Economy meets environment – an integrated life cycle approach

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As Head of the Centre for Facility Management and Security in the Department of Building and Environment of the Danube University of Krems, he is involved in scientific research, teaching, management and consulting. In the last few years he has specialized in the field of life cycle costs. He has published countless articles in professional journals on this topic and is a member in various professional associations. Since 2002 he is the chairman of the appropriate Austrian Standards' Committee 240. Furthermore he is successfully leading his own business in Facility Management Business Consulting since 2001.

Christina Ipser

Is a member of the scientific staff in the Centre for Facility Management and Security in the Department of Building and Environment of the Danube University of Krems. She is responsible in managing research projects in the fields of life cycle analyses of estates as well as constituting economic and environmental life cycle models and strategies. Simultaneously she pursues her scientific work with other scientific institutes including the Vienna University of Technology and international research partners.

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Is the director of the Austrian Sustainable Building Council – ASBC, whose main goal is enhancing quality standards of the Austrian building industry, in compliance with sustainable building. Having studied biology, she later specialized in the field of technical environmental protection. Based on her long-term experience in research

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Is Deputy Managing Director and a longtime board member of IBO as well as CEO of the baubook GmbH, which is owned 50% each by IBO -Österreichisches Institut für Bauen und Ökologie GmbH and the Energy Institute Vorarlberg. Being a physicist she is head of the department for product testing at IBO, specialised on building and material ecology in consulting, research and education. Since 2005 she is member of various standardisation committees, such as CEN TC 350 "Sustainability of construction works".

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Is research associate at the Austrian Energy Agency, which aims to prepare the grounds for decisions in politics, public administration and the industry by delivering detailed research about new technologies, renewable energy and energy efficiency. Ulrike Radosch has been working in various different fields after her dissertation in mathematical and computational methods. Since 2008 she is managing and operating projects in the fields of energy technologies and energy systems at the Austrian Energy Agency.

Abstract:

The objective of the research project LEKOECOS is to quantify the environmental and economic resources consumed by a building during planning, construction and in the utilisation and operation stage. The complexity of the utilisation process over the long life span requires a calculation model with well-orchestrated normative definitions and idealisations.

The presented economical-environmental model is based on the life cycle costs model LEKOS, developed by the Danube University Krems, and the environmental assessment software ECOSOFT by IBO. A new consistent model architecture was built up in order to synchronise the different characters of the environmental and economic resources of the building along its life cycle. This new architecture enabled a holistic consideration of the consumption of the environmental resources from elements as well as from services over the whole life span.

Purpose of the system integration is a combined economic and environmental life cycle model for buildings, realised in an easy-to-use tool for the evaluation of life span resource consumptions at different stages of the design process. In addition specific life cycle resource consumption parameters are defined. This allows to compare the environmental and economic impact of different building types of different sizes and of different planning variants.

Keywords:

Life cycle costs; life cycle assessment; economical and environmental building optimization; consistent life cycle model architecture; specific life cycle resource consumption parameter

Classification:

Research Paper

Economy meets environment – an integrated life cycle approach

LEKOECOS, the joint research project of the Danube University Krems, the Austrian Institute for Healthy and Ecological Building, the Austrian Energy Agency, and SERA energy & resources, aims to answer the following: Is it possible to create a life cycle model for buildings incorporating the varying goals for environmental sustainability? And there's more: Can a long-term common goal for environmental sustainability optimize the balance between costs and resource usage?

Idea of the project

Scheduled to continue until 31 January 2014, FFG-funded project LEKOECOS aims to create an easy to apply tool for calculating resource usage of a building's life cycle. The tool's particular purpose is its implementation during building planning. It will include a brand new life cycle model for buildings based upon the Danube University's FFG-funded life cycle cost model [1] as well as ECOSOFT, a tool developed by the Austrian Institute for Healthy and Ecological Building (IBO) for the ecological assessment of buildings and their components. The earlier a strategic resource management is carried out during the life cycle, the more effective it is. The resulting LEKOECOS building life cycle model already allows economic and environmental optimisation during the early stages of planning, at a time at which fundamental decisions are made and many changes are still possible. Life cycle cost calculation is of particular interest to all parties involved in construction, operation and usage, because it offers the possibility to already evaluate long-term affordability of real estate during the planning phase. On the other hand, environmental indicators such as the Global Warming Potential and its optimisation are of equal importance concerning environmental sustainability, as well as taking future environmental taxes such as a CO_2 tax into account.

Initial situation: the life cycle cost programme LEKOS and the eco software ECOSOFT

ECOSOFT, the Excel-based tool developed by IBO, is used to ecologically assess building components and HVAC components in the field of new buildings and refurbishments. Calculations are based on the IBO reference values table comprising the ecological characteristics of over 500 materials, which comes standard with the programme. However, other data records may also be incorporated into the programme. The following environmental parameters can be calculated: Global Warming Potential (GWP), Acidification Potential (AP), demand for renewable and non-renewable energy (PEI e, PEI ne), Photochemical Ozone Creation Potential (POCP), Eutrophication (EP) OI3 index (ratio of GWP, AP, PEI), waste management indicator (EI). The calculation results are clearly presented in the form of a "building ecology pass". Evaluation of these environmental parameters is based on the standardised method of LCA (Life Cycle Assessment), systematically determining the environmental impact of products, services or processes during certain stages of their lives or throughout their entire life cycles.

LEKOS, the Danube University's forecasting model for life cycle cost for buildings, originated from the basic research project "life cycle cost for buildings", which was funded by the "Future Energy" programme's climate and energy fund. At the same time, the model's development process provided the basis for the new standardised life cycle cost structures in ÖNORM B1801-2[2]. Since 2009, comprehensive analyses and parameter studies according to ÖNORM B1801-2 have been performed with LEKOS on various newly constructed and refurbished residential buildings, office buildings, and business centres, determining life cycle cost values to generate planning recommendations for optimised follow-up costs. The current version of LEKOS has been available since 2012 as a product of the construction software ABK by the company "ib-data". The LEKOS model is clearly

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[1] Floegl, Helmut (2008-2009) *Berechnung von Lebenszykluskosten von Immobilien,* Research project „Nachhaltig massiv" of the Trade Association of the Stone and Ceramics Industry of the Austrian Federal Chamber of Economy

[2] Austrian Standards Institute (2011) ÖNORM B1801-2 – Buildings project and property management – part 2: Follow-up costs, 2011-04

structured according to the current standards of ÖNORM B1801-1[3] and ÖNORM B1801-2. It contains no database, but is, however, equipped with various default settings and values.

Stages and boundaries of economical and environmental sustainability of buildings

One of project LEKOECOS' major challenges is the consistent combination of different approaches. Figure 1 shows two general approaches on the environmental and economical sustainability of a building's life cycle. The life cycle cost is the total cost of a building amounting throughout its life cycle. It is divided into construction and follow-up costs according to standards. Construction costs are those occurring during the planning and construction stage, whereas follow-up costs comprise of usage costs during the period of utilisation, and costs of demolition and disposal of the building. Life cycle cost can be seen as a parameter for a building's economical sustainability.

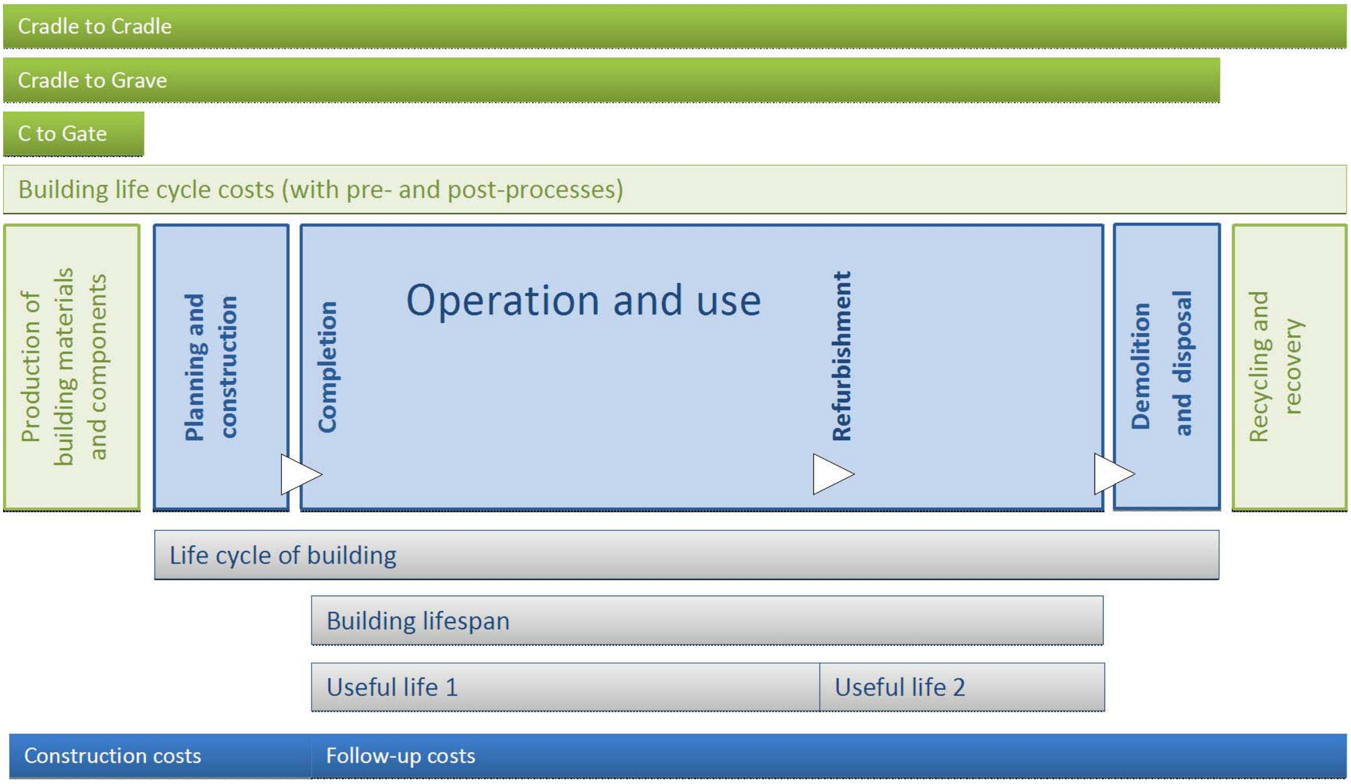

Figure 1. Building life cycle costs and resources

The stage before planning and construction, in which the construction materials and components of the building are produced, is often taken into account for the evaluation of environmental sustainability of buildings. From an environmental point of view, the processes taking place after demolition and disposal of the building, such as recycling, recovering, or re-usage of materials and components, are of additional interest. Taking into account merely the production of building materials and components from raw material extraction to dispatching at the factory gates is called a "Cradle-to-Gate" view. Incorporating the stages of planning, construction, and usage as well as demolition is called a "Cradle-to-Grave" view. Closing the environmental cycle and recycling, recovering, or re-using construction waste material is called "Cradle-to-Cradle".

Concept of the new economical-environmental life cycle cost model LEKOECOS

Corresponding with the different concepts of economy and ecology, the evaluation models LEKOS and ECOSOFT also differ fundamentally regarding their data structures and their level of detail. While the life cycle

[3] Austrian Standards Institute (2009) ÖNORM B1801-1 – Buildings project and property management – part 1: Building construction, 2009-06

cost analysis is primarily focussed on the costs themselves, ECOSOFT concentrates on a more detailed level of elements, such as building structures, components, and HVAC. An analysis of the basic models has shown that the life cycle cost programme LEKOS has not only a much more complex structure than the ecological materials evaluation tool ECOSOFT, but also offers a comprehensive analysis of the building's entire life cycle. Therefore, the decision was made to build the LEKOECOS model upon the existing structure of the life cycle cost programme LEKOS and add to its environmental scope using components of the ECOSOFT model.

Figure 2 schematically shows costs and environmental impacts collected by the LEKOECOS model throughout the entire life cycle. The colour coding indicates which of the existing components of the base models can be adapted and used, and which model extensions are required. The life cycle cost model LEKOS (blue) covers the building's entire life cycle fairly well, whereas the ECOSOFT tool (green) is particularly suitable for the environmental assessment of building materials and components contained in shell construction and extension, as well as in HVAC. As a result, model components are added (brown) allowing environmental assessment of the life cycle stages planning and construction, operation and usage, as well as demolition and disposal or recycling.

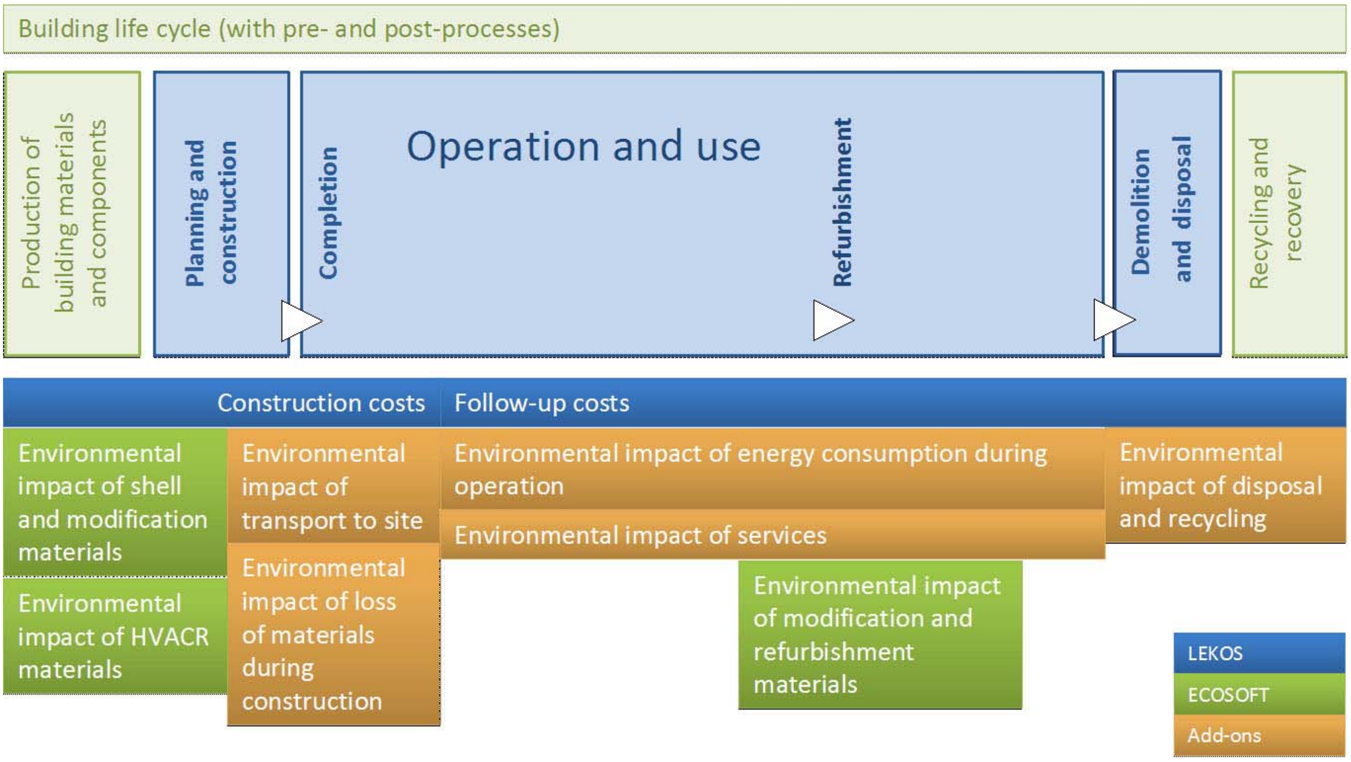

Figure 2. Costs and environmental impacts in a building's life cycle

Environmental impacts due to transport of materials and components to the building site and due to loss of material during construction are mapped with the LEKOECOS model during the construction stage. The energy consumption during construction is only partially taken into account since is negligible in comparison to the life cycle energy consumption. The environmental impacts during the stages of operation and usage mainly result from the energy consumption during building operation. The LEKOECOS model, however, maps not only the former, but also the environmental impacts resulting from services that are directly related to the operation of the building, such as buildings management or maintenance and cleaning services.

Results of the economical-environmental evaluation

The results of the LEKOS life cycle cost model are organised according to ÖNORM B 1801 part 1 (construction costs – Building component classification) and ÖNORM B 1801 part 2 (follow-up costs). An analysis of the results' structures from an environmental point of view has shown that they are also suitable, with a few minor modifications, for presenting the environmental model's result. Not only the costs themselves, but also environmental indicators are displayed per cost position in the combined environmental and economical life cycle cost model. For the first version of the model the Global Warming Potential (GWP) was selected as a suitable indicator. It is comparatively easy to let the LEXOECOS model calculate further environmental indicators (AP, PEI, etc.) by extending the stored data sheets at a later date.

Figure 3 presents the economical and environmental model's result showing costs and Global Warming Potential (GWP) as an example for individual cost positions, such as construction costs (floor construction) as well as annual (electrical engineering) and perennial (façade repair) follow-up costs.

Position in accordance with B 1801-1 and 2 Examples		Costs	GWP
E2.C.04	Floor construction	€	kg CO_2 eq.
F3.1.b	Auxiliary power	€/year	kg CO_2 eq./year
F7.1-4.C	Repair of façade	€/repair	kg CO_2 eq./repair

Figure 3. Presentation of economical and environmental model's result

Environmental relevance and definition of system boundaries

As mentioned above, the cost structuring according to ÖNORM B 1801 parts 1 and 2 generally illustrates the result of the economical and environmental model quite well. Some cost positions were, however, further subdivided to meet environmental demands. On the other hand, ecologically relevant environmental impacts are not associated with each individual cost position, nor is it possible to scientifically represent these with the data and methods currently available.

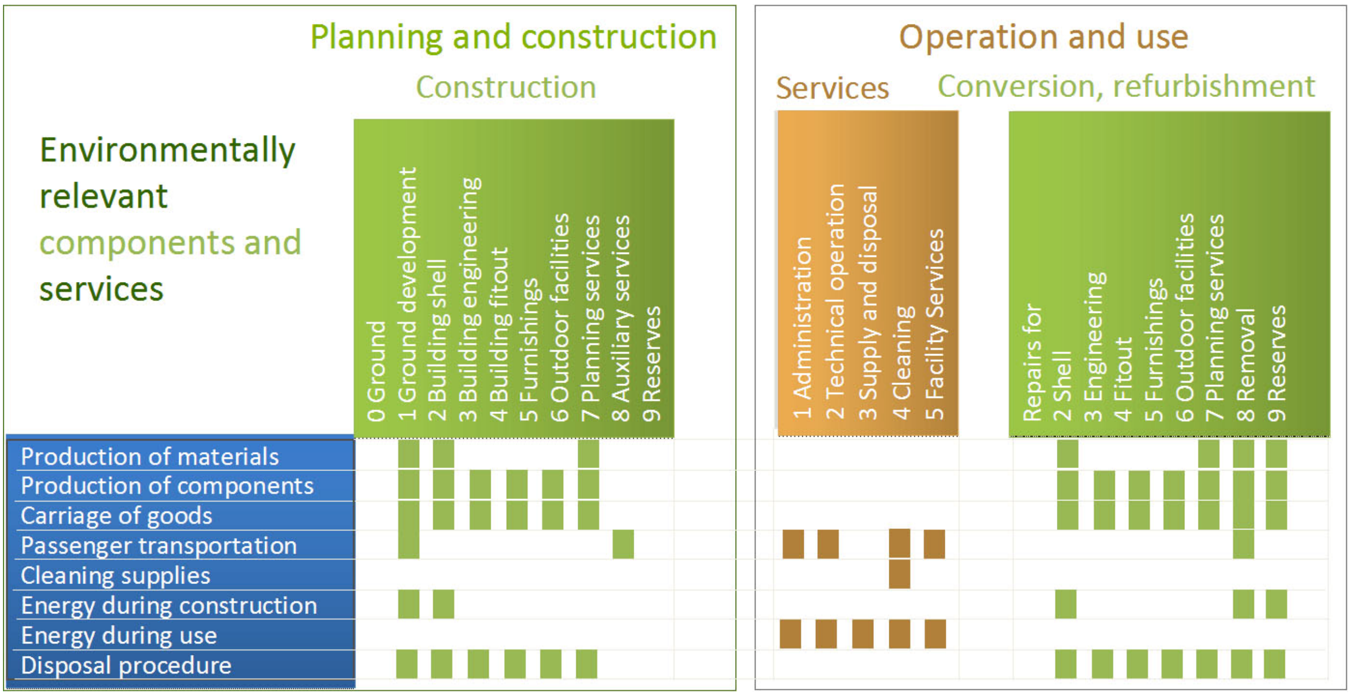

Figure 4. Environmental impacts of products, processes, and services of the building life cycle

To define system boundaries, an evaluation of the environmental relevance of the individual products, processes and services of the building life cycle was therefore performed. In essence, each cost position was examined for relevant environmental impacts of various pre-products and sub-processes. The following environmental impacts were taken into account: production of materials and building components, freight and passenger transport, usage of cleaning agents, energy consumption during construction and building operation, waste disposal processes.

Alongside the relevant costs, the LEKOECOS model also calculates and displays environmental parameters of cost positions considered environmentally relevant in the procedure, as well as any environmental effects that can be presented with the available data and methods. Figure 4 depicts the simplified results of this environmental impacts analysis, and thus the system boundaries of the LEKOECOS model.

Data input and basic elements catalogue for building construction and HVAC systems

Due to the goal of comprehensively determining costs and consumption of environmental resources throughout the entire life cycle, the handling of large amounts of data cannot be avoided even with the simple LEKOECOS model. Various measures are therefore implemented to simplify the application of the LEKOECOS programme and to enable its use in the early stages of planning. These include task-related user guides and a structured, application-based configuration of various default values, which can be selectively adjusted in a few steps to different building types and usages. If more accurate data is established, the default values can be overwritten at any time.

Another measure to simplify data input is the presence of stored basic elements catalogues. These include typical building structures and HVAC systems for building types such as office buildings, schools, and residential buildings, as well as their respective environmental parameters. Predefined elements can be selected from the catalogues and customised as needed.

Energy consumption during operation

During the early stages of planning, accurate data on building quality is not yet available. On the other hand, information on energy requirements and energy sources is necessary to oppose environmental parameters of the construction and operational stage to parameters on construction costs and follow-up costs, and to achieve overall optimisation. The classifications "low", "medium", and "high" quality buildings are used in real estate benchmarking to make reasonable assumptions on the many parameters required without having comprehensive knowledge. Different building concepts and costs are associated with these classifications and are activated when selecting one. The real estate benchmarking approach of classification is also used by LEKOECOS to determine energy-relevant environmental parameters. If at the time of calculation accurate figures on energy requirements are not yet available, the user can activate background-defined scenarios by selecting the type of building and the energy sources used, and by classifying energy requirements as "low", "medium" and "high".

Model structure

Since the LEKOECOS model is intended to be made available to the public and accessible to a broad group of users after the end of the project in February 2014, it will be available for download on the project website free of charge after its completion as an Excel programme. The design of the tool allows the user to rapidly assess life cycle resource consumption and environmental impacts by initially entering key object characteristics using a few selective steps. If more detailed data is available, the stored default values can be overwritten and more accurate calculations can be made. To make the application well-organised, the programme is composed of three different types of spreadsheets. Input sheets offer a user guide and are used to enter the minimum required data and information. Data sheets contain the calculational model, stored default values, basic elements catalogues, and further data such as environmental parameters, duration of usage, etc... All data can be edited by the user as needed. The input sheets guide the user to the corresponding data sheets. Finally, the third type of spreadsheet presents the results.

Synergies of joint calculation of economical and environmental values

The LEKOECOS project shows very clearly that the ambitions and requirements of economy and environment do not differ greatly when considering the entire building life cycle. In both cases, the focus is on optimising life cycle resource consumption. The individual resources may also be viewed financially, such as raw materials or energy. By combining the economical and environmental life cycle analysis, the user can simultaneously optimise all resources pertaining to the building life cycle. The LEKOECOS model allows the determination of important parameters for which, at present, calculations using two or more different tools are needed, causing partial overlapping of the respective input data and not guaranteeing complete consistency of parameters. The model's development also demonstrated that input data for cost determination can be, to some extent, gathered from the intermediate results of the life cycle analysis and vice versa. Apart from the simplified comparability of environmental and economical parameters, another major advantage of LEKOECOS is the reduced time and effort concerning data input.

The model's development also shows that methods and tools for economical evaluation have provided valuable input for the scope and system boundaries of the evaluation of environmental resource consumption. Thus, portions of the life cycle cost tool LEKOS have been adapted accordingly and used for the determination of environmental parameters. An inverse approach is also conceivable.

The LEKOECOS model will allow us to obtain new insights into the economical-environmental optimisation of a building during its entire life cycle. We will be able to identify potential conflicts of economical and environmental goals at the planning stages of buildings and solve them by optimising planning.