Benefits of Building Information Models in Energy Analysis

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SUMMARY

The importance of energy analysis in building design has grown, but it is still mostly done by simple static calculations or estimates. Accurate dynamic simulation software have been available already for decades, but these tools are still not widely used by practitioners in building projects. The main barrier of wider usage of dynamic energy analysis has been the required big manual input work. By utilising BIM as a data source for energy analysis, the data input will be more efficient and the existing data more reusable. Only by using BIM, the verification of thermal performance can truly happen in different phases of the building process. This paper describes a new concept and interoperable software environment for management of thermal performance during the whole building life cycle. Real project experiences also show that BIM based environment allows to use whole building spatial simulation instead of traditionally used zone based models.

INTRODUCTION

The importance of analysing energy performance in building design is growing, because of the increasing awareness of it's role in building life cycle costs and environmental impacts. However, energy analysis is still mostly done by statistical estimates or using simple static calculations.

Dynamic energy simulation softwares have been available already for decades. Commonly known softwares, such as TRNSYS, ESP, DOE-2 and BLAST, have been developed already in 1970's. Also new tools, such as Energyplus and IDA, have been developed for even more accurate thermal simulation. All these tools have been mostly used by researchers, not by practitioners in building projects.

Energy analysis in building design has to meet both the cost and schedule requirements of practical projects. The main barrier of wider usage of dynamic energy analysis methods has been the required big manual input work. Most of the building element specific information needed in energy simulation is described in the building information model (BIM). By utilising BIM as a data source for energy analysis, the data input will be more efficient and the existing data more reusable. It also makes possible to benefit spatial whole building models instead of zone based models often used today in energy simulation. Only by using BIM, the verification of energy performance can truly happen in different phases of the building process. Some of the public building owners, such as in USA [1], Denmark [2] and Finland [3], are starting to demand BIM in their projects, which creates more possibilities to get benefits for thermal analysis.

Other barriers for wider utilisation of BIMs in energy analysis have been the missing interoperable data interface implementations in thermal simulation tools and the lacking guidelines. The Industry Foundation Classes (IFC) [4] provides today an open standard for description and exchange of information within the life cycle of a constructed facility. To use BIM effectively however, and for the benefits of its use to be released, the quality of communication between the different participants in the construction process needs to be improved. The Information Delivery Manual (IDM) by the Norwegian BuildingSMART project [5] is developed to provide the integrated reference for process and data required by BIM by identifying the discrete processes undertaken within building construction together with the information that is required for and results from their execution. There has also been several national projects in different countries, where guidelines for the BIM based design have been developed.

Using BIM is the only practical way to verify energy performance truly in different phases of the building process. The experiences from many BIM based projects show that interoperable energy analysis software is not enough for the management of thermal performance during the building process, but it requires also tools to manage different revisions of BIMs, to compare thermal performance of these revisions and to visualise this by easy-to-understand way. This paper shows the recent developments for concept and interoperable software environment to manage spatial thermal performance. The results show also examples of using BIM based energy analysis in real projects.

METHODS

Thermal performance management can benefit a lot by utilising building information models as a data source for thermal analysis: The data input will be more efficient and the existing data more reusable. The latter is especially important for continuous thermal performance management through the whole building life cycle.

Wider utilisation of BIM requires instructions both to the actual work and to the true understanding of the potential benefits. This paper presents the results of the development of new methods and interoperable software environment to manage spatial thermal performance. The key components in the interoperable software environment are thermal simulation and spatial requirements management, but it supports also building services system modelling and the later phases of building process by linkage to commissioning and facilities management. The Finnish ProIT project [6] has produced guidelines for the BIM based design. The guidelines for building services design [7] are used here to describe the role of thermal performance management in BIM based building process (Figure 1).

The IDM has produced the most detailed guidelines for BIM based energy analysis [8]. It contains both the energy and condition analysis process description and the requirements for information exchange throughout the building process. The IDM process of developing energy analysis throughout the design stages of a project is considered to be divided into 2 key parts:

1. **Speculative**: This is the analysis work undertaken during the programming stage of the project. It is about providing advice on the potential energy performance of a building and its systems to other design roles. The aim of this advisory role is to have an impact on the overall building design, determine the feasibility of concepts in an energy context and to establish energy targets.
2. **Analytical**: This is the analysis work undertaken during the sketch, full concept and coordinated design stages of the project and assumes the availability of geometric information about the building layout. The overall process is the same at each stage of

work, the difference being simply about the extent of the information available and the level of certainty that can be applied to the information.

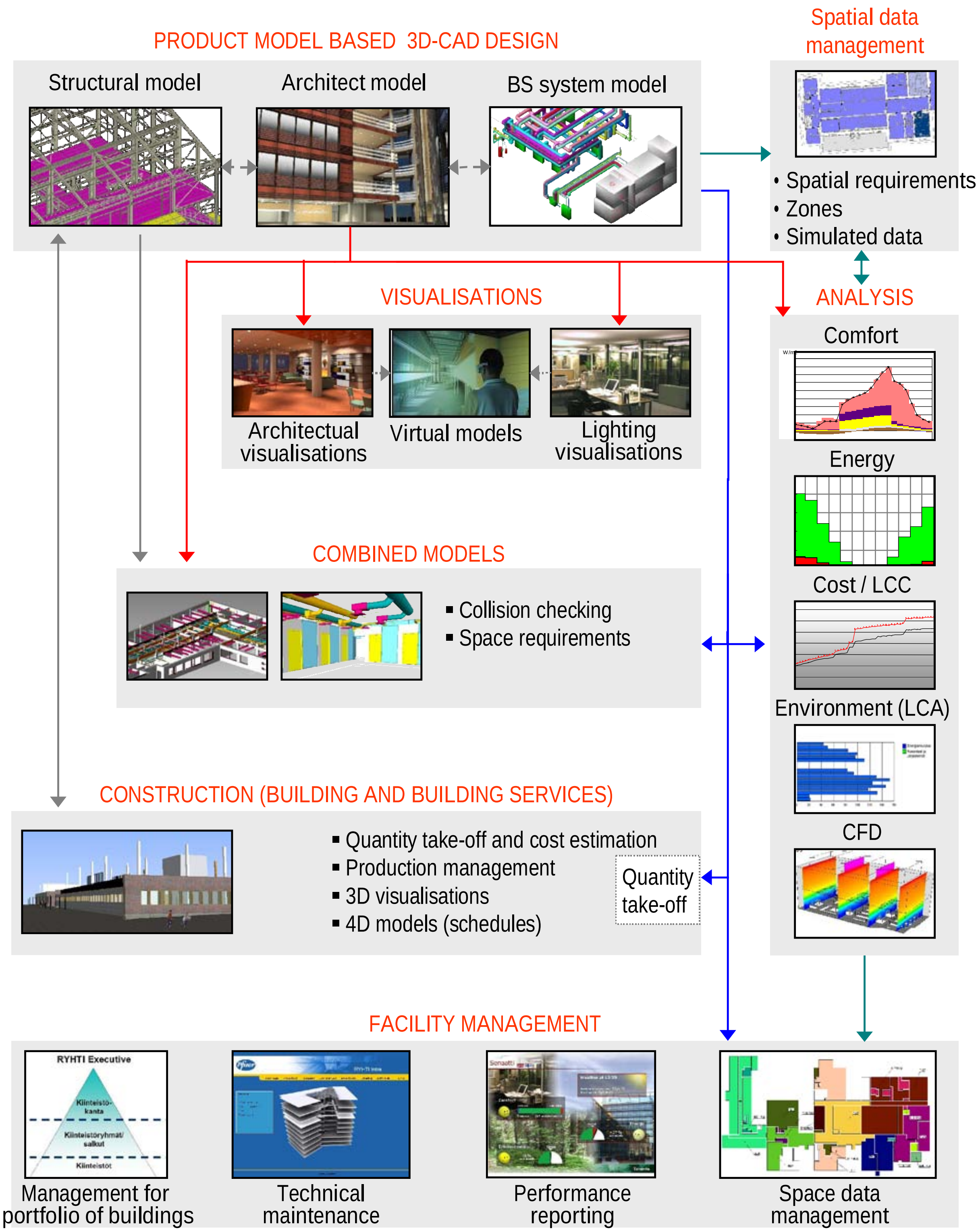

Figure 1. Energy analysis has an important role in the use of building information modelling according to the ProIT guidelines.

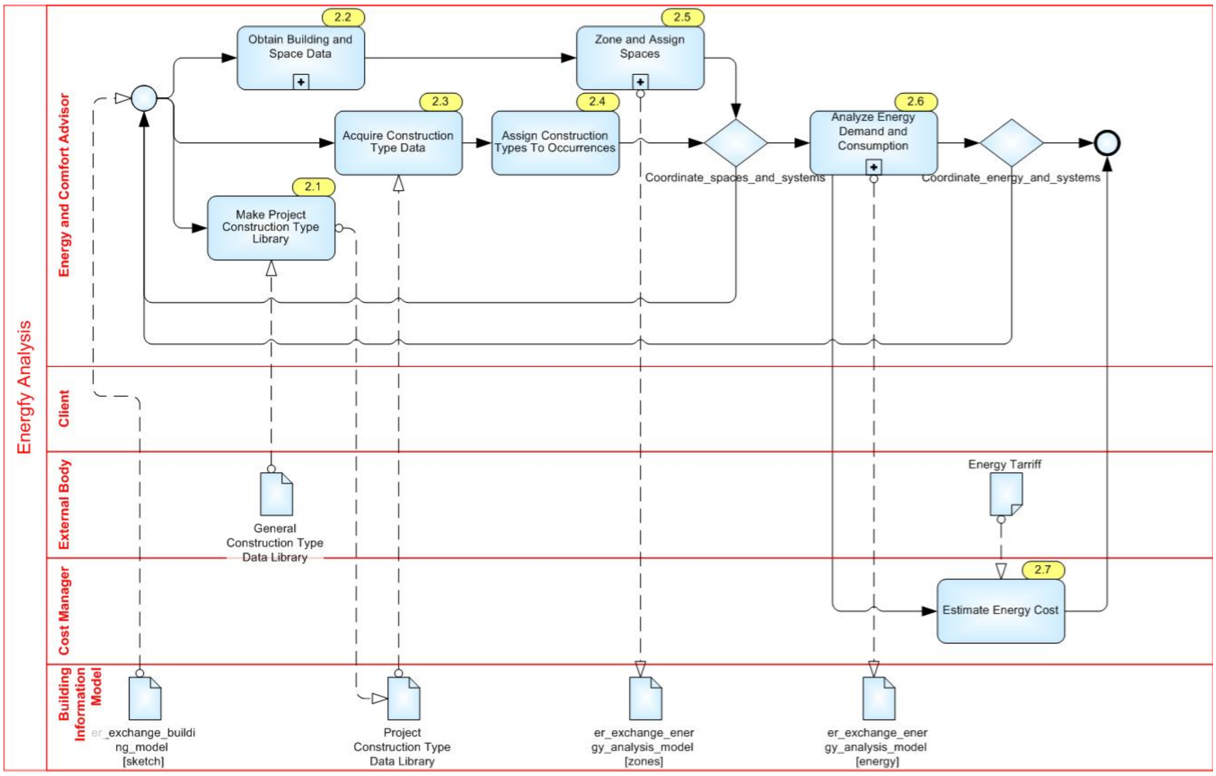

Figure 2. The IDM process map for energy analysis.

RESULTS

The main result of the development was the concept for thermal performance management utilising BIM based environment (Figure 3). The key components in the implementation of the interoperable software environment are energy simulation software RIUSKA [9] and spatial requirements management software ROOMEX. It supports also BIM based building services system modelling and the later phases of the building process by linkage to commissioning and facilities management.

Thermal requirements

Thermal requirements (task 1 in the figure 3) are defined at space type level and so this does not require 3D model of the building. It is necessary to capture client's requirements for different space types, to achieve all the later benefits of BIM based thermal performance management. This task defines both the thermal parameters and the equivalent thermal loads (Table 1). One relevant definition from the electricity calculation viewpoint is also the required lighting intensity.

Utilisation of geometry model

In the utilisation of geometry model (tasks 2 and 3 in figure 3) an architectural 3D model is imported to the environment and validated by automatic checking routines (to report of missing spaces, floors, etc.) and by visual checking (by 3D viewer).

Most of the building element specific information needed in energy simulation is described in the BIM. This includes as mandatory information: spaces with code and name specifications and building structures (walls, windows, etc.) with type definitions. To illustrate the large amount of required building model related data for energy simulation input: As an example a medium size building of 8000 m^2 contains 387 spaces, 295 exterior walls, 912 interior walls, 1439 windows, 760 doors and 57 different type of structures. All this information is needed for spatial level energy simulation, and by utilising BIM this information can be imported to the simulation software. The required information is too much for manual input, which means that traditionally whole building spatial simulation is not practical, and a simplified zone level approach is used instead.

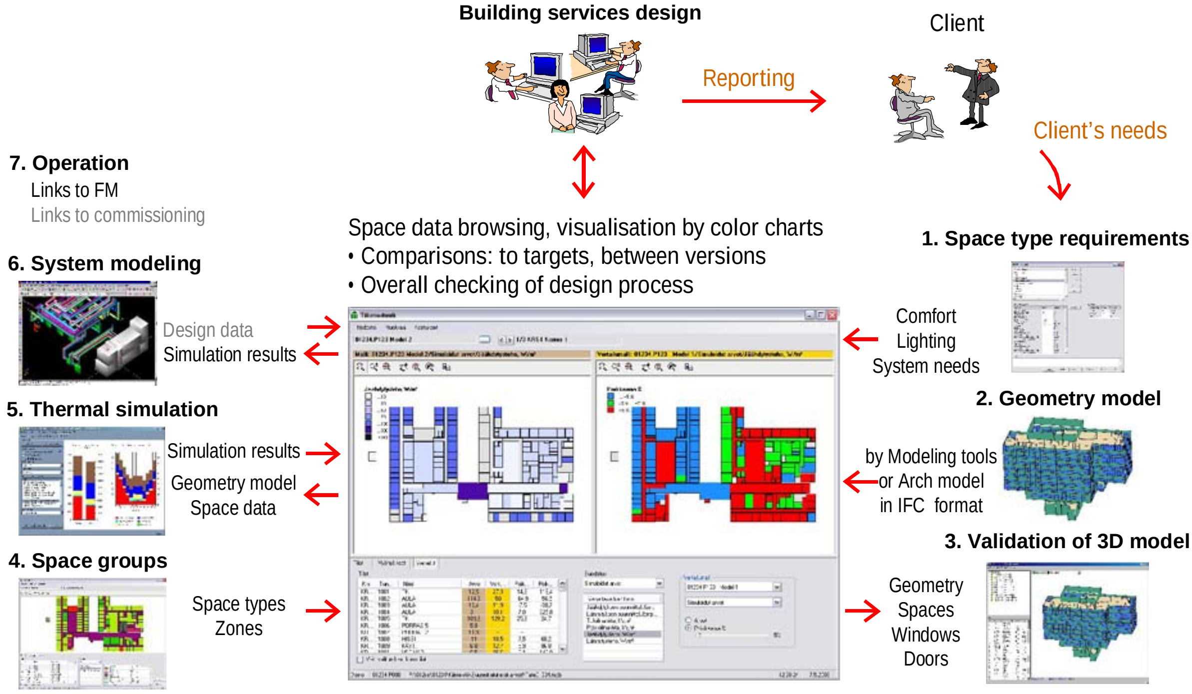

Figure 3. The developed concept for BIM based thermal performance management (the implemented tasks at black, still missing tasks at grey color). The interface in the center shows BIM revision comparison of required thermal parameters against simulated performance.

Table 1. The air quality targets and equivalent loads defined at space type level.

Air quality targets

Attribute	Value	Unit
Indoor temperature, summer	26	°C
Indoor temperature, winter	21	°C
Relative humidity, summer		%
Relative humidity, winter		%
Air velocity, summer	0,25	m/s
Air velocity, winter	0,17	m/s
Carbon dioxide content (CO2)		ppm
Supply air flow	1,5	dm³/s,m²
Supply air flow		dm³/s, per
Sound level		db(A)
Filtering class		EU
Air purity class		P

Loads

Loadtype	Design...	Max value	Unit
People	0,1		p/m²
Lighting	15		W/m²
Equipment	15		W/m²

Sizing val. = Load used in sizing
Max val. = Maximum load

Values of relative humidity are agreed together with the client

Calculated air-flow/person = 15 dm³/s, per

To utilise BIM in energy simulation, IFC model is simplified by pre-processing it. Some format of building objects (Proxys and BREP walls) do not contain the information needed for energy simulation. Figure 4 shows an example from the HITOS project [10], where the biggest part of the architectural BIM was beneficial for thermal analysis to create the required input, but some of the facades were modeled by using BREP format wall objects instead of parametric representation. By visualising the problematic parts (red color) of the model, architect was able to correct the model in the next revision to meet also the requirements of energy simulation.

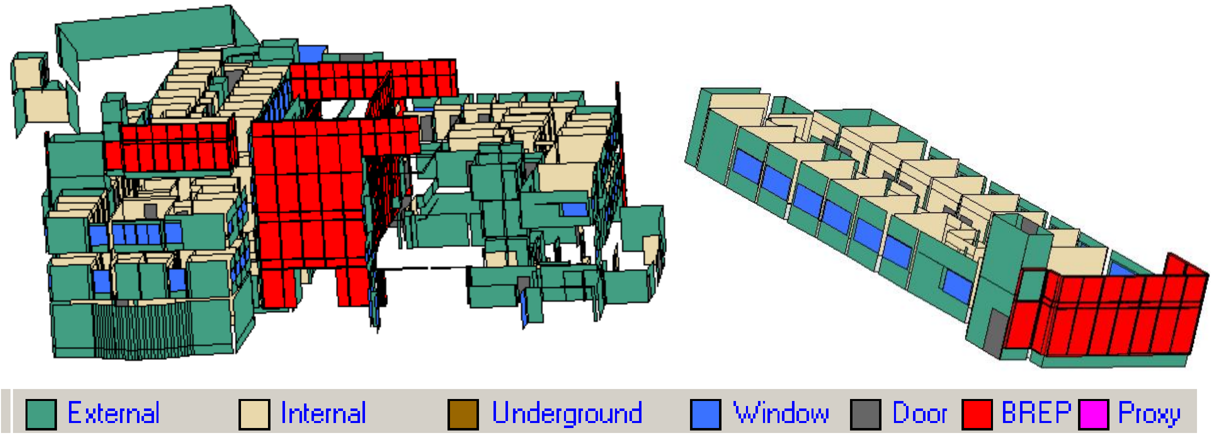

Figure 4. The architectural model of building elements can be imported to energy analysis. It is important to validate that the model meets the requirements of energy analysis.

Space grouping

Space groups (task 4 in figure 3) are created both to define spatial requirements by mapping the space type requirements to actual spaces and for zoning the spaces into different categories, such as air handling unit service areas or lighting control areas. These specifications should be done in the beginning of the building services conceptual design. The same information is needed as input data for energy analysis.

Thermal simulation

In thermal simulation (task 5 in figure 3) the building geometry related data, spatial requirements, loads and air-conditioning and lighting system zones are imported as input data. Additional input, such as usage schedules, HVAC and electrical system specifications and weather data, is defined by using the energy simulation software user interfaces. The simulation results of the spatial thermal performance are exported back to the BIM, allowing performance verification against targets and generation of input data for the HVAC system modelling.

Energy analysis in several projects (Figure 5) has been done by using IDM process descriptions and information exchange requirements. The IDM supports also the creating of energy analysis software specific training material, like the example in figure 6 to describe the required actions in energy analysis to acquire construction type data and assign it to occurrences.

Key requirements for wider use of energy simulation in practical projects are:

- modern user interfaces for practitioners instead of researchers
- efficient data input by reusing the existing information by linkage to BIM and
- using of intelligent data libraries.

Efficient computing is required to move from zone based models to spatial whole building approach. This means also balancing between solver accuracy and efficiency.

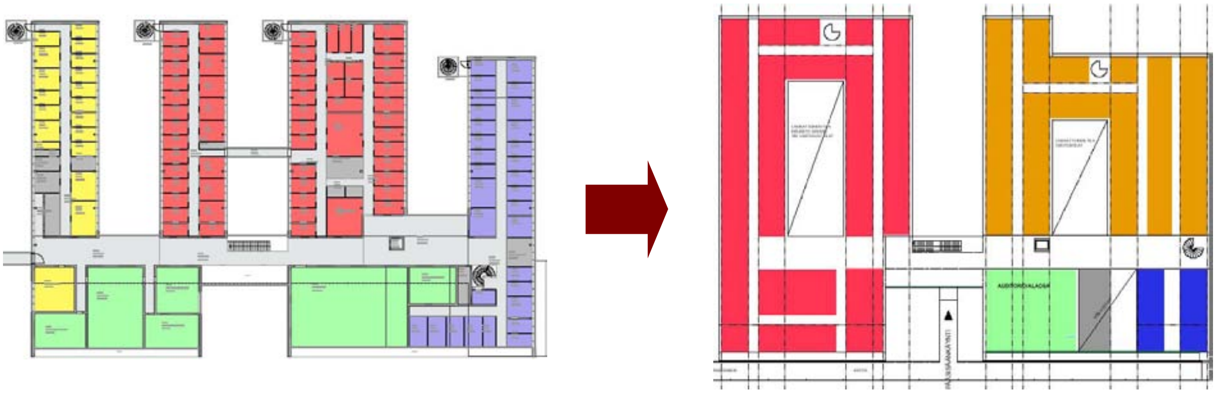

Figure 5. The energy efficiency of the architectural design of the Aurora 2 building [11] was developed during the programming phase by using BIM based energy analysis. From the first solution of cellular office plan with narrow building body (left, a “comb” type of layout), the envelope area was reduced by using glazed inner courtyards for distribution of daylight for the surrounding office spaces (right).

Building services system modelling

The results from thermal simulation can be transferred as starting point to building services system modelling (task 6 in figure 3). The information, such as spatial air flow, heating and cooling needs, is used to select air conditioning equipment for HVAC system model.

Operation and maintenance

Thermal performance management should continue during operation and maintenance phase (task 7 in figure 3). Figure 6 shows an example how the self-reporting building system [12] is used for thermal performance management during operation phase.

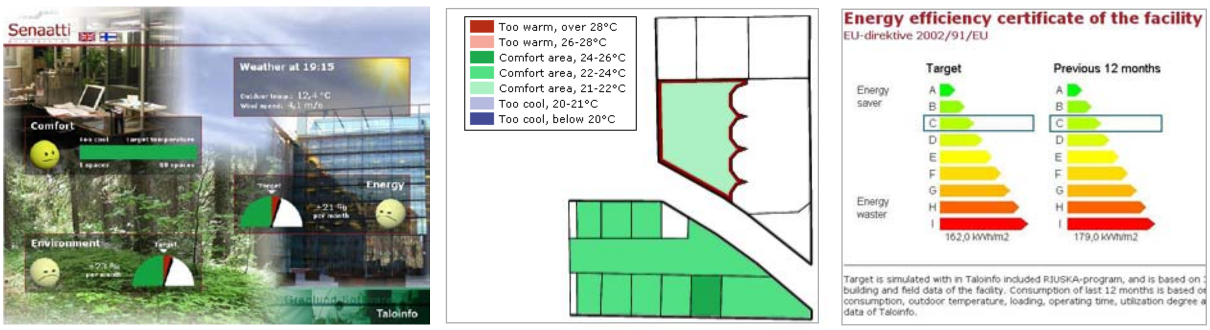

Figure 6. Self-reporting building system for BIM based performance management, including reports for top level performance evaluation (left), spatial comfort requirements verification (center) and on-line energy efficiency certificate (right).

BIM based approach also allows possibility to react on the changes in the use of the building by easy updating of energy and condition targets for monitoring and management systems.

DISCUSSION

The results show potential benefits of utilising BIM based concept in energy analysis: more efficient data input and more reuse for the existing data, possibility to use dynamic energy simulation instead of traditionally used static methods, support to use whole building spatial simulation instead of traditionally used zone based approach. However from the whole building process perspective, the biggest benefit is that by using BIM it is possible to bring continuous verification of energy performance for the whole building life cycle.

The real project experiences also showed, that successful BIM based energy analysis requires BIM revision management with comparison possibilities between different revisions, easy-to-understand visualisations of the thermal performance for clients and architect model validation for energy analysis purposes.

ACKNOWLEDGEMENT

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