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INTEGRATED LCA-TOOL FOR ECOLOGICAL DESIGN

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ABSTRACT

To meet the requirements of building owners and users in environmental issues, life cycle assessment (LCA) has become an important method to monitor the ecological perspective during design and decision making processes. Existing LCA tools are separately available, but are missing the important links to other design tools, such as architectural, technical system design and energy simulation softwares. This paper presents a new integrated tool BSLCA for ecological design and analysis of building services. The tool utilises standard methods of exchanging design information with other software tools based on the Industry Foundation Classes (IFC).

INTRODUCTION

To meet the requirements of building owners and users in environmental issues, life cycle assessment has become an important method to monitor the ecological perspective during design and decision making processes. During the design process it is necessary to compare different technical solutions and their ecological and financial properties during the life cycle of the building. From the building owners' point of view the assessment reports should be uniform, easy to read and comparable from project to project. A systematic evaluation of environmental impacts means, that the results of LCA calculations should be clear and transparent and also the inventory and evaluation methods in use should be commonly accepted.

Existing LCA tools are separately available, but are missing the important links to other design tools, such as architectural, technical system design and energy simulation softwares.

The major constraint on the everyday use of powerful calculation tools at different stages of the building design process has been time consuming manual data input, especially related to the building geometry data. However, the continuing development of the Industry Foundation Classes IFC-standard by the International Alliance for Interoperability (IAI) creates new possibilities for achieving interoperability for design software through the use of a common object model of the building and its open data transfer standard. Several architectural CAD tools are already IFC compliant.

However, software development experience has shown that an in-depth knowledge of the highly complex IFC object model is required to develop IFC compliant software. To make this work easier for developers not familiar with the IFC, a new so called middleware tool, BSPro COM-Server for IFC Files, was developed. Using this tool, a software developer of new or existing tools can achieve IFC compatibility with a quite reasonable amount of work.

LCA-TOOL STRUCTURE AND LINKS

This paper presents a new integrated tool BSLCA for ecological design and analysis of building and technical systems that has been developed by Olof Granlund Oy. This tool is a database solution with a Windows interface and it handles environmental impacts of the building envelope and the building services systems such as HVAC and electrical systems.

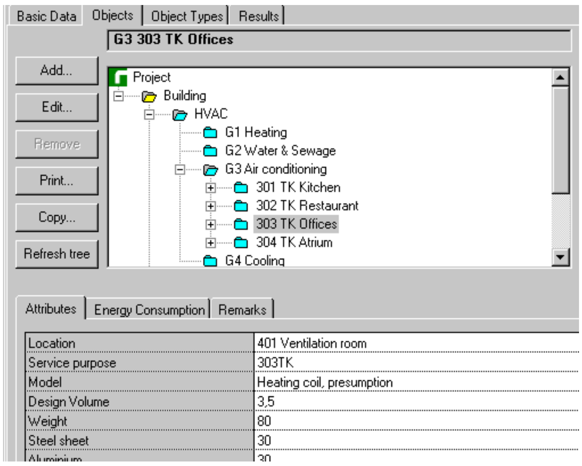

Figure 1. The information in BSLCA is stored in a systematic hierarchy format.

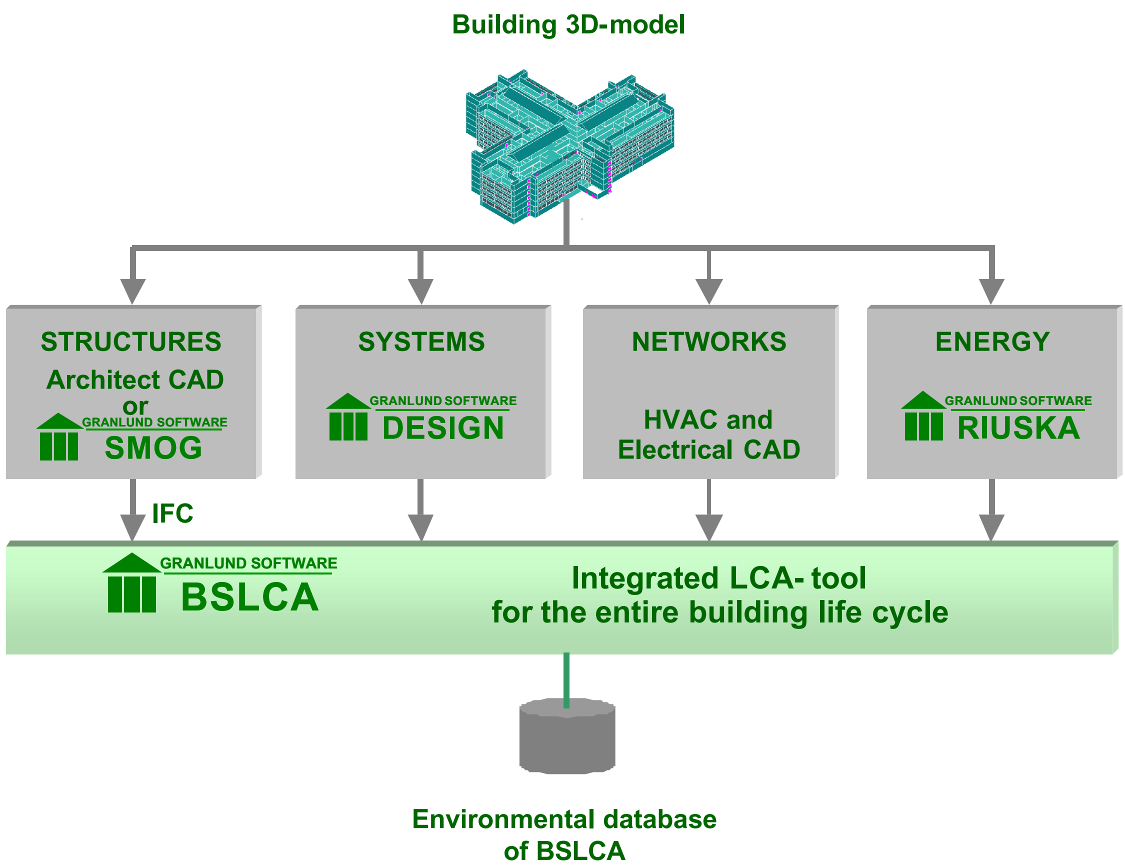

Figure 2. BSLCA is a tool for ecological design of buildings and systems with links to other softwares.

Information in the LCA database is stored in a systematic hierarchy format, which makes it possible to analyse results on different levels, from building level to system and equipment level (Figure 1).

Several interoperable software tools provide information needed in the LCA of the building envelope and its technical systems – very little additional work is required for the LCA calculation itself as most of the essential information already exists.

The tool is developed for integrated and/or interoperable design environment, where existing information can be used as an input for BSLCA. This means links to other design tools, such as architectural, technical system design, ducting and piping design and energy simulation softwares (Figure 2).

The tool utilises standard methods of exchanging design information with other software tools based on IFCs. The use of IFCs facilitates in the first phase importing of building structures related geometry data from architectural CAD systems. If the architect is not using IFC compliant CAD software, the object oriented building 3D model can be produced by a special space modelling software SMOG and exported in IFC format.

The building services system design data is linked to the BSLCA tool by using compatible database structure. The system DESIGN tools cover the whole range of building services: HVAC, electrical, building automation, kitchen and hospital equipment. These tools are used in the everyday design work routinely by project engineers to save technical information into a building services database. This BS database forms also the basic data for the facilities management system in the building operation phase.

The building services networks are designed by

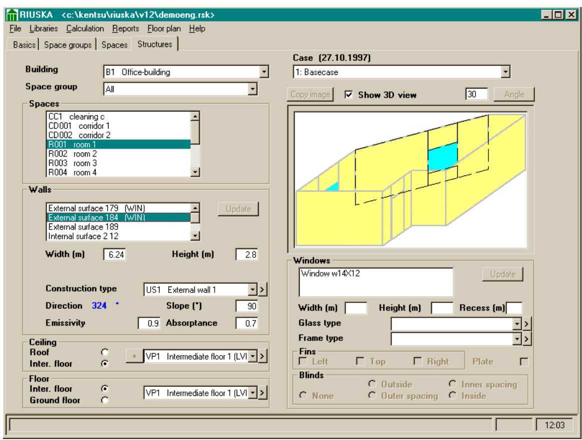

Figure 3. RIUSKA is used for energy simulation.

using HVAC and electrical CAD softwares. Material consumption related to BS networks can be significant. Accurate information about ducting and piping quantities requires using 3D based HVAC CAD solutions with links to real product data.

The energy consumption is calculated by using RIUSKA, a dynamic simulation tool of comfort and energy consumption (Figure 3). RIUSKA utilises DOE2.1E software as a simulation engine. RIUSKA makes it easy for HVAC engineers to compare a variety of design alternatives for clients and architects, and to ensure optimal indoor air conditions and energy costs. It is also IFC compliant.

The reporting from the BSLCA-tool is based on easy to understand comparisons. User may navigate on different levels of the building hierarchy which makes it possible to analyse the ecological impacts of alternative design cases on different levels. For example, if the life cycle impact of two different cooling systems are compared, it is possible to make changes in individual equipment dimensioning and observe the changes in the environmental loads

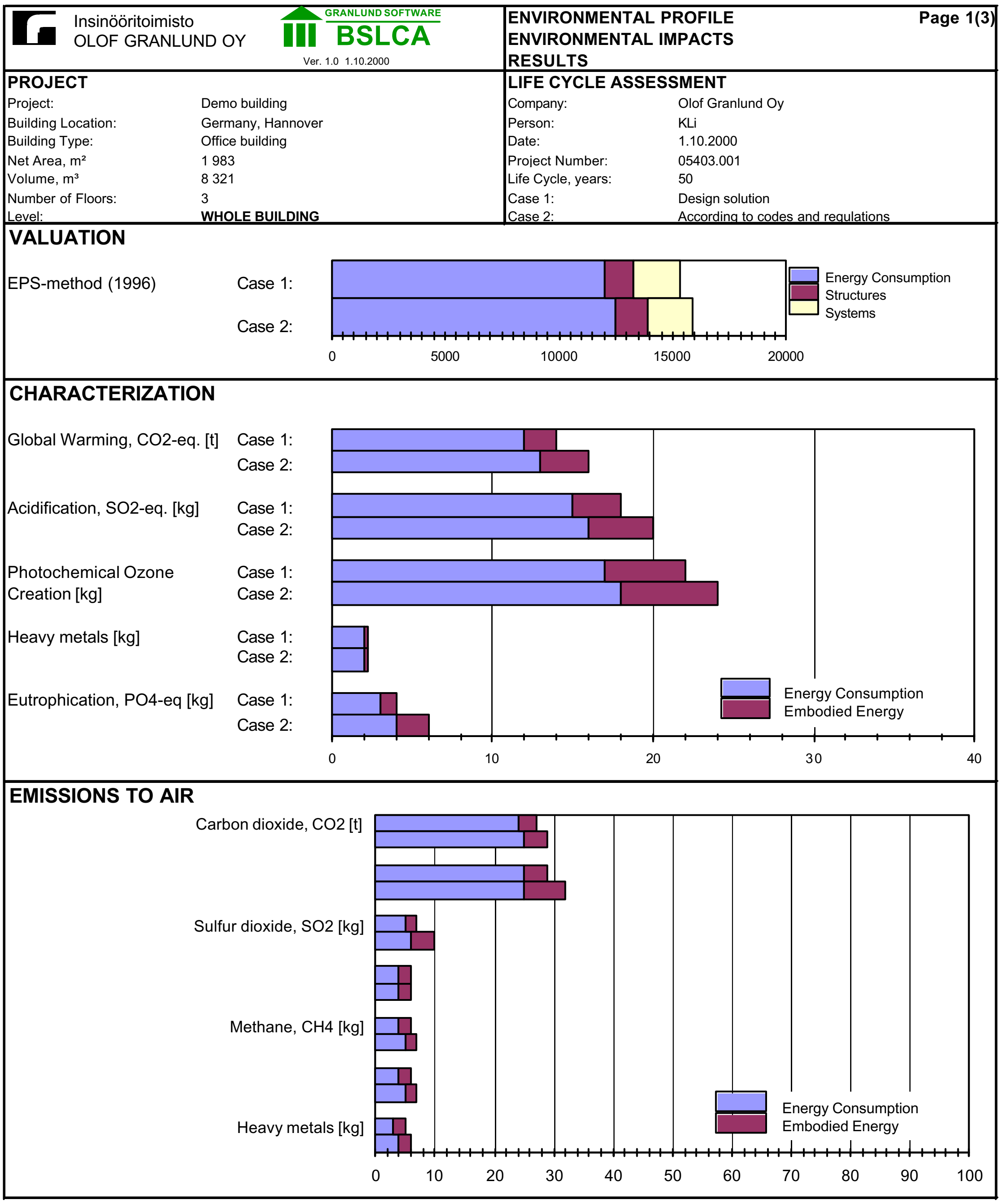

Figure 4. An example of the BSLCA report, characterised and weighted environmental impact and emissions.

(materials and energy) of the specific cooling system, of all cooling systems, of the whole HVAC system or of the whole building. This feature is unique for illustrating the things that are important in ecological sense – what is the meaning from the whole building and the whole life cycle point of view.

The results are characterised and weighted according to different methods in order to enable diverse and understandable comparisons. Figures 4 and 5 show some examples of the BSLCA reports of the environmental profile of the building.

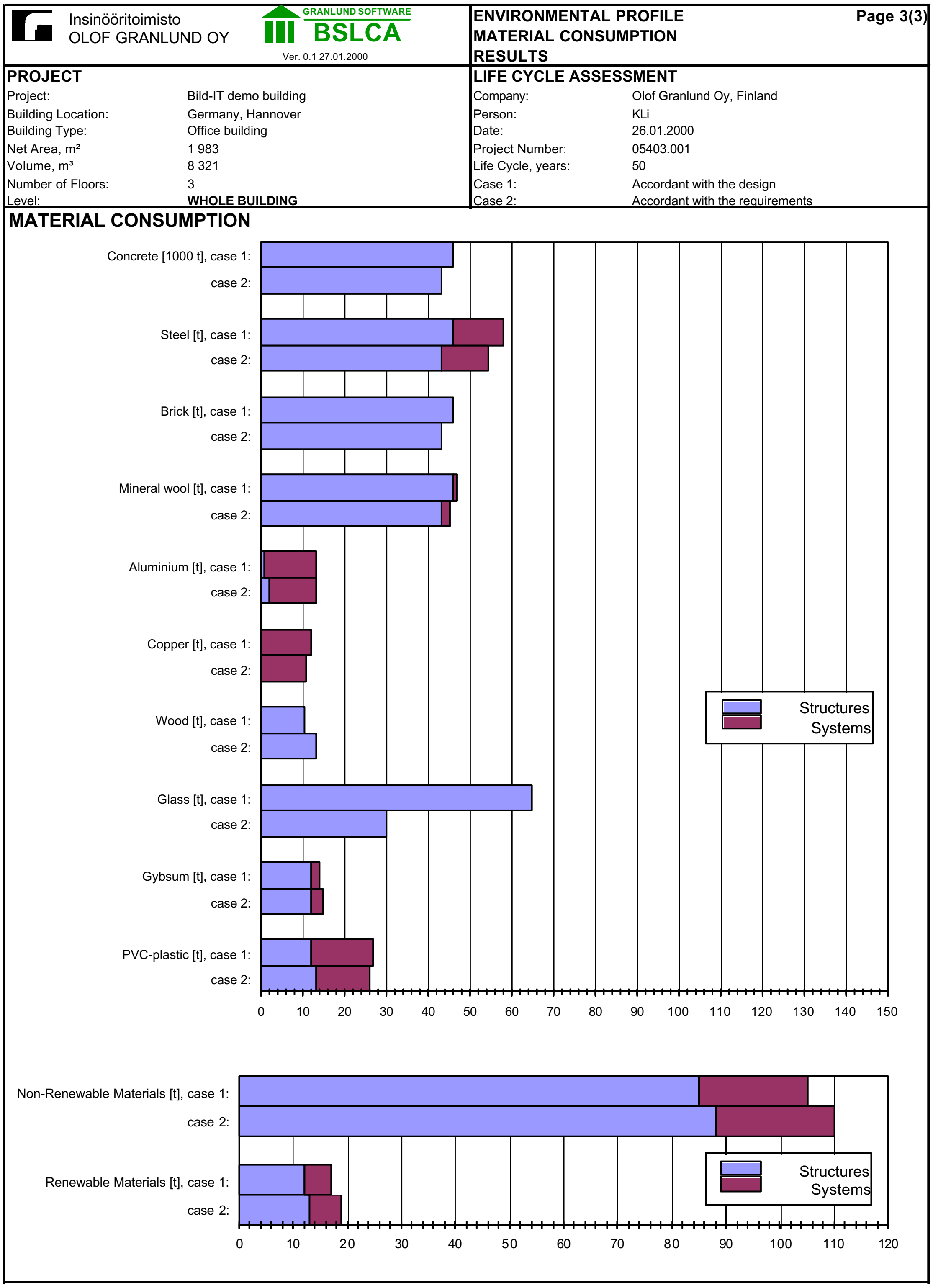

Figure 5. An example of the BSLCA report, material inventory.

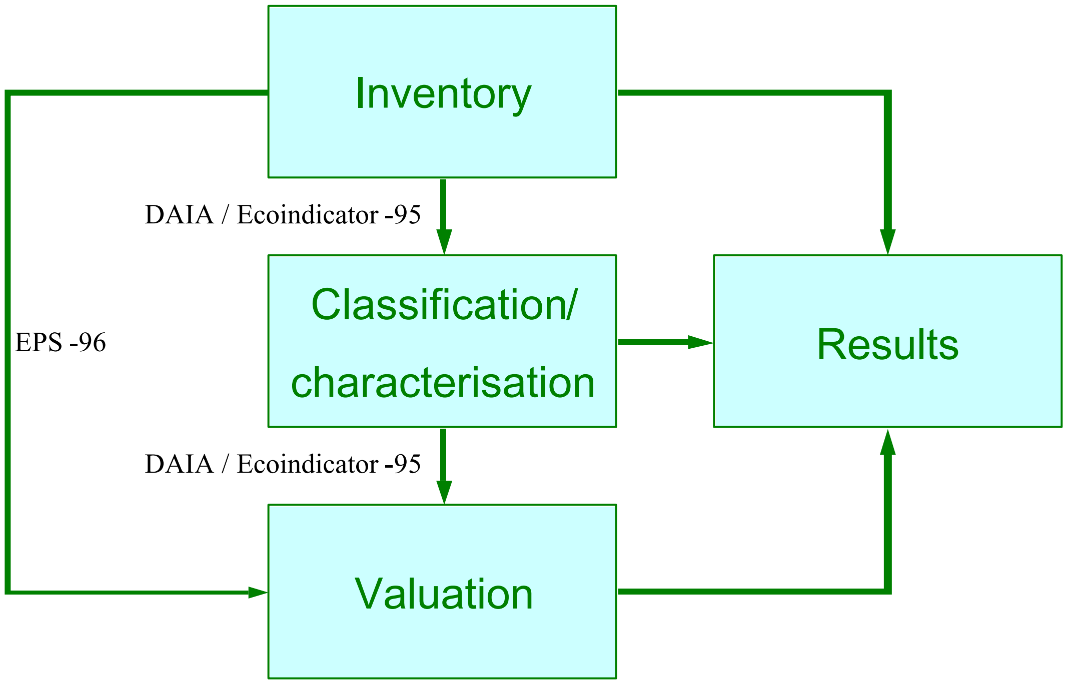

Figure 6. Characterisation and/or valuation methods used in the BSLCA tool.

CALCULATION PRINCIPLES

The LCA calculation principles used in BSLCA software are based on standards and methods of international status. The implemented characterisation and/or weighting methods in the tool are: Swedish EPS (Environmental Priority Strategy), DAIA (Decision Analysis Impact Assessment) and Ecoindicator95 methods (Figure 6).

The quantities and masses of the building envelope and the building service systems are linked from design data to the BSLCA tool as already explained. In the BSLCA tool the designed objects are connected to actual products, designed structures to layers of building materials and energy consumption data to the database of different energy forms.

The product library includes data on actual products used in HVAC and electrical systems. The weight and material data of products is added in projects to make the database as complete as possible. The products are named with actual type, model and manufacturer labels when the weight and material information is available from the manufacturer. The structure library includes the typical building constructions and the project specific information is added to the database. The product and structure libraries are linked to the material database.

As default library values in the BSLCA tool environmental profiles of materials used in building service systems are defined as they have been published by VTT Building Technology. The profiles are valid for materials produced in Finland and they include the manufacturing and transportation of the main components. The library includes also some building materials for which the environmental profiles have been published by the Helsinki University of Technology. The profile of all materials is not known (e.g. brass, stainless steel, porcelain) and for these the profile of a corresponding material has been used. This information can be added to the database when available.

The environmental profiles of different energy forms are stored into the database. For the moment the database includes the average profiles of district heating and electricity in Finland as they have been published by VTT Building Technology. Other energy forms and their profiles can be added if available.

In the classification phase the inventory data is divided into impact categories. The calculation tool uses the impact categories of different emissions and characterisation methods as they have been published by VTT Building Technology. New characterisation methods can be added to the method library later.

The calculation takes into account the emissions that have an impact on climate change and uses the characterisation factors for a period of 100 years. All characterisation methods use the same factors. The emissions are given in CO_2-equivalents.

The calculation tool uses the emissions having an impact on acidification and ozone depletion and the corresponding weighting factors as given in the DAIA and Ecoindicator95 characterisation methods.

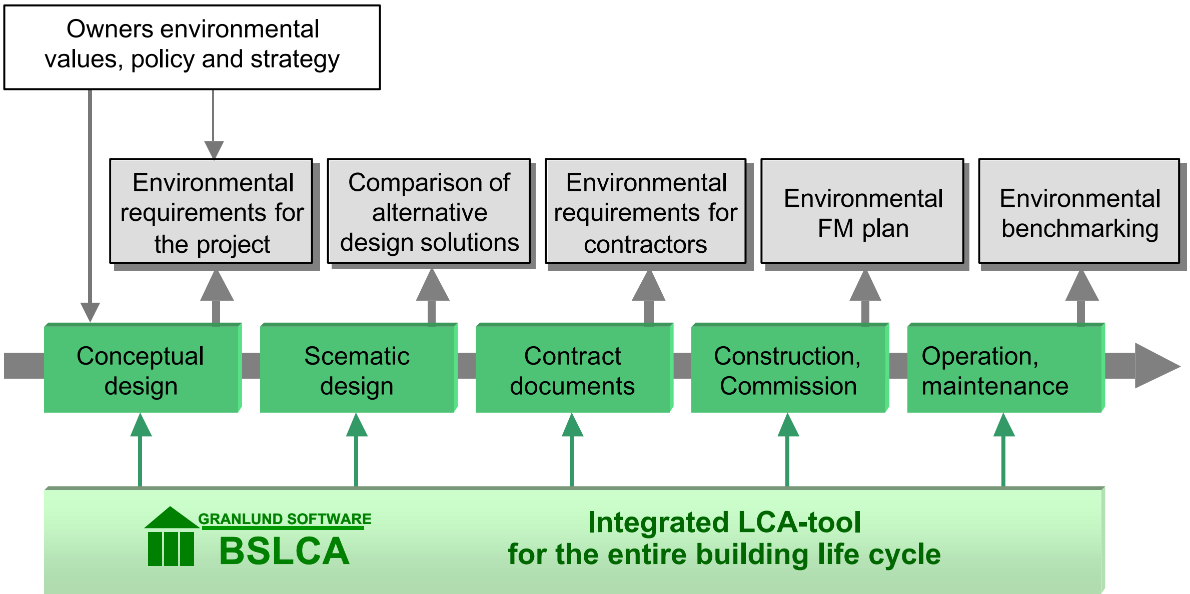

Figure 7. BSLCA is used through the entire building life cycle, from conceptual design to facilities management.

The Ecoindicator95 method takes the heavy metal emissions into account as emissions into air and into water. The tool uses the corresponding emissions and their characterisation factors. So far there is very little information available on the heavy metal emissions of different products.

In the weighting phase of the Life Cycle Assessment the classified indicator values are combined to a total indicator value. Weighting the classified results using a certain method means that the corresponding characterisation method has been used. The calculation tool uses DAIA and EPS methods for weighting. The software structure allows easy adding of new methods later.

LCA IN DESIGN PROCESS

The objective was to develop both the design process and design software towards sustainable development. This means that ecological aspects are included already in the conceptual phase and the data, which is rough at first will become more specific during the design process.

The integrated design process also means that the information created during the process will be available and utilised from design into construction and facilities management - on the other words during the whole life cycle of the building.

The ecological design process includes LCA calculations for different purposes at different stages. In the conceptual phase the energy use and environmental impacts of different building shapes, orientations and structural solutions may be compared. In the following phase different technical systems are compared using more detailed energy simulations and life cycle analysis. When the project proceeds to detailed design it is possible to compare the environmental impacts of actual system components, equipment and even materials using manufacturers' data.

Very little additional work is required for the LCA calculation itself as most of the essential information already exists through links to other interoperable tools. The life cycle inventory (LCI) of materials (building constructions and technical systems) is very laborious and beyond the scope of a normal design project if done manually. The BSLCA-tool, based on use of design database and links to other tools, does this inventory quickly and produces both LCI and LCA.

The BSLCA-tool uses a library of the environmental profiles of different building materials and of mechanical and electrical system components and equipment. It is possible to do the calculation on various levels: starting at building level (using material-per-m²-data) and going deeper into system details (using actual equipment data). Also the environmental data of various energy forms is included. The outputs from the BSLCA are the life cycle environmental emissions from the building, characterised according to a chosen method.

BSLCA-tool has an important role in Granlund's information system for the whole building life cycle (Figure 8). The softwares consist of interoperable tools for building services design, life cycle analysis, thermal and CFD simulation, 3D space modelling and visualisation. The information is saved in databases, updated in construction and commissioning phase and re-used in operation phase by our clients in facilities management system.

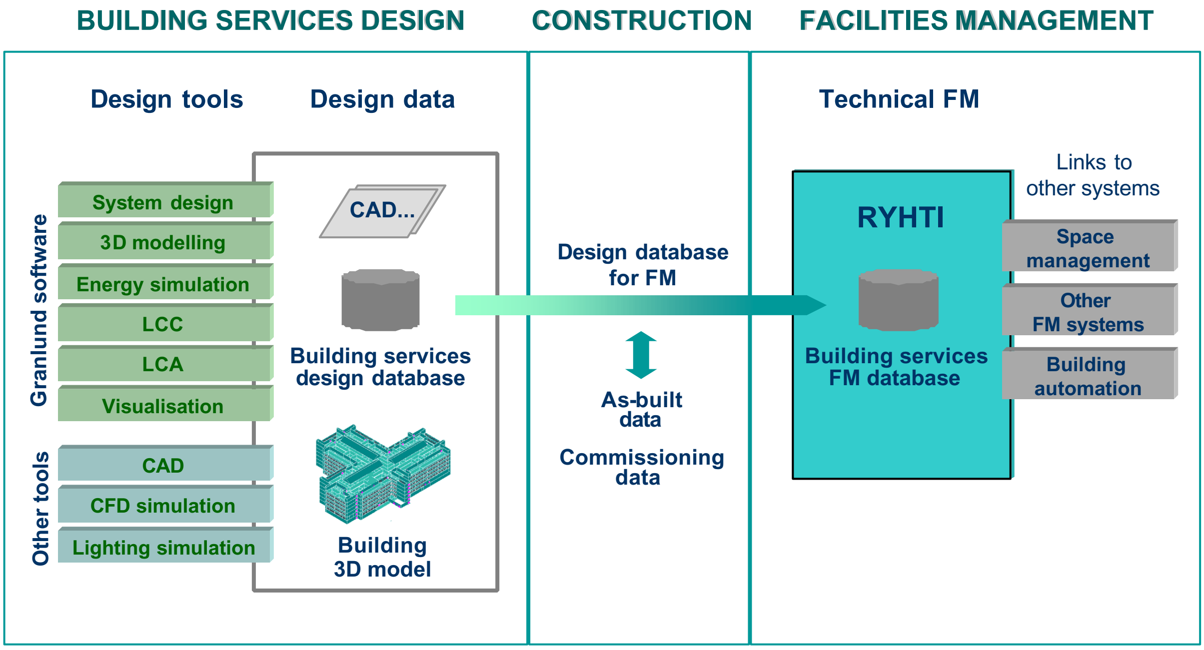

Figure 8. Granlund's information system for the whole building life cycle.

CONSTRAINTS

The contents of the IFC standard limit the possibilities to build all data transfer requirements based on IFCs. In this phase only building geometry and the data of structure types is imported through IFC file. The link from the system and equipment data is automatic through unstandardised database format but energy consumption results and ducting/piping data are transferred manually. The HVAC equipment definitions and the whole electrical system part need to be further developed before all links can be done by using IFCs.

The characterisation and valuation methods implemented in the BSLCA tool are in the current version Ecoindicator95, DAIA and EPS. New methods can be added through the user interface, but all methods have to be based on characterisation and valuation of environmental emissions and material resources. Valuation methods that are based on scoring, such as BREEAM, can not be used.

Also calculation is limited only to the facility and building level and infrastructure is not covered.

ACKNOWLEDGEMENTS

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CONCLUSIONS

BSLCA is a life cycle assessment tool to analyse, valuate and compare environmental impacts of design alternatives of the building structures, technical systems and equipment. It can be applied to decision making at all stages in the building design process – from conceptual design to facilities management.

BSLCA is a highly integrated software and is compliant with Granlund's building services design system. It links together structural data from the 3D building model, system data from the building services design database, ducting and piping data from commercial HVAC-CAD tools and energy consumption data from the building energy simulation tool. Integration and design data re-use enables environmental analysis in the course of design.

BSLCA is the first integrated LCA-tool which uses a database containing data on building constructions and technical systems. The unique integrated software tools and the database including data of systems, equipment and materials make it possible to use the BSLCA for calculating the environmental impacts at the different stages of the design process as well as the whole life cycle of the building.

BSLCA prints out the environmental profile of the building and this profile shows clearly which alternative building parts or systems produce the most significant environmental loads. The profile is a useful help for the building owner in decision making at different stages of the building life cycle and also in steering the design and construction process towards ecological and sustainable solutions.

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