EcoEasy - Summary

Development of a methodology for assessing the potential environmental impacts of buildings in the early design phases
Summary - July 2012

TECHNISCHE
UNIVERSITÄT
DARMSTADT

Editors:

Technische Universität Darmstadt
Energy-efficient building design unit
Prof. Manfred Hegger
Dipl.-Ing. Joost Hartwig (project management)
Dipl.-Ing. Michael Keller
cand. arch. Larissa Elschen
cand. arch. Patrick Pick

BEIBOB Medienfreunde Lode, Mathes, Möller GBR
Dipl. Inf. Tobias Lode
Dipl. Des. Dirk Mathes

Drexler Guinand Jauslin Architekten GmbH
Dipl.-Arch. ETH Architekt Hans Drexler M. Arch (dist.)
Dipl.-Ing. Anne Bauer

The research report was funded by the Research Initiative "Zukunft Bau" of the Federal Institute of Building, Urban Affairs and Spatial Development.

Reference number: SF – 10.08.7- 10.17 / II 3 – F20-10-1-033

The responsibility for the content of this report lies with the authors

Research project "EcoEasy"

As part of the research project "EcoEasy - Developing a methodology for assessing the potential environmental impacts of buildings in the early design phases" was developed a prototype software tool that allows a rough life cycle assessment of a building in the early design phases, to optimize the building design accordingly.

Buildings contribute in substantial measure to the environmental damage and resource consumption by the society. About 40% of global energy consumption and more than a third of global greenhouse gas emissions are attributable to the construction and operation of buildings[1]. Also buildings contribute to more than half of the total waste generation in Germany[2]. According to the United Nations buildings play a key role in the fight against climate change.[3].

To reduce the environmental impact of buildings, experts and legislator so far focused primarily on the reduction of operating energy, as caused by production, maintenance and decommissioning emissions from buildings were negligibly small. With improved technology and changing legal requirements (Wärmeschutzverordnung, Energieeinsparverordnung), the energy standard of the newly constructed and renovated buildings increased substantially. For new buildings with energy-optimized operation the environmental impacts from the manufacture, maintenance and disposal of the building construction play a larger role (see Figure 1). This trend will be reinforced by the establishment of net-zero energy homes.

[1] UNEP SBCI: Buildings and Climate Change. Summary for Decision-Makers. Paris 2009, S. 6. Abrufbar im Internet. URL: www.unep.org/sbci/pdfs/SBCI-BCCSummary.pdf. Stand: 25.7.2012.

[2] Statistisches Bundesamt: Abfallwirtschaft. Hohe Wiederverwertung, kaum noch Deponierung von Abfällen. Wiesbaden 2007. Abrufbar im Internet. URL: https://www.destatis.de/DE/Publikationen/STATmagazin/Umwelt/2007_11/Umwelt2007_11.html. Stand: 25.07.2012.

[3] United Nations Environment Programme: Buildings Can Play a Key Role in Combating Climate Change. Oslo 2007. Abrufbar im Internet. URL: http://www.unep.org/Documents.Multilingual/Default.asp?DocumentID=502&ArticleID=5545&l=en. Stand: 25.7.2012.

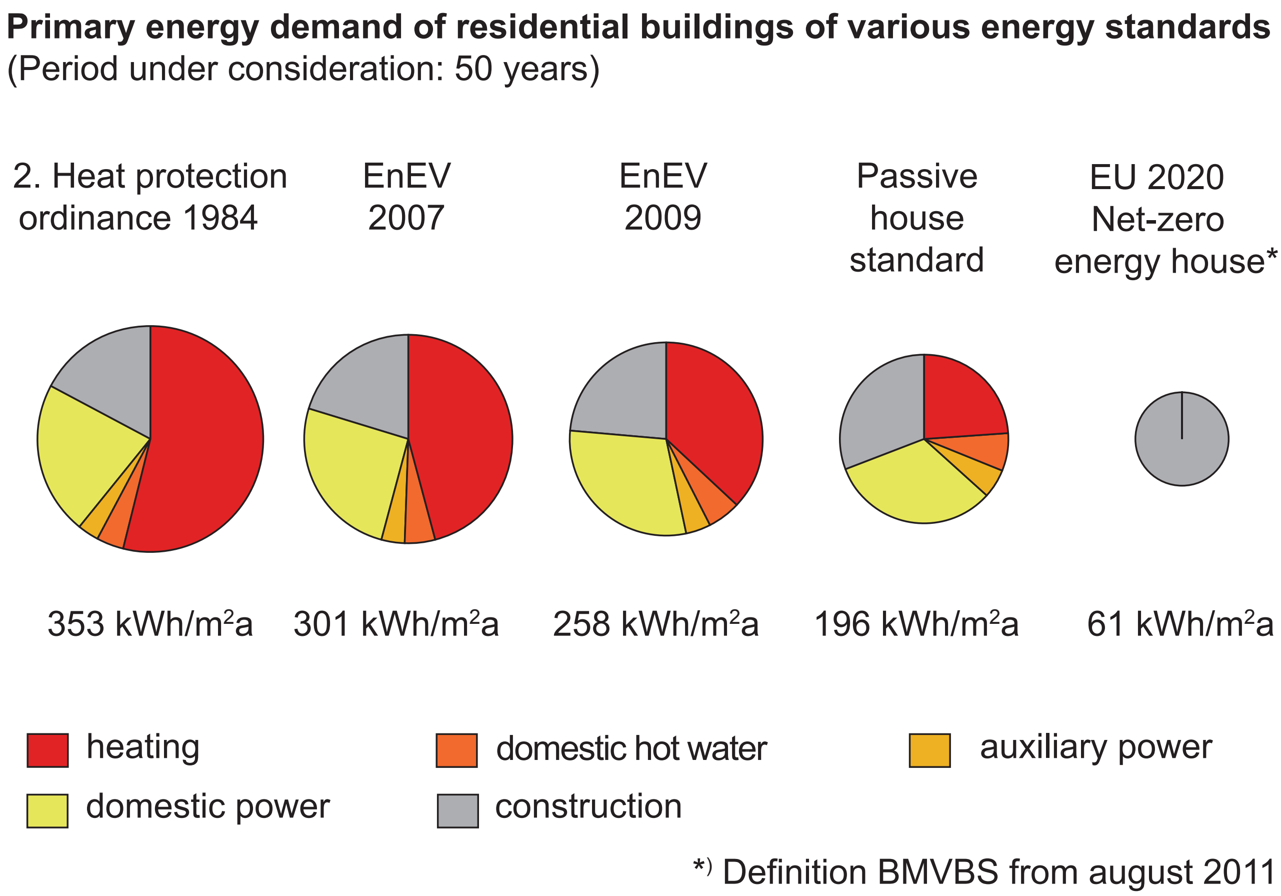

Abbildung 1: Demand for primary energy supplied (eg via the electricity grid) for residential buildings in various energy standards (period under consideration: 50 years). The reduction of heat demand will see its final results by the "net-zero energy building" of the EU in 2020. These buildings will cover their energy needs for heating, hot water and electricity supplies by themselves. Mathematically, the primary energy demand then only expenses for manufacture, maintenance and disposal of building construction.
The presented net zero energy house 2020 is based on the "Förderprogramm für Modellprojekte im Effizienzhaus Plus Standard" of the Federal Ministry of Transport, Building and Urban Development (BMVBS).[7].

A next logical step to reduce energy consumption and environmental impact of buildings is the consideration of manufacturing, maintenance and disposal of building construction throughout the entire life cycle in terms of their possible optimization. For this purpose the method of life cycle assessment is cleared for use in the construction industry has been adjusted. A life cycle assessment analyzes the life cycle of products. For this purpose one considers the life stages of raw material extraction, production, processing and transportation, and if necessary, use, reuse and disposal. In a so-called inventory analysis relevant material and energy conversion processes for the product system are initially recorded and quantified. The impact assessment then determines the contribution of the Life Cycle Inventory results for certain impact categories. Impact categories describe a certain potential environmental impact (eg global warming potential) and are shown by an equivalent material (such as CO2 equivalent). All material flows of the life cycle, with a contribution to a particular impact category are defined by characterization factors in the respective equivalent material translated and summarized. This makes it possible to describe hundreds emissions in a few

[7] Bundesministerium für Verkehr, Bau und Stadtentwicklung: Richtlinie des Bundesministeriums für Verkehr, Bau und Stadtentwicklung über die Vergabe von Zuwendungen für Modellprojekte im Effizienzhaus Plus-Standard im Jahre 2012. 2012. URL: http://www.bmvbs.de/SharedDocs/DE/Artikel/B/forschungsinitiative-zukunft-bau-foerderrichtlinie-modelle-ehp-standard.html?nn=75494. Stand: 17.7.2012.

potential environmental effects. In some building certification systems this method is already used to assess the environmental effects of the life cycle.

Goal of the research project

These developments require that planners can assess and analyze environmental impacts of their project in different design phases and in order to optimize them. Previously available LCA practices require detailed information on construction and therefore only found application in late stages of planning. Then adjustments regarding to the results of an LCA can only be implemented with an considerable amount of time, costs and delays in the planning process. In contrast, in the early planning stages the potential for development of a project is greatest, while the data basis for decisions is at its lowest. However, basic specifications usually made at the beginning (type of walls, the primary construction material) that characterize the building and its environmental consequences are often more important than the design details in later planning stages. This is the starting point of the research project: To develop an easy-to-use Life Cycle Assessment tool, which comes for use in the early design and planning phases and gives feedback on the expected environmental consequences of the future building in time. This makes it possible to make LCA an integral part of creating sustainable buildings and to establish itself in the planning process.

Accomplishment of the research task

Basic assumption of the research project EcoEasy is that buildings with similar characteristics (size, orientation, construction, energy standards) have comparable environmental impacts. If reference values for these characteristics are collected in a database, then one building to be examined can be easily classified and its environmental impacts can be assessed.

Originally, the data base should have been generated of entered projects. Therefore EcoEasy server-based, which means that theoretically all users use the same data base . As a result, the data base would increase with each acquisition and improve the predictive accuracy of the environmental impacts . There are values such as environmental impacts per square meter and year which can be generated as a rough overall average of all building entered into EcoEasy .
During the project, however, several problems were identified in this procedure. On the one hand, the prediction accuracy is very low, so the user would still face big jumps in results while later specifying the geometry, the building structure and the heating system, on the other hand there is no linear work process, because the user is indeed getting an estimation of the results but can not develop it in the context of planning. On the contrary, the user would have to change the same parameters gradually, successively combine them and then compare their results with each other. The program sequence was therefore modified accordingly in order to maintain the character of the accompanying planning tool.

The prototype software

Basically EcoEasy is organized in two program areas: the project area in which the projects are managed and edited and the component library in which building components are created and stored. A project wizard helps you create a new project. This wizard generates a generic model of the building with only a few entries. Required fields are:

- the construction and energy standards as "Timber frame EnEV"
- Geometric information to the building (length, width and height of the building)
- Information on the orientation
- Number of floors / basements
- Percentage of window area

- site region according to DIN 4108-6 Appendix A

From these inputs, a building model is created which is equipped with components specified in the components library. These are stored for the selected construction and the targeted energy standard in the database. The windows are evenly distributed on all fronts according to the window surface proportion . As the heating system by default, the system diagram 1 (natural gas / fuel oil boilers low temperature) is used. On the basis of the calculated U-values of the building components, of the solar and internal gains and the system technology, the program calculates heating - and final energy demand. Type and quantity of materials provide the environmental impact of building construction. Of final energy use and the corresponding data set of the heating system, the environmental impact of building operation are derived. All results are also graphically provided to the user.

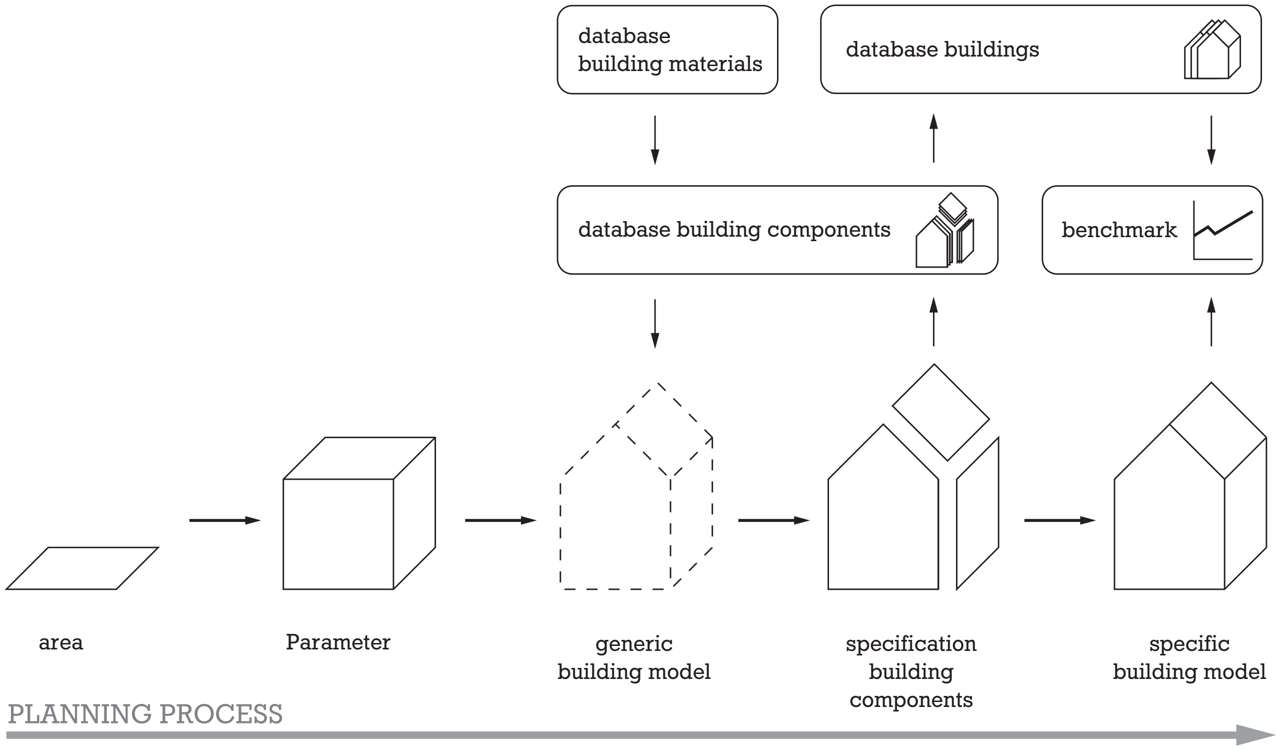

Abbildung 2: Program run by EcoEasy. From a few parameters a generic building model is developed that uses components of the EcoEasy database. Through the specification of the components the building model will be adapted to the real building. The results then can be compared with other projects from EcoEasy.

Based on these initial results, the user can start specifying the building geometry and optimizing aspects of the LCA (see Figure 2). About the impact of any change to the building model, the user is informed by automatically updated graphics directly (see Figure 3). These pictures show not only distribution of environmental impact on the different segments of the building life cycle (production, maintenance, operation and disposal) for various impact categories of LCA (global warming potential, acidification, etc.) and their development through during the life cycle but also allow the comparison with other buildings in the database or with established benchmarks, such as certification systems use.

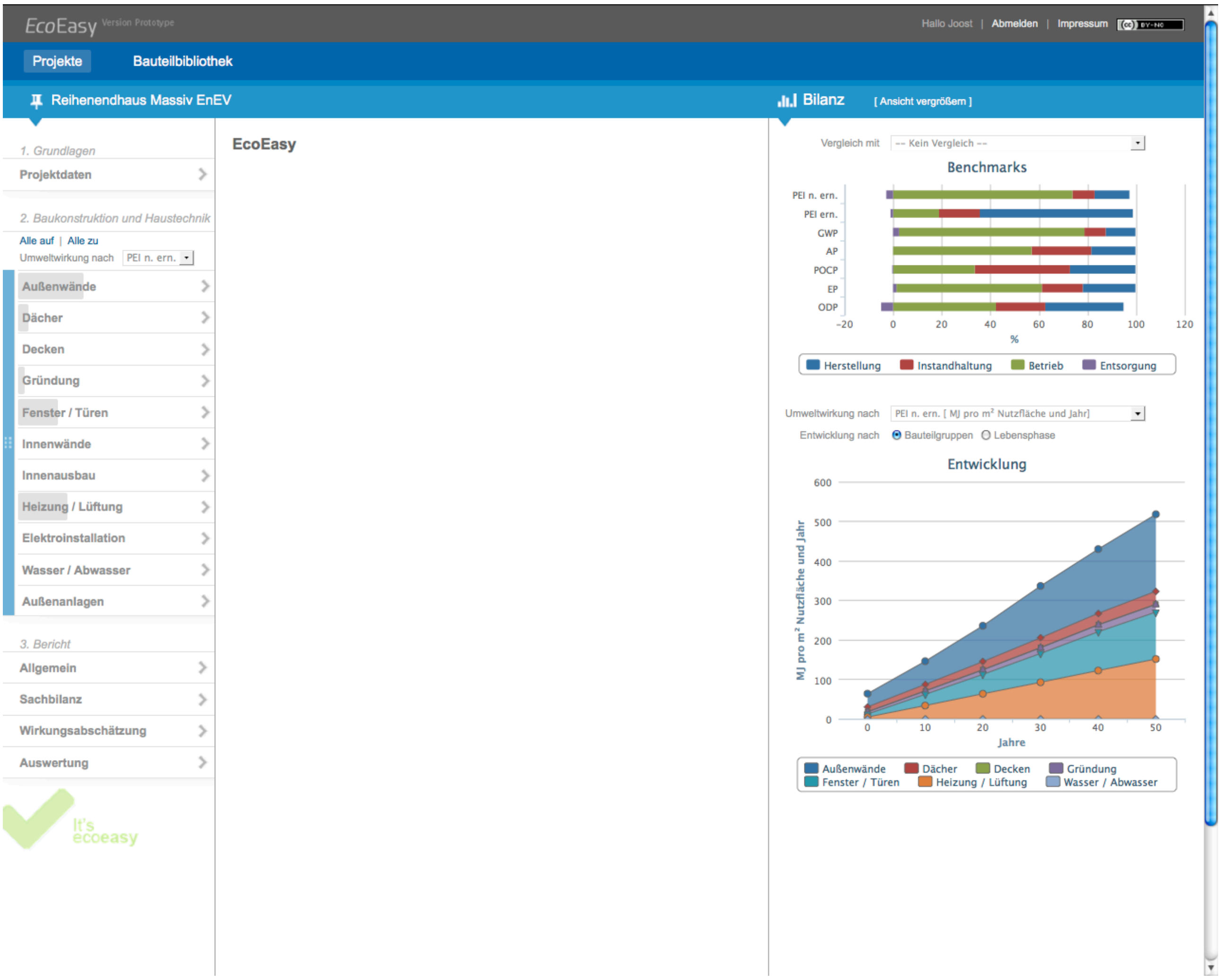

Abbildung 3: Interface of EcoEasy. This is organized into three areas: the navigation on the left, the work area in the middle (empty in illustration) and the results area on the right. In the navigation area the user can easily indentify the components with a particularly high proportion of the selected impact category by the gray bars and directly start modifing them. On the right side the results of building life cycle assessment in different representations can be read. These representations are updated with each change in building model by the user.

The sorting of the components is based on DIN 276. By a graphical output in the field of navigation, the user is advised of the components that have a particularly large share of a pre-selected impact category. These can be optimized by the user at first. Besides rough estimations in early stages of planning with EcoEasy it is also possible to full LCAs for detailed planning.

Summary of results

In the second step of the project it was examined, if the predictions made by EcoEasy in the early correspond to a later carried out, full life cycle assessment. For that, a complete balance of a building with EcoEasy and Microsoft Excel was created. Both accounts use as a data base Ökobaudat 2009. By means of comparison of both results could first be ensured that the calculations are correct in EcoEasy. After that the building was entered again by using the project wizard. From the comparison of the results could be draw conclusions for the prediction accuracy.

The results of the newly created project vary in the different sections of the life cycle considerably from the results of the complete balance sheet. As part evaluation were several reasons for the differences between new input and detailed balance are identified. These include:

- Other areas and volumes
- Other building typology (in this case a row house)
- contrary heating system
- reference evaluation

In a second step, therefore, these causes were handled preferentially. A few modifications that a skilled user can carry out in a short time increase the prediction accuracy significantly. In particular, the choice of heating system and adaptation to the real development situation have a big impact. In a further development of EcoEasy it needs to be examined, if these issues can be included in the project wizard.

EcoEasy was developed as a methodology and tested in a software prototype. To develop a functional software the consideration of the following other aspects would be necessary:

- User Management
- Operational Concept (technical and functional)
- Continuous adaptation to technical, scientific and methodological developments
- Improvement of user comfort (ease of use)
- Modularization of the program components to improve the integration of additional program modules
- Establishment of interfaces to other programs

The existing prototype software offers a number of approaches for development. These include:

- Integration of life-cycle cost analysis analogous to the ecological life cycle
- Integration of other building typologies: Extended input cooling requirements, ventilation, lighting and electricity usage (calculation of energy requirements according to DIN 18599 or other simplified procedures for non-residential)
- • Holistic optimization: integration of other relevant modules (expansion of the scope of examination)
    - Ecological effects of the mobility by the user of the building (including the location in the analysis)
    - Water consumption of the building construction
    - Infrastructure (development pipes, public buildings)
    - land use, buildings and related infrastructure
- Comparison of alternatives within the software
- Improved validation checks for data base entered building and components.

Overall, the results confirm the hypothesis of the project that buildings with similar characteristics (size, orientation construction energy standards) have comparable environmental impacts. The project has developed a software prototype, which still does not allow for optimal estimations but has optimizing potential by some modifications. The project results provide substantive and technical approaches for further research and development projects.