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Integrating Environmentally Responsive Elements in Buildings

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ABSTRACT

Significant improvement have been achieved on efficiency improvements of specific building elements like the building envelope and building equipment and services and whilst most building elements still offer opportunities for efficiency improvements, the greatest future potential lie with technologies that promote the integration of responsive building elements and building services in integrated building concepts.

In order to address some of these issues an international research effort, IEA-ECBCS Annex 44 has been initiated. The paper especially presents the annex activities regarding development of Energy and Environmental Building concepts including discussion of the selected design strategy and technical solutions, the integrated design approach and design methods and tools.

KEYWORDS

Integrated Building Concept, Responsive Building Elements, Design Strategy, Integrated Design Approach

INTRODUCTION

Research into building energy efficiency over the last decade has focused on efficiency improvements of specific building elements like the building envelope, including its walls, roofs and fenestration components, and building equipment such as heating, ventilation, air handling, cooling equipment and lighting. Significant improvement have been achieved, and whilst most building elements still offer opportunities for efficiency improvements, the greatest future potential lie with technologies that actively respond to changing conditions and also promote the integration of responsive building elements and building services.

In this perspective *Integrating Building Concepts* are defined as solutions where responsive building elements together with building services are integrated into one system to reach an optimal environmental performance in terms of energy performance, resource consumption, ecological loadings and indoor environmental quality. *Responsive Building Elements* are defined as building construction elements which are actively used for transfer of heat, light and air. This means that construction elements (like floors, walls, roofs, foundation etc.) are logically and rationally combined and integrated with building service functions such as heating, cooling, ventilation and energy storage. With the integration of responsive building elements and building services, building design completely changes from design of individual systems to integrated design of "whole building concepts, augmented by "intelligent" systems and equipment.

In order to address some of these issues an international research effort has been initiated. IEA-ECBCS Annex 44: "Integrating Environmentally Responsive Elements in Buildings" is a task-shared research project initiated by the IEA implementing agreement Energy Conservation in Buildings and Community Systems (ECBCS). The project runs for 4 years from 2005-2008 and involves about 25 research institutes, universities and private companies from 14 countries around the world.

IEA-ECBCS Annex 44 address the following objectives:

- State-of-the-art review of responsive building elements, of integrated building concepts and of design methods and tools
- Improve and optimise responsive building elements
- Develop and optimise new building concepts with integration of responsive building elements, HVAC-systems as well as natural and renewable energy strategies
- Develop guidelines and procedures for estimation of environmental performance of responsive building elements and integrated building concepts

More information about the Annex is available from the websites: http://www.ecbcs.org/annexes/annex44.htm and www.civil.aau.dk/Annex44.

ENERGY AND ENVIRONMENTAL BUILDING CONCEPT

A whole building concept or integrated building concept includes all aspects of building construction (architecture, facades, structure, function, fire, acoustics, materials, energy use, indoor environmental quality, etc…). In Annex 44 we define an integrated building concept to consist of three parts:

- the architectural building concept,
- the structural building concept and
- the energy and environmental building concept

This corresponds to the three different main professions involved and each concept is developed in parallel by the three professions using their own set of methods and tools - but in an integrated design process leading to an integrated solution – the Integrated Building Concept.

In Annex 44 an Energy and Environmental Building Concept is defined as:

> "Integrated design solutions where responsive building elements and energy-systems are integrated into one system to reach an optimal environmental performance in terms of energy performance, resource consumption, ecological loadings and indoor environmental quality".

Design Strategy and Technical Solutions

In order to reach an integrated design solution and develop an Energy and Environmental Building Concept it is necessary to define and apply a certain design strategy. In Annex 44 the design strategy is based on the method of the “Kyoto Pyramid”, see figure 1.

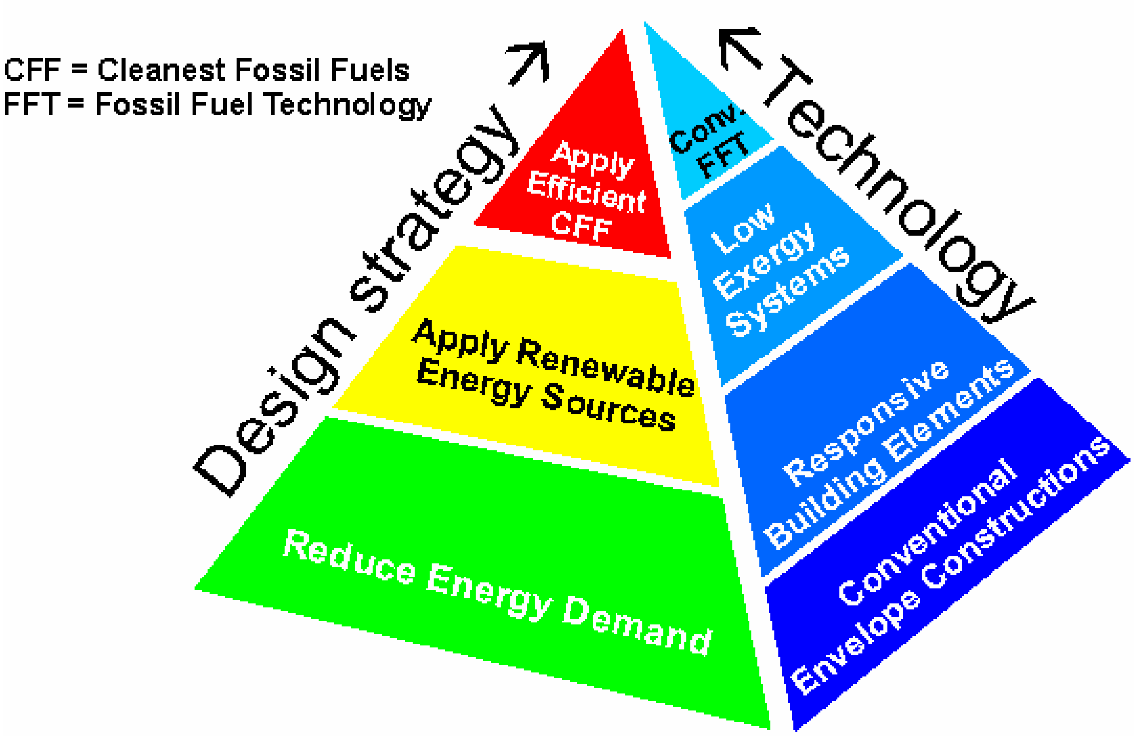

Figure 1: Illustration of Annex 44 Design Strategy and corresponding Technologies

The *Kyoto Pyramid* (KP) is a strategy that has been developed for the design of low energy buildings in Norway, (Dokka and Rødsjø, 2005). It is based on the Trias Energetica method described by Lysen (1996). The left side of the pyramid shows the design strategies, and the right side of the pyramid shows the techical solutions that may be applied in each of the steps. In an integrated design strategy, you start at the bottom of the pyramid, applying the strategies and technologies as follows:

1. *Reduce Demand*

   Optimize building form and zoning, apply super insulated and air tight conventional envelope constructions, apply efficient heat recovery of ventilation air during heating season, apply energy efficient electric lighting and equipment, ensure low pressure drops in ventilation air paths, etc.

   Apply Responsive Building Elements if appropriate including advanced façades with optimum window orientation, exploitation of daylight, proper use of thermal mass, redistribution of heat within the building, dynamic insulation, etc.

2. *Utilize renewable energy sources*
   Provide optimal use of passive solar heating, dayligthing, natural ventilation, night cooling, earth coupling. Apply solar collectors, solar cells, geothermal energy, ground water storage, biomass, etc. Optimise the use of renewable energy by application of low exergy systems.

3. *Efficient use of fossil fuels*
   If any auxiliary energy is needed, use the least polluting fossil fuels in an efficient way, e.g. heat pumps, high-efficient gas fired boilers, gas fired CHP-units, etc. Provide intelligent control of system including demand control of heating, ventilation, lighting and equipment

The main benefit of the method is that it stresses the importance of reducing the energy load before adding systems for energy supply. This promotes robust solutions with the lowest possible environmental loadings.

Classification

The purpose of classification of Energy and Environmental Building Concepts is to define/specify what is meant by the concept and to get an idea of what direction to take in the preliminary design phase.

A general classification should not be too complicated and not with too many categories. An “Energy and Environmental Building Concept” can be classified according to the following categories and parameters:

TABLE 1
Categories and parameters for classification of Energy and Environmental Building Concepts

Category	**Parameter**
Climate	Cold, moderate, warm, hot-dry, hot humid, …
Context	Urban, suburban, rural
Building use	Office, school, residential, ...
Building type	High-rise, low-rise, row-houses, single houses, multifamily buildings, ...
Demand reduction strategies	Thermal insulation, air tightness, buffering, reduction of heat and contaminant loads, building form, zoning, demand control, efficient air distribution, solar shading, ..
Control strategy	Natural mechanism, adaptive/rigid, user control/automatic
Renewable energy technologies	Passive and active solar heating, wind, natural cooling, geothermal heat/cool, biomass, dayligthing, natural ventilation,..
Efficient energy conversion	CHP, HE gas boiler, heat pump, …

In the development of existing energy and environmental building concepts the main focus has typically been on some of the above mentioned steps in the design strategy and corresponding technical solutions. Examples are:

- The “Passive House” concept which mainly focuses on super insulated and air tight envelopes combined with high efficiency heat recovery

- The “Solar House” concept which mainly focuses on utilization of renewable energy technologies such as passive and active solar heating and solar cells

- The “Smart House” concept which mainly focuses on advanced solutions for demand control and efficient use of fossil fuel technologies

- The “Adaptive Building” concept in which building elements actively respond to changing climate conditions and indoor environmental conditions as required by the occupants

The Energy and Environmental Building Concepts developed in Annex 44 will search for an optimum combination of the existing concepts by using the described design strategy and the full range of technical solutions.

INTEGRATED DESIGN APPROACH

In the development of a whole building concept or integrated building concept an integrated design approach is needed to enable the designer(s) to control the many parameters that must be considered and integrated, when creating more holistic building concepts.

Design Methods and Tools

In order to facilitate this design approach different types of design methods and tools that based on the selected design strategy makes it possible in a strategic way to select the most suitable technical solutions for the specific building and context.

In the Annex 44 state-of-the-art review different existing design methods and tools were reviewed and further work will include further development of these methods and guidelines for their use. The review identified 5 main categories of design methods and tools: design process methods/tools, design strategy methods/tool, design support methods/tools, design evaluation methods/tools, and simulation tools.

The *design process methods/tools* gives guidelines on how to organise the work process itself, i.e. who should take care of what tasks at what stages of the development and design of an Integrated Building Concept. It is necessary that the methods allow for consideration and solution of technical as well as aesthetical problems and that it focuses on the creative element in the process, in order to identify new opportunities and to work strategically in creating innovative solutions in a new building design.

The *design strategy methods/tools* are concerned with what issues should be considered at different stages of the development of an Energy and Environmental Building Concept.

The *design support methods/tools* are typically used in the early stages of the design to get an idea of what approaches and technical solutions are the most promising for the given project and should be included in the developed Energy and Environmental Building Concept.

The design evaluation methods and tools are typically used later in the design process to check the performance of a given design concept and technical solutions.

Simulation tools are used in all stages of design in order to predict the performance of the building and technical systems. Computer simulation tools for predicting energy use, indoor environmental quality and impact on the environment are typically used as basis in the different categories of design methods. In fact, in order to succeed in creating effective integrated building concept, it is often very useful to apply advanced computer simulation tools even in the early design stages.

There are no sharp borders between the different types of design methods and tools. For example, the design support methods and tools may in some cases also be used as design evaluation methods and tools, and vice versa.

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