshops	P									
Plenary meetings	P									
PhD meetings	P									
early timetable definition	MC									
WG meetings	I									
MC meetings	I									

mandatory WG and MC meetings
plenary meetings
meetings combined with conference workshops

F. Economic dimension

The following COST countries have actively participated in the preparation of the Action or otherwise indicated their interest: Belgium, Denmark, Finland, Germany, Greece, Hungary, Italy, Netherlands, Norway, Poland, Slovenia, Sweden, Switzerland, United Kingdom.
On the basis of national estimates provided by the representatives of these countries, the economic dimension of the activities to be carried out under the Action has been estimated, in 2006 prices, at roughly Euro 4.5 million.
This estimate is valid under the assumption that all the countries mentioned above but no other countries will participate in the Action. Any departure from this will change the total cost accordingly.

G. Dissemination plan

This item presents a detailed development of the Dissemination Work Package (WP4) outlined in item C.

Target audience

The target audience includes: other researchers working on exergy in the built environment; other researchers working on exergy in other disciplines (e.g. mechanical engineering, chemistry, sustainable product design); research institutes and academia; industry represented by manufacturers and service providers: (building

designers including architects as well as building-services and building-physics consultants).
The COST framework helps to enhance visibility among planners, policy makers and standards bodies.

Website and E-mail network

The COSTeXergy Action will have its own website. E-mail networks from participants (e.g. conferences, professional associations) and public bodies (e.g. managenergy) will also be used for dissemination.

Publications

The intended participants publish in specialised conferences, journals and through other research networks (e.g. IEA). A COST action provides a good forum for joint technical publications, and for targeting a broader audience with non-technical publications. Depending on budget availability, possible publications may include books (scientific, technical and/or for the general public) and workshop proceedings.

Events

Several participants are experienced in organising workshops and international conferences related to sustainable buildings and energy. Public events of COSTeXergy will focus on (one-day) workshops in the framework of relevant international conferences. Depending on budget availability, specific events may also be organised, e.g.: training sessions for researchers and professionals (e.g. from New Member States) in the framework of “energy efficiency in buildings”; presentation sessions for CEN working groups; specialised meetings on specific subjects (e.g. EPBD and other directives). . The targeted audience will include standards bodies, planners and policy makers, in addition to industry, research and education bodies.

Short-Term Scientific Missions

Depending on budget availability, short-term scientific missions will focus on exchanges of PhD researchers and may include other collaborative activities such as joint seminars on exergy/energy analysis, brainstorm meetings on innovative concepts, information exchange on practical issues.

Education

Participants working at universities have the opportunity to integrate results from exergy research into their teaching curricula. For example, at the Delft University exergy lectures have been introduced in graduate courses on built environment and renewable energy.
A network of PhD researchers will also be set up within the framework of the proposed action. This PhD exchange has an educational dimension and contributes to dissemination, including spin-off effects in the longer-term.
Increasing the awareness and commitment of industrial players to the exergy concept is also an important objective of this action (working objective O1). Educational activities will also be targeted at educating the general public about exergy analysis and low-exergy systems (WP1).

Annexes

1. History of proposal

So far, ca. 30 individuals from 14 COST member states plus Japan have expressed interest in joining the action. These individuals originate from various networks, including LowExNet, COST (C12 meeting in Innsbruck, January 2005), the IEA Future Building Forum (meeting in Padova, April 2005) and international conference networks. LowExNet is the International Society for Low Exergy Systems in Buildings (www.LowEx.net), set up in 2003 by members of IEA Annex 37 in order to maintain and expand the collaboration developed during work in the Annex. The LowExNet group is expanding and now has members from 10 European countries. Its members organise Exergy workshops, write joint papers and exchange researchers. Representatives from industry (manufacturers) and service providers (architects, technical consultants) attend and contribute to the workshops. The initiative to propose the COSTeXergy Action was taken by a board member of LowExNet in January 2005, during a visit to the final meeting of the C12 action in Innsbruck.

Relationship to other COST actions and to IEA Annex 37

This Action is related to two proposed COST Actions: “Sustainability of constructions” (Cxx, proposed) and “Sustainable strategies for the urban built environment” (C23 Strategies for a Low Carbon Built Environment).
The first Action (Cxx) has a broader focus on sustainability in the built environment; it has possible synergies with COSTeXergy mainly regarding energy-saving, health & comfort, and energy performance).
The Action C23 has a strong emphasis on CO_2 emissions and non-technical aspects (e.g. regulations, costs). Information exchange is of interest with a view to possible complementarities, chiefly regarding the socio-economic and urban dimensions.
The COSTeXergy Action has a more technical focus and a stronger medium-term orientation. Exergy is concerned chiefly with minimizing resource depletion, and has already been used in other fields (e.g. chemical and power plants, car recycling). The COSTeXergy focuses on the emerging field of exergy in the built environment.

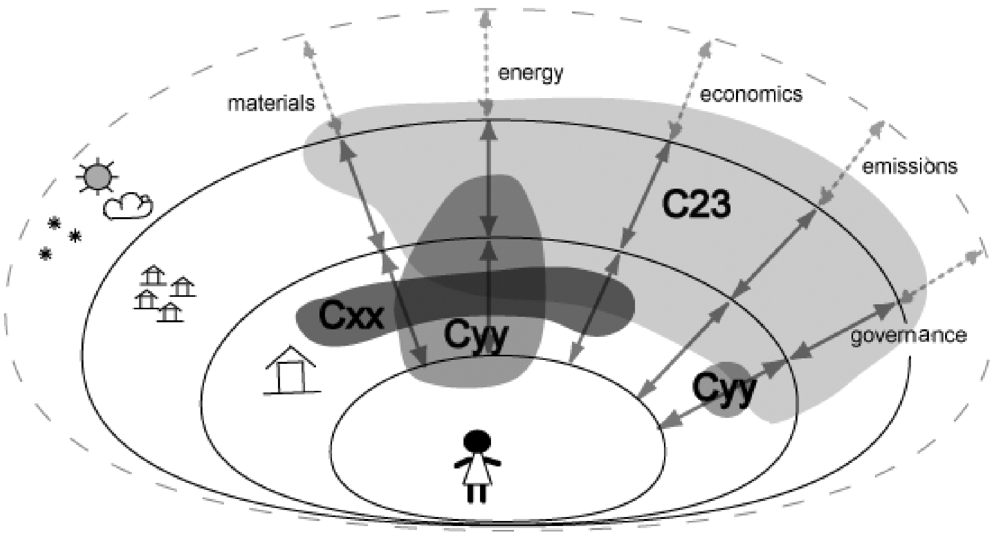

Figure 5 COSTeXergy (Cyy) positioning relative to ‘building sustainability’ (Cxx) and ‘urban built environment’ (C23).

Figure 5 illustrates the relationship between COSTeXergy (Cyy) and two other related actions. In this figure, the three actions are positioned in terms of scale (human, building, district) and domain (materials, energy, economics, emissions and governance). Both Cyy (COSTeXergy) and Cxx (sustainability) focus more on technical issues (energy, materials), but Cxx also includes economic aspects and Cyy has a small pre-normative work component that is likely to have governance implications. Cxx has a strong focus on the building scale, while Cyy also extends to the human body and district levels. In contrast, C23 has a stronger focus on non-technical issues (economics, emissions, governance) and targets mainly the urban scale. Energy is a common denominator to all three actions, albeit from different perspectives and on different scales. Figure 6 indicates the positioning of COSTeXergy (Cyy) relative to IEA Annex 37 (IEA 37). Annex 37 focused technical and user-acceptance aspects of low-temperature heating systems. COSTeXergy stretches beyond heating and cooling, to include renewable energy supply on the one side of the spectrum and human thermal comfort on the other hand. The added value of COSTeXergy has been explained in item C under the heading "new knowledge and innovation relative to state-of-the-art".

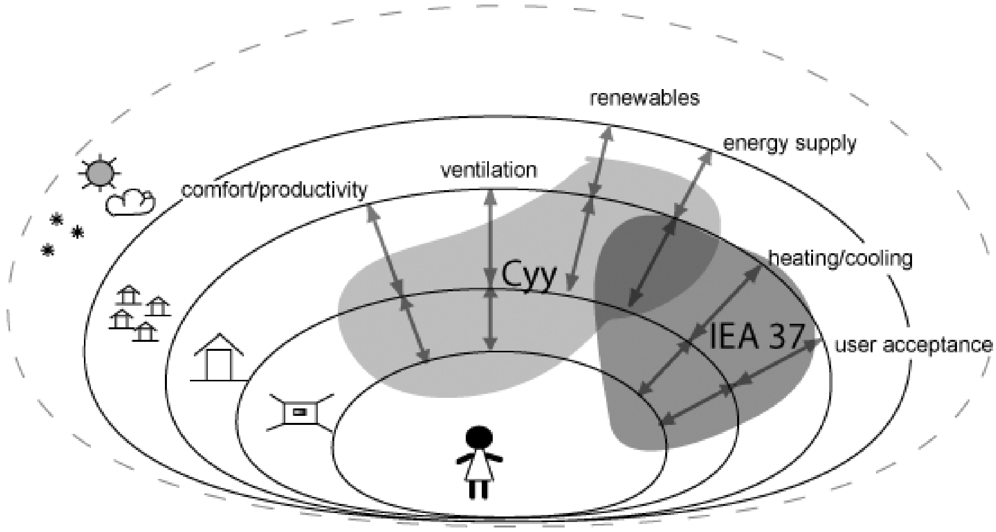

Figure 6 COSTeXergy (Cyy) positioning relative to IEA Annex 37

2. List of interested countries and experts

As of 1 December 2005, 29 persons from 14 COST countries plus Japan have expressed interest in joining the action (Table 2). Four other persons have relevant expertise but have not yet been contacted (Table 3). Table 4 provides an overview of the number of participants per country

Table 2 Interested experts who have already expressed interest

Interested individuals are listed in alphabetical order of first name.

Name	**Institute**	**Country**	**E-mail**
Adam Rybka	Rzeszow University of Technology	PL	akbyr@prz.rzeszow.pl
Adriana Angelotti	Politecnico di Milano	IT	adriana.angelotti@polimi.it
Aleš Krainer	University of Ljubljana	SI	akrainer@kske.fgg.uni-lj.si
András Zöld	Technical University Budapest	HU	zold@egt.bme.hu
Bjarne W. Olesen	Technical University of Denmark (DTU)	DK	bwo@mek.dtu.dk
Bernd Döring	RWTH Aachen University	DE	bdo@stb.rwth-aachen.de
Christopher Koroneos	University of Western Macedonia / Aristotle University	GR	koroneos@aix.meng.auth.gr
Dietrich Schmidt	Fraunhofer Institute for Building Physics	DE	dschmidt@uni-kassel.de
Dirk Müller	Technical University of Berlin TUB	DE	dirk.mueller@tu-berlin.de
Elisa Boelman	Delft University of Technology	NL	cost.exergy@bk.tudelft.nl
Fabio Peron	IUAV University of Venice	IT	fperon@iuav.it
Giulio Solaini	Politecnico di Milano	IT	giulio.solaini@polimi.it

Gudni Jóhannesson	KTH, The Royal Institute of Technology	SE	Gudni.Johannesson@byv.kth.se
Hansjürg Leibundgut	Amstein+Walthert	CH	hansjuerg.leibundgut@amstein-walthert.ch
Jo Dewulf	Ghent University, Faculty of Bioscience Engineering	BE	jo.dewulf@ugent.be
Lars Kühl	TU Braunschweig	DE	kuehl@igs.bau.tu-bs.de
Markku Lampinen	Helsinki University of Technology	FI	markku.lampinen@hut.fi
Markku Virtanen	The Finnish Development Center For Building Services LTD (on leave from VTT)	FI	markku.virtanen@take-finland.com
Markus Kuhnhenne	RWTH Aachen University	DE	mku@stb.rwth-aachen.de
Martin Erlandsson	Swedish Environmental Research Institute	SE	martin.erlandsson@ivl.se
Masanori Shukuya	Musashi Institute of Technology	JP	shukuya@yc.musashi-tech.ac.jp
Michele DeCarli	University of Padua	IT	michele.decarli@unipd.it
Paul Ramsak	SenterNovem Netherlands Agency for Innovation and sustainability	NL	p.ramsak@senternovem.nl
Per Gundersen	Norwegian Building Research Institute	NO	per.gundersen@byggforsk.no]
René Wansdronk	Wansdronk Architects	NL	rw@wansdronk.com
Roberto Zecchin	University of Padua	IT	roberto.zecchin@unipd.it
Sebastian Herkel	Fraunhofer Institute for Solar Energy Systems	DE	sebastian.herkel@ise.fraunhofer.de
Simos Yannas	Architectural Association Graduate School	UK	simos@aaschool.ac.uk
Wolfram Trinius	Ingenieurbüro Trinius	DE	contact@trinius.de

Table 3 Experts who have not yet been contacted

Andy van der Dobbelsteen	Delft University of Technology	NL	
Christoph Maria Ravesloot	ChristophMaria@Ravesloot.nl	NL	
Laure Itard	Delft University of Technology	NL	
Wouter van Marken Lichtenbelt	W.v.Marken.Lichtenbelt@tue.nl	NL	

Table 4 Number of participants per country

Countries	BE	CH	DE	DK	FI	GR	HU	IT	JP	NL	NO	PL	SE	SI	UK
Participants	1	1	7	1	2	1	1	5	1*~3	3*~6	1	1	2	1	1

* the asterisks indicate the number of persons who have already expressed interest

3. Recent publications

Books, research reports and doctoral dissertations

Authors	Title	Type	Publisher	Year	Reference	Country	Language
Shukuya, M., ed.	Theory on exergy and environment	Book		2004	00160-8-27052	JP	Japanese
Ala-Juusela, M.; Schmidt, D. et. al	Heating and Cooling with Focus on Increased Energy Efficiency and Improved Comfort. Guidebook to IEA ECBCS Annex 37	Summary report + CD+website	VTT Building and Transport	2004	VTT Research notes 2256	FI	English
Schmidt, D.	Methodology for the Modelling of Thermally Activated Building Components in Low Exergy Design	Doctoral dissertation	KTH	2004	ISRN KTH-BYT/R-04/194-SE	SE	English
Kühl, L.	Heat supply systems for buildings in optimised low energy standard	Doctoral dissertation	TU Braunschweig	2004		DE	German
Pelczynski, J. Supervised by Rybka, A.	The influence of materials and spatial solutions on energy saving of a building	Doctoral dissertation	Rzeszów University of Technology	2004		PL	
Angelotti A.	Summer cooling by thermal coupling with the ground	Doctoral dissertation	Politecnico di Milano	2004		IT	English
Gundersen. P.	Energy flexible, low temperature heating systems.	Report	Norwegian Building Research Institute	2002	NBI report 317	N	Norwegian
De Carli M.	New Technologies in radiant heating and cooling	Doctoral dissertation	University of Padua	2001		IT	English
Döring, B.	Use of renewable energies in public buildings of Northrhine-Westphalia	Book	Landesinsitut für Bauwesen, Aachen	1997	ISBN 3-930860-51	DE	German

Journal, conference and course publications

Authors	Title	Journal, conference or course	Volume, Number	Pages	Year	Location	Conference or course date
Dewulf, J.;Van Langenhove, H.	Integrating industrial ecology principles into a set of environmental sustainability indicators for technology assessment	Resources, Conservation and Recycling	In Press		2005		
Gundersen, P., Peter.G.Schild.	Low exergy ceiling heating/cooling systems for future buildings	7th Nordic Symposium on Building Physics		506-513	2005	Iceland	June 14-15
Sakulpipatsin, P.; Boelman, E.;	Exergy analysis tool for building and	Sustainable Building			2005	Tokyo, JP	Sep.27-29

Schmidt, D.	building services design	Conference					
Asada,H.; Boelman, E.	Exergy analysis of a low temperature heating system	Building Services Engineering Research and Technology, CIBSE[11]	Vol.25, No.3	197-210	2004	--	--
Boelman, E.; Sakulpipatsin, P.	Critical analysis of exergy efficiency definitions applicable to buildings and building services	Plea2004 - The 21st Conference on Passive and Low Energy Architecture			2004	NL	Sep.19-22
Dewulf, J.;Van Langenhove, H.	Thermodynamic optimization of the life cycle of plastics by exergy analysis	International Journal of Energy Research	28	969–976	2004		
Angelotti, A.; Pagliano, L.; Solaini, G.	Summer cooling by earth-to-water heat exchangers: experimental results and optimisation by dynamic simulation	EuroSun2004	2	678-686	2004	Freiburg, DE	June 20-23
Döring, B., Sedlacek, G.	Improvement of thermal comfort in light weight buildings made of steel with new concepts for slab systems	Nordic Steel Construction Conference 2004		35-44	2004	Copenhagen, DK	Jun. 7-9
Döring, B., et al.	Thermally activation of prefabricated slab elements	HLH	V. 55, No. 3	29-35	2004	DE	
Kuhnhenne, M., Sedlacek, G.	Improved Energy performance of Buildings using steel elements	Nordic Steel Construction Conference 2004		625-636	2004	Copenhagen, DK	Jun. 7-9
Olesen, B.W., Dossi, F.C.	Operation and Control of Activated Slab Heating and Cooling Systems,	CIB World Building Congress 2004			May 2004	Toronto	
Plesser, S.; Bremer, C.; Fisch, M. N.	EVA – Research Project for Evaluation of Energy Concepts for Office Buildings (in German)	Intelligente Architektur	Heft 01-102	52-55	2004	--	--
Rybka A.; Drozd B.	Architectural shaping of detached house using the sun energy source	Rzeszow University of Technology Scientific Notebooks	208	36	2004	--	--
Rybka A.	Rules of thermal protection in architectural design of multi family houses	Rzeszow University of Technology Scientific notebooks	211	37	2004		
Ziller, C., Döring, B.	Double facades – From experimental model to custom-made suit	TAB	No. 12	58-63	2004	DE	
Schmidt, D.; Ala-Juusela, Mia	Low Exergy Systems for heating and Cooling of Buildings	Plea2004 - The 21st Conference on Passive and Low Energy Architecture			2004	NL	Sep.19-22
Schmidt, D.; Jóhannesson, G	Optimized RC Networks Incorporated Within Macro Elements for Modeling Thermally Activated Building Constructions	Nordic Journal of Building Physics, submitted			2004	--	--
Schmidt, D.:	Design of Low Exergy Buildings –	The International Journal	Vol 3	1-47	2004	--	--

[11] CIBSE stands for Chartered Institute of Building Services Engineers

	Method and a Pre-Design Tool	of Low Energy and Sustainable Building					
Brunello, P., De Carli, M., Tonon, M., Zecchin, R.	Applications of heating and cooling thermal slabs for different buildings and climate	ASHRAE Annual meeting			2003	Kansas City, USA	July 2003
Currò Dossi, F., De Carli, M., Del Bianco, R., Fellin, F., Tonon, M., Zecchin, R.	A pilot project for a low energy building equipped with thermal slabs, heat pump and ground heat storage	Building Simulation	Vol. 1	275-282	2003	Eindhoven, NL	August August 2003
Aste, N.; Beccali, M.; Solaini, G.	Experimental validation of a simulation model for a pv/th collector	ISES Solar World Congress 2003		paper n. 3-20	2003	Goteborg, SE	June 14-19
Dewulf, J.;Van Langenhove, H.	Exergetic Material Input Per unit of Service (EMIPS) for the assessment of resource productivity of transport commodities	Resources, Conservation and Recycling	38	161-174	2003	--	--
Olesen, B. W., Koschenz, M., Johansson, C.	New European Standard Proposal for Design and Dimensioning of Embedded Radiant Surface heating and Cooling Systems.	ASHRAE Transactions, Volume 109, Part 2, 2003.			2003		
Schmidt, D.; Shukuya, M.	New ways towards increased efficiency in the utilization of energy flows in buildings	Second Building Physics Conference		671-681	2003	Leuven, Belgium	Sept. 14-18
Boelman, E.; Asada,H.	Refrigerated facilities	Energy Efficiency and the Quality of Energy in the Food Processing Industry	I	41-56	2002	NL	Nov.
Beccali, M.; Siciliano, A.; Solaini, G.	A method for the experimental comparison of two heating and cooling radiant systems in different climatic conditions	Sustainable Building 2002		paper n. 195	2002	Oslo, NO	Sept. 23-25
De Carli, M., Olesen B. W.	Field Measurements of Operative Temperature in Buildings Heated or Cooled by Embedded Hydronic Radiant Systems	ASHRAE Transactions	Vol. 108, Part 2	714-725	2002	Honolulu, USA	June 2002
Kühl, L, Schröter, A.; Fisch, M. N.; Krause, T.; Wendker, K.	Solar heating in practical use – Monitoring results of the advanced solar combisystem “SolvisMax” (in German)	12. OTTI conference on thermal use of solar energy			2002	Bad Staffelstein, DE	Apr.24-26
Platell, P; Schmidt, D.; Johannesson, G.	Geoexchange & LowExergy Buildings	9th International Conference on Indoor Air Quality and Climate	IV	307-312	2002	Monterey, USA	Jun.30-Jul.5
Rybka A.; Pelczynski J	Simulation engineering in low-energy building design	Current Scientific-Research Issues of Civil Engineering			2002	--	--
Schmidt, D.; Shukuya, M.	New ways towards increased efficiency in the utilization of energy flows in buildings	9th International Conference on Indoor Air Quality and Climate	IV	307-312	2002	Monterey, USA	Jun.30-Jul.5
Jóhannesson, G.; Schmidt, D.	Energy or exergy – a matter of quality	Research for Sustainability	V.3, No.4	8-9	2001	--	--
Olesen, B. W., de Carli, M	Field measurements of thermal	Clima 2000/ World			September	Napoli, IT	

	comfort conditions in buildings with radiant surface cooling systems".	Congress			2001.		
Schmidt, D.; Jóhannesson, G.	Model for the Thermal Performance of Double Air Gap Wall Constructions	Nordic Journal of Building Physics	Vol. 2	59-78	2001	--	--
Dewulf, J; Van Langenhove, H; Mulder, J.; van den Berg, M.M.D.; van der Kooi, H; de Swaan Arons, J.	Illustrations towards quantifying the sustainability of technology	Green Chemistry	2	108-114	2000	--	--
Rybka A.; Pelczynski J	Energy simulations in design of energy-saving buildings	Current Scientific-Research Issues of Civil Engineering			2000	--	--
Weber, T.; Schmidt, D.; Jóhannesson, G.	Concrete Core Cooling and Heating – A Case Study about Exergy Analysis on Building Components	International Building Physics Conference	--	91-98	2000	Eindhoven, NL	Sep.18-21
Beccali, M.; Ferrari, S.; Solaini, G.	Mapping the "energy rehabilitation demand" of buildings as a tool for urban scale stategies. The case of Palermo (Italy)	PLEA 2000			2000	Cambridge, UK	July 2-5
Olesen, B. W	Possibilities and Limitations of Radiant Floor Cooling".	ASHRAE Transactions	V. 103, Pt. 1		February 1997		
Zold, A. and S. Szokolay	Thermal Insulation	PLEA International / University of Queensland	PLEA Note 2		1997		

4. Related research projects

Type of activity	Name of activity	Context	Period	Country	Led by	Carried out by	Financed by
Joint research	Annex 37, Low Exergy Systems for Heating and Cooling of Buildings	International Energy Agency	2000-2004	CA, DK, FI, FR, DE, IT, JP, NL, NO, PL, SE	M. Virtanen (VTT-FI)	15 participants	participating countries
Research	Water-based heating systems for modern well insulated buildings	Norwegian research project	2002-2005	N	P. Gundersen	Norwegian Building Research Institute	50% Research Council of Norway and 50 % industry
Application research	Improved thermal performance of building envelopes made of light weight steel construction		2002 - 2006	DE	M. Kuhn-henne	M. Kuhn-henne	German Light Weight Steel Association
Research	Energy efficient buildings through innovative systems in steel	European research project	2003 - 2005	DE, BE, SP, FI, UK	L.-G. Cajot, (Arbed LUX)	M. Kuhn-henne, B. Döring et al.	European research fund for coul and steel
Application research	Joint research programme: LowEx	German national project	2004-	DE	D. Müller , H.M. Henning B. Glück D.	several research groups	German Ministry of Economy and

					Schmidt		Labour
Application research	TABS coupled with ground source heat pumps	Italian national project	2004	IT	R. Zecchin (IT)	University of Padua and 2 other companies	Private founds
Application research	Thermal and photovoltaic roof for low energy houses	Italian national project	2004-2005	IT	R. Zecchin (IT)	University of Padua and another companies	Private founds
Application research (under application)	Nutzung von Regenerativen Energiequellen in Gebäuden durch den Einsatz von Niedrig-Exergiesystemen (part of German LowEx)	German national project	2005-2007	DE	D. Schmidt (FhG IBP)	FhG IBP project group Kassel	German Ministry of Economy and Labour
Research	Development of thermal active systems to avoid icing on bridges	National research project	2005 - 2007	DE	B. Döring	M. Kuhn-henne, B. Döring	Federal Ministry of Transport, Building and Housing
Research	Polylevel energy management for a sustainable built environment	National research project	2005-	SE	G. Jóhannesson, P. Lundquist, M. Westermark		
Student exchange	Monbusho Scholarship (application under review)	Doctoral research in Japan	2005-2006	DE, JP	D. Schmidt (DE), M.Shukuya (JP)	M.Schweiker	Japanese government
Student exchange	Socrates Program	Doctoral research in Italy	2005	DE, IT	D. Schmidt (DE), M. De Carli (IT)	A.Papparotto	Socrates program
Doctoral research	Occupant responses and energy use in buildings with moderately drifting temperatures	Ph.D project	2005-2007	DK, PL	B. Olesen	Jakub Kolarik	
Joint Research	Systems approach to exergy – LowEx.nl	Dutch national Project	2006-2009	NL	E.Boelman M.deWit J.Brouwers	3 Doctoral researchers	SenterNovem - NL
Doctoral research	Exergy efficient building design		2004-2007	NL	E.Boelman, P. Luscuere	P. Sakulpipatsin	Delft University
Post-doctoral research	Architect-friendly exergy analysis and design tools for building environment control systems		2002	NL, JP	P. Luscuere	H. Asada (JP), E.Boelman (NL)	Delft University and NWO
Research (under application)	Thermofluidodynamic study of adaptative façade components for comfort and energy saving	Italian national project	2006-2008	IT	F.R. D'Ambrosio	Several Italian university research groups	Italian Ministry of University and Research, Politecnico di Milano
Applied research	Low energy cooling systems in the framework of BIRD Project (Progetto Bioedilizia	Italian project	2005-2008	IT	A. Bettoni	Aler Brescia, Politecnico di Milano	Lombardy Region, Municipality of

	Inclusione Risparmio energetico Domotica)						Brescia, Aler Brescia
Research	Micro CHEAP - diffusion and developing of micro cogeneration	European Community research project	2005-2007	DE, DK, FR, FI, I, NL, UK, SE, GR, SP,	Chalex (UK)	university IUAV of Venice and other	European Union 6th framework program
student exchange	Occupant response on microclimate changing for comfort investigation	Ph. D. project	2005-2006	I, USA	F. Bauman - F. Peron	E. Buchberger	Padua University

5. Contact information

Elisa C. Boelman, TU Delft-NL, is preparing this proposal. For questions and remarks, please write to **cost.exergy@bk.tudelft.nl** Thank you.

Markus Kuhnhenne	Dipl.-Ing.	RWTH Aachen University	Institute of steel and light weight constructions	Building physics / numerical simulations / European standards / experimental investing-ations (in situ and lab) / development of new en-ergy saving constructions	DE
Masanori Shukuya	Prof. Dr.	Musashi Institute of Technology		Exergy / daylighting / architecture / indoor environment / human thermal comfort. *Architecture & Indoor Environment*	JP
Michele DeCarli	Dr. Eng.	University of Padua	Applied Physics	Radiant systems / building physics / renewable energy / thermal comfort / modeling	IT
Paul Ramsak	Ir.	SenterNovem Netherlands Agency for Innovation and sustainability	Energy Research Group	Energy research strategy management / built environment. *Energy Engineering / Architecture / Building Science*	NL
Per Gundersen	Dipl. - Ing.	Norwegian Building Research Institute	Building Services	Building services (HVAC) / radiant systems / building physics / num-erical simulations / exper-imental investigations	NO
René Wansdronk	Architect				NL
Roberto Zecchin	Prof.	University of Padua	Applied Physics	HVAC systems / building physics / energy management / modeling / energy production	IT
Sebastian		Fraunhofer Institute	Department	Solar buildings	DE

Herkel		for Solar Energy Systems	Thermal Systems and Buildings		
Simos Yannas	Dr.	Architectural Association Graduate School	Environment & Energy Studies Programme	Environmentally-responsive and energy efficient architecture	UK