REEB
European strategic research **R**oadmap to ICT enabled
Energy-**E**fficiency in **B**uildings and constructions

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Lecture Notes on Energy Efficiency in Building Construction

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X	**PU** = Public
	PP = Restricted to other programme participants (including the Commission Services)
	RE = Restricted to a group specified by the consortium (including the Commission Services)
	CO = Confidential, only for members of the consortium (including the Commission Services)

Document history			
V	***Date***	***Author***	***Description***
0.0	*2009-10-31*	*Raimar Scherer*	*First draft, overall document structure and organisation of contributions*
0.1	*2009-12-01*	*Peter Katranuschkov*	*Detailed draft, including the structuring of all modules (lecture entities and sequences as well as determined fixed checkpoints and events).*
0.2	*2009-12-23*	*All authors (see title page)*	*Full text, with integrated partner input*
1.0	*2009-12-30*	*Raimar Scherer* *Peter Katranuschkov*	*Final editing; Deliverable issued for submission to EC.*
2.0	*2010-03-31*	*Raimar Scherer* *Peter Katranuschkov* *Tatiana Suarez*	*Additional description and development of selected lectures.*

Disclaimer

Executive Summary

The present version of the Deliverable "Lecture Notes on Energy Efficiency in Building Construction" is the final version of this document, in this new version it is included a new chapter (Chapter 6: Development of a Specific Lecture) which contains the development of selected lectures in detail, describing the content material in PPT slides and its corresponding extended concept explanation.

As specified in the previous version of this document, the modification included a new distribution of the Modules and the contained Lectures description, as well as the Synopsis section which synthesizes the evolution and development of the Lecture Notes Deliverable until this final version.

For this final version it was necessary to select a specific Lecture to be developed and described, taking into account the REEB outcomes and the objectives of the Project, it is understandable that it's not feasible to develop the whole content of this Deliverable.

The current version of the document contains the following principal parts:

1. Description of the evolution of the Deliverable versions (Synopsis)
2. An introduction, providing a general overview (Chapter 1)
3. The baseline of the e-learning lectures, including a description of the expected audience (Chapter 2).
4. The framework of the lecture notes (Chapter 3).
5. The overall structuring of the lecture notes (Chapter 4)
6. The structure of the separate lecture modules with detailed outline of all lectures and their key topics to be addressed (Chapter 5)
7. The development of a selected Lecture with the corresponding description (Chapter 6)
8. Short conclusions, acknowledgments and references sections (Chapters 7–9).

Synopsis

The "Lecture Notes on Energy Efficiency in Building Construction" provide the public document D5.32, delivered in the context of WP5, Task 5.3: Dissemination of REEB outcomes.

The objectives of task 5.3 are the dissemination of REEB outcomes. This is done through (1) website and related facilities, (2) newsletters, (3) lecture notes and (4) conferences.

Task 5.3 collects the results of the others WPs and synthesizes them to the Lecture Notes reported herein.

The **first step** of this task was to collect this input in a topic list, the Table Of Content (TOC). Based on the TOC the lecture notes are designed. This includes structuring the results of the other WPs in adequate lecturing units, modularizing them and finally generalizing them in order to be customised to different audiences, namely students, architects and engineers but also building owners, energy suppliers and governmental authorities. Each of these lecture units (called modules) does have a different background and objectives and hence needs other lecture contents and/or other presentation forms for one and the same topic. They are described in the form of Learning Outcomes (LOs).
*(This is the specific result presented in **D5.32 version 0**).*

In a **third step** each module is detailed in individual lecture entities, where each entity is about equivalent to a lecture hour (90 min) and is described by a list of bullet points, keying the main learning targets and objectives.
*(This is the specific result presented in **D5.32 version 1**).*

In a **final step** a selected subset of lectures is worked out. To develop the content of all possible lectures is not feasible for the purpose of REEB and this specific deliverable. Therefore concentration is on the EE related view of building design and in particular the BIM, i.e. the model-based working and selected lecture notes in the form of PPT presentations that are in the focus of the REEB tasks and according to the preferences of the REEB partners meeting the REEB objectives.
*(This is the specific result presented in this final version: **D5.32 version 2**).*

The lectures include new ICT-based concepts, technologies and practices as well as products and solutions for improving the energy efficiency in Building Design (AEC) and Operation (FM), aiming to promote and stimulate the innovative use of ICT in EE to reach the widest audience as a support for future initiatives.

Contents

Abbreviations

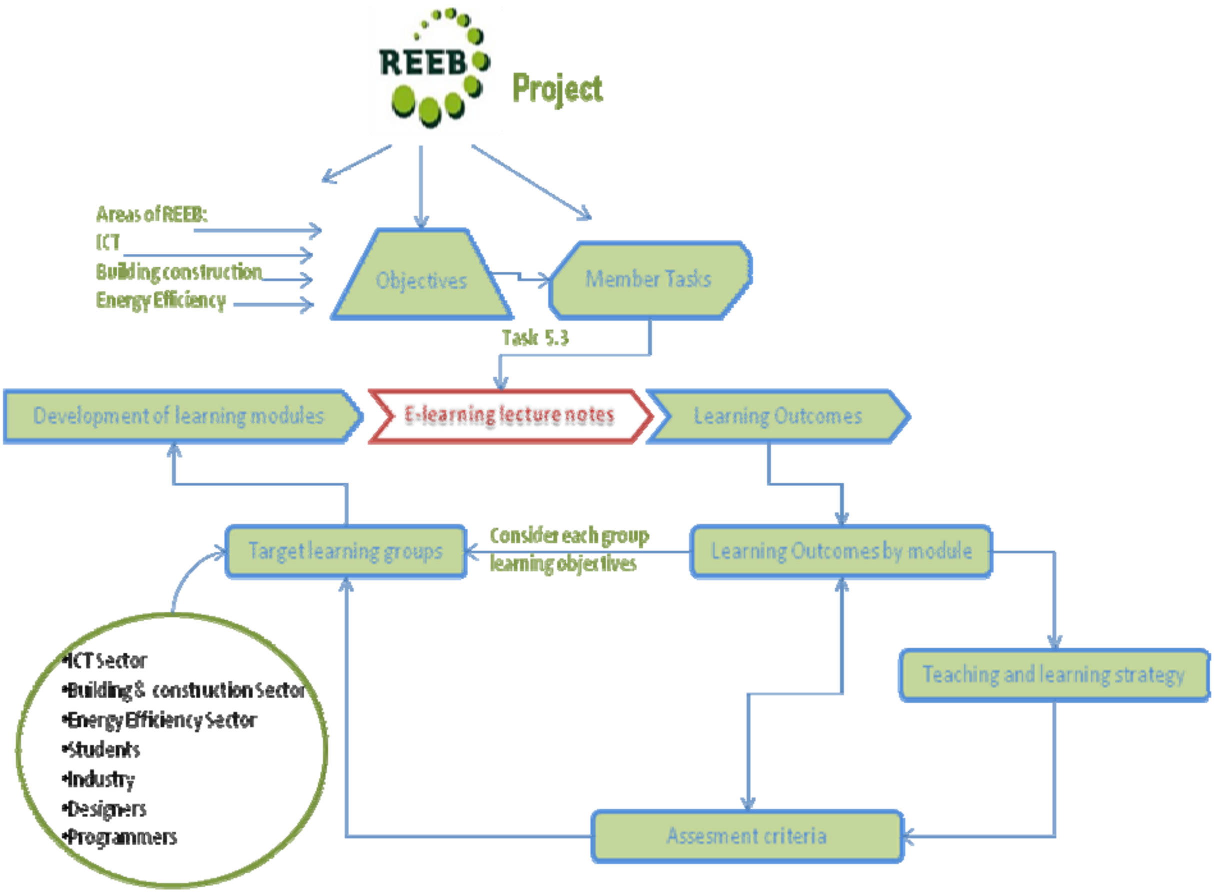
AEC	Architecture, Engineering, Construction
BACS	Building Automation & Control Systems
BAS	Building Automation System
BAMS	Building Automation and Management System
BEMS	Building Energy Management System
BIM	Building Information Modelling
BMS	Building Management System
CCMS	Central control & Monitoring Systems
CHP	Combined Heat and Power
DDC	Direct Digital Control
ECTS	European Credit and Accumulation System
EE	Energy Efficiency
EPC	Energy Performance Classes
FM	Facilities Management
HVAC	Heating, Ventilation and Air Conditioning
IBAS	Integrated Building Automation System
ICT	Information and Communication Technologies
IFC	Industry Foundation Classes
IES	Integrated Energy Systems
LCC	Life-Cycle Costs
LCIA	Life-Cycle Impact Assessment
MEP	Mechanical, electrical and plumbing engineering
PLC	Programmable Logic Controller
REEB	European strategic research **R**oadmap to ICT enabled **E**nergy-**E**fficiency in **B**uildings and constructions
SCADA	Supervisory Control & Data acquision
STEP	STandard for the Exchange of Product Data (ISO 10303)
TMB	Technical Building Management Systems
VAV	Variable volume air-handling units
WSNs	Wireless Sensor Networks

1. INTRODUCTION

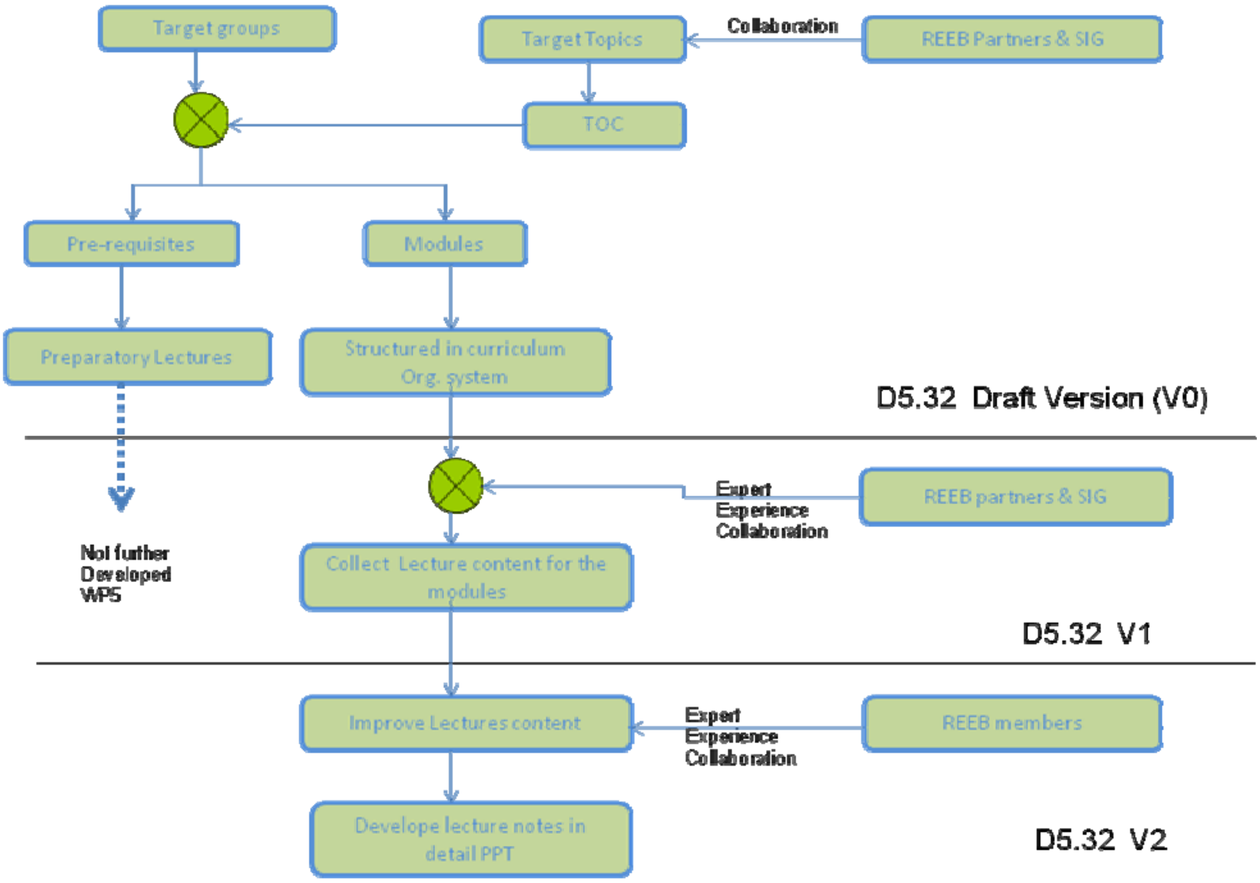
This report contains the organization of the e-learning material from base educational lessons in ICT applications for Energy Efficient Building Design, incorporating multimedia techniques to produce an authentic, online course education as a final result. The development of this course through online lessons is based on modules containing these lectures notes, targeting a wide audience of educators, students, industry and investors.

These Lecture Notes are based on a shared vision investigation targeting the planning, design of buildings and the related controlling and monitoring systems concerning the ICT applications for the improvement of the Energy Efficiency of Buildings.

The design of the lecture notes are based on the results of the others WP´s and are based on the experience of the authors, the institute "Construction and Informatics", which is strong in BIM data structure, product and process modelling and the related institute of "Building Climate" which is strong in building energetic analysis and building energetic design.



E-learning lectures vision



E-learning lectures development

2. BASELINE OF THE E-LEARNING LECTURES

These lectures are based on the planning, organization, management and experience of previous e-learning activities combined with new subjects on the field of ICT for Energy Efficiency in Building Design.

2.1 OBJECTIVES AND PERSPECTIVES OF THE E-LEARNING LECTURES

The related information and technologies about energy efficiency are growing very fast and getting more and more complex, to handle and disseminate the information effectively, an efficient way of information management is needed. It is important to provide the necessary information, both to the decision-maker and to the public at large, creating an e-learning environment to support education and professional training and promoting learning self-study of the subject.

For all these reasons the objectives and perspectives are the following:

- The lectures aims at broadening the understanding and hence the application of the use of ICT in EE of BC in AEC, FM and related communities through e-learning illustrated case studies and applications.
- To extend the application of the ICT in EE of BC communities to the e-learning field through illustrated case studies and applications.
- It is expected the learning public to receive the information knowledge effectively, promoting engaging investigation of the theory and research of new technologies aspects.
- To make the information more accessible to building designer, policy makers, researchers and others involved in the building life-cycle.
- To keep the learning public motivated and encourage them to become more aware of the potential and benefits of energy efficiency.
- To increase technical, economic and environmental interest in energy efficiency and ICT related applications.

2.2 DEFINITION OF THE E-LEARNING COMMUNITY

The participants of this e-learning programme will be confirmed by a wide audience interested in the energy efficiency and Building construction related field: experts and professionals, programmers and non programmers, students, industrials, investors, training specialists, products developers, service developers, architects, building engineers, mechanical engineers, electrical engineers and facility asset managers.

They can be structures in 3 groups:

1) Basic participants
2) Intermediate participants
3) Advanced participants

It is expected that the e-learning community will be open and wide as possible.

2.3 CRITERIA TO CHOSE LEARNING LECTURES

The structure and design of these lectures integrate the main concepts which are included in the learning material. The subjects included in the learning material are the following:

- ICT based solutions as an enabler for energy efficiency
- ICT tools for the management of energy systems
- ICT tools for the design (CAD) of Energy-efficient buildings
- EE factors and challenges, planning design & control system
- EE program & performance analysis.

The learning modules are articulated based on the content management and on learning experience.

2.4 E-LEARNING PLATFORM

The Web-based system of the e-learning platform aims to establish a rich information network with comprehensive information made to reach a real broad audience. This platform should be held in an open system Website and it would be recommended to make a development work on the national level and language- of each member- to draw a better public attention. However in the first step English will be chosen.

It is intended that the test platform will be provided and tested, at the beginning of this program with university students in the universities of the academics REEB members and in the near future will be open to the public (see 2.4)

It is intended to hold the e-learning programme as a test site in collaboration with the ICT Euromaster e-learning course. http://euromaster.itcedu.net/.

This platform will be adjusted to easy access and distribution for self directed lessons, and it is expected to count with a multimedia strategy to expand the public interaction.

3. FRAMEWORK OF THE E-LEARNING PROGRAMME

3.1 COURSE AIMS AND OBJECTIVES (LEARNING OUTCOMES)

After successful completion of this course, participants will acquire awareness and competence about:

- Advanced knowledge about and training in ICT for energy-efficient building design.
- Development of integrative energy efficiency systems.
- Energy life-cycle analysis of buildings.
- Detailing energy zones and rooms to obtain optimal climatic conditions.
- Detailing building elements to avoid cool bridges and moisture problems.
- Designing the sensor systems for optimal climatic control.
- Design (customize) the controlling system.
- Analysing gaps in the energetic behaviour of existing building and developing plans for improvement.
- Energy-efficient operation of buildings.

The e-learning lectures will facilitate knowledge diffusion and a new learning/ teaching experience approaches that assures

- Shared responsibility toward improved energy performance in buildings and through communities;
- Transforming behaviour by educating and motivating the building transactions professionals into alters their course toward improved energy efficiency in buildings;
- Raising awareness of energy efficiency value by those involved in the development, operation and use of buildings.

3.2 COURSE PREREQUISITES

Due to the variable targeted public it is expected that the structured modules will include preliminary introduction to each area of study, although the participants should have basic knowledge in:

- Energy resources and consumption
- Building elements
- Software applications

The curriculum is focused on:

- Professionals with an academic knowledge in the building field, structural engineering, surveying, construction or architecture.
- Students but with basic knowledge in structural engineering, building construction or architecture.
- Professionals in ICT which will use their knowledge in the application to the energy efficiency field.
- Professionals involved in energy technology field.
- Designers, developers, providers related and interested in the study field.

Due to this heterogeneity of the potential audience it was felt that preparatory modules may be helpful which will offer the basic prerequisite knowledge about energy source, energy methods, climate, system capturing, system control, life-cycle analysis. However it was decided, that the development of these modules are not in the focus of this WP.

3.3 COURSE CREDITS

The credit distribution is based on the European Credit Transfer and Accumulation System (ECTS) to ensure that the courses are compatible with the academic system and can be seamlessly merged in academic curricula. Therefore it is based on the principle that 60 credits measure the workload of a full-time student during one academic year with around 1500 hours per year and one credit stands for around 25 working hours.

The working hours are divided into direct lecture hours and indirect ones, namely pre- and post-preparation hours, i.e. to self-study the lecture material, to solve lecture-accompanying tasks and to prepare individual semester project work.

As a whole, the "ICT Application in Energy Efficiency Building Design" program is a sequence of six learning modules, included in a standard learning structure for regular students. The entire programme is planned to cover one full year, divided in two semesters of 30 credits each with 25 hours/credit per semester and 15 weeks per semester (in the mean).

3.4 ACCREDITATION AND CERTIFICATE

At present the member's participants - TUD and UCC - can implement these learning lectures as a part of their current university activities. The students will receive the accumulative credits for taking part in the courses. Free students who perform the required activities and assignments and passed written examination will receive a personal teacher certificate. Any professional taking part in the courses is counted as a free student.

4. LEARNING MODULES STRUCTURE

4.1 RECOMMENDATION GUIDELINES

The extension of the course will depend on the learning options of every participant; the users will be able to choose the lessons that best suit their learning activities. The modules are accordingly sub-structured in order of knowledge level, i.e. basic knowledge (modules M1 & M2), main working knowledge (modules M3, M4 & M5) and advanced analyses and evaluation (M6).

The modules M1 and M2 provide an introduction to the basic aspect of energy efficiency application in building design and are recommended to non experienced people in the field.

The intermediate modules (M3, M4 & M5) are considered to be the beginning of the learning modules for experienced public and will thereby include various application technologies of interest. The final module (M6) is a practice based application**.**

Each lecture within the modules will include literature recommendations. Reading material will include a website link to implement the learning process and free or trial software downloads (sites) for practice application.

4.2 MODULE OVERVIEW

4.2.1 First Semester

- **Number of modules:** 3
- **Target learning public:** No preliminary prerequisites; open to students and professionals in building construction; ICT or energy efficiency. However, preparatory lectures should be taken into account.
- **Learning Objectives:** To integrate the pre-design schematics ideas and most suitable concepts for the pre-design of a new building structure or significant retrofitting facilities. The principal aim is to prepare the target public to recognize the key issues that should be addressed in the early pre-design stage for a more energy efficiency integrated building design. The learning public will acquire the necessary basic introduction to the design overview application and will have a better level of maturity and perception of sustainable and "green" buildings.

Module M1: ICT Applications in EE Building Design

Number of credits:	6
Lecture hours per week:	5
Lecture hours in total:	75 h
Working load in total:	150 h
Level:	Basic knowledge

Module M2: Energy Basic Aspects in Building Design

Number of credits:	12
Hours per week:	9
Lecture hours in total:	135 h
Working load in total:	300 h
Level:	Basic knowledge

Module M3: Energy Efficient Planning System

Number of credits: 12
Hours per week: 9
Lecture hours in total: 135 h
Working load in total: 300 h
Level: Intermediate knowledge

4.2.2 Second Semester

- **Number of modules:** 3
- **Target learning public:** The modules M1, M2 and M3 are a mandatory prerequisite for non expert students; the module is open to experts with intermediate knowledge in energy efficiency building construction design.
- **Learning Objectives:** These modules aim to provide the performance analysis and development tools to their application on the design process, after the culmination of the three final modules the learning public will be able to develop a strategy for an optimal energy efficiency building design from a modelling point of view and their environmental evaluation and control system.

Module M4: Energy Efficient Design System

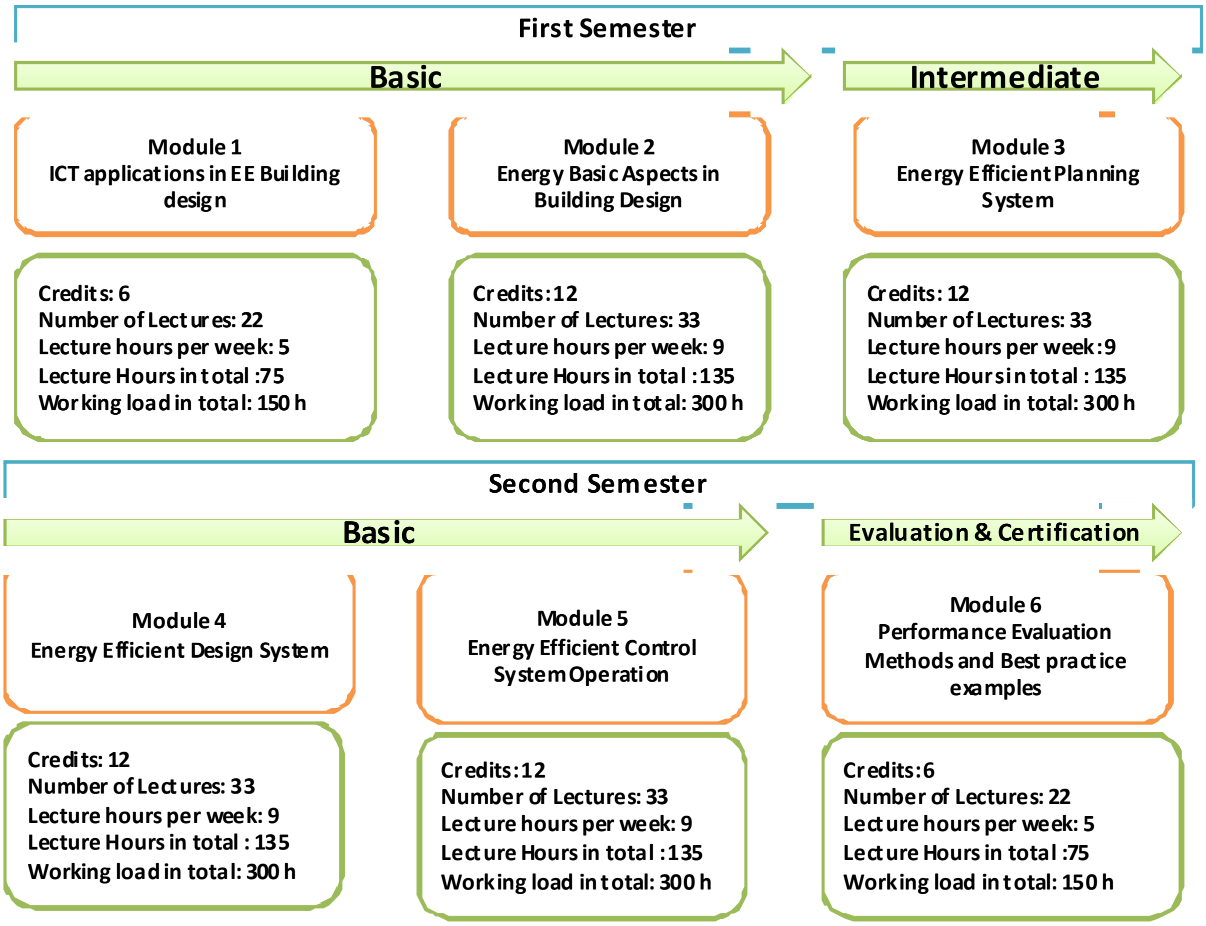
Number of credits: 12
Hours per week: 9
Lecture hours in total: 135 h
Working load in total: 300 h
Level: Intermediate knowledge

Module M5: Energy Efficient Control System Operation

Number of credits: 11
Hours per week: 9
Lecture hours in total: 135 h
Working load in total: 300 h
Level: Intermediate knowledge

Module M6: Performance Evaluation Methods and Best Practice Examples

Number of credits: 6
Lecture hours per week: 5
Lecture hours in total: 75 h
Working load in total: 150 h
Level: Evaluation and certification.



Learning modules structure

4.3 PRINCIPAL STRUCTURING OF THE INDIVIDUAL MODULES

For the Last present Version of the following document (V 3.0), it was made a little adjustment of the superficial global structure of each modules credit; the main observation concentrates in the large amount of Lectures and the real capacity to cover the number of teaching hours expected. For these reasons, the applied modification was punctual to the summary of number of lectures and the consequent number or teaching hours; however the modules remain the same as the last version structure.

As decided, all modules were conceived in the form of alternating lectures and exercises in ratio 1:1, suitable for both in-class and guided on-line presentation. Accordingly, the two modules comprising 68 lecture hours (M1 and M6) will include 17 lectures with corresponding exercises lectures, and the four modules comprising 124 lecture hours (M2–M5) will include 30 lectures with corresponding exercise lectures as well.

The exercises will be additionally subdivided into two types:
(a) guided exercises (tutorials), and (b) hands-on exercises (mainly students own work).

In each module, there will be one lecture (at approximately 2/3 of the full duration) specifically dedicated to discussion/specification of individual semester project work and one lecture (at the end) summarising the lessons learned, providing evaluation of the semester project work and extending recommendations for further studies.

Furthermore, in each module specific attention will be paid to ICT related issues regarding EE in Building Construction, in alignment with the vision and roadmap of REEB.

The overall working load of each module takes into account the above mentioned curricula, the individual project work and the anticipated hours for self-studies.

The following Chapter 5 presents a synopsis of each module and the outline of all lectures, including the key topics to be addressed. All lectures are numbered in uniform manner as follows:

M<*module #*>.L<*lecture #*>

As an example, M1.L3 means the third lecture (L3) of module one (M1), and M4.L25 means the twenty-fifth lecture (L25) of module four (M4).

There are also some cases where the learning material extends over two lectures while providing one integral learning goal. Such “double” lectures are marked with two numbers, e.g. M1.L7/8 means that the included learning material will be presented in lectures L7 and L8 of M1.

It is expected that this document describe a modular Learning structure to give an overview of the learning methods and important points in the area of main importance of REEB but the possibility to integrate and develop the whole two semester’s lectures is a matter of future arrangements in the Learning plan of UCC and TUD.

5. LEARNING MODULES CONTENTS

5.1 MODULE 1: ICT APPLICATIONS IN EE BUILDING DESIGN

(PREPARATORY MODULE FOR EE BUILDING)

5.1.1 Synopsis

In this module the energy efficiency factors variation in buildings according to geography, climate, building type and location are analysed, mapping the energy resources with regard of energy system development, as important part of the decision basis for potential measures. It includes the critical factors and challenges, awareness, training and availability of material, equipments and technologies. Basic principles of ICT support of EE of buildings are introduced and explained.

The objective of the module is to establish the basic standards and basic assessment that need to be known in order to provide adequate ICT-supported energy efficient design.

Overall, the module structure is as follows:

- Lectures **L1-L6** provide an **overview** of the various aspects related to EE building and construction that need to be considered (energy resources, thermal performance, lighting performance, building diagnostics, ICT use in various EE related building sub-systems)
- Lectures **L7-L13** present fundamental principles of **systems modelling** needed for proper understanding of major issues in all subsequent modules
- Lecture **L14** is specifically dedicated to the discussion and specification of the individual **semester project work**
- Lectures **L15-L21** provide an overview of various **basic and advanced ICT concepts and architectures** for use in EE building and construction, including also EE related standards, regulations and guidelines as well as critical factors and challenges to be taken into account
- The final lecture **L22** provides a **summary evaluation** of the learned material and the achieved results in the individual semester project work, and gives recommendations for further reading and future practice.

5.1.2 Outline of Lectures

M1.L1 Introduction to ICT APPLICATIONS IN EE BUILDING DESIGN

- Motivation and objectives of the module, learning goals
- Introduction to research principles, designs and methods with regard to building performance modelling and energy efficient building and construction
- Introduction to thermal, acoustic and lighting modelling and building simulation using CAD
- State-of-the-art review and current best practice examples

M1.L2 Energy resources survey

- Overview of resources with regard to EE building and construction, in the context of production and consumption
- Types of resources and their relevance to design/construction/FM decisions
- Discussion of potentials for improving energy efficiency

M1.L3 Thermal building performance

- Basic concepts
- Overview of design and computational methods
- Outline of computational tools for prediction and analysis of a building's performance (specifically: thermal performance) with regard to building physics

M1.L4 Lighting building performance

- Basic concepts
- Overview of design and computational methods
- Outline of computational tools for prediction and analysis of a building's performance (specifically: lighting performance) with regard to building physics
- Review of further building performance aspects

M1.L5 Building Diagnostics

- Basic concepts, objectives and benefits
- The concept of "intelligent building"
- Development of building diagnostic systems (historical review)
- Review of modern building diagnostic systems and building control

M1.L6 Scenarios of ICT applications for energy efficient building and construction

- ICT devices components and systems application for the improvement of EE in building design and construction and their relevance in the reduction of energy consumption and costs
- Facilitating EE factors via ICT
- Principal use scenarios in new construction and in retrofitting existing buildings
- Principal use scenarios in FM

M1.L7/8 Introduction to system modelling

- Basics of system theory
- Types of systems in building design and their relevance for EE building
- Fundamentals of system modelling
- System components and inter-relationships, super- and sub-systems
- System interoperability
- Meta-models and multi-models
- Principal concepts of system design

M1.L9 Process modelling

- Basic concepts, objectives and benefits for EE building and construction
- State-of-the-art and brief historical review
- Process modelling paradigms, levels of process modelling
- Process modelling languages - introduction to IDEF0, EPC and BPMN
- Process modelling and ICT

M1.L10/11 Product modelling

- Basic concepts, objectives and benefits for EE building and construction
- State-of-the-art and brief historical review
- Product modelling paradigms and product modelling levels
- Formal and graphical product modelling languages – introduction to STEP/EXPRESS XML Schema and RDFS
- Product models in Building Construction – ISO STEP AP225, STEP CDS, CIS/2, IFC
- Domain-specific modelling
- Modelling hints and caveats
- Product modelling and ICT: The BuildingSMART initiative

M1.L12 Lifecycle and cost modelling

- Basic concepts, objectives and benefits for EE building and construction
- Use of process and product models in life cycle modelling and management
- The concept of "Cost Elements"
- Integration issues
- Review of LPM systems and their potential benefits for EE building and construction

M1.L13 Simulation modelling

- Basic concepts of energy simulation – what is simulation, why is it important and how does it help to save energy
- Principles of simulation modelling
- Types of simulation models
- The overall simulation modelling and performance process
- Modelling hints and caveats

M1.L14 Semester project seminar

The students explore and articulate ideas for a semester project work of choice; each student presents a proposal that outlines the project, its motivation and background, as well as the methodology to be used; the proposals are reviewed and approved by the lecturer and/or the student advisor(s)

M1.L15 ICT architectures for EE building design

- Introduction to software architectures
- Architecture components
- Architecture types
- Design principles and tools
- UML - brief overview; use of UML on detailed process and product modelling levels (activity diagrams, sequence diagrams, component diagrams, class diagrams)

M1.L16 Distributed ICT systems

- Fundamentals of distributed systems
- System topologies and their consequences with regard to software configuration, development and use
- Client-server systems, Peer-to-peer systems, Grid systems and Cloud computing – principles, advantages, disadvantages, examples and potential use

M1.L17 Ontologies

- Basic concepts, objectives and benefits for EE building and construction
- Types of ontologies
- Representational issues, difference between ontologies and product models
- Ontology languages – KL-ONE, DAML/OIL, OWL, F-Logic
- Ontology tools – overview, examples, current and potential use

M1.L18 EE related basic tools and media

- Software tools and media that are commonly used to support knowledge-based design decision making, to conduct research, and to disseminate results
    - Spreadsheets
    - Databases
    - Mathematical and statistics packages
    - Presentation media and script languages
    - Simulation applications
- Comparative analysis and synthesis of features

M1.L19 Standards, regulations and policy guidelines for EE building design

Part I:
- Scope of building energy codes and regulations
- Basic structure overview of selected regulations – calculations guidelines, required minimum performance levels, building design and control requirements and recommendations

Part II:
- Use of codes and regulations in everyday practice work
- Use of codes and regulations in EE related ICT

M1.L20 Critical factors and challenges for EE building design

- Levels of energy performance and cost effectiveness
- Low-power technologies and design solutions
- Optimisation issues with regard to energy utilisation
- Adaptive energy management
- ICT as facilitator for EE building design
- Coordination and integration issues

M1.L21 Advanced topics in EE related building science

- Presentation by academic and/or industry experts of current and recently accomplished research activities and projects
- In-depth discussion of selected international trends in the target areas

M1.L22 Project work evaluation and module wrap-up

- In-class presentations of selected semester project work by students
- Summary evaluation of semester project work
- Summary of the overall module contents
- Synthesis of the lessons learned
- Advice for further reading and future practice

5.2 MODULE 2: ENERGY BASIC ASPECTS IN BUILDING DESIGN

5.2.1 Synopsis

This module includes the introduction to building design and its important aspect influencing the overall design:

- Climatic environment and climatic design with site elements and architectural planning;
- Building envelope: exterior walls, windows, roof, underground slab and foundations
- The factors determining the heat flow across the building envelope: temperature differential, area of the building exposed and heat transmission value of the exposed area
- The Building Energy Systems: Heating, ventilation and air-conditioning (HVAC) systems with the proper evaluation of thermal comfort criteria, load calculation methods, system characteristics, equipment and plant operation (part-load); general design strategies for lighting design and other building services systems consuming energy – electrical installations, lifts and escalators, utilities supply conditions (gas and electricity) etc.

The objective of the module is to give an overview of the basic building design elements and the factors determining the heat flow across the building envelope.

Overall, the module structure is as follows:

- Lecture **L1** begins the module with a **presentation of the main EE aspects** that need to be taken into account in EE building design
- Lectures **L2-L18** are dedicated to the subject of **building climatology**
- As in the previous module, at 2/3 of the total duration of the module one lecture (**L19**) is dedicated to the discussion and specification of individual **semester project work**
- The following lectures **L20-L32** are dedicated to the principal architectural and building services concepts related to **energy optimised building design**; as practical reference the Autodesk Green Building Studio is presented in a lecture and a hands-on seminar (L23-L24)
- Finally, the last lecture **L33** provides a **summary evaluation** of the learned material and the achieved results in the individual semester project work, and gives recommendations for further reading and future practice.

5.2.2 Outline of Lectures

M2.L1 Introduction to energy basic aspects in building design

- Motivation and objectives of the module, learning goals
- Basic EE aspects in building design
- Energy sources and conversions (Renewable sources, local generation and energy storage - ground heat, heat recovery, geothermal and solar energy use, rainwater collection etc., energy generation and transmission)
- Climatic environment and climatic design
- State-of-the-art review

M2.L2 Building Climatology

- Objective and purpose of study
- Domain topics addressed
- Macro, mesa and micro climate
- Building climate control and its relation to overall EE building design

M2.L3 The indoor climatic environment

- Room climate – overall design concepts
- Parameters and measurable values of the indoor climatic environment
- Room temperature (environment temperature, operative temperature etc.)
- Humidity and air circulation
- Energy management of the human body and its consideration in building design

M2.L4/5 Architectural influences on the indoor climatic environment

- Room climate and habitants
    - Influences
    - Tolerable, comfortable and energy optimal room climate conditions
    - Minimal room climate requirements
    - Basic protective measures
- Planning measures regarding temperature
- Planning measures regarding humidity
- Planning measures regarding air circulation and velocities
- Overall climatic adjustment measures
    - Design considerations
    - Overview of design methods and tables
    - Overview of prescribed regulatory measures

M2.L6/7 Climate-friendly construction

- Autogenous heating, ventilation and air conditioning
- Energogeneous heating, ventilation and air conditioning
- Heat transfer
- Convection and heat radiation
- Influences of the building envelope – walls, windows, roof, foundations
    - Factors determining heat transfer
    - Determining temperature differentials
    - Determining the heat transmission values of exposed building areas

M2.L8 Calculation of the thermal resistance

- Basic definitions
- Minimal thermal protection – basic concepts and calculation methods
- Condensation water protection – basic concepts and calculation methods
- Mould protection calculation

M2.L9 Thermal bridges in different construction elements and their influences

- Basic features of thermal bridges
- Thermal bridges in walls
- Thermal bridges in floors and roofs
- Principal prevention methods
- Example details

M2.L10 Water Vapour Diffusion

- Sources and reasons of water vapour diffusion
- Influence of water vapour diffusion on different construction materials – consequences and prevention measures
- Computational methods according to regulations
- Advanced scientific methods

M2.L11 Examples of Thermal Bridges and Water Vapour Diffusion

- Various examples of complex construction parts such as flat roofs, facades etc.
- Selected detailed analyses
- General construction hints

M2.L12 Outdoor climatic environment

- Basic influences and parameters
- Climatic regions and their characteristics
- Measurable values of weather conditions

M2.L13 Outdoor air temperature

- Definitions and measurable values
- Daily temperature and its calculation
- Monthly and yearly temperature, calculation of average values, derivation of characteristic values related to EE building design

M2.L14 Sun radiation

- Definitions and measurable values
- Characteristic radiation angles
- Calculation of the sun radiation taking into account the influence of clouds and haze, shading, etc.
- Influence of sun radiation on the building exterior
- Derivation of characteristic values related to EE building design

M2.L15 Outdoor air humidity, wind and atmospheric pressure

- Definitions and measurable values
- Daily values and its calculation
- Monthly and yearly values, calculation of average values and derivation of characteristic values related to EE building design

M2.L16 City climate

- Basic concepts and definitions
- Antropogenous climatic factors and their influences on the EE of buildings
- Wind influences in city regions (pressure differences, turbulences, good and bad influence on the building exterior and the EE of buildings as a whole)
- Basic architectural protection measures

M2.L17/18 Natural ventilation

- Natural air movement and its calculation
- Types of natural ventilation – joint / window / shaft / roof ventilation
- Ventilation shafts and their importance in EE building design
- Pollution concentration
- Water vapour concentration
- Heat transport
- Examples: ventilation of an office room, ventilation of a humidor

M2.L19 Semester project seminar

The students explore and articulate ideas for a semester project work of choice; each student presents a proposal that outlines the project, its motivation and background, as well as the methodology to be used; the proposals are reviewed and approved by the lecturer and/or the student advisor(s)

M2.L20 Architectural concepts of energy optimised building design and construction

- Objectives and relevant socio-economic aspect
- Historical review
- State-of-the-art examples
- Current and upcoming energy efficiency policies and regulations

M2.L21/22 Energy optimised buildings

(conceived as invited lectures by experts from industry)

- Types of energy optimised buildings – principal concepts, design and life-cycle considerations
- The zero energy house
- The passive house
- Solar architecture
- The low energy and the energy plus house
- The self-sustained house
- Best practice examples

M2.L23 The Autodesk Green Building Studio (AGBS)

(conceived as invited lecture by an expert from industry)

- Overview of the Autodesk Green Building Studio web-based energy analysis service
- Use of AGBS in early design
- Interaction with Autodesk's Revit
- Carbon Neutral Design with AGBS

M2.L24 The Autodesk Green Building Studio – Hands-On Seminar

The students explore the capabilities learned in the previous lecture in a guided hands-on seminar, in which additional features of the Green Building Studio are explained and various theoretical and practical hints are given. Preparation for practical use (in the following exercises as well as in future professional life) is part of the learning goal.

M2.L25 Designing the HVAC system

- Structure and purpose of an HVAC primary and secondary system
- The hierarchical set of HVAC objects
  (Loops, Supply/Demand components, Branches, Connectors,
  Splitters and Zone Splitters, Mixers and Zone Mixers)
- EE design considerations
- Loop types in HVAC systems – air loop, zone equipment loop, plant loop supply side, plant loop demand side, condenser loops

M2.L26 Designing the HVAC system – Advanced topics

- Special type secondary systems (dual air stream system, under-floor air distribution, evaporative cooling system, low temperature system)
- Terminal units and terminal systems
- Induction units
- Fan-coil units
- Hints and caveats in HVAC system design

M2.L27 Zones and Surfaces

- Basic concepts and definitions
- Defining and working with zones
- Defining and working with surfaces
- Activity modelling for zones

M2.L28 Designing the lighting system

- Structure and purpose of the lighting system
- The hierarchical set of lighting objects
- EE design considerations
- Major EE related components

M2.L29 Designing the water supply and sewage system

- Structure and purpose of the water supply and sewage system
- The hierarchical set of the water supply and sewage system objects
- EE design considerations
- Major EE related components

M2.L30 Primary energy systems

- Basic concepts and definitions about primary energy systems (central plants)
- Primary energy system components – compressors, condensers, evaporators, heat exchangers, absorption chillers, heaters (boilers, furnaces)
- Effects of primary plants on the EE in buildings

M2.L31 Primary energy systems – advanced topics

- Interconnection between primary energy systems and buildings
- Thermal energy storage and controls
- Basic EE design considerations
- Modelling primary system loops and equipment

M2.L32 Planning and modelling the building envelope

- Basic concepts and definitions
- The elements of the building envelope
- Relationship of the Building Envelope to the EE related systems
- EE related calculations with regard to the building envelope
- Basic architectural measures for better EE design of the building envelope

M2.L33 Project work evaluation and module wrap-up

- In-class presentations of selected semester project work by students
- Summary evaluation of semester project work
- Summary of the overall module contents
- Synthesis of the lessons learned
- Advice for further reading and future practice

5.3 MODULE 3: ENERGY EFFICIENT PLANNING SYSTEM

5.3.1 Synopsis

This module targets acquisition of knowledge about the strategy and preliminary information needed to perform energy system plans that are capable to meet sustainable development goals by computational performance analyses based on statistic calculation models or physical energy consumption calculation models for application in the building process. It explains also the practice of simplified planning models for the estimation of the total energy demand, as well as the specific heating and lighting energy demand.

The BIM design and strategy specification is included, defining building form, materialisation and technical systems performance calculation at an early design stage. The building design is integrated with the energy efficient plan for high-quality, sustainable residential design. In this stage the performance baselines are developed, therefore physical analysis models for the precise calculation of detailed energy tasks as well as overall energy consumption and side-effect energy supply are also targeted.

Overall, the module structure is as follows:

- Lectures **L1-L11** introduce the **baselines for EE planning and building performance** as well as various architectural approaches and measures for sustainable EE building and construction
- Lecture **L12** presents **principles of strategic energy data management and analysis** and introduces building information modelling (BIM) as a fundamental strategic issue for successful EE planning
- The following lectures **L13-L18** discuss various issues related to the **efficient use of BIM**, including current, planned and envisaged IFC extensions for EE building and construction various integration and interoperability issues such as model views, filtering, mapping etc.
- As in the preceding modules, at 2/3 of the total duration of the module one lecture (**L19**) is dedicated to the discussion and specification of individual **semester project work**
- The following lectures **L20-L32** focus on **advanced BIM integration and interoperability topics** such as model views, filtering, mapping etc., present an overview of BIM tools and provide best practice examples for the benefits of BIM to EE planning
- Finally, as in the preceding modules, the last lecture **L33** provides a **summary evaluation** of the learned material and the achieved results in the individual semester project work, and gives recommendations for further reading and future practice.

5.3.2 Outline of Lectures

M3.L1 Introduction to ENERGY EFFICIENT PLANNING SYSTEM

- Motivation and objectives of the module, learning goals
- Overview of emerging technologies for EE building and construction
- State-of-the-art review
- European and World policies until 2025

M3.L2 Energy performance baselines

- "Green" goals related to function, security and costs based on the environmental and EE requirements
- Design cooperation with regard to the "green" planning process
- Coordination of the design professionals involved in the building design plan – key "green" topics, holistic checks and milestones

M3.L3 Building technology and strategies for sustainability

- Basic strategies for reducing the energy costs of buildings (non-mechanical system approach, building envelope: insulation and/or isolation, solar strategies, heating), alternate cooling strategies: air movement, roof cooling, roof radiator), earth coupling
- Currently available technology solutions
- Green input: trombe walls, movable/transparent insulation, thermal mass etc.

M3.L4 Architectural measures regarding EE in building performance

- Heat storage
- Glazing
- Sun blinds
- Other architectural measures
- Pros & Cons (comparison of the introduced measures)

M3.L5 EE dedicated to existing buildings

- Specific features of the retrofitting of existing buildings in comparison with new design
- EE related requirements
- Overview of architectural and other design measures
- Best practice examples

M3.L6 Energy motivated heat protection

- Basic concepts, main requirements and side effects
- Energy modelling approach
- Analysis of the A/V-relationship with regard to energy efficiency
- Energy consumption of different building types, climatic influences

M3.L7 Simplified heat protection calculation according to standard regulations
(The EnEV standard is relevant for courses held in Germany, in other countries the focus may be on other relevant regulations, as appropriate for the audience)

- Basic parameters (required yearly heating volume, specific transmission heat loss, temperature correction coefficients, material properties etc.)
- Specific heat loss due to ventilation
- Solar heat gain
- Practical examples

M3.L8 Energy motivated solid state lighting

- Basic concepts of the technology
- Energy modelling approach
- End uses, R&D needs and costs
- Energy consumption and comparison of the new and existing approaches
- Potential energy savings

M3.L9 Energy motivated geothermal heating

- Basic concepts of the technology
- Energy modelling approach
- End uses, R&D needs and costs
- Energy consumption and comparison of the new and existing approaches
- Potential energy savings

M3.L10 Integrated Energy Equipment

- Basic concepts of the emerging new technology
- End uses, R&D needs and costs (cost of the new technology, cost effectiveness)
- Energy consumption and potential savings

M3.L11 Smart roofs

- Basic concepts of the technology
- Energy modelling approach
- Examples, end uses, R&D needs and costs (cost of the new technology, cost effectiveness measures etc.)
- Energy consumption and potential energy savings
- Summary of the presented innovative EE technologies in lectures 6-11

M3.L12 Strategic energy data management and analysis

- Energy management at site/project scale (planning and financing, design and construction, operation and maintenance)
- Energy management at building scale (with subtopics as above)
- Data organisation for analysis/simulation tasks
- Overview of physical and statistical design models
- Overview of BIM-based EE design

M3.L13 The concept of BIM

- Vision, goals, background concepts and contents of BIM
- Historical development of the BIM idea and current state of BIM use in research and industry
- BIM in the context of BuildingSMART
- Modelling languages and paradigms with regard to BIM
- Best practice examples

M3.L14 Types of BIM and their use in the EE life-cycle

- Basic concepts
- The requirements model
- Site BIM, Inventory BIM, Spatial group BIM and Spatial BIM
- Preliminary Building Element BIM (PBE BIM)
- Detailed Building Element BIM (DBE BIM)
- The As-Built BIM

M3.L15 Basic structure of the IFC model

- Overview and principal architecture of the IFC model
- Modelling paradigm – differences with regard to STEP/EXPRESS
- Main components of the kernel model
- The product extension and the process extension layers
- Resources, relationships and property objects
- Domain model extensions – concept, modelling approach, current state and development plans

M3.L16 Relevant IFC elements for EE in building design and life-cycle performance

- The concept of shared elements
- Relevant shared building elements – description, relationships, EE related features
- Relevant shared building services elements – description, relationships, EE related features
- Relevant shared management and facilities elements
- Overview of principal modelling approaches for enhancement of existing elements with EE related features

M3.L17 Model view definition for EE related design tasks

- The purpose of model views
- Prerequisites for the definition of a BIM view for Energy Analysis
- Main elements
- Relationship to and interaction with other BIM views
- Current state and R&D issues

M3.L18 Definition of space boundaries for energy analysis in BIM

- Basic concepts
- Building elements as boundary of two or more spaces
- Virtual space boundaries and openings. curved space boundaries (curved walls, curve-bounded slabs) and sloped boundaries
- IFC representation and mappings to/from CAAD and energy simulation models

M3.L19 EE related BIM visualisation

- Visualisation methods and principles
- Visual model evaluation
- Model consistency checking
- Incorporating engineering rules with the model

M3.L20 Semester project seminar

The students explore and articulate ideas for a semester project work of choice; each student presents a proposal that outlines the project, its motivation and background, as well as the methodology to be used; the proposals are reviewed and approved by the lecturer and/or the student advisor(s)

M3.L21 BIM-based energy performance assessment in early design stages

- State-of-the-art and needs
- BIM-based strategy specification and energy performance modelling in early design
- Preliminary building envelope design with BIM
- Energy analysis with BIM
- Calculation of key performance indices (transmission heat losses of the envelope, ventilation heat losses, solar heat gains, internal heat gains, lighting power, resulting heat demand etc.)
- Exergy analysis – concept, calculation of the heating chain, results and conclusions from the exergy calculations
- Using the Design Performance Viewer (DPV)

M3.L22/23 General modelling technology requirements with regard to EE building design

- Software to be used
- Handover of the models to the client
- Coordinate systems and units of measurement
- Dimensional accuracy and scalability of the models
- Requirements to the objects used in modelling for EE building design
- Required breakdown of models – integration and interoperability issues
- Coordination, archiving and communication of changes
- Updating and publishing of models
- Normative requirements – state of the art and trends

M3.L24 Interoperability

- Basic concepts and definitions
- Approaches to interoperability – pros and cons
- Interoperability in distributed ICT systems
- Achieving interoperability via BIM
- Main interoperability methods in BIM – filtering, mapping, matching and merging; model consistency and change management

M3.L25/26 Model filtering

- Basic goals, concepts and definitions
- The overall filtering process in BIM
- Class level (static) vs. instance level (dynamic) filtering
- Attribute and relationship filtering
- Formal filtering definitions and queries
- The GMSD language
- Filtering tools
- Practical examples and open issues

M3.L27/28 Model mapping

- Basic goals, concepts and definitions
- Mapping types and mapping patterns
- The overall mapping process
- Static schema mapping vs. interactive run-time partial mappings – pros, cons, scope of possible use and challenges
- Formal mapping representation – mapping languages vs. embedded definitions
- Model mapping with the help of the EXPRESS-X language
- Model mapping with the help of XSLT
- Mapping tools
- Practical examples and open issues

M3.L29/30 Matching, merging and consistency checking

- Basic goals, concepts and definitions
- Model matching, merging and consistency checking as set theoretical problem
- Finding changed objects
- Model re-integration approaches regarding two model versions)
- Overall model merging approaches
- Using AI methods for model merging and consistency checking
- Matching, change management and consistency checking tools
- Overview of SOLIBRI Model Checker
- Practical examples and open issues

M3.L31 BIM tools

- Open software tools, free software tools and license tools – pros, cons, challenges
- Fundamental ICT tools for BIM support (model parsers, model servers, model viewers, model checkers, general-purpose utilities, import/export utilities, embedded utilities and plug-ins)
- Specialised BIM tools for engineering design
- Interoperability of EE related design tools and BIM tools – overview, current state and development trends

M3.L32 Best practice examples of BIM-based energy efficient planning. Benefits of BIM

Invited presentation by an industry expert regarding EE building projects performed with the help of BIM

M3.L33 Project work evaluation and module wrap-up

- In-class presentations of selected semester project work by students
- Summary evaluation of semester project work
- Summary of the overall module contents
- Synthesis of the lessons learned
- Advice for further reading and future practice

5.4 MODULE 4: ENERGY EFFICIENT DESIGN SYSTEM

5.4.1 Synopsis

This module concentrates on the sustainable building design system and energy analysis operated to maintain user comfort and functionality, a building needs and the defined amount of energy that has to be supplied. This analysis includes the energy demand that has to be supplied and additional energy input needed for lighting, ventilation and for the operation of building systems: transmission of the heat losses of the envelope; ventilation heat losses; Solar heat gains through windows and other internal energy gains caused by appliances and users as well as solar gains through openings to diminish the amount of heating energy.

The practical application involves computer-based programs like Design Builder, RevitMEP and DDS-CAD, for a more accurate detailed design. Uses of BIM and interoperability issues are specifically emphasised.

Overall, the module structure is as follows:

- Lectures **L1** and **L2** provide a **brief introduction to the principles of energy calculation and detailed EE design**, including concepts for the use of BIM
- Lectures **L3-L15** are dedicated to the in-depth presentation of **Design Builder**, a fundamental architectural software tool for EE design, with special emphasis to modelling capabilities
- Following the Design Builder presentation, in lectures **L16-L19** the major concepts of **BIM to MEP engineering** and the interoperability of BIM-based tools for EE detailed design are discussed
- As in the preceding modules, at 2/3 of the total duration of the module one lecture (**L20**) is dedicated to the discussion and specification of individual **semester project work**
- The following lectures **L21-L32** focus on three advanced and widely acknowledged MEP and FM ICT systems, i.e.:
    - **Revit MEP** (L21-L24)
    - **DDS-CAD** (L25-L28)
    - **Olof Granlund Suite** (L29-L32)
- Finally, as in the preceding modules, the last lecture **L33** provides a **summary evaluation** of the learned material and the achieved results in the individual semester project work, and gives recommendations for further reading and future practice.

5.4.2 Outline of Lectures

M4.L1 Introduction to ENERGY EFFICIENT DESIGN SYSTEM

- Motivation and objectives of the module, learning goals
- Principles of detailed EE design
- Overview of energy calculation and analysis methods
- Introduction to ICT tools for detailed EE design

M4.L2 Core concepts of model-based ICT supported EE design

- Model data hierarchies and data inheritance and relationships
- Templates
- Blocks
- Model customization
- Model navigation

M4.L3 Overview of **Design Builder**

- Major concepts, capabilities and scope
- Typical uses
- Use of EnergyPlus in Design Builder to generate performance data
- Use of Design Builder as communication aid
- Introduction to the GUI

M4.L4/5 Creating Building Models with Design Builder

- Basic concepts
- Defining Sites and Buildings
- Site model data – structure, objects, principal relationships
- Building model data – structure, objects, principal relationships
- Geometric functions (creating and shaping bodies, geometry manipulation functions, bookkeeping functions etc.)
- Drawing aids
- Miscellaneous modelling utilities

M4.L6 Input of climatic and construction data

- Types of climatic data in Design Builder
- Types of construction data in Design Builder
- Modelling aids
- Modelling the building envelope

M4.L7 Model data management

- Using the model data inheritance mechanism to edit building models
- Tools for managing and manipulating model data
- Loading data from templates
- Simulation calculation options
- Interoperability options

M4.L8 Defining and managing component data

- Overall principles
- Layers, images, input and calculated data
- Detailed discussion of component data
  (Constructions, Glazing, Materials, Panes, Schedules, Textures,
  Window gas, Window blinds, Shading, Vents)

M4.L9 Working with templates

- Basic concepts
- Using activity templates
- Using construction templates
(using glazing templates, using façade templates, using lighting templates, using HVAC templates, using location templates, using crack templates, using energy code templates, using sector templates, using wind pressure coefficient templates)

M4.L10/11 Performing Simulations

- Types of energy simulations with Design Builder
- Overall modelling and reporting principles
- Heating design simulation – calculation and display options, understanding the results
- Cooling design simulation – calculation and display options, understanding the results
- Simulation using real weather – calculation and display options, understanding the results
- Energy performance indicators simulation – calculation and display options, understanding the results
- *EnergyPlus* interoperability – current state and future possibilities

M4.L12 Visualisation

- Types and purpose of visualisations
- Visualisation controls
- Creating and using movies
- Advanced topics

M4.L13 Reporting

- Basic concepts
- Exporting data
- Compiling reports
- Report topics
- Hints for using reports to improve EE-related design decisions

M4.L14/15 Advanced modelling aspects in Design Builder

- Working with large models
- Ground modelling
- Modelling adjacent buildings
- Defining setpoint temperature schedules
- Modelling electrochromic glazing
- Modelling trombe walls
- Autosizing
- Daylight saving
- Using hourly weather data

M4.L16 BIM to MEP Engineering

- Basic concepts
- Key issues of BIM used to improve the MEP design process
- Interaction of the HVAC design process with architectural and structural workflows
- Interaction of the electrical design process with architectural and structural workflows
- Interaction of the water supply and sewage design process with architectural and structural workflows

M4.L17/18 BIM-based MEP Analysis

- Energy analysis and simulation capabilities using BIM – state-of-the-art, pros, cons, perspectives
- CFD simulations
- Simulation of ambient conditions
- Analysis of MEP life-cycle costs
- Environmental impact analyses
- Lighting visualisation and simulation
- Analyses generated from BIMs on varying levels
- Performing the analyses, presenting the results and drawing design/FM conclusions with BIM support

M4.L19 Interoperability of BIM-based ICT tools for EE detailed design

- Basic requirements, concepts and features
- Import/export functionality
- BIM interfaces and Plug-Ins
- Advantages and disadvantages of the different interoperability paradigms

M4.L20 Semester project seminar

The students explore and articulate ideas for a semester project work of choice; each student presents a proposal that outlines the project, its motivation and background, as well as the methodology to be used; the proposals are reviewed and approved by the lecturer and/or the student advisor(s).

M4.L21 The Autodesk **Revit MEP** Suite

- Major concepts, capabilities and scope
- Typical uses of the platform
- Model database
- GUI and APIs

M4.L22 MEP modelling and design with Revit MEP

- Systems modelling and layout
- Schematic design
- Single/double line design
- Smart annotation of objects
- Enhanced piping design
- Specific features and hints regarding EE detailed design with Revit MEP

M4.L23 Creating construction documentation with Revit MEP

- Basic concepts
- Discipline-specific engineering utilities that automate the production and organization of project documentation – features, typical uses and practical hints
- Fabrication documentation for contractors

M4.L24 Revit MEP collaboration features

- Collaboration processes with Revit MEP
- Integration with other Autodesk tools (AutoCAD MEP, Autodesk Green Building Studio, Autodesk Navisworks, Autodesk Design Review and Autodesk Buzzsaw)
- Export/import to/from ACIS Solids, DXF/DWG and BIM
- Coordinating design information
- Hybrid MEP design and documentation

M4.L25 Overview of **DDS-CAD**

- Major concepts, capabilities and scope
- Typical uses
- The DDS-CAD GUI
- The DDS-CAD Explorer
- The DDS-CAD Building Model
  (structuring , components, attributes, inter-relationships)

M4.L26/27 MEP modelling and design with DDS-CAD

- Basic modelling and design concepts
- Overall model management
- Using and customising component libraries and EE related data
- Designing the HVAC system (Equipment characteristics, BIM and library inputs, calculation algorithms, parameter adjustments)
- Designing the ventilation system
- Designing the lighting system
- Visualisations and result presentation
- Specific features and hints regarding EE detailed design with DDS-CAD

M4.L28 DDS-CAD collaboration features

- Overall collaboration processes
- Export/import functionality
- BIM interfaces
- Coordinating and exchanging design information with DDS-CAD
- Interoperability hints and caveats

M4.L29 The **Olof Granlund** Suite

- Major concepts, capabilities and scope
- Business model
- Typical uses
- GUIs and APIs
- Building modelling concepts in the Olof Granlund Suite

M4.L30/31 MEP modelling and design with the Olof Granlund Suite

- Basic modelling concepts
- HVAC design
- Electrical and lighting design
- Refrigeration design
- Special calculation and building performance services
    - Simulation of thermal comfort
    - Flow simulations
    - Energy simulations
    - Life cycle cost (LCC) analyses
    - Life cycle impact assessment (LCIA) analyses
    - Energy storage calculations
- Using and customising product libraries
- Specific features and hints regarding EE detailed design with the Olof Granlund Suite

M4.L32 Collaboration features of the Olof Granlund Suite

- Overall collaboration processes
- Tool integration within the Olof Granlund Suite
- Export/import to/from Ansys CFX and VIVA
- BIM/IFC middleware level interoperability using BSPro
- Coordinating design information using the Olof Granlund Suite

M4.L33 Project work evaluation and module wrap-up

- In-class presentations of selected semester project work by students
- Summary evaluation of semester project work
- Summary of the overall module contents
- Synthesis of the lessons learned
- Advice for further reading and future practice

5.5 MODULE 5: ENERGY EFFICIENT CONTROL SYSTEM OPERATION

5.5.1 Synopsis

This module teaches the monitor assessment for performance implementation, showing the interacting energy flow-paths encountered within buildings and their environmental control systems. Such systems are often considered to be equivalent to electrical networks of time-dependent resistances. Rooms and built elements are treated as finite volumes of fluid and solid material characterized by thermo-physical properties such as conductance and capacitance, and possessing "variables of state" such as temperature and pressure. Since different building components (floors, windows, floor slabs, etc.) have different thermal capacities, the discussed problems are essentially of dynamic nature, i.e. components respond at a different rate as they compete to capture, store and release energy. It is this dynamic behaviour that makes the building modelling problem such a complex and challenging task.

Inside the featured control systems, the use of ICT for Energy Efficiency, the lighting system, the sensor system application and other advanced application technologies as well as applicable standards are analysed. Special consideration is given to the interaction with and the use of BIM-based data in system monitoring and control.

Overall, the module structure is as follows:

– Lectures **L1-L9** provide an **overview of building monitoring and control**, including the principal scenarios of use, the major EE aspects involved, the available automation alternatives and current applied software architectures
– Lectures **L10-L18** proceed with in-depth explanation of **building automation and management systems (BAMS)**, including various important ICT implementation issues such as protocols, middleware, standards, interoperability issues etc.
– As in the preceding modules, at 2/3 of the total duration of the module one lecture (**L19**) is dedicated to the discussion and specification of individual **semester project work**
– Lectures **L20-L32** focus on the roadmap of various **advanced on-going and planned research efforts related to EE building control** such as the interoperability of BIM and BAMS, the use of ontologies for information/system integration, the use of high-level semantics, establishing and using building diagnostics laboratories for EE life-cycle operation and so on
– Finally, as in the preceding modules, the last lecture **L33** provides a **summary evaluation** of the learned material and the achieved results in the individual semester project work, and gives recommendations for further reading and future practice.

5.5.2 Outline of Lectures

M5.L1 Introduction to ENERGY EFFICIENT CONTROL SYSTEM OPERATION

- Motivation and objectives of the module, learning goals
- Demand of monitoring and control
- The “intelligent EE building” – vision, goals, concepts. roadmap
- State-of-the-art in EE control system operation, current legal requirements

M5.L2 Building systems and controls

- Introduction to sustainability analysis of buildings and building components
- Principles of life-cycle assessment and environmental impact analysis
- Gathering life-cycle data for building monitoring and control

M5.L3 Major usage scenarios

- Scenario development methodology
- Types of users and user profiles
- Usage scenarios for HVAC management and control
- Usage scenarios for lighting control
- Overall scenario synthesis

M5.L4 Efficient operations technologies

- Basic concepts and state-of-the-art examples
- Energy consumption and costs (cost characterisation, cost effectiveness, LCC)
- Comparison of existing and emerging new approaches
- Potential energy savings
- Modelling approaches for ICT-based building monitoring and control

M5.L5 Intelligent energy control

- Intelligent control vision, concepts and roadmap
- Review of traditional ICT techniques; differentiation wit regard to intelligent systems
- Principal system architecture for intelligent energy control
- Major system components

M5.L6/7 Automation alternatives

- Time-dependent control – concept, characteristic aspects, equipment, EE potential
- Presence-dependent control – concept, characteristic aspects, equipment, EE potential
- Daylight-dependent control – concept, characteristic aspects, equipment, EE potential
- Methods for comparison and choice of alternative(s)
- Comparison of automation alternatives with regard to life-cycle and cost effectiveness
    - amortisation and pay-off
    - energy cost reduction
    - facility management and building automation saving potentials
- Further comparisons, synthesis of features and conclusions

M5.L8 System architectures for HVAC control

- Basic concepts and components
- Manually controlled systems
- Automated systems:
  (a) self-sustained systems,
  (b) network systems (master-slave, peer-to-peer etc.)
- Space management
- Integration in the overall facilities management

M5.L9 System architectures for lighting control

- Basic concepts and components
- Manually controlled systems vs. automated systems
- Space management
- Integration in the overall facilities management
- Synthesis of differences and similarities of HVAC and lighting control

M5.L10 Basic principles of building automation and management systems (BAMS)

- Types of building automation and management systems and their relationship with EE building operation control
- Principal hard- and software architecture
- Basic BAMS components (sensors, datapoints, bus controllers, gateways etc.)
- Integration and interoperability challenges – state-of-the-art and R&D roadmap and trends

M5.L11/12 Wired networked solutions

- Basic concepts and definitions
- Overview of current realisations
- The BACnet protocol (EN ISO 16484)
- The KNX protocol (EN 14908)
- The LON protocol (ISO/IEC 14543-3)
- ICT design tools for wired network solutions (LNS for LON, ETS Falcon for KNX, java tools for BACnet etc.)
- Storing and exchanging information on the network
- Integration and interoperability issues – current state and development roadmap

M5.L13/14 Wireless networked solutions

- Basic concepts and definitions
- Overview of current realisations and solution approaches
- The EnOcean solution approach
- The ZigBee solution approach
- The novel Z-Wave solution approach
- Storing and exchanging information on the network
- Advanced concepts for network-centric databases
- Integration and interoperability issues – current state and development roadmap

M5.L15 Building automation and management middleware

- Basic concepts and definitions
- Major middleware components
- Database access utilities
- Information gathering utilities
- Integration and interoperability utilities
- BAMS integration via IP-based middleware gateway solutions

M5.L16 Intelligent energy control components and algorithms

- Basic concepts and definitions
- Data Preprocessors
- Optimiser and Predictor Network
- Recursive predictive control
- Practical examples and development roadmap

M5.L17 Information synthesis and interoperability with EE BIM

- Principal concepts and methods for the synthesis of live performance data and their integration with energy-related BIM data
- Synthesising data from sensors and other ICT building control sub-systems, such as security/surveillance systems, information logistics and management systems, FM systems etc.
- Information synthesis methods
    - Time series and trends
    - Derivation of stochastic mean values and schedules
    - Aggregated performance indicators etc.
- Interoperability approaches (wrap-up of methods from module M3 with discussion of their applicability for EE building control – current state and R&D trends)

M5.L18 Building automation and management – hands-on seminar

The students explore the capabilities learned in the preceding group of lectures (L2-L17) in a guided hands-on seminar, in which additional features of the introduced systems are explained and various theoretical and practical hints are given. Preparation for practical use (in the following exercises as well as in future professional life) is part of the learning goal.

M5.L19 Semester project seminar

The students explore and articulate ideas for a semester project work of choice; each student presents a proposal that outlines the project, its motivation and background, as well as the methodology to be used; the proposals are reviewed and approved by the lecturer and/or the student advisor(s).

M5.L20 BIM-based performance assessments

- Selection of "green" monitoring and control strategies with the help of BIM
- Integration of BIM-based analysis results with EE performance control
- Modelling performance between building data and EE BAMS application: principal concepts, information objects and components
- Requirements to BIM

M5.L21 Suggested BIM enhancements for EE building diagnostics and control

- Basic concepts, assumptions and scope
- Current state, gaps and roadmap
- The BuildingSMART projects BS-9 "Network IFC: IFC for cable networks in buildings" and FM-1 "Engineering maintenance"
- Suggested / needed enhancements to the IFC2x3 Building Services Domain Model Extension – entities, property sets, relationships

M5.L22/23 Ontology for integrated ICT system management

- Ontologies as enabling mechanism for high-level semantics and interoperability in distributed and heterogeneous building automation systems
- Purpose of a system-wide ontology for integrated ICT system management: basic assumptions, use cases and background
- Scope of the ontology
- Major ontology components and inter-relationships
- Capturing energy and emissions related concepts from installation bus protocols and other ICT building control sub-systems and their inter-relationships with BIM data
- Differences between ontology-based information and BIM
- Principal ontology-based services
- Ontology-based platform realisations: current research and development trends

M5.L24 Advanced ontology based engineering query language and GUI

- Purpose of an ontology-based engineering query language
- Vision, concepts, assumptions and background
- The ontology query language SPARQL
- Semantic queries of energy related BAMS information and high-level selection of control actions
- Example action templates
- GUI approaches (fat client, thin client, web browser based) – current research and development trends

M5.L25/26 Intelligent information access services

- Basic concepts, definitions and assumptions
- Providing ontology-based information access – benefits, perspectives, challenges and caveats
- Semantic integration of sensing data and other ICT-based control system information
- Services for intelligent role-based data access
- Services for mapping of BAMS data to/from the ontology
- Advanced rule-based engineering services
- Technical realisation options
    - Using the Java-based OSGi framework
    - Using the Linux EIB Daemon
    - Using the MS Windows OPC middleware
- Envisaged technology-independent interoperability on the basis of the oncoming EN ISO 16484-4 standard

M5.L27 Building diagnostics laboratory

- Purpose and concept of a building diagnostics laboratory
- Typical uses
- Architecture and suggested components
- Enabling building ecology with the help of a building diagnostics laboratory
- Case studies

M5.L28/29 Integrated virtual energy laboratory

- Basic concepts
- Combining simulation and control
- Web-based simulation approach
- Integration approaches with regard to monitoring/control, simulation and BIM data and services
- Distributed web-based service realisation vs. Stand-alone (fat) clients
- Service Launcher and other related utilities
- Added-value of virtual labs in comparison to a building diagnostics laboratory – summary of current development status, visions and roadmap

M5.L30 Advanced features
(eventually to be held as invited presentation by an academic / industry expert or a highly qualified person from a research organisation in the field)

- Developments in recently finished and on-going research projects
  Example: The AUTEG project (Germany)
    - Development of an adequate ontology used for automatic generation interoperable system designs out of requirements
    - Novel BIM-based integration approach etc.
- EC policy towards EE building control in FP7
- Discussion of emerging new standards and related governmental activities

M5.L31 EE building control – hands-on seminar

The students explore the capabilities learned in the preceding group of lectures (L25-L30) in a guided hands-on seminar, in which detailed features are explained in depth and various use cases are gone through, including selected real-life examples (eventually via visit to an operational intelligent building of choice). Hints for practical use in future professional life is part of the learning goal.

M5.L32 Best practice examples

Invited presentations by an academic or industry expert regarding recent achievements, ongoing and planned research and visions of future EE control system operation and intelligent building monitoring and management

M5.L33 Project work evaluation and module wrap-up

- In-class presentations of selected semester project work by students
- Summary evaluation of semester project work
- Summary of the overall module contents
- Synthesis of the lessons learned
- Advice for further reading and future practice

5.6 MODULE 6: PERFORMANCE EVALUATION METHODS

5.6.1 Synopsis

This module wraps-up and extends the energy design evaluation and the cost effectiveness evaluation methods of any energy conservation measures (total life cycle costing). Simulation techniques that provide the tools for assessing different design options based on their energy performance and life cycle costs are especially focused. The IT-based building energy simulation that will provide this power and allow greater flexibility in design evaluation is specifically discussed on the example of EnergyPlus as well as the Delphin4 and Champs programs.

Energy audits identify areas where energy is being used efficiently or is being wasted, and spotlight areas with the largest potential for energy saving. These audits are useful for establishing consumption patterns, understanding how the building consumes energy, how the system elements interrelate and how the external environment affects the building. They are closely associated with the synthesis of simulation results and their appropriately summarised presentation.

- Lectures **L1** and **L2** provide an **introductory overview of EE related simulation and performance evaluation models and methods**, wrapping-up and extending the lessons learned in preceding modules
- The following lectures **L3-L19** (with the exception of L15) present an in-depth discussion of the modelling and simulation features of **EnergyPlus**, one of the major tools used world-wide for EE analysis tasks
- Building upon the preceding material, lectures **L20-L21** discuss selected **advanced energy analysis and evaluation topics** enabled by the ICT tools DELPHIN4 and CHAMPS
- As in the preceding modules, at 2/3 of the total duration of the module one lecture (**L15**) is dedicated to the discussion and specification of individual **semester project work** and the last lecture **L22** provides a **summary evaluation** of the learned material and the achieved results in the individual semester project work, and gives recommendations for further reading and future practice.

5.6.2 Outline of Lectures

M6.L1 Introduction to PERFORMANCE EVALUATION METHODS

- Motivation and objectives of the module, learning goals
- Main concepts of energy simulation (wrap-up from prior modules and advanced issues)
- Basic definitions and goals in energy simulation – load calculations, energy analyses, LCAs etc.

M6.L2 Performance evaluation and simulation models and methods

- Overview of ICT-based energy performance and process analysis
- Concepts and purpose of simulation and life-cycle performance models
- Types of energy simulations (wrap-up from prior modules and advanced issues)
- Energy audits
- Integrated energy system vs. specialised ICT tools – comparison, visions, trends
- Current state in specialised ICT-supported energy simulation (EnergyPlus, Energy-10, DOE-2, TRNSYS, DELPHIN4, CHAMPS)

M6.L3 The energy simulation tool EnergyPlus

- Goals and scope of EnergyPlus
- Typical uses
- Background concepts
- Specific EnergyPlus concepts
- Program structure and GUI

M6.L4 EnergyPlus' Integrated Simulation Manager

- Goals and structure of the integrated simulation manager
- Modules and components (goals, features, inter-relationships and dependencies)
- Input/output capabilities and interoperability with other software

M6.L5 Basic input and output issues in EnergyPlus

- General philosophy
- Input/output files
- Overall file structure
- Input object structures and input data dictionaries
- Weather files

M6.L6 Understanding EnergyPlus results

- Output variables, meters and reports
- Meter types
    - resources (electricity, gas, oil, coal etc.)
    - end use (heating, general lights, task lights, exterior lights, cooling, humidification, heat recovery, exterior equipment, fans, pumps etc.)
- Results interoperability
- Critical issues

M6.L7 Controlling the exterior environment of a simulation and simulation run control

- Specifying the building location, weather and ground temperature data
- Other climatic features
- Controlling the time span of the simulation
- Run controls

M6.L8/9 Building modelling in EnergyPlus

- Structure and components of the EnergyPlus building model
- Overall building characteristics
- Building envelope hierarchy
- Groups of surfaces (zones)
- Building elements - walls, roofs, ceilings, floors, partitions
- Materials and groups of materials (regular and regular-R materials, special case: air)
- Surface geometries, types of surfaces and their influences on energy simulation
- Defining thermal zones by objective and by design conditions
- Defining loads
- Solar distribution options (minimal shadowing, full exterior, full interior and exterior)

M6.L10/11 EnergyPlus simulation modelling and BIM

- Understanding the relationship of thermal zones, rooms and spaces
- Levels of detail
- Input data from BIM
- Output data to BIM
- The process of building definition: (a) without BIM, (b) based on BIM; Differences, advantages/disadvantages, opportunities, threats
- Case example

M6.L12 Defining schedules and internal heat gains

- Concept and purpose of schedules
- Major factors (occupancy density, occupancy activities, lighting profiles, thermostatic controls, shading element density etc.)
- Influence of schedules on internal gains as more precise measure than mean values
- Schedule types in EnergyPlus
- Types of internal gains in EnergyPlus (people, lights, equipment, infiltration)

M6.L13 Modelling zone controls and the overall thermal simulation

- Obtaining heating and cooling load for zones without defining the entire HVAC system
- Calculating approximate air flows for zones
- Control parameters of the thermal simulation in EnergyPlus
- Understanding the solution algorithm (inside convection, outside convection, convection coefficients, shadowing calculation, airflow)

M6.L14 Using templates and autosizing in EnergyPlus simulation modelling

- Purpose of templates and autosizing
- HVAC templates – concept, principal use, template structure, typical templates, example inputs/results
- HVAC sizing options – component sizing, zone sizing, system sizing, plant sizing
- Autosizing – concept, applicability (what inputs can be autosized), options

M6.L15 Semester project seminar

The students explore and articulate ideas for a semester project work of choice; each student presents a proposal that outlines the project, its motivation and background, as well as the methodology to be used; the proposals are reviewed and approved by the lecturer and/or the student advisor(s)

M6.L16 Modelling ventilation

- Basic concepts – mixing, cross mixing, ventilation, multi-zone airflows
- Defining the type of ventilation (natural/mechanical, wanted/unwanted etc.)
- Defining air movement between interior spaces
- Approximating the effect of ventilating a building
- Defining the ventilation network – legal and illegal airflow models
- Detailed air movement calculations using EnergyPlus link to external software services such as COMIS

M6.L17 Air loop simulation

- Basic concepts and definitions
- Describing a central forced air system (equipment, system controls, day and night cycles)
- Modelling zone air paths and air distribution units (single/double duct constant volume and VAV reheat, powered induction units etc.)
- Modelling VAV and thermal reheat systems in EnergyPlus

M6.L18 Modelling ground heat transfer

- Role and importance of ground heat transfer
- Main modelling Aspects: ground temperature, ground slab heat transfer
- Modelling hints and common errors
- Use of the "Slab" program with EnergyPlus

M6.L19 Modelling outside air and radiant systems (RS)

- Impact of outside air on building energy requirements
- Outside air system as HVAC subsystem component
- Outside air system equipment and controllers – operation in normal and economizer mode
- Overview and impact of radiant systems – characteristics, advantages, potential problems
- Radiant system types (low temperature RS, high temperature RS, hybrid systems)
- Specifying radiant systems in EnergyPlus
- Wrapping-up: overall modelling and simulation hints

M6.L20/21 Use of DELPHIN4 and CHAMPS for advanced EE related design

- Goals, scope and typical uses of DELPHIN4 and CHAMPS as advanced specialised tools in EE related design
- Numerical modelling
- Balance equations
- Numerical solution by finite Control Volume Method (CVM)
- GUIs and program use
- Examples
  Suggested:
    - Rijksmuseum Amsterdam (Netherlands)
    - Kumamoto Castle (Japan)
    - Historical City Centre Dresden (Germany) etc.
- Wrapping up: Modelling and simulation hints

M6.L22 Project work evaluation and module wrap-up

- In-class presentations of selected semester project work by students
- Summary evaluation of semester project work
- Summary of the overall module contents
- Synthesis of the lessons learned
- Advice for further reading and future practice

6. DEVELOPMENT OF SELECTED LECTURES

A set of representative lectures of each module will be developed introducing the Energy Efficiency basic concepts and applications and in particular the module-based working concept, i.e. the BIM. The relevance of these lectures relates the ICT technologies for the application in buildings and dwellings which are the main importance area of REEB. This lecture was selected from a group of Lectures which were the most representative and the more related to the authors' expertise.

The following 9 lectures have been selected to be developed as PPT presentation:

Lecture M2L1/L2	Building Climatology
Lecture M3L13	The concept of BIM
Lecture M3L15	Basic structure of the IFC model
Lecture M3L29/30	Matching, merging and consistency checking
Lecture M3L31	BIM tools
Lecture M4L1	Introduction to energy-efficient design systems
Lecture M5L10	Basic principles of building automation & management systems (BAMS)

6.1 LECTURE M2L1/L2

Short Outline

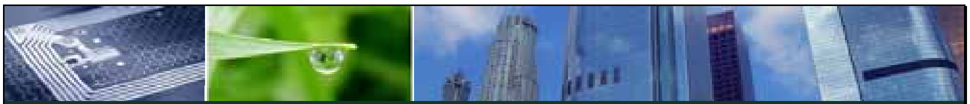
M2.L1 Introduction

- Motivation and objectives of the module, learning goals
- Basic EE aspects in building design
- Energy sources and conversions (Renewable sources, local generation and energy storage – ground heat, heat recovery, geothermal and solar energy use, rainwater collection etc., energy generation and transmission)
- Climatic environment and climatic design
- State-of-the-art review

M2.L2 Building Climatology

- Objective and purpose of study
- Domain topics addressed
- Macro, mesa and micro climate
- Building climate control and its relation to overall EE building design

Powerpoint Outline



Lesson example M2L1/L2

Lecture Notes on energy Efficiency in Building Construction

REEB

Raimar Scherer & Tatiana Suarez- TUD

TECHNISCHE UNIVERSITÄT DRESDEN

1

Sources

- Whole Building Design by Don Prowler, FAIA-Donald Prowler & Associates

http://www.wbdg.org/wbdg_approach.php
- Technical building Systems: HVAC,Lighting & Water Use
- Survey of Energy Resources

http://www.worldenergy.org/publications/survey_of_energy_resources_2007/coal/627.asp
- The thermCO Project: low-energy cooling and thermal comfort by Jens Pfafferott, Doreen E. Kalz
- Compressed-Air Startup to Inflate Utility Power Generation by Craig Rubens

http://earth2tech.com/2008/08/26/compressed-air-startup-to-inflate-utility-power-generation/
- Introduction to Energy Efficient Building Design By Sm C. Hui
- Indoor and Outdoor Microclimate - Analysis of Green Buildings by R. Rawcliffe and Ray Sinclair
- ITC Euromaster Course-IT For Energy in buildings_ Lecture in Building Information Modelling by Dr. Dominic O´Sullivan.

2

D 5.32 Lecture Notes on EE in BC

Module 2 Lesson 1/Lesson 2 Description content

- **M2.L1 Introduction**
  - Motivation &Objectives, learning goals
  - Basic EE aspects in building design
  - Energy sources & conversions
  - Climatic Environment & Climatic Design
  - State-of-art Review
- **M2.L2 Building Climatology**
  - Objective and purpose of study
  - Domain topics addressed
  - Macro, mesa and micro climate
  - Building climate control and its relation to overall EE building design

3

Building Design

Whole Building Design is an essential way of approaching building projects and the understanding of the whole Building Design concepts will enable you to think and practice in an integrated fashion to meet the demands of today's as well as tomorrow's high-performance building projects.

Buildings today are life support systems, communication and data terminals, centers of education, justice, and community, and so much more. They are incredibly expensive to build and maintain and must constantly be adjusted to function effectively over their life cycle. The economics of building has become as complex as its design.

The knowledge, materials, and systems exist and are readily available to make a positive impact on the environment and on the quality of life of building occupants.

4

The Integrated Design Approach

Each design objective is significantly important in any project, yet a truly successful one is where project goals are identified early on and held in proper balance during the design process; and where their interrelationships and interdependencies with all building systems are understood, evaluated, appropriately applied, and coordinated concurrently from the planning and programming phase. A high-performance building cannot be achieved unless the integrated design approach is employed.

Design Objectives of Whole Building Design

In buildings, to achieve a truly successful holistic project, these design objectives must be considered in concert with each other:

- **Accessible**: Pertains to building elements, heights and clearances implemented to address the specific needs of disabled people.
- **Aesthetics**: Pertains to the physical appearance and image of building elements and spaces as well as the integrated design process.
- **Cost-Effective**: Pertains to selecting building elements on the basis of life-cycle costs (weighing **options** during concepts, design development, and value engineering) as well as basic cost estimating and budget control.
- **Functional/Operational**: Pertains to functional programming—spatial needs and requirements, system performance as well as durability and efficient maintenance of building elements.
- **Historic Preservation**: Pertains to specific actions within a historic district or affecting a historic building whereby building elements and strategies are classifiable into one of the four approaches: preservation, rehabilitation, restoration, or reconstruction.
- **Productive**: Pertains to occupants' well-being—physical and psychological comfort—including building elements such as air distribution, lighting, workspaces, systems, and technology.
- **Secure/Safe**: Pertains to the physical protection of occupants and assets from man-made and natural hazards.
- **Sustainable**: Pertains to environmental performance of building elements and strategies.

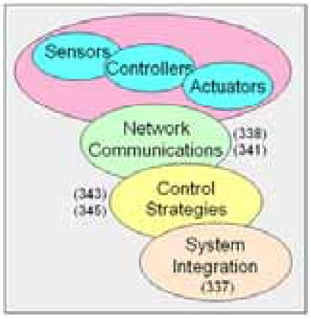
Principles of EE Building System

Two aspects matter for the ecological procurement during the planning of technical services and logistics for building systems:

➢*the creation of comfortable and healthy indoor conditions,* especially in terms of thermal comfort and indoor air quality.

➢*the protection of non-renewable resources: in-house burners* count among the biggest consumers of fossil fuels (crude oil, natural gas and coal).

- *Thermal comfort*
- *Sick Building Syndrome (SBS)*
- *Visual comfort*
- *Day light use*
- *Integrated planning*
- *Integrate users into the planning process*
- *Contracting of engineers*
- *Requirement guidelines for the facility*
- *Less resource input by means of intelligent planning and implementation:*
- *Local energy balancing*
- *Energy services, energy contracting, savings guarantee, and facility management*



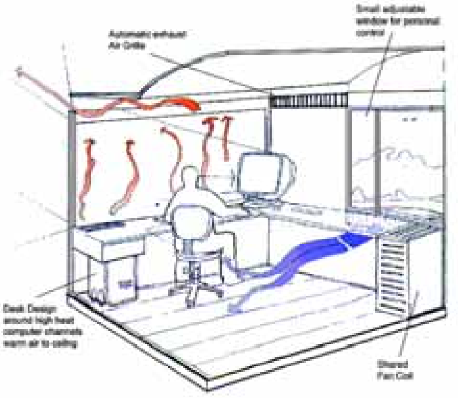
Principles of EE Building System

➢*Thermal comfort*
during the cold seasons and in summer: for the heated period air temperatures of 20-22°C in living spaces, 20°C in offices and 16° in recreation rooms are recommended, whereas in summer 20-27/28°C are advised.

➢*Sick Building Syndrome* (SBS)
Indoor air pollution may cause skin irritations and inflammation of mucous membranes, headaches, tiredness etc. Some troubles that are described in more detail might be caused by the HVAC-system.

➢*Visual comfort*
light planning in facilities aims at reaching visual comfort which not only touches energy issues (day light vs. artificial light) but also effects work efficiency (the relationships between illumination and tiredness, performance and accidents can be shown graphically).

➢*Day light use*
Depending on the glass quality of windowpanes, daylight strongly influences energy consumption for heating.



Principles of EE Building System

➢Integrated planning
Increasing demands and complexity of technical building systems make it necessary to proceed with and integrated planning process right from the outset of planning the building. It is recommended to contract all relevant members of the design team early and to meet regularly.
➢Integrate users into the planning process
Indoor room climate can be enhanced if users are given the opportunity to articulate their wishes and requirements.

➢Contracting of engineers
Engineers tend to neglect integrated and adapted planning falling back on schematic solutions. A procedure is proposed for the evaluation of the bidding to take into account on the one hand the competencies of the bidder in energy efficient and "green" technologies and on the other hand the ecological aspects of his technical solution.

➢Requirement guidelines for the facility
Fixing the aims referring to the facility and technical services in guidelines for the design team can also include energy consumption and other environmental goals.

Principles of EE Building System

Less resource input by means of intelligent planning and implementation:
Co-ordination among companies in the field of technical building systems can be improved and thereby a better environmental performance achieved.

Local energy balancing:
The introduction of energy balancing by local authorities provides an overview of energy consumption in facilities run by the local authority. Various energy-indexes are described and pre-conditions of successful implementation are listed.

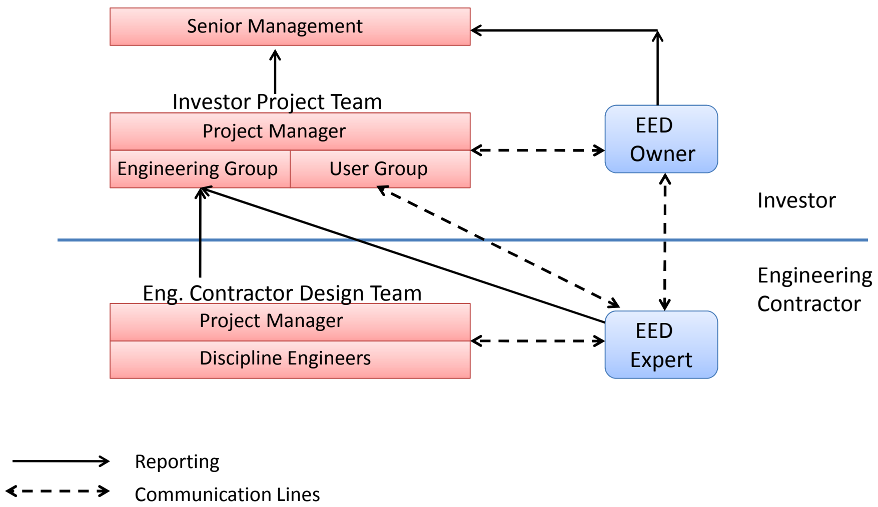
Energy services, energy contracting, savings guarantee, and facility management
A number of energy services can be outsourced and demands can be fulfilled by contractors
who commit themselves to reducing energy costs. Example questions that should be discussed with the contractor are given as well as a list of possible contractors.

Basic EE aspects in Building design

Energy Efficient Design (EED) is a structured process which assists investors to design, construct and manage installations so that they use energy efficiently and at the lowest total costs possible.

- EED has two key aspects: Organisation and Methodology. EED requires changes to the traditional project organisational structure so as to ensure the methodology is systematically implemented throughout the lifecycle of the project.

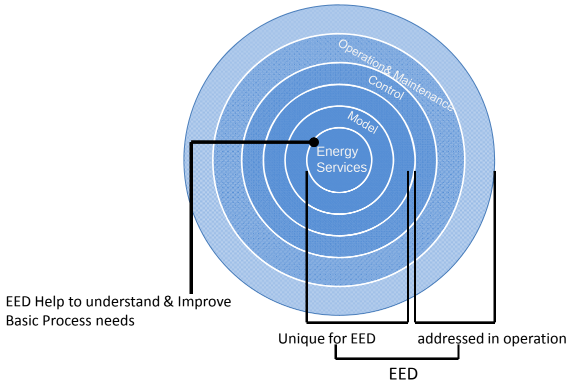
Basic EE aspects in Building design



Basic EE aspects in Building design

Energy Efficient Design – The Methodology

Analyse & Challenge Proposed Design



- Agree & Implement Alternatives

Basic EE aspects in Building design

Building Design Tool

- Site and Building Orientation
- Envelope and Façade Design
- HVAC System Performance
- Daylight requirements

Basic EE aspects in Building design

Site and Building orientation

- Building orientation entails
  - Sun exposure
  - Wind speed and direction
  - Noise & Pollution
  - Shape of the building
- Building orientation can have a great impact on costs of
  - Heating
  - Lighting
  - Cooling

Basic EE aspects in Building design

Site and Building orientation

- Sun

Depending on the building orientation there are various aspects that should be considered:

- Daylight
- winter time solar gains
- summer solar gains
- Shading

Computer modelling techniques allow tracing the path of the sun through the sky for each day of the year

Basic EE aspects in Building design

Site and Building orientation

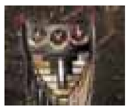
- Wind
  - enhance natural ventilation
  - cooling breeze during summer months
  - cross-ventilation
  - taller buildings more affected
  - energy generation
  - increase infiltration

The local weather data files used in dynamic modelling include wind data for each specified location.

Site and Building orientation

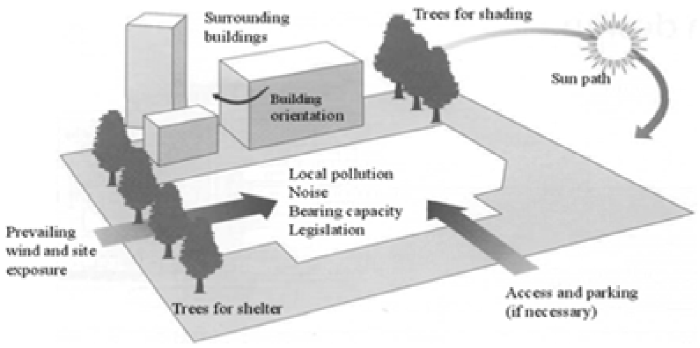
- Building Shape considerations:

- minimize heat losses and gains through external constructions – high volume of floor space to external surfaces (deep plan buildings)
- maximize daylight via increased glazing areas and minimized depth of the buildings
- space for renewables (wind turbines, solar panels, etc)



Site and Building orientation

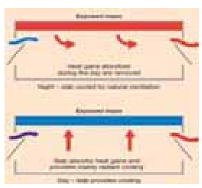
➢Summary

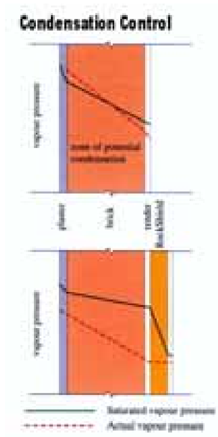


Envelope and Façade Design

Testing various scenarios of building constructions and materials used

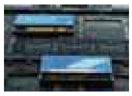
- U values - optimisation of insulation
- Heat and moisture movement within the building fabric
- Air tightness
- Thermal mass effectiveness

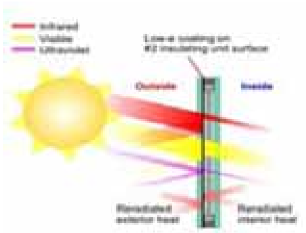


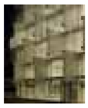


Envelope and Façade Design

- Glazing – area and glass performance
- Shading - solar control performance
- Double and triple façades
- Operable windows – location, size,
- Obstructions

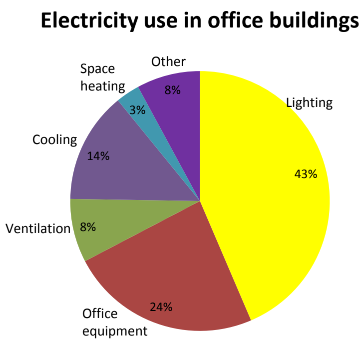






HVAC System Performance

- Fuel – gas/oil/electricity, CHP or District heating/coolingVentilation system
  - Natural ventilation
  - Mixed mode
  - Mechanical (CAV, VAV, single/double duct, heat recovery)
- Heating system – radiators, underfloor heating, radiant heating
- A/C system - chilled beams, fan coils, ventilation
- Chilled water production

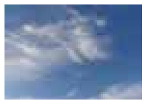


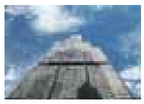
Daylight & Lighting analysis

- Daylight analysis
- Electrical lighting design
- Overshadowing of the existing buildings

Right-to-light

➢Daylight access - Planning Issue!!!
– 'Site Layout Planning for Daylight and Sunlight' BRE design guide
–25° rule – the angle drawn on the vertical plane from the centre of the lowest existing window



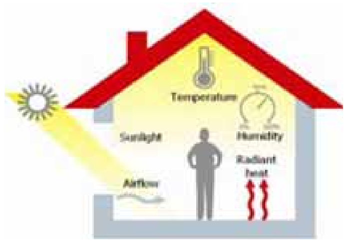


➢Vertical sky component (VSC) – measurement of the amount of sky visible upon the face of an existing window / ratio of unobstructed hemisphere of the sky

Thermal Comfort cross-check

Thermal Comfort cross-check

•Allow checking on a room-by-room basis if thermal comfort is maintained, if designed system and control strategy meets the heating and cooling needs.
•Calculate number of hours when the design criteria are not met, e.g. if temperature exceeds 25°C for more than 5% of the occupied hours.



Energy Sources & conversions

- Renewable Sources
- Local generation & energy storage
- Ground heat, heat recovery
- Geothermal & solar energy use
- Rainwater collection
- Energy generation & transmission

Energy sources

Renewable energy : energy generated from natural resources:

- Sunlight(Photovoltaic, or solar-electric systems)
- Wind (airbone wind turbine)
- Rain (Rainwater usage)
- Geothermal heat (grown heat)

Energy Content of Naturally Occurring Energy Flows

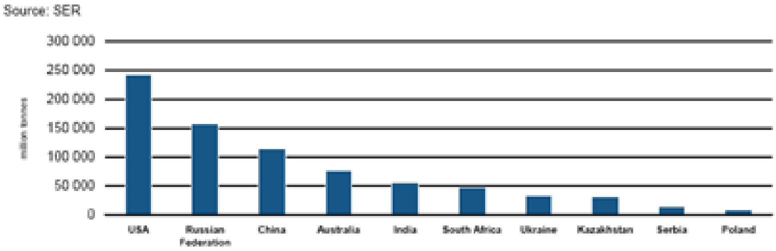
The ideal renewable energy sources are naturally occurring energy flows. The energy is free, but harvesting it could be very costly. The following table indicates some of the possibilities.

Source$	Natural Energy Flows Providing 1 kW of Available Power	
Wind Turbine	Wind speed 12.5 m/s	Turbine swept area 0.85 m²
	Wind speed 4 m/s	Turbine swept area 31.84 m²
Hydro Turbine	Water flow 1 m³/s	Head of water 0.1 metres
	Water flow 100 litres/sec	Head of water 1.0 metres
Solar PV (Electromagnetic Radiation)	Surface perpendicular to the sun's rays at noon with sun directly overhead	Surface area 1m²
	For an hourly average of 1kW taken over a day	Surface area 2.5 m² to 5 m² depending on location
Geothermal	(Ocean) Temperature difference 20°C	Water flow rate 10.8 litres/min *
	(Hot rocks) Temperature gradient 40°C/km, Area 1 km², Depth 3.5 km	Water flow rate 0.2 litres/min *
	(Aquifers) Temperature gradient 30°C/km, Area 1 km², Depth 3.0 km	Water flow rate 0.24 litres/min *

* After Garnish J. D. (1976) - Geothermal Energy (HMSO)

Reserves

The fact that global coal reserves at end-2005 were, at 847.5 billion tonnes, some 61.5 billion tonnes or 6.8% lower than the corresponding total at end-2002 represents more of a refinement than a revision. After centuries of mineral exploration, the location, size and characteristics of most countries' coal resources are quite well known. What tends to vary much more than the assessed level of the resource (in other words, the potentially
accessible coal in the ground) is the level classified as proved recoverable reserves (that is, the tonnage of coal that has been proved by drilling etc. and is economically and technically extractable).

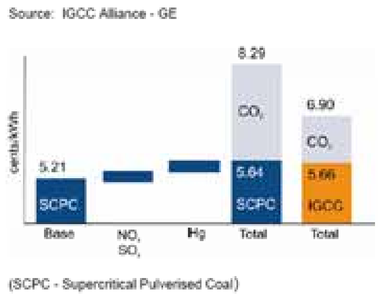


Proved recoverable coal reserves: the top ten countries

Energy Demand & Energy security

Fossil fuels will continue to provide more than 80% of the total energy demand well into the future, and
– according to the International Energy Agency – coal will see the largest demand increase in absolute terms, from some 2 772 mtoe in 2004 to 4 441 mtoe in 2030. The greatest increase in the demand for coal will be in the developing countries, with 86% in developing Asia, where reserves are large and low-cost. India's coal use is expected to grow by some 3.3% per annum to 2030, more than doubling in absolute terms. OECD coal use is likely to grow modestly.

A further key factor is coal's relative affordability and lack of price volatility. Coal has consistently outperformed oil and gas on an equivalent-energy basis, and despite a potential cost of carbon, coal is likely to remain the most affordable fuel for power generation in many developing and industrialised countries for several decades. Events in 2006 led to oil prices rising to around US$ 80/bbl and gas prices spiking to new highs, underlining coal's key role in power generation worldwide.



Cost of electricity comparison

Natural Ventilation

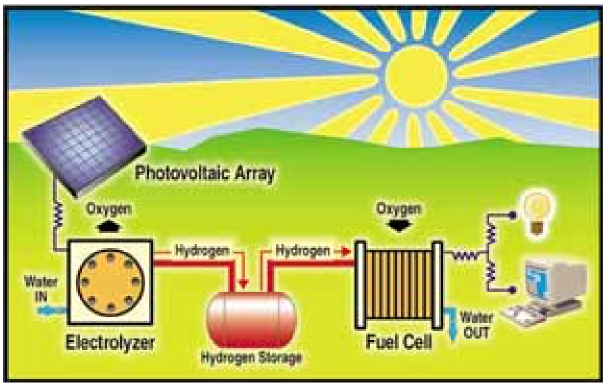
There are three basic natural ventilation strategies that can either be used exclusively, in combination with each other, or in combination with mechanical ventilation (a hybrid system). The three basic natural ventilation strategies are [Emmerich et al. (2001)]:

1. Wind driven cross ventilation - ventilation openings, typically windows, on opposite sides of an enclosed space. Requires a significant difference in wind pressure between the inlet and outlet openings and a minimal internal resistance to flow. As well, McCreary (2001) recommends locating naturally ventilated kitchens, laundries and bathrooms on the leeward side of the building to avert hot humid air from being re-entrained into other spaces.

2. Buoyancy driven stack ventilation - relies on density differences to draw cool, outdoor air in at low ventilation openings and exhaust warm, indoor air at high ventilation openings. Typically uses chimneys or atria to generate sufficient buoyancy forces to achieve the required flow. Wind will also induce pressure distributions on the building envelope that will also act to drive airflow and may well be more important than buoyancy effects. Successful designs will seek ways to take full advantage of both.

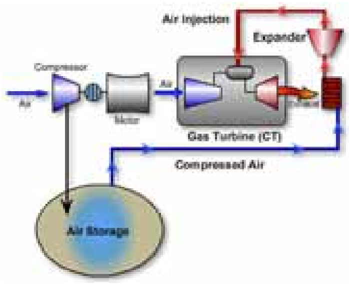
3. Single sided ventilation - ventilation airflow is driven by room-scale buoyancy effects, small differences in envelope wind pressures, and/or turbulence. Consequently, driving forces for single-sided ventilation tend to be relatively small and highly variable. This is the least attractive solution but can serve single offices.
$

Energy storage is expected to play an increasingly important role in the evolution of the power grid particularly to accommodate increasing penetration of intermittent renewable energy resources and to improve electrical power system (EPS) performance. Coordinated, consistent, interconnection standards, communication standards, and implementation guidelines are required for energy storage devices (ES), power electronics connected distributed energy resources (DER), hybrid generation-storage systems (ES-DER), and plug-in electric vehicles (PEV).



The idea of compressed-air energy storage isn't new, but cheap and plentiful energy has precluded much research. The low-tech explanation goes like this: excess energy from a power plant is used to run air compressors, which pump air into an underground cave, where it is stored under pressure. When released, the air powers a turbine, creating electricity. The initial energy used to force the air underground can come from wind, solar, nuclear or any source. Energy Storage and Power plans to market and license its technology to electric utility companies, independent power producers, wind developers and transmission owners. The company hopes to start deploying its technology within 5 to 10 years.
An earlier version of Nakhamkin's design is already in use at a 110-megawatt natural gas power plant in Alabama, showing that the technology is viable. And Energy Storage and Power isn't alone. The Department of Energy, Sandia National Labs, and several Midwestern utilities are already at work designing a compressed air storage system for a plant in Iowa scheduled for completion by 2012.

compressed-air energy storage



Grid energy storage

Grid energy storage (also called large-scale energy storage) refers to the methods used to large-scale store electricity within an electrical power grid. Electrical energy is stored during times when production (from power plants) exceeds consumption and the stores are utilized at times when consumption exceeds production. In this way, electricity production must not be so drastically scaled up and down to meet momentary consumption – instead, production is maintained at a more constant level. This has the advantage that fuel-based power plants (i.e. coal, oil, gas) can be more efficiently and easily operated at constant production levels.

In particular, the use of grid-connected intermittent energy sources such as photovoltaics and wind turbines can benefit from grid energy storage. Intermittent energy sources are by nature unpredictable – the amount of electrical energy they produce varies over time and depends heavily on random factors such as the weather. In an electrical power grid without energy storage, energy sources that rely on energy stored within fuels (coal, oil, gas) must be scaled up and down to match the rise and fall of energy production from intermittent energy sources (see load following power plant).

Thus, grid energy storage is one method that the operator of an electrical power grid can use to adapt energy production to energy consumption, both of which can vary randomly over time. This is done to increase efficiency and lower the cost of energy production, and/or to facilitate the use of intermittent energy sources.

Electrical interconnection guidelines

Electrical interconnection guidelines and standards for energy storage, hybrid generation-storage, and other power electronics-based ES-DER equipment need to be developed along with the ES-DER object models for power system operational requirements.

Objectives*:*
Involve a broad set of stakeholders to address ES-DER electric interconnection issues, including utilities from different regions, the international community, groups addressing similar issues (such as wind turbine interconnection), vendors, researchers, and others.

➢Develop Scoping Document to identify the ES-DER interconnection and operational interface requirements for the full spectrum of application issues: high penetration of ES-DER, ride-through of power system anomalies, plug-in electric vehicles, and all sizes of ES-DER systems, including those at customer sites, within distribution systems, and at transmission level. These may end up with multiple projects, some of which may be done in parallel, and may lead to a planning guideline.

➢Develop Use Cases to identify interconnection and object modeling requirements for ES-DER before electrical connectivity standards are developed. These Use Cases would include coordination with PEV and Wind Use Cases.

➢Update or augment the IEEE 1547 distribution level standards series as appropriate to accommodate the wide range of ES-DER system requirements.

ES(energy storage) systems

Various types of ES-DER systems are emerging. Each type will have different ranges of abilities to respond to power grid management requests, and will use different system parameters and technology specific constraints for forecasting their availability. Furthermore, the storage needs (power, energy, duty cycle, and functionality) will also depend on the grid domain where the storage is used (e.g., transmission, distribution, consumer, etc.). These considerations should be included in the storage and hybrid generation-storage interconnection and information model standards.

Examples of the different storage requirements for grid services include:

➢Ancillary Services – including load following, operational reserve, frequency regulation, and 15 minutes fast response.
➢Peak shaving
➢Black start, islanding
➢Renewables integration: ramp rate control, solar cloud ride thru
➢Managing diurnal cycles for wind/solar: large energy capacity, peak shift
➢Relieving congestion and constraints: short-duration (power application, stability) and long-duration (energy application, relieve thermal loading).
➢As part of a microgrid.

Storage technologies

Examples of storage technologies :

- Pumped Hydro
- Compressed Air Energy Storage (CAES)
- Flywheels
- Batteries, mobile and stationary
- Super-Capacitors (SuperCaps)
- Superconducting Magnetics
- Thermal Storage
- Fuel Cells (reversible)
- Hydrogen Storage

- Cool Roof materials reflect the sun's heat before it enters the interior of the building. This will lower cooling costs.
- Insulation Upgrades can increase efficiency and help to maintain the interior temperature without additional heating or cooling costs.
- Window Film or Solar Awnings can reduce the amount of sunlight entering the building reducing the amount of heat gain. This can protect interior finishes, furniture and equipment. If a Solar Awning is used, not only can it shade the interior, it will also produce free electricity.
- Green Roof materials (plants, waterproof membranes and growing medium) can also help to keep the roof cooler and absorb less heat. The green roof will also help with rainwater runoff and give tenants or employees and outdoor space in an urban environment.

Passive Cooling and Sun Control

Passive systems - internal conditions are modified as a result of the behaviour of the building form and fabric.

General strategies for passive heating and cooling:

- Cold winters - maximise solar gain and reduce heat loss.
- Hot summers - minimise solar gain and maximise heat removal.
- Correct orientation and use of windows.
- Appropriate amounts of thermal mass and insulation.
- Provision for ventilation (natural).

Strategies for *shading and sun control*:

- *External projection* (overhangs and side fins).
- *External systems* integral with the window frame or attached to the building face, such as lourves and screens.
- *Specially treated window glass*, such as heat absorbing and reflecting glass.
- *Internal treatments* either opaque or semi-opaque, such as curtains and blinds.

For hot and humid climate like Hong Kong, extensive shading without affecting ventilation is usually required all year round. Shading of the east and west facades is more important.

Daylighting

Daylight can be used to augment or replace electric lighting. Efficient daylighting design should consider:

- Sky conditions
- Site environment
- Building space and form
- Glazing systems
- Artificial lighting systems
- Air-conditioning systems

The complex interaction between daylight, electric lights and HVAC should be studied carefully in order to achieve a desirable solution.

Advanced window technologies have been developed to change/switch the optical properties of window glass so as to control the amount of daylight. There are also innovative daylighting technologies now being investigated:

- Light pipe systems
- Light shelves
- Mirror systems
- Prismatic glazing
- Holographic diffracting systems

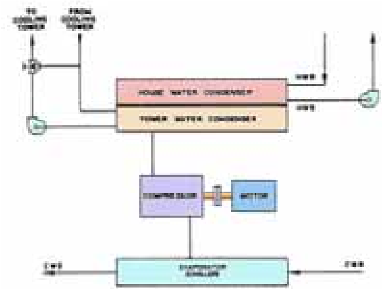
HVAC Systems

Energy efficiency of many HVAC sub-systems and equipment has been improved gradually over the years, such as in air systems, water systems, central cooling and heating plants.

Energy efficient HVAC design now being used or studied include:

- Variable air volume (VAV) systems to reduce fan energy use
- Outside air control by temperature/enthalpy level.
- Heat pump and heat recovery system
- Building energy management and control systems.
- Natural ventilation and natural cooling strategies.

Thermal storage systems (such as ice thermal storage) are also being studied to achieve energy cost saving. Although in principle they will not increase energy efficiency, they are useful for demand-side management.

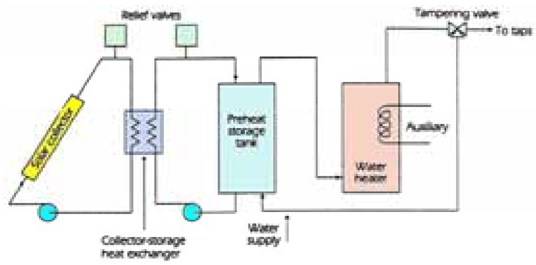


Waste heat recovery in a doule-bundle chiller plant

Active Solar and Photovoltaics

Solar thermal systems (active solar) provide useful heat at a low temperature. This technology is mature and can be applied to hot water, space heating, swimming pool heating and space absorption cooling.

The system consists of solar collectors, a heat storage tank and water distribution mains. An integrated collector storage system has also been developed recently to eliminate the need for a separate storage tank.

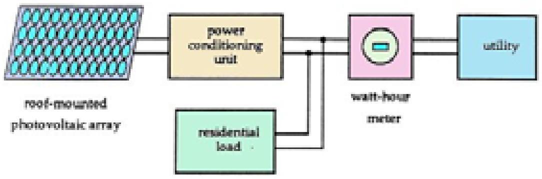


Schematic of a typical solar hot water system

Photovoltaic (PV) systems convert sunlight into electricity using a semi-conductor device. The main advantages of PV systems include:

- Reasonable conversion efficiencies (6-18%).
- PV modules can be efficiently integrated in buildings, minimising visual intrusion.
- Their modularity and static character.
- High reliability and long lifetime.
- Low maintenance cost.

In practice, PV technology can be used for central generation or building-integrated systems (BIPV). The systems can be of the standalone type, hybrid type or grid-connected type. Although the cost of PV is still high at present, it may become cost-effective in the hear future.



Grid-connected solar photovoltaic system

Classification of Climates

Many different systems of climate classification are in use for different purposes. Climatic zones such as tropical, arid, temperature and cool are commonly found for representing climatic conditions. For the purposes of building design a simple system based on the nature of the thermal problem in the particular location is often used.

- ***Cold climates***, where the main problem is the lack of heat (under heating), or an excessive heat dissipation for all or most parts of the year.
- ***Temperate climates***, where there is a seasonal variation between underheating and overheating, but neither is very severe.
- ***Hot-dry (arid) climates***, where the main problem is overheating, but the air is dry, so the evaporative cooling mechanism of the body is not restricted. There is usually a large diurnal (day - night) temperature variation.
- ***Warm-humid climates***, where the overheating is not as great as in hot-dry areas, but it is aggravated by very high humidities, restricting the evaporation potential. The diurnal temperature variation is small.

The general climate (*macroclimate*) is influenced by the topographty, the vegetation and the nature of the environment on a regional scale (*mesoclimate*) or at a local level within the site itself (*microclimate*).

Importance of Climatic Design

Climate has a major effect on building performance and energy consumption. The process of identifying, understanding and controlling climatic influences at the building site is perhaps the most critical part of building design. The key objectives of climatic design include: To reduce energy cost of a building
To use "natural energy" instead of mechanical system and power
To provide comfortable and healthy environment for people

Climatic Elements

The main climatic elements, regularly measured by meteorological stations, and published in summary form are:

- ***Temperature*** - dry-bulb temperature.
- ***Humidity*** - expressed as relative humidity or absolute humidity, or the web-bulb temperature or dew-point temperature may be stated, from which the humidity can be deduced.
- ***Air movement*** - both wind speed and direction are indicated.
- ***Precipitation*** - the total amount of rain, hail, snow, dew, measured in rain gauges and expressed in mm per unit time (day, month, year).
- ***Cloud cover*** - based on visual observation and expressed as a fraction of the sky hemisphere (tenths, or 'octas' = eights) covered by clouds.
- ***Sunshine duration*** - the period of clear sunshine (when a sharp shadow is cast), measured by a sunshine recorder which burns a trace on a paper strip, expressed as hours per day or month.
- ***Solar radiation*** - measured by a pyranometer, on an unobstructed horizontal surface and recorded either as the continuously varying irradiance (W/m^2), or through an electronic integrator as irradiance over the hour or day.

Factors Affecting Climatic Design

The local micro-climate and site factors will affect the actual environmental conditions of the building. The important site-related factors should be considered when making the climate analysis:

- ***Topography*** - elevation, slopes, hills and valleys, ground surface conditions.
- ***Vegetation*** - height, mass, silhouette, texture, location, growth patterns.
- ***Built forms*** - nearby buildings, surface conditions.
- Major thermal design factors to be studied include: solar heat gain, conduction heat flow and ventilation heat flow.

The design variables in architectural expression that are important will include:

- ***Shape*** - surface-to-volume ratio; orientation; building height.
- ***Building fabric*** - materials and construction; thermal insulation; surface qualities; shading and sun control.
- ***Fenestration*** - the size, position and orientation of windows; window glass materials; external and internal shading devices.
- ***Ventilation*** - air-tightness; outdoor fresh air; cross ventilation and natural ventiation.

CLIMATE ANALYSIS

Different design situations will require different weather data for the study. Climate analysis carried out at initial design stage may be used for:

- develop design strategies
- check condensation problems in some cases
- optimization of insulation

Load and energy calculation carried out at outline and detail design stages will require weather data for:

- calculation of cooling and heating requirements
- design of heating, ventilating and air-conditioning (HVAC) systems
- energy estimation of buildings

Microclimate

Each specific site has its own unique climatic characteristics that need to be analyzed. The climatic aspects of the specific site or areas on the site are called the microclimate. The specific characteristics of the site are analyzed only after one has a good understanding of the macroclimate and general climatic characteristics which give an overview of the climate for your region. The microclimate must be studied not only for the natural elements, but for how any man-made elements, such as buildings and landscaping are affecting and/or will affect the site.

The intention of sustainable design is to create higher performance buildings that are integrated with the environment. Both the outdoor and indoor microclimate play a significant role in a building's ability to achieve these objectives, whether it be related to safety issues such as wind and snow loads, energy issues such as solar gains and ventilation; or comfort issues such as temperature andair quality.
Although there are valuable benefits for building owners and tenants to be derived from theinclusion of sustainable concepts in a building's design, there can be risks if microclimate issues arenot effectively addressed. The risks can range from occupant discomfort to health and safety concerns and, almost always, result in increased costs - operating, retrofit and/or repair.

Design reviews and detailed engineering studies carried out by microclimate specialists offer an approach that is tailored to the design and siting of the specific building, thereby refining the design and increasing the potential for achieving the project objectives. Physical scale model tests in a boundary layer wind tunnel and CFD computer simulations are two effective tools that can predict many important microclimate impacts and prove the building performance under normal oremergency conditions.

KEY ISSUES

A number of the issues related to the outdoor and indoor microclimate are outlined below. Although not all of the issues are specific to Green Buildings, they are relevant to the creation of higher performance buildings, which is the intention of sustainable design:

1. Wind - Cladding and structural loads, pedestrian level comfort, natural ventilation, energy production.
2. Solar - Daylighting, solar heating, cooling load reduction, energy production and conservation.
3. Temperature and Humidity - Natural ventilation, thermal comfort.
4. Noise, Vibration & Acoustics - Sound and vibration isolation (external and internal), performance of acoustically sensitive spaces.
5. Air Quality - Exhaust re-entrainment, ambient pollution levels.
6. Air Distribution - Thermal comfort, indoor air quality, condensation control, smoke management.
7. Snow - Structural loads, sliding ice and snow.

THE RISKS AND BENEFITS OF MICROCLIMATE ISSUES

Some of the potential risks that microclimate issues present to building designers are outlined in the
following table. The table also includes some of the potential benefits associated with addressing these issues early in the building design:

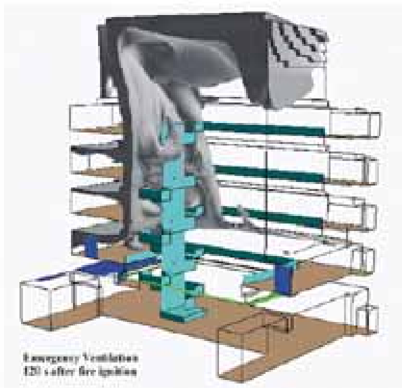
Potential Risks	Potential Benefits
• Failure to achieve design objectives • High operating costs • Poor occupant health and satisfaction • Potential retrofit costs • Mold/mildew and Sick Building Syndrome • Contamination of adjacent sites • High noise levels and poor acoustics • Potential for loss of life from fire • Higher snow management costs • Loss of use of facilities • Repair costs for building damage	• Lower construction costs • Lower operating costs • Improve occupant health, safety and comfort • Smoke management systems that perform as intended • Achieve project objectives

MICROCLIMATE ASPECTS

Air Distribution

The effective distribution of air inside buildings under normal and emergency operating conditions is essential to achieving occupant health, comfort and safety as well as managing building deterioration from condensation, mold and mildew. Building codes provide minimum rates for the supply of outside air under normal operating conditions but do not typically provide any guidance on the distribution of supply air.

Under fire conditions they are more specific in that they limit make-up air velocities for smoke management systems to 200 fpm but again provide little or no guidance on where make-up air intakes should be located.
CFD modeling can predict the performance of the proposed ventilation system. The output from the CFD modeling includes air speed and temperature. This information can illustrate the level of thermal stratification, draft, condensation potential, thermal comfort of occupants and distribution of solar loads.



Atrium Smoke CFD Simulation

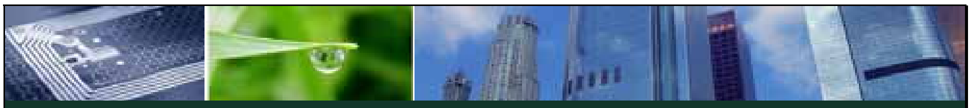
6.2 LECTURE M3L13

Short Outline

M3.L13 The concept of BIM

- The concept of shared elements
- Relevant shared building elements – description, relationships, EE related features
- Relevant shared building services elements – description, relationships, EE related features
- Relevant shared management and facilities elements
- Overview of principal modelling approaches for enhancement of existing elements with EE related features

Powerpoint Outline



Lesson example M3L13

Lecture Notes on energy Efficiency in Building Construction

Karsten Menzel - UCC

TECHNISCHE UNIVERSITÄT DRESDEN

1

Sources

- Karsten Menzel Lectures ITC Euromaster Course
- Energy Analysis Tools by Richard Paradis- Steven Winter Associates
- Energy Performance Evaluation of an Educational Facility: The Adam Joseph Lewis Center for Environmental Studies, Oberlin College, Oberlin, Ohio by S.D. Pless and P.A. Torcellini

2

Module 3 Lesson 13 description content

First Semester

Intermediate

Module 3
Energy Efficient Planning System

Credits: 12
Number of Lectures: 33
Lecture hours per week: 9
Lecture Hours in total : 135
Working load in total: 337 h

- **M3.L13 The concept of BIM content**
  - **Vision, goals, background concepts and contents of BIM**
  - Historical development of the BIM idea and current state of BIM use in research and industry
  - BIM in the context of BuildingSMART
  - Modelling languages and paradigms with regard to BIM
  - Best practice examples

3

Module 3 Lesson 13: The Concept of BIM

Vision, goals, background concepts and contents of BIM

Building Information Modelling

• BIM is a software tool that uses relational database together with a behavioural model that captures and presents building information dynamically.

• This means, for example, revising windows from one type to another not only produces a visually different graphic representation in all views of your building but the insulation value of the glazing is also changed.

• Due to integration of the data, running various types of analysis is greatly simplified.

4

Module 3 Lesson 13: The Concept of BIM

Vision, goals, background concepts and contents of BIM

Building Information Modelling

•The approach to building design is moving away from conventional CAD software to follow the way design has evolved in the manufacturing sector.

• Buildings can now be working prototypes

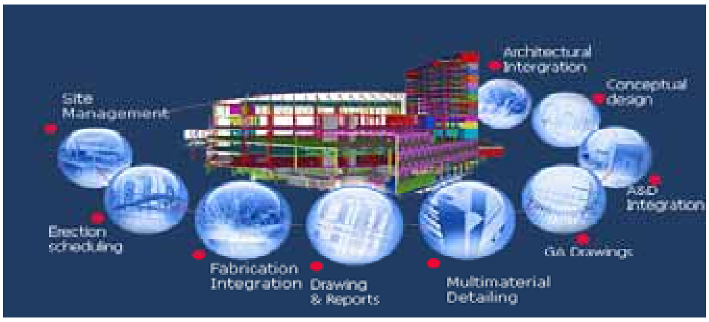
• Sustainable design is driving this solution to ensure that buildings are designed, constructed and operated in a manner that minimises their environmental impact.

5

Module 3 Lesson 13: The Concept of BIM

Vision, goals, background concepts and contents of BIM

Building Information Modelling



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Module 3 Lesson 13: The Concept of BIM

Vision, goals, background concepts and contents of BIM

Building Information Modelling

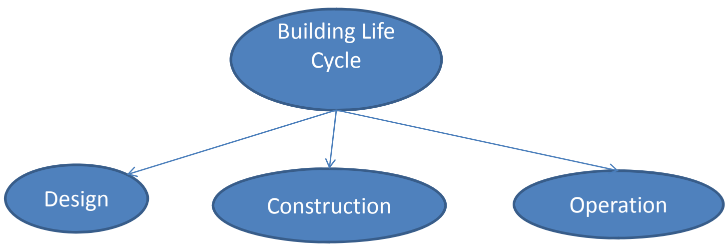
- Multiple design options can be assessed.
- Using BIM's helps with the demanding aspects of sustainable design, such as solar applications and daylight harvesting, and also automates routine tasks such as documentation.
- Schedules can be generated directly from the model.
- More accurate plant sizing can result.

7

Module 3 Lesson 13: The Concept of BIM

Vision, goals, background concepts and contents of BIM

Building Information Models are useful carried forward to the operational phase of a Building Lifecycle



8

Module 3 Lesson 13: The Concept of BIM

Vision, goals, background concepts and contents of BIM

Considering the Underlying Data

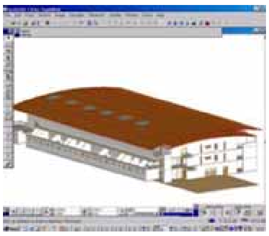
• Data needs to be standardised to enable seamless interaction between tools
– IFC' s offer such an option

9

Module 3 Lesson 13: The Concept of BIM

Vision, goals, background concepts and contents of BIM

The geometrical object model can be compiled into a suitable export file



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#9 = IFCAPPLICATION ('ArchiCAD', 'ArchiCAD 7.0
(Graphisoft)', '7.0', #8);
#10 = IFCPERSONANDORGANIZATION (#6, #7, ());
```

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Module 3 Lesson 13: The Concept of BIM

Vision, goals, background concepts and contents of BIM

This file can then be used to import design data into the database ready for operation.

```
ISO-10303-21;
HEADER;
FILE_DESCRIPTION (('ArchiCAD generated IFC file.'),
'2;1');
FILE_NAME ('RoomandSensor.IFC', '2002-07-15T11:03:14',
('Architect'), ENDSEC;
DATA;
#6 = IFCPERSON ('FamilyName', $, $, $, (), ());
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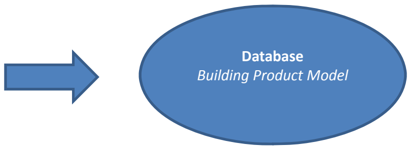
#8 = IFCORGANIZATION ('Graphisoft', (), (), $);
#9 = IFCAPPLICATION ('ArchiCAD', 'ArchiCAD 7.0
(Graphisoft)', '7.0', #8);
#10 = IFCPERSONANDORGANIZATION (#6, #7, ());
#11 = IFCTRANSACTION (1026727393, #10, #9);
#12 = IFCAUDITTRAIL (1026727393, $, #10, $, #9, $,
(#11));
#14 = IFCSIUNIT (*, .LENGTHUNIT., .MILLI., .METRE.);
#15 = IFCSIUNIT (*, .AREAUNIT., $, .SQUARE_METRE.);
#16 = IFCSIUNIT (*, .VOLUMEUNIT., $, .CUBIC_METRE.);
```



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Module 3 Lesson 13 description

First Semester

- **M3.L13 The concept of BIM**
  - Vision, goals, background concepts and contents of BIM
  - **Historical development of the BIM idea and current state of BIM use in research and industry**
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  - Best practice examples

Intermediate

Module 3
Energy Efficient Planning System

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Module 3 Lesson 13: The Concept of BIM
Historical Development of the BIM

Benchmark historical and current performance

Once baseline measures have been established, it is important to next develop and evaluate the baseline data relative to the relevant performance benchmarks. Benchmarks provide intuitive insight into the comparative performance of a facility or a component within that facility. Benchmarks can be based on industry standards as identified by a host of credible industry associations and research organizations, such as the Uptime Institute, Lawrence Berkley National Labs (LBNL), and the newly created Green Grid consortium. In addition to these whole-facility metrics, organizations like the Environmental Protection Agency's Energy Star organization and the American Society of Heating Refrigeration and Air-Conditioning Engineers (ASHRAE) offer component-level efficiency ratings.

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Module 3 Lesson 13: The Concept of BIM
Historical Development of the BIM

Building Representation

A building can be described as composed of:
- rooms, which have functions, requirements & delimited by construction elements & contain system elements elements, which have a physical reality and performances.
- They are either construction elements (separation and structure functions) or system elements (technical functions, converting or transporting different media).
- they have other characteristics like their status (degree of realization: average, planned, new, refurbished etc.)
- Their reference units refer to their composition (material layers, duct characteristics), performance (e.g. acoustic absorption, efficiencies) and use of resources (cost, materials, land, time).
- use processes of rooms, which are dynamic .Their reference units relate to the requirements (e.g. internal loads in W/m2). They consume resources and create emissions.
- construction and maintenance processes, which are dynamic and which refer to elements (set up time, probable life span). Their reference units are those of the specifications. They consume resources and create emissions.
- resources of different types. Their reference units are related to mass, energy and time flows.

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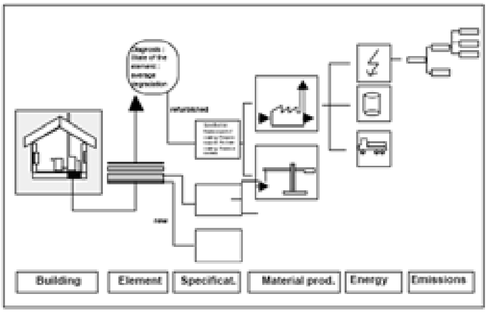
Module 3 Lesson 13: The Concept of BIM

Historical Development of the BIM

Topological relations between rooms and elements



Building Representation based on elements & specifications

Rooms defined by surfaces of construction elements & contain technical system elements.
Technical systems have their own compositional structure (generally hierarchical).
The reference units are interrelated through the composition of the building. They can generally be recomposed by generalization from the "building as built" to earlier stages.
The "building as built" can be considered as the most complete representation of a building.

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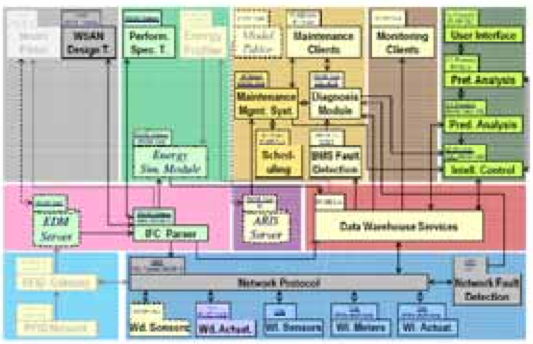
Module 3 Lesson 13: The Concept of BIM

Historical Development of the BIM



System Architecture
This architecture represents a new and affordable ICT for energy-intensive systems for:
(1)design and simulation of energy use profiles covering the entire life-cycle of energy-intensive
products (manufacturing, use and disposal), services and processes;
(2) intelligent and interactive monitoring of energy production, distribution, trading and use, e.g. intelligent metering, network management, in-house consumption management; and
(3) innovative tools, business models and platforms for energy efficiency service provision providing continuous
and accurate information to decision makers, in industry and policy making

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Module 3 Lesson 13: The Concept of BIM

Historical Development of the BIM

System Integration

The System provider shall furnish and install a fully integrated Building Management System (BMS), incorporating distributed control techniques and standard open communication networks. The system shall be implemented as an integrated, open solution, which enables Service Center connectivity through standard Building Operating System (BOS) interface.
The integrated systems shall include controls and monitoring of the whole building (BMS and Security) and each room/apartment whenever applicable.
Integrated Building Management and Security Systems shall include the following subsystems:
- BMS / Building automation (cooling/heating control, ventilation control, pumps, etc.)
- Lighting control of common areas
- Consumption measurements of water, electricity and cooling (heating) energy
- Access control system for common areas
- Intruder alarm system for common areas
- Video monitoring system for common areas
- Fire alarm system
- Central battery system

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Lecture Notes structure V2.0 (D5.32) Module 3 Lesson 13 description

First Semester

Intermediate

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  - Best practice examples

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Module 3 Lesson 13: The Concept of BIM

BIM in the context of BuildingSMART

Smart buildings to meet future needs

The 'building Smart Buildings', bSB, platform can act as a vehicle for continuously generating and capturing creative ideas, needs and inventions on new products and services, and new business models within the IB/Intelligent City domain. bSB will also support subsequent product design, development, evaluation as well as high-tech products and business promotion (demonstration, test installations, training, feed-back capture). The platform can also provide a living environment and laboratory for end users, companies in particular SME´s, and university research groups with possible inclusion of real smart buildings and parts of smart cities. End-user, company and researcher should participate and innovate in all stages of the new product and business development.
bSB should embrace methods and tools to secure high motivation for platform participants. This is achieved through establishment of communities of interest and communities of practice where goals and rewards are formulated and revised both in a social and a business context.

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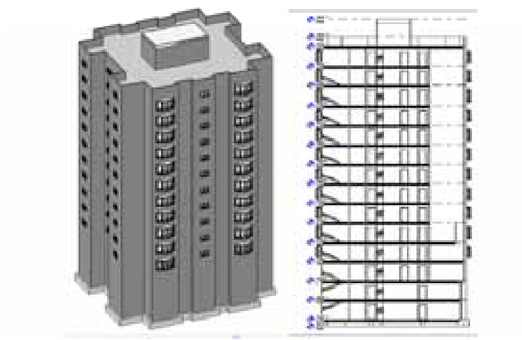
Module 3 Lesson 13: The Concept of BIM

BIM in the context of BuildingSMART

Modelling the Building
The BIM software drawings are used to create, used and obtain concrete building information that can be easily use.



Revit Architecture Model and section

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Module 3 Lesson 13: The Concept of BIM

BIM in the context of BuildingSMART

Modelling a Building Systems

A completed 3D BIM model which was created using Autodesk Revit was the starting point for addition of MEP systems. The mechanical and electrical systems produced for the Revit MEP model included combination boiler radiator heating system, extract fan ventilation system, domestic water supply, hot water supply from combination boiler, soils and waste removal and gas supply for the aforementioned combination boiler.
Revit produces excellent 3D and 2D drafting drawings and intelligent 3D object based building models, however it does not perform energy simulation on the model. The Revit model was combined with IES for a dynamic thermal simulation to analyse variables such as location, orientation, constriuction, plant/equipment, use etc.

Separate room spaces/volumes need to be identified on the model for IES to recognize them This procedure is done graphically using side by side views of plan and section. Once created, each individual volume can be renamed for location and type of use.

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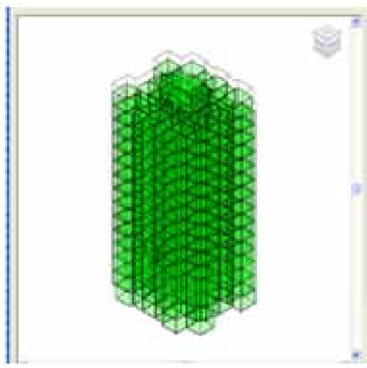
Module 3 Lesson 13: The Concept of BIM

BIM in the context of BuildingSMART

Heating and Cooling Loads allows variables relating to Building Type, Construction, Services and location to be altered. For example type was set as Multi Family for separate families homes within a single building structure and Services were set as "Central Heating Radiators".



Options for Construction and Place and Location opens separate windows as shown

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Module 3 Lesson 13: The Concept of BIM

BIM in the context of BuildingSMART

Simulation Results

A number of simulations were performed altering different building façade properties for comparisons.
For example; a simulation was performed with poor quality single glazed windows with a uvalue of 5.5475w/m2ºC. This resulted in a total heating load of 134kW for the building or 72 w/m2 which is a reasonable result.
The second simulation performed replaced the poor quality single glazed windows with Double Glazed Reflective windows having a u-value of 2.921 w/m2ºC. This resulted in an improved total heating load of 116kW for the building or 63 w/m2.

For the building type and climate this can be considered to be a reasonable result. This also proves that the Revit/IES programme responded correctly to the improved construction.
All results provided can be considered to be reasonable and accurate. When the entire design process is taken into account, the benefits of Revit Architecture and Revit MEP are clear to see.

BIM properties have huge potential to save design and construction time and the software has the potential to become the central hub of any future complex design. Moreover this integration supports a holistic framework for information management and decision support.

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Module 3 Lesson 13 description

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Intermediate

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Module 3 Lesson 13: The Concept of BIM

Modelling languages and paradigms with regard to BIM

Energy analysis tools

Energy analysis tools can be classified as being one of four generic types.

Screening Tools for use primarily during budgeting and programming of retrofits.
- FRESA
- FEDS

Architectural Design Tools for use primarily during programming, schematics, and design development of new construction and major retrofit.
- ENERGY-10
- Building Design Advisor
- Energy Scheming

Load Calculation and HVAC Sizing Tools for use primarily during design development and construction documentation of new construction and major retrofit.
- HAP
- TRACE
- DOE-2
- BLAST
- VisualDOE
- EnergyPlus

Economic Assessment Tools for use throughout the design process.
- BLCC
- Quick BLCC

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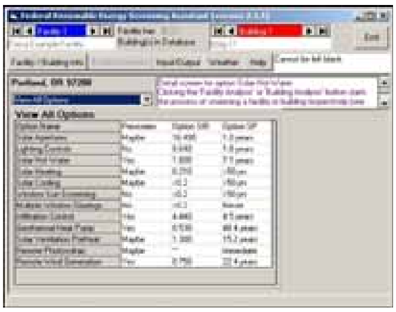
Module 3 Lesson 13: The Concept of BIM

Modelling languages and paradigms with regard to BIM

FRESA (The Federal Renewable Energy Screening Assistant, USA)

Allows federal energy auditors to evaluate renewable energy opportunities and energy systems options for possible inclusion in a facility's energy program. The purpose is to focus feasibility study efforts on those applications most likely to prove cost-effective. FRESA can screen facilities for the following renewable energy systems:

- Daylighting Controls/Infiltration Control
- Daylighting Apertures
- Active Solar Cooling
- Multiple Glazings
- Window Shading Alternatives
- Utilization of Wind Energy
- Utilization of Water Power
- Solar Thermal Electric
- Solar Swimming Pools
- Ground Coupled Heat Pumps
- Active Solar Space Heating
- Solar Hot Water
- Photovoltaic Applications
- Solar Ventilation Reheat
- Conversion to Biomass
- Conversion to Refuse



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Module 3 Lesson 13: The Concept of BIM

Modelling languages and paradigms with regard to BIM

FEDS (The facility Energy Decision System)

Provides a comprehensive method for quickly and objectively identifying energy improvements that offer maximum savings. It is an easy to use tool for identifying retrofits, selecting minimum life cycle costs, determining payback, and enabling users to prioritize options. The FEDS system allows data input to range from minimal to extremely detailed.

Key Strengths	Key Weaknesses
• Technology and Fuel Independence • Life Cycle Cost Optimization • Peak Tracking • Alternate Financing Analysis • Optimizes retrofit opportunities	• Cannot evaluate interaction of some strategies • Not a buildings design tool

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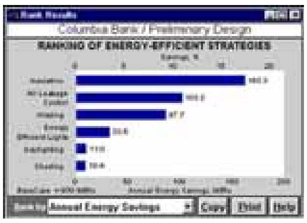
Module 3 Lesson 13: The Concept of BIM

Modelling languages and paradigms with regard to BIM

ENERGY-10

Design tool for small residential or commercial buildings that can be treated as one- or two-zone increments. Performs whole-building energy analysis for 8,760 hours/year, including dynamic thermal and daylighting calculations. New features in Version 1.7 include: New window construction dialogue, two new HVAC system types: VAV DX Cooling and Fixed COP Heat Pump, International weather data, and 3D bar graph display.

Key Strengths	Key Weaknesses
• Hour-by-hour simulation • AutoBuild defaults building attributes • Everything is editable • Excellent educational tool • Life cycle cost analysis • Climate Specific	• Not all strategies are active



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Module 3 Lesson 13: The Concept of BIM

Modelling languages and paradigms with regard to BIM

Building Design Advisor

The BDA is a computer program that supports the concurrent, integrated use of multiple simulation tools and databases, through a single, object-based representation of building components and systems. BDA (Building Design Advisor) acts as a data manager and process controller, allowing building designers to benefit from the capabilities of multiple analysis and visualization tools throughout the building design process. BDA is implemented as a Windows-based application and is linked to a Schematic Graphic Editor and two simplified simulation tools, one for daylight and one for energy analyses.

Key Strengths	Key Weaknesses
• Graphic input • Does not require in depth knowledge to use linked tools for energy and daylighting	• Limited database of options for building components and systems

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Module 3 Lesson 13 description

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Intermediate

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Module 3 Lesson 13: The Concept of BIM

Best Practice Examples

Best Practice Building Description

The Lewis Center at UCC, Cork, Ireland is a two-story, 13,600-ft2 (1,260-m2) building with classrooms, offices, an auditorium, an atrium, and an on-site wastewater treatment system used by the students in the Environmental Studies Program.

1 = PV array
2 = Location of ground wells for heat pump loop
3 = Passive solar heating and ventilation; daylighting
4 = Sunspace for ecological wastewater system

A roof-integrated, 60-kW photovoltaic (PV) system that produces electricity on-site. The system, covers the entire roof, is connected to the local utility grid and does not have a battery backup system. The PV system exports power to the utility grid when the PV system produces more power than the building is currently using. The building imports electricity from the utility when the PV system cannot meet the load. Electricity meets all energy needs, including mechanical systems and domestic hot water. This all-electric system was a requirement in order to meet the future net energy producing vision for the building. Using nonrenewable energy on-site could not have been recovered by the PV system.

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Module 3 Lesson 13: The Concept of BIM

Best Practice Examples

Building Envelope

The design team orientated the building to face south and elongated the east–west axis to maximize solar heat gain and to improve the efficiency of the passive solar features and PV system. The building orientation, combined with engineered window overhangs and fenestration, contributes to the solar heat gain in the winter, solar load avoidance in the summer, and the increased use of natural light. Thermal mass is integrated into the design with exposed masonry in the atrium floors. The thermal mass stores heat from the sun in the winter and moderates summer temperatures to reduce peak loads on the building.

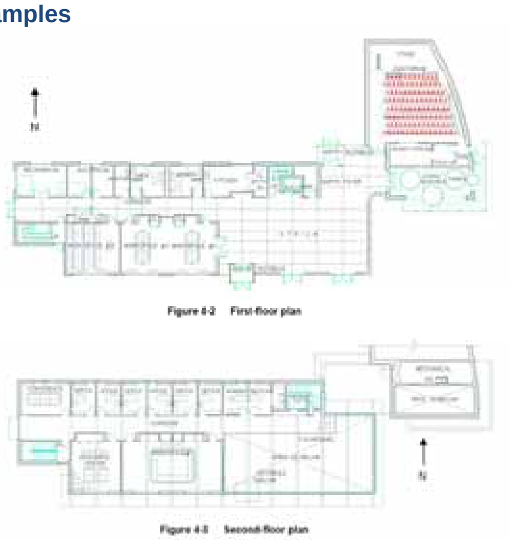

Figure 4-2 First-floor plan

Figure 4-3 Second-floor plan

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Module 3 Lesson 13: The Concept of BIM

Modelling languages and paradigms with regard to BIM

Lighting and Daylighting

The indoor lighting zones include mechanical rooms, bathrooms, kitchen, corridor zones, classrooms, offices, atrium, and auditorium. Figure 4-7 and Figure 4-8 show the type and location of each luminaire. Table 4-3 describes each luminaire; lighting controls are described in Table 4-4. The highly occupied
classroom lighting zones are located on the south side of the building to maximize the daylighting potential. The minimally occupied spaces, such as the mechanical rooms, are located on the north side of the building partially below grade. A north-facing clerestory allows diffuse daylight to assist in illuminating the second-floor corridor, north-facing offices, and south-facing classrooms. The auditorium
has no windows or clerestory, as defined by the original program for the building.

Figure 4-7 First-floor lighting plan

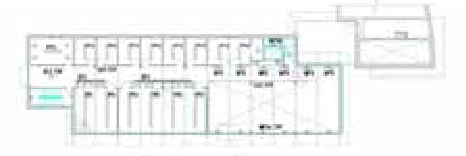

Figure 4-8 Second-floor lighting plan

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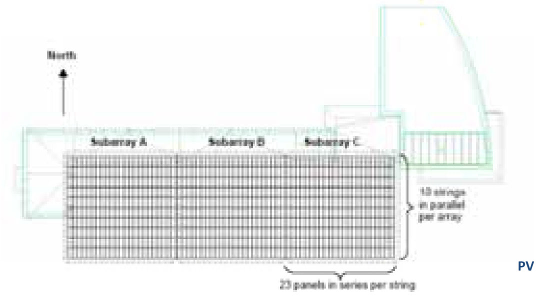
Module 3 Lesson 13: The Concept of BIM

Best Practice Examples

The PV system is wired as three separate but identical subarrays. Subarray A represents the first onethird section of the total array on the west end of the building, subarray B the middle one-third, and subarray C the east one-third. Each subarray consists of 23 modules in series oriented east to west with 10 of these strings wired in parallel from north to south. Each subarray in this wiring configuration is rated at 19.54 kW (414 volts DC and 47.2 amps) at the peak output under standard test conditions.
The Figure show a roof plan view of the subarray configuration.



PV Panel Layout

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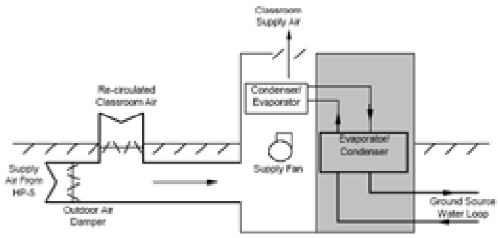
Module 3 Lesson 13: The Concept of BIM

Best Practice Examples

Mechanical Systems

The primary intent of the heating, ventilating, and air-conditioning (HVAC) design was to decouple ventilation from the heating and cooling systems. As a result, the heating and cooling systems were decentralized by zone. To accomplish this, individual room heat pumps were used for the individual classrooms and offices. Figure 4-13 shows a schematic of a typical console heat pump at the Lewis Center. The descriptions provided in this section represent the equipment and operation in March 2001, at the beginning of the performance evaluation.



Schematic of the console heat pumps & how they operate

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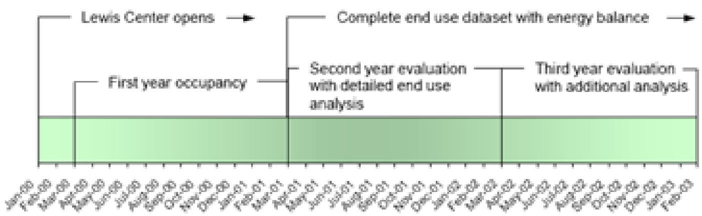
Module 3 Lesson 13: The Concept of BIM

Modelling languages and paradigms with regard to BIM

Whole-building Evaluation Methodology

The NREL High-Performance Buildings team, in collaboration with students and faculty from the Oberlin College Environmental Studies Program, began the whole-building analysis by measuring the energy consumption at many end uses as well as energy supplied to the building from the PV system and the utility company. Researchers then verified that the energy data collection meters were working properly through an energy balance at the building's main electrical distribution panel. After NREL confirmed that the meters were working properly, energy performance metrics were measured. Researchers then created a computer-simulated building model of a conventional energy code compliant building (base case) and a model of the Lewis Center building as constructed (as-built). The evaluation timeline is shown



Evaluation Timeline

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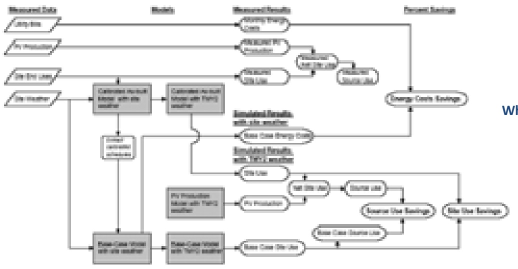
Module 3 Lesson 13: The Concept of BIM

Best Practice Examples

Building Monitoring Methods

The NREL and Oberlin team installed a permanent data acquisition system (DAS) to measure energy flows of the Lewis Center. Energy flows were measured with watt-hour meters. These meters converted the electrical energy measurements into pulse outputs. The DAS recorded the pulses as minute and hourly totals. The manufacturer of the watt-hour meters reports the accuracy to be 0.45% of the reading (Continental Controls Systems 2003). The DAS also measured pulses directly from utility meters. As shown in Figure, the utility meter measured electricity supplied to the building from the utility grid on the primary side of the 500-kVA building transformer. The DAS and the utility company both measured the electricity supplied to the building by the PV system.



Whole- building evaluation flowchart

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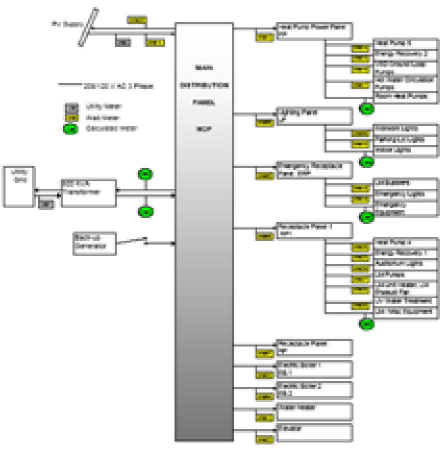
Module 3 Lesson 13: The Concept of BIM

Best Practice Examples

The DAS (data acquisition system)and the utility company both measured the electricity supplied to the building by the PV system. The Figure shows thi meter as UM2. The calculated meters (CM1 through CM6 in Figure 5-3) were computed, rather than measured, and represent the difference when performing an energy balance around the electrical main distribution panel (MDP) or subpanels.



Single-line Building electrical system plan & DAS meter Locations

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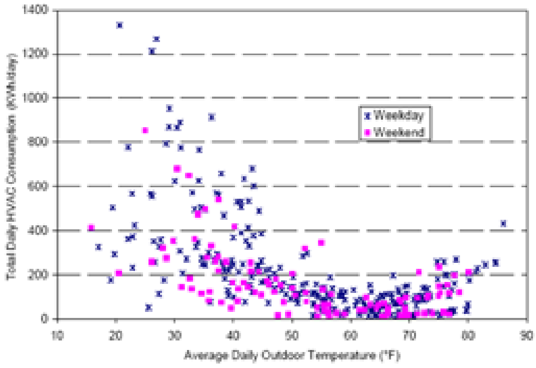
Module 3 Lesson 13: The Concept of BIM

Best Practice Examples

HVAC Performance Evaluation

By evaluating the whole-building annual energy performance, NREL determined that HVAC was responsible for 59% of the total energy consumed in the building during the second year of occupancy. To further understand HVAC energy performance, Figure 6-1 was developed, an X-Y plot of the daily total HVAC electricity use from March 1, 2001, through February 28, 2002, versus the corresponding average daily outdoor temperature.



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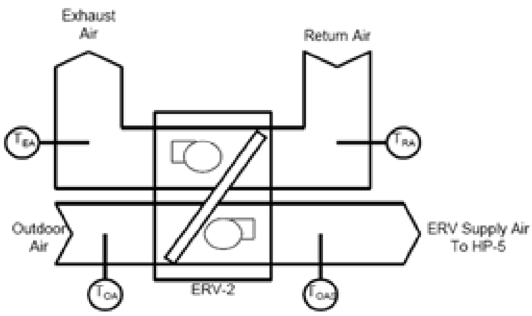
Module 3 Lesson 13: The Concept of BIM

Modelling languages and paradigms with regard to BIM

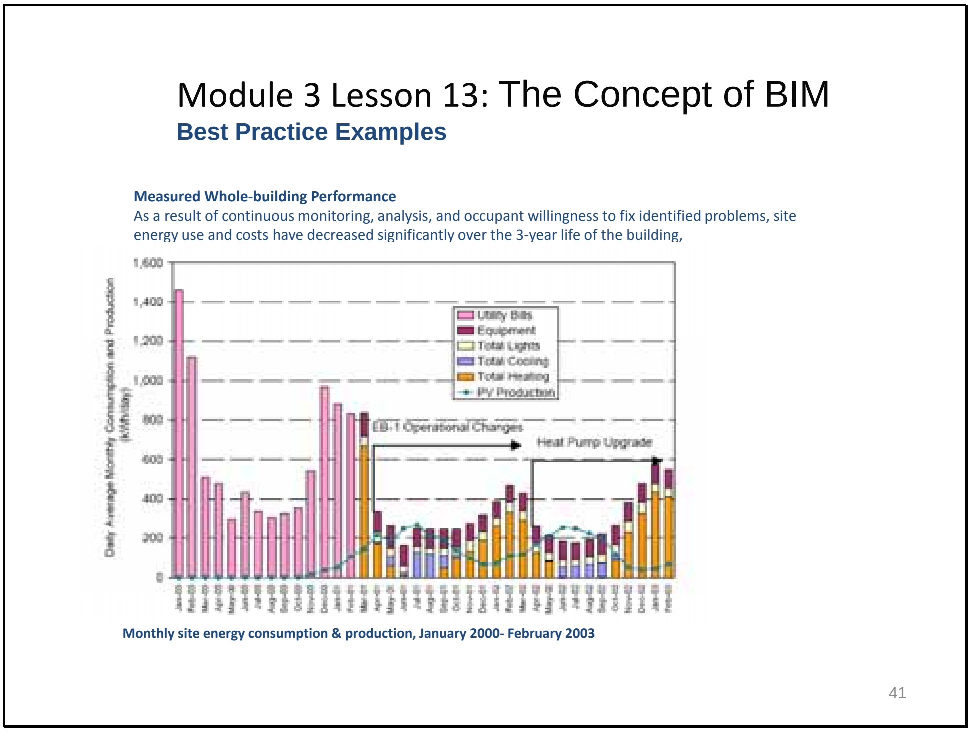
Energy Recovery Ventilators

To determine the general installed performance of the exhaust energy recovery (ERV) units, air temperatures on the supply (TOA and TOAS) and exhaust sides (TRA and TEA) of ERV-1 and ERV-2 were measured, as shown in Figure 6-3. These measurements were made with thermocouples located in the air ducts.



ERV-2 air temperature measurements

40



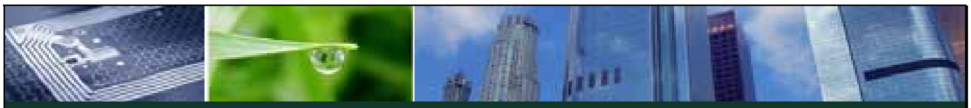
6.3 LECTURE M3L15

Short Outline

M3.L15 Basic structure of the IFC model

- Overview and principal architecture of the IFC model
- Modelling paradigm – differences with regard to STEP/EXPRESS
- Main components of the kernel model
- The product extension and the process extension layers
- Resources, relationships and property objects
- Domain model extensions – concept, modelling approach, current state and development plans

Powerpoint Outline



Lesson example M3L15

Lecture Notes on energy
Efficiency in Building Construction

Raimar Scherer - TUD

TECHNISCHE UNIVERSITÄT DRESDEN

1

Content

➢Basic structure of the IFC model

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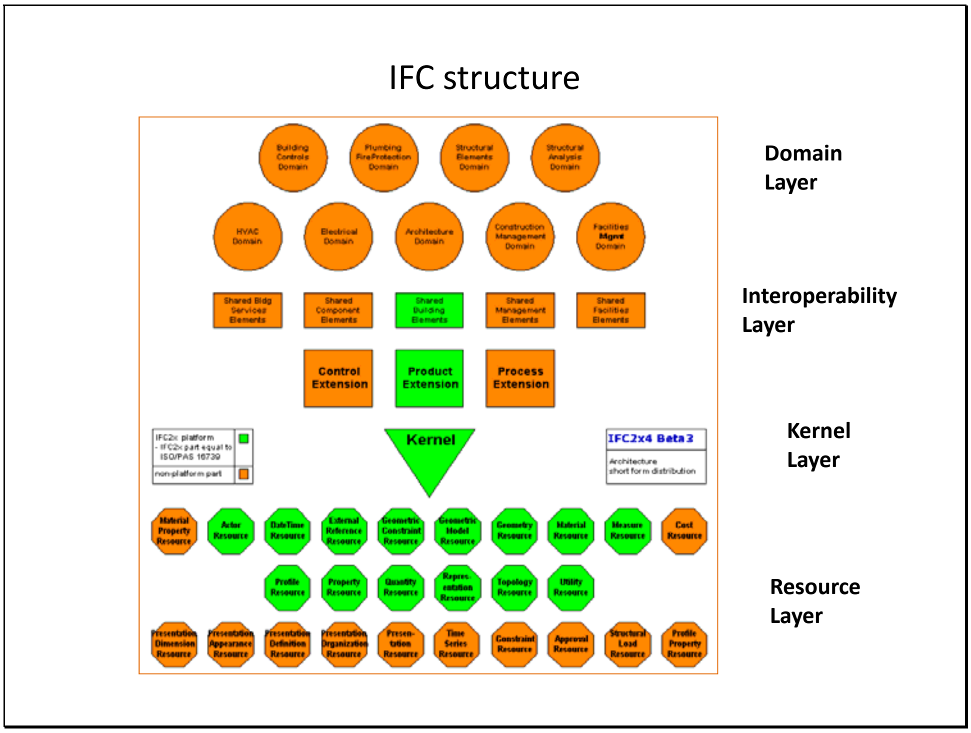
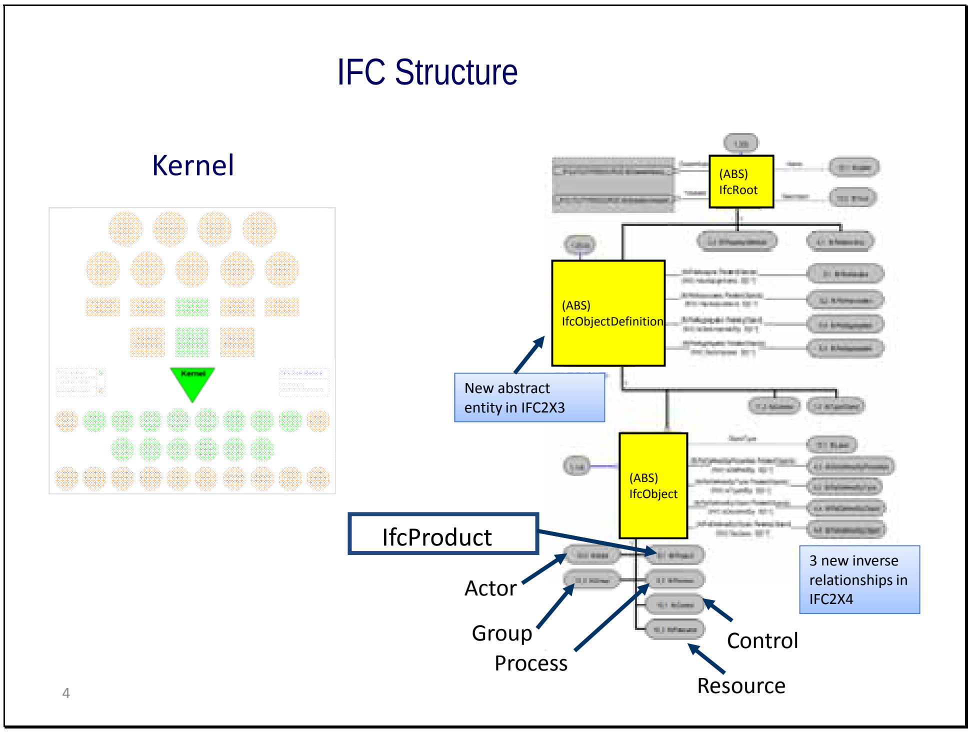
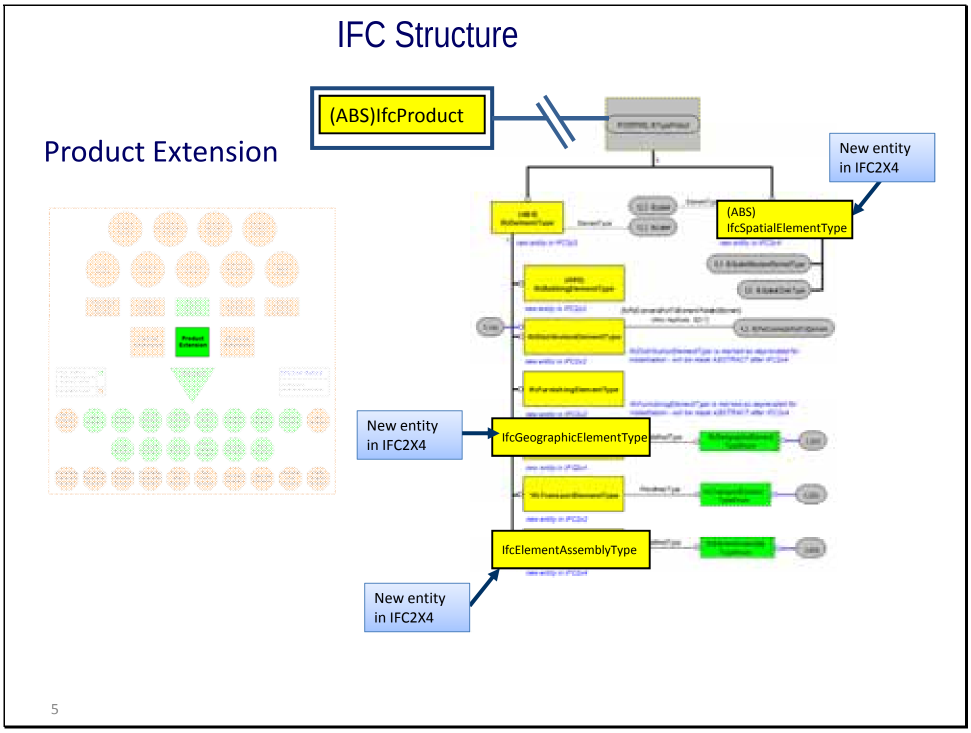
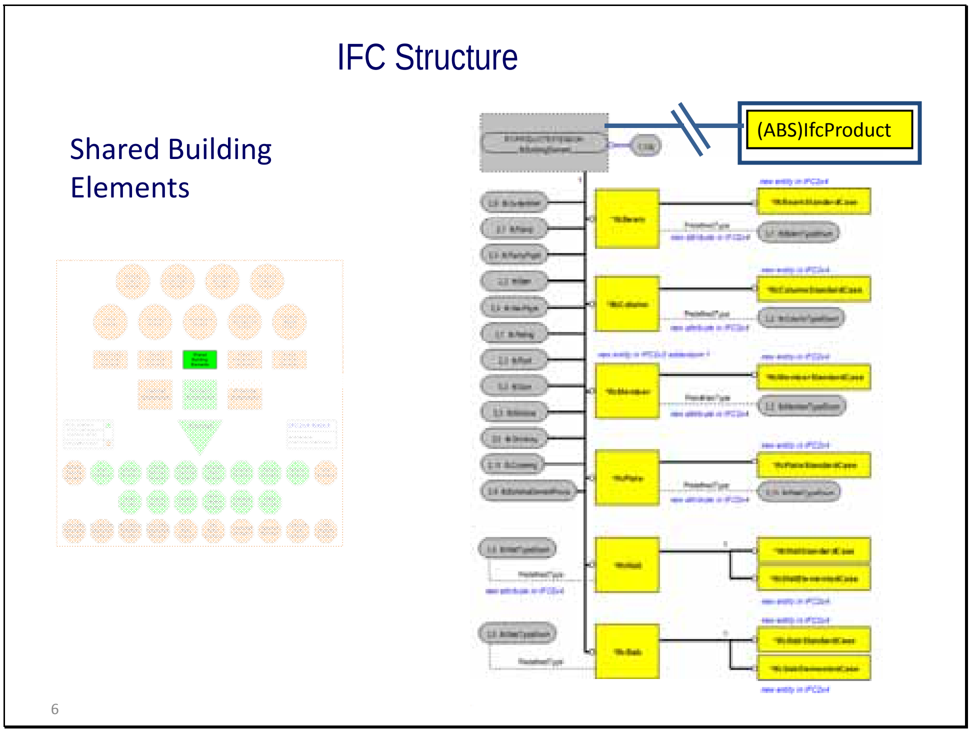
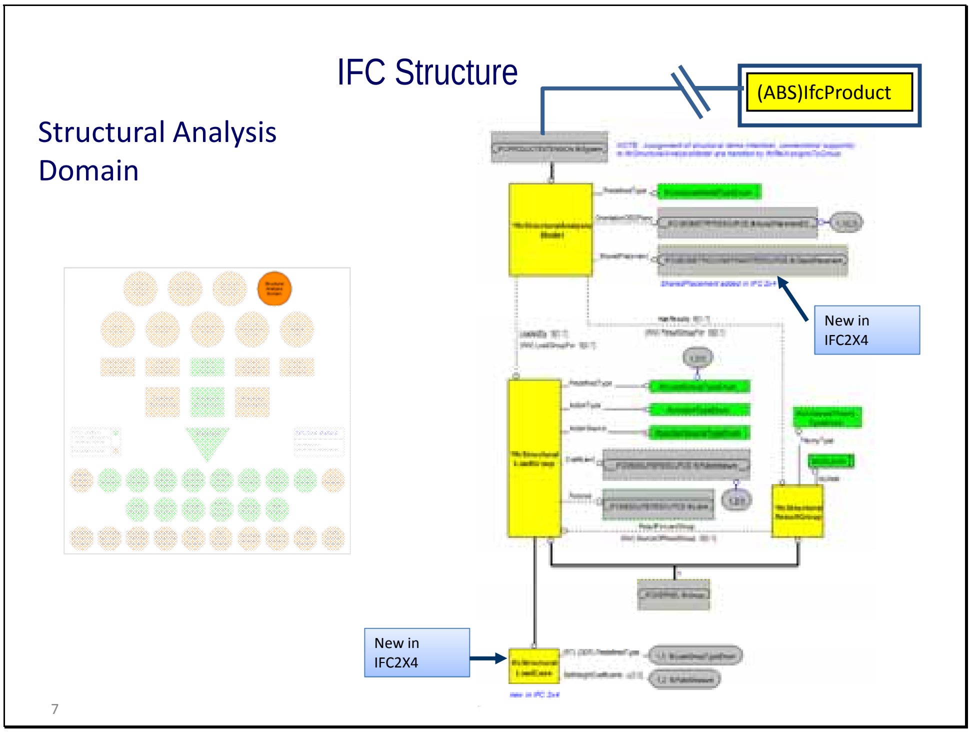
2

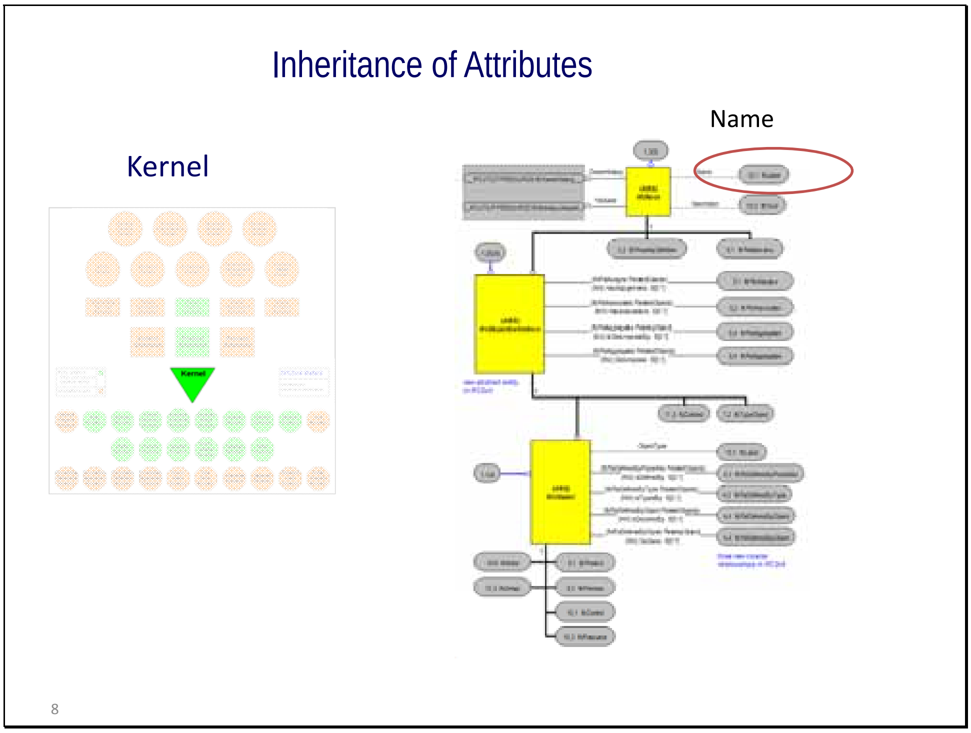

IFC structure
Building Controls Domain
Plumbing FireProtection Domain
Structural Elements Domain
Structural Analysis Domain
HVAC Domain
Electrical Domain
Architecture Domain
Construction Management Domain
Facilities Mgmt Domain
Shared Bldg Services Elements
Shared Component Elements
Shared Building Elements
Shared Management Elements
Shared Facilities Elements
Control Extension
Product Extension
Process Extension
Kernel
IFC2x4 Beta 3
Domain Layer
Interoperability Layer
Kernel Layer
Resource Layer

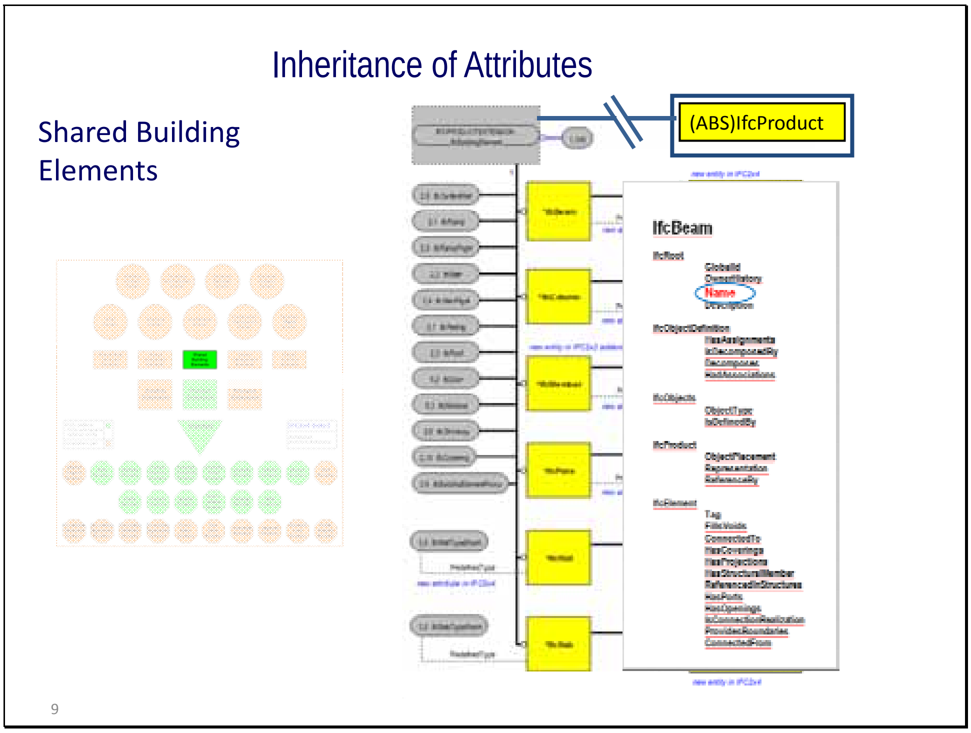

IFC Structure
Kernel
(ABS) IfcRoot
(ABS) IfcObjectDefinition
New abstract entity in IFC2X3
(ABS) IfcObject
IfcProduct
Actor
Group
Process
Control
Resource
3 new inverse relationships in IFC2X4
4

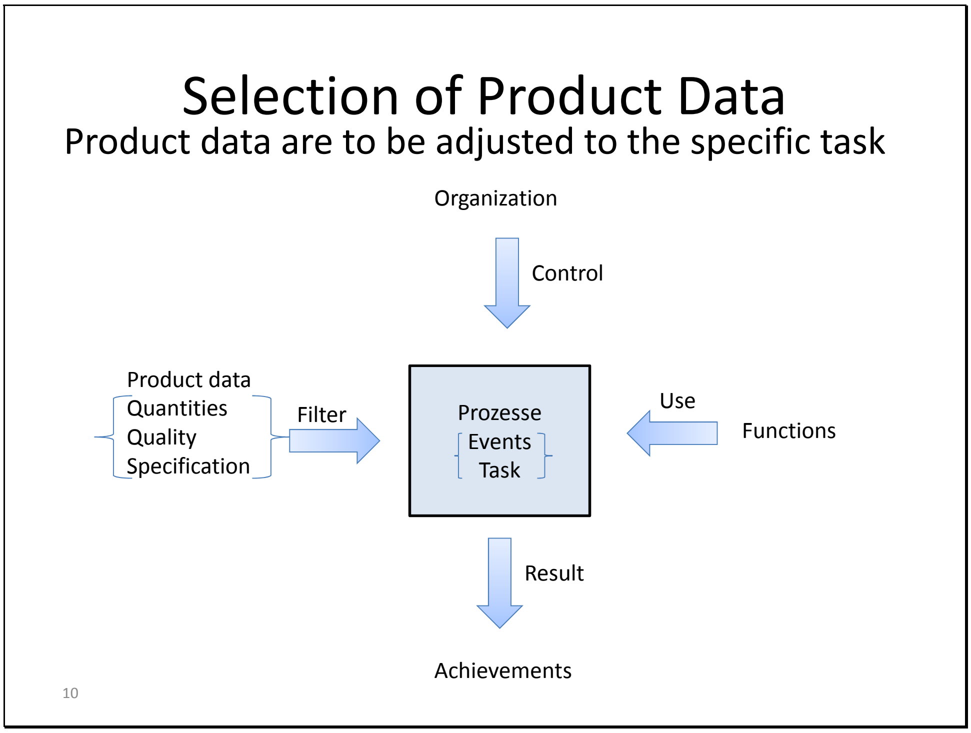

IFC Structure
Product Extension
(ABS)IfcProduct
New entity
in IFC2X4
(ABS)
IfcSpatialElementType
New entity
in IFC2X4
IfcGeographicElementType
IfcElementAssemblyType
New entity
in IFC2X4
5


IFC Structure
Shared Building
Elements
(ABS)IfcProduct
6


IFC Structure
Structural Analysis Domain
(ABS)IfcProduct
New in IFC2X4
New in IFC2X4
7

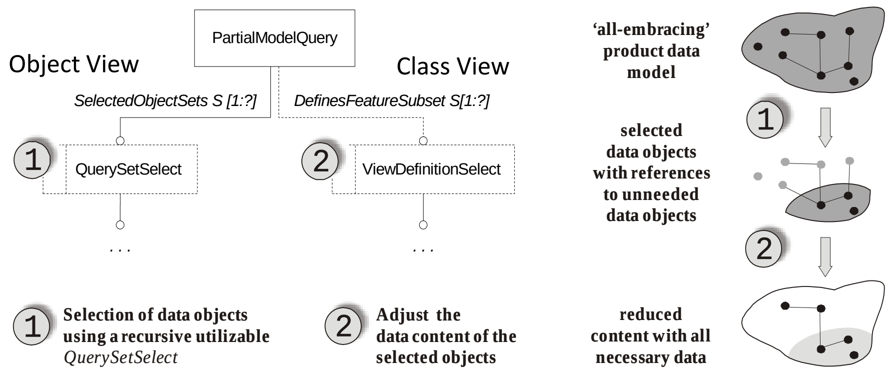

Inheritance of Attributes
Kernel
Name
8


Inheritance of Attributes
Shared Building
Elements
(ABS)IfcProduct
IfcBeam
Name
9


Selection of Product Data
Product data are to be adjusted to the specific task
Organization
Control
Product data
Quantities
Quality
Specification
Filter
Prozesse
Events
Task
Use
Functions
Result
Achievements
10

Formalised product data filter

For the supply of product data , a 2- level filter method will be developed, which is formalized in EXPRESS and can be merged into pre-defined process cycles.

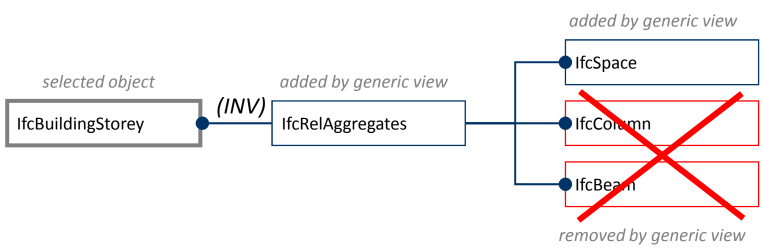


11

Formalised product data filter

Class views:

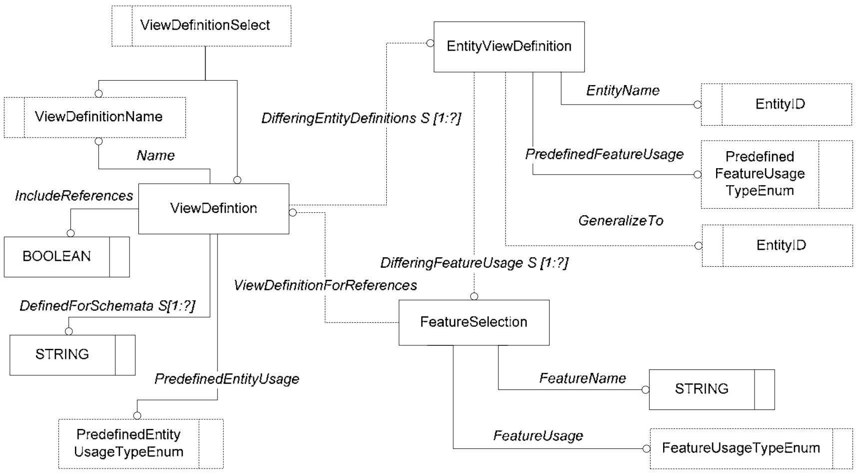
- based on BIM definition, e.g. IFC
  (differention based on class- and attribute level
  as well as reference paths)
- definition of design data belonging to selectable objects
  (evaluation of referenced objects by using the concept of subviews)



12

Formalised product data filter

Top level entities for definition of predefined views (EXPRESS-G)



13

Formalised product data filter

Object selection:

- selection of design state
  (required in a versioned system)

- selection of „important“ objects
  (container objects are preferred, e.g. building storey, system, ...)

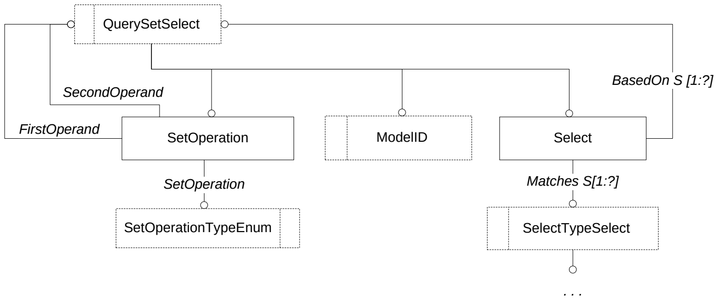
- possible criterions for object selection
  - object id
  - object typ (including inheritance concept)
  - attribute values
  - references
  - boolean operations for selected object sets

result of an object selection = object set

14

Formalised product data filter

Top level entities for dynamic object selection (EXPRESS-G)



15

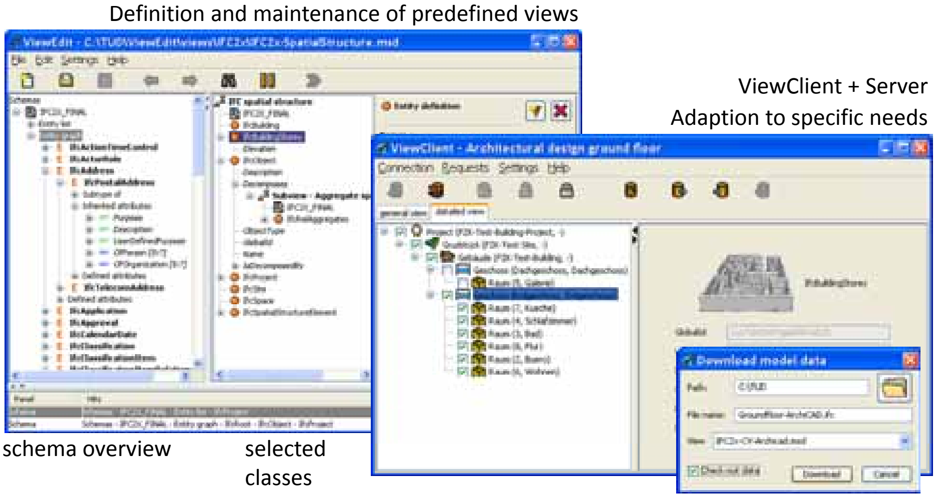
Implementation

ViewEdit

Definition and maintenance of predefined views

ViewClient + Server

Adaption to specific needs



schema overview

selected classes

selected objects

16

Opposing IFC and GAEB Data Structure

IFC

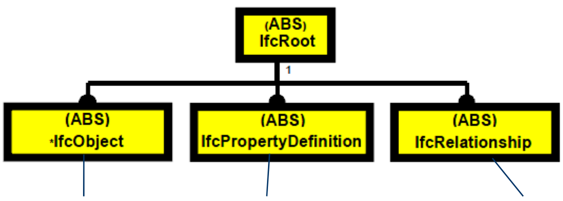
1) Basis-Classes
2) Object (IfcObject): fundamental object types
    1) Product (IfcProduct)
    2) Proxy (IfcProxy)
    3) Process (IfcProcess)
    4) Actor (IfcActor)
    5) Project (IfcProject)
3) Units (IfcUnit)
4) Principle of the object relations
5) Fundamental relations types
    1) Assignment
    2) Grouping
    3) Decomposition
    4) Project and building structure
    5) Association
    6) Definition
    7) Connection
8) Geometry concept
9) Representation concept

GAEB

1) General Information
    1) Organisation
    2) Tasks
2) Data exchange
    1) Information structure
    2) Activity structure
    3) Process steps– exchange phases
    4) Data exchange scenario
    5) AVA-Software system – Architectur
    6) Standard description
    7) GAEB-XML-Schema

Basis-Classes

„Root-Class“
all Classes in IFC (except Ressources-Classes)
are Subclasses of IfcRoot



IfcObject is the Super class of all things (and/or objects)

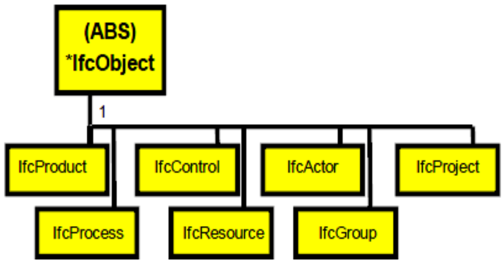
IfcPropertyDefinition Is the SuperClass Of all the Objects characteristics that can be assigned

IfcRelationship is the SuperClass of all relationships between objects

Object

The IFC pattern contains 7 fundamental object types:

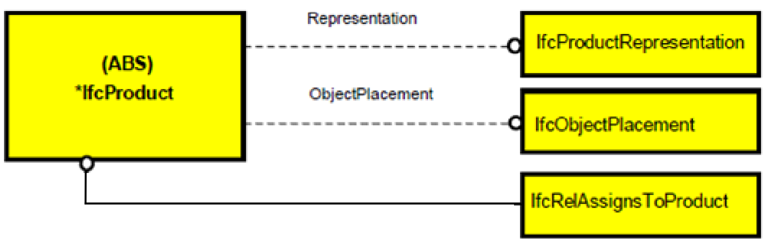
- ➢Product: are material Objects
- ➢Processes: are activities (e.g. advertisement, execution of construction, FM)
- ➢Control : Concepts that the other objects steer or limit (e.g. standards, Regulations)
- ➢Resources: Concepts that use an Object within a process description.
- ➢Actors:Persons or Organisations
- ➢Project: Execution of activities that one product produce
- ➢ Group: freely selectable grouping of objects



Product

IfcProduct covers all materials that are part of a project (by supply, production or from several products that the production is been developed)

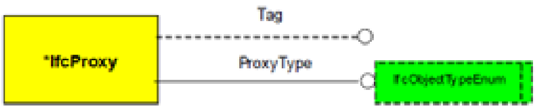
- •ObjectPlacement can:
  - – be absolute (relative to the absolute cartesian coordinate system)
  - – be relative (relative to local coordinate-systems from some other products), or
  - – take place based on a scanning system (relative to scanning axles)
- •Representation is the container for all geometrical representations of a product
  - – all geometric representations are referred to the object placement that defines the local coordinate system



Proxy

IfcProxy is a special SubClass of IfcProduct, where new objects can indivdually be defined which are not contained in the IFC model

- A Proxy-Object can possess a geometrical representation and a placement
- Proxy-Objects can be further specified by means of PropertyDefinitions



Process

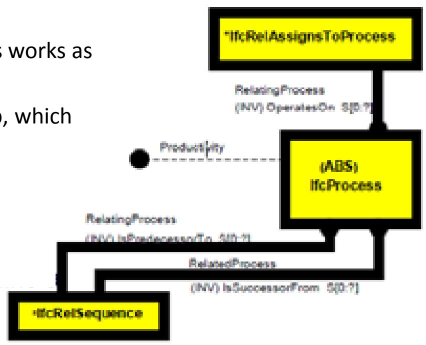
- IfcProcess covers activities

-Work/achievement is implemented/furnished in a certain time

- Processes can be designated and described

- Processes can contain a measure for productivity

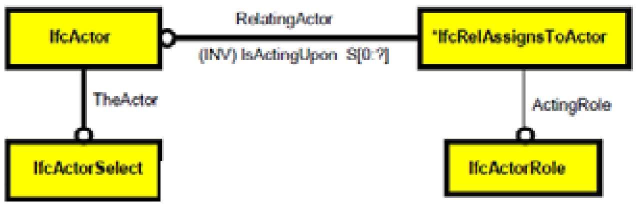
- IfcProcess connects objects, on which the process works as input or output
- Predecessors and successors define a relationship, which describes the remark sequence (IfcRelSequence)



Actor

IfcActor describes persons or organizations who are active in a project

- Covers information about :
  - -Participation on a Project
  - -Future users (in FM-context)
- Participants can possess name, addresses, affiliation, roles, and allocation of objects



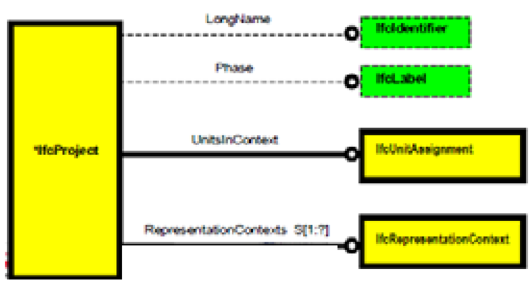
Project

IfcProject is the container for all information which can be exchanged

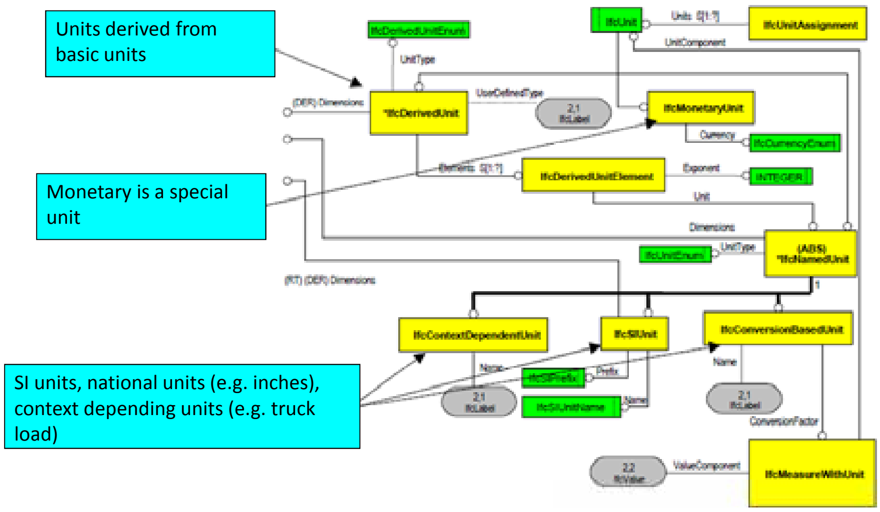
•In each IFC- file (or Data base) only one object of the IfcProject class can be contained

•IfcProject specifies the global information about a project (that only once can be declare):

- -Used standard units
- -Absolute Cartesian coordinate system
- -Coordinate dimensions
- -Used accuracy of the geometrical representations
- -An order related to the absolute Cartesian coordinate system

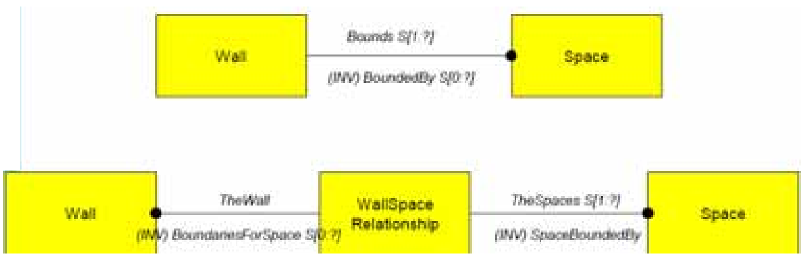


Units



Principle of the object relations

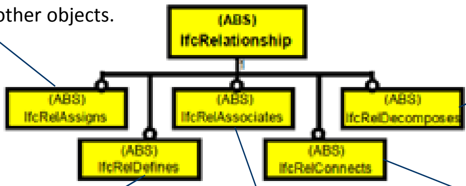
> Relations between classes as objects shown → objective Relations



Object relations

The IFC pattern contains 5 fundamental relations types:

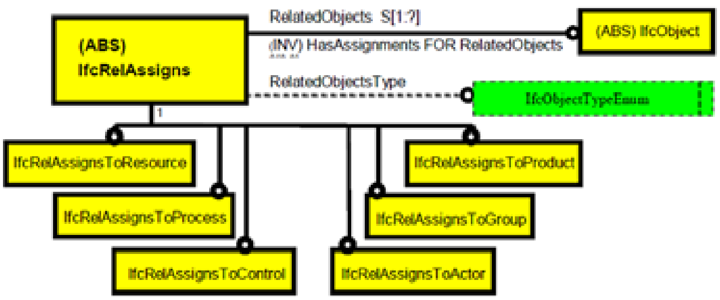
- Make possible that a Client-Object use the services of other objects.
- Defines one „partial-of “-hierarchy and/or structure



- Applies a type definition or a property-set definition to an Object
- Defines a connection between objects
- Makes possible the correlation of external information (e.g. classifications, libraries, documents)

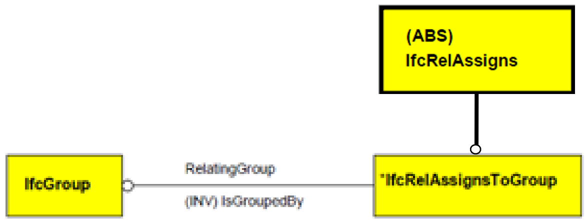
Object relations: Assignment

IfcRelAssigns is the most general form of an object relationship in IFC
- it permits relations between all object types, which are Sub Classes of IfcObject



Object relations: Grouping

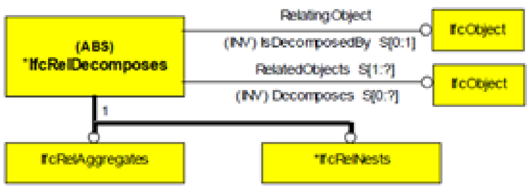
IfcGroup unites several objects to a logical unit within a project
- An Individual object can be part of several groups
-A group can be part of another group (however not part of it´s own)

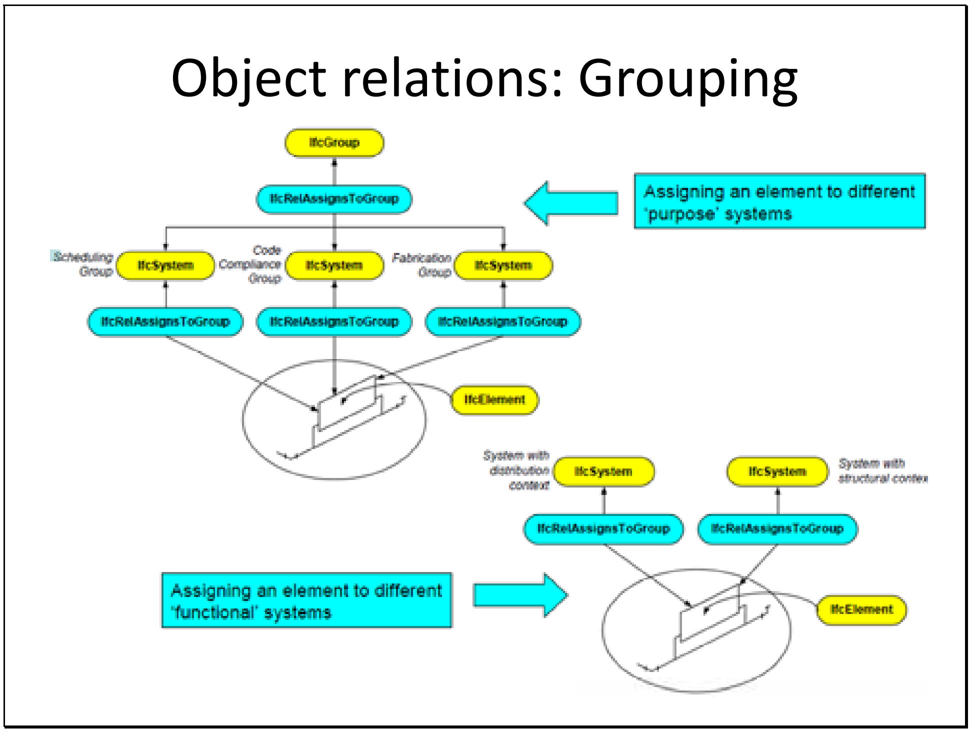


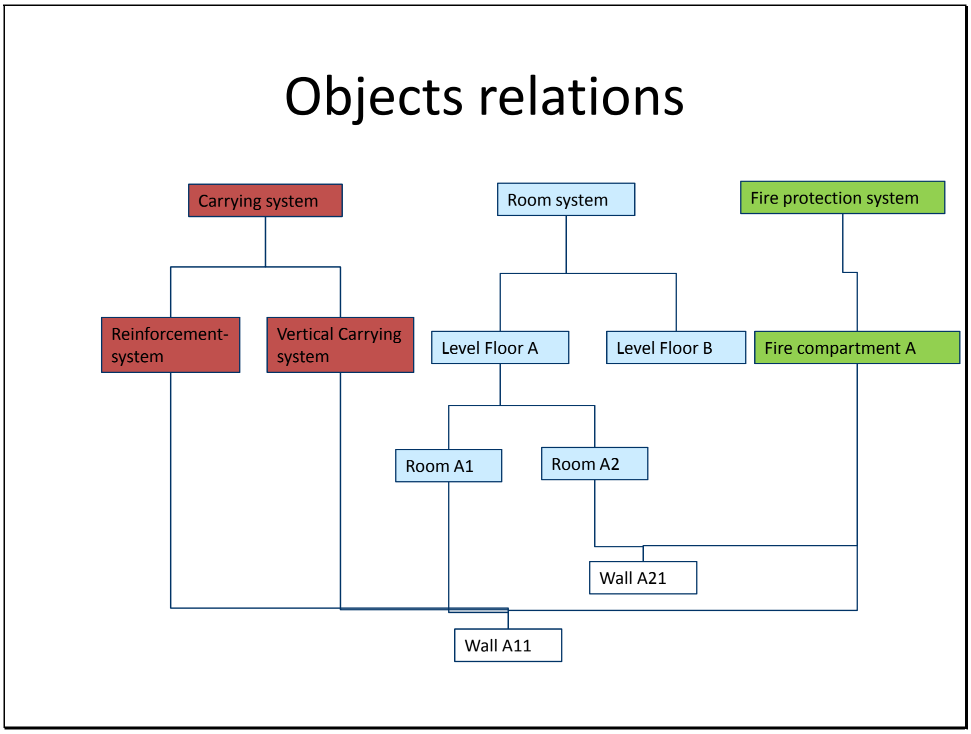
Object relations: Decomposition

IfcRelDecomposes permits „partialof "- relations

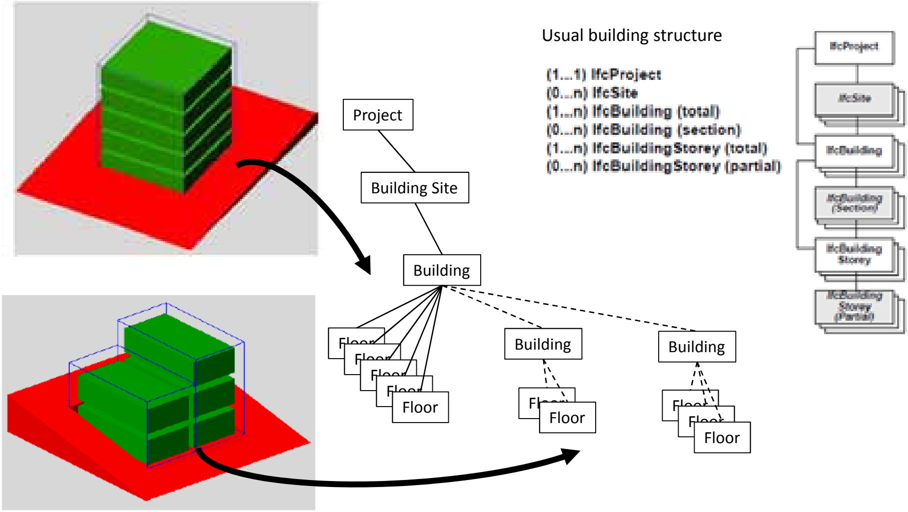
- Nesting divides objects of the same class
  - -E.g.. Dismantling of a System– IfcSystem – into Sub-Systems
- Aggregation divides objects of different classes




Object relations: Grouping
IfcGroup
IfcRelAssignsToGroup
Assigning an element to different 'purpose' systems
Scheduling Group
IfcSystem
Code Compliance Group
IfcSystem
Fabrication Group
IfcSystem
IfcRelAssignsToGroup
IfcRelAssignsToGroup
IfcRelAssignsToGroup
IfcElement
System with distribution context
IfcSystem
IfcSystem
System with structural context
IfcRelAssignsToGroup
IfcRelAssignsToGroup
Assigning an element to different 'functional' systems
IfcElement

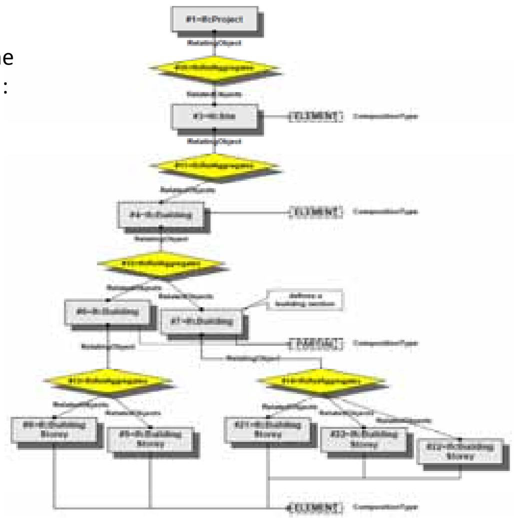

Objects relations
Carrying system
Room system
Fire protection system
Reinforcement-system
Vertical Carrying system
Level Floor A
Level Floor B
Fire compartment A
Room A1
Room A2
Wall A21
Wall A11

Object Relations: spatial building structure



Object Relations: spatial building structure

Decomposition hierarchy of the project and building structure :

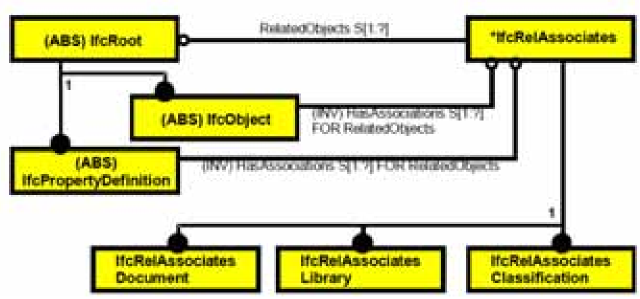


Object relations: Association

IfcRelAssociates permits relations between objects and
-(external) Documents
- as indicators on the document as containers

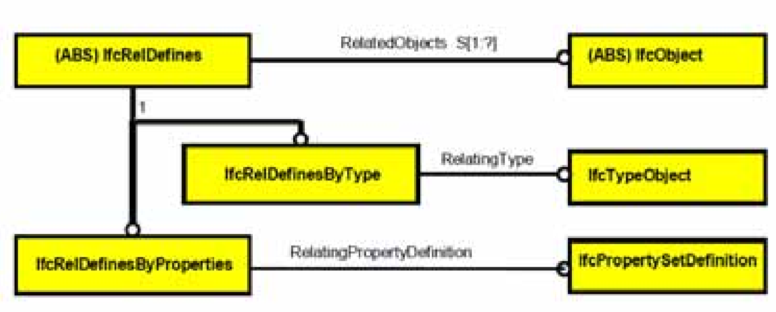
-One or several classifications

-Libraries



Object relations: Definition

IfcRelDefines is used for the description of objects by means of characteristic quantities or Type definitons



Object relations: Connection

A connecting relationship can be physical or logical.

IfcRelVoidsElement: defines the opening relationship between an opening and a physical object

IfcRelFillsElement: defines the filling relations between an opening and a physical object

IfcRelContainedInSpatialStructure: defines the hierarchical connection between different spatial structures (building ground, building, floor, area)

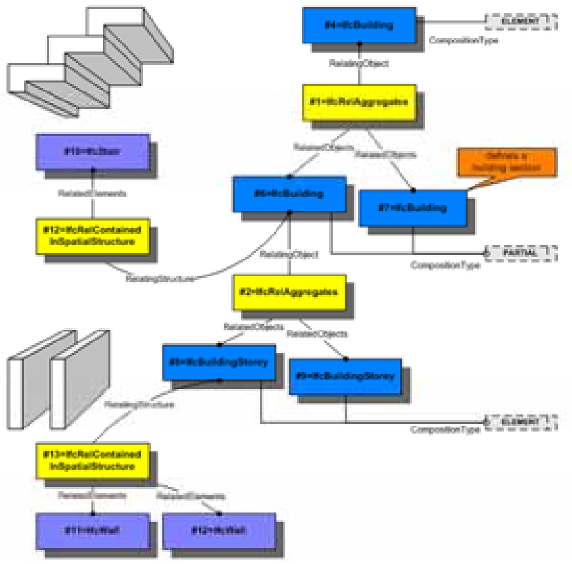
IfcRelSpacceBoundary: defines the connection between an area and the circumscribing physical objects

IfcRelConnectsElements: defines the physical connection (as 1:1 relationship) between objects (e.g. Walls)

IfcRelConnectsPorts: defines the logical connection between building service elements and connection points

Object relations: Connection between Structures

Example: Connection of one stairs and two walls to different Hierarchic levels of a building



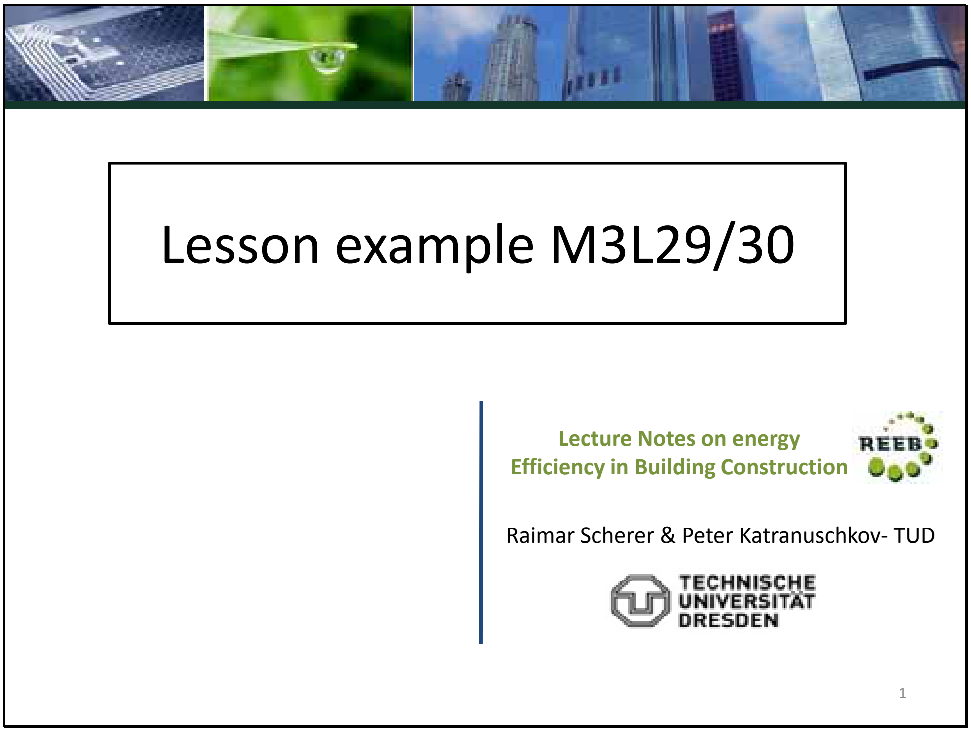
6.4 LECTURE M3L29/30

Short Outline

M3.L29/30 Relevant IFC elements for EE in building design and life-cycle performance

- The concept of shared elements
- Relevant shared building elements – description, relationships, EE related features
- Relevant shared building services elements – description, relationships, EE related features
- Relevant shared management and facilities elements
- Overview of principal modelling approaches for enhancement of existing elements with EE related features

Powerpoint Outline



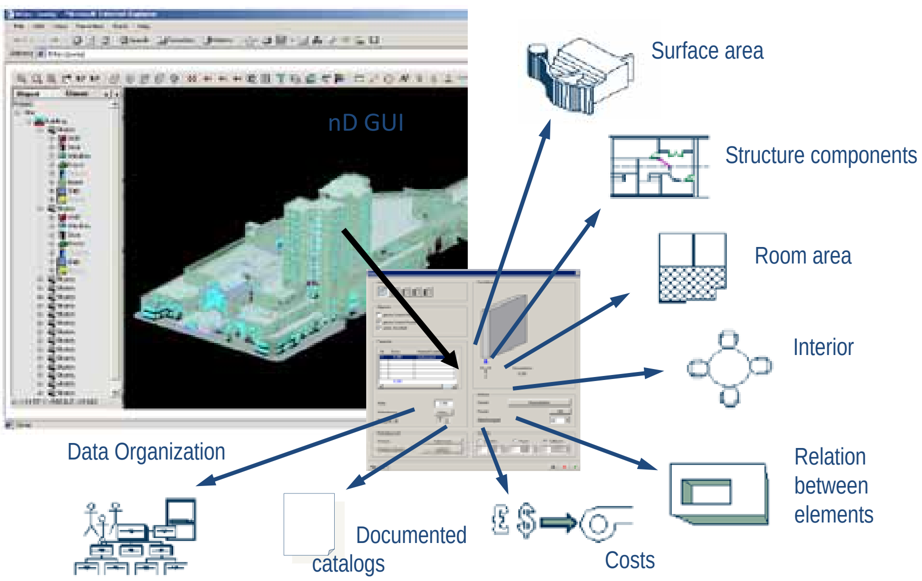
Content

➢Relevant IFC elements for EE in building design and life-cycle performance

•The concept of shared elements
•Relevant shared building elements – description, relationships, EE related features
•Relevant shared building services elements – description, relationships, EE related features
•Relevant shared management and facilities elements
•Overview of principal modelling approaches for enhancement of existing elements with EE related features

2

BIM-basic work



3

Data models

Definitions

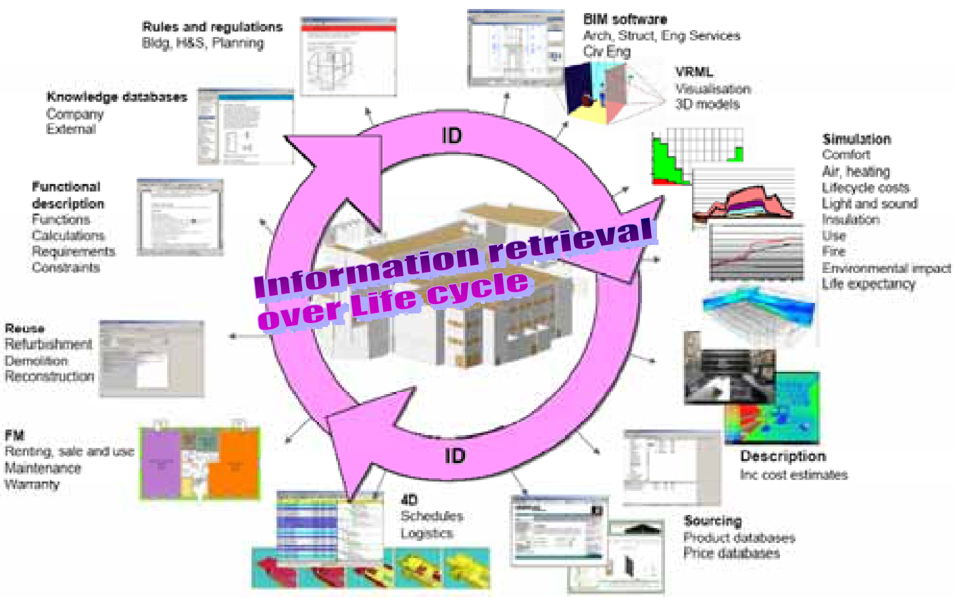
- *Meta-Datamodel* –
  describes the constructed conceptual principle such as object, relation, attribute, rules, transmission, etc
- *Datamodel*–
  describes the conceptual pattern for a product class (building, bridges…)
- *Productmodel* –
  describes a concrete product (and/ or building)

Types

- Standardised kernel models → IFC Projectmodel
- Domain models
- Proprietary of models
- Model- view
- Ontology models: Metainformation of the models

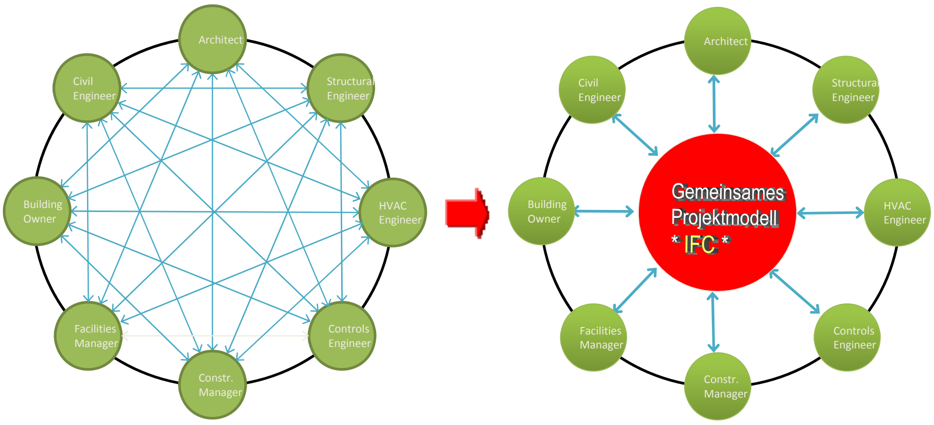
4

The Vision of Interoperability



5

Vision of IAI: Common seed project data model



n:m Data integration

1:n Data integration with common data model

6

Problem of the Model consistency

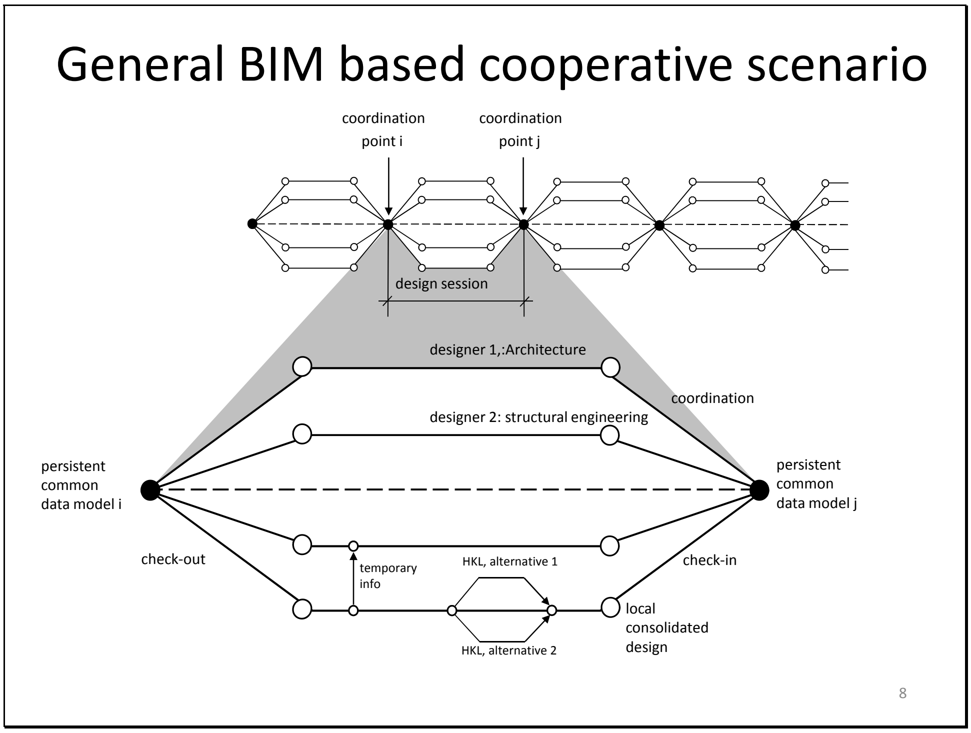
Problem:
- Long Transactions
  - relativ long Offline-Treatment of the planning data
  - Parallel treatment by several parties involved (data locks not possible)
  - Complex, high-grade interdependent data
  - Use of different specialized models (view)
  - Data loss by incomplete data manipulations

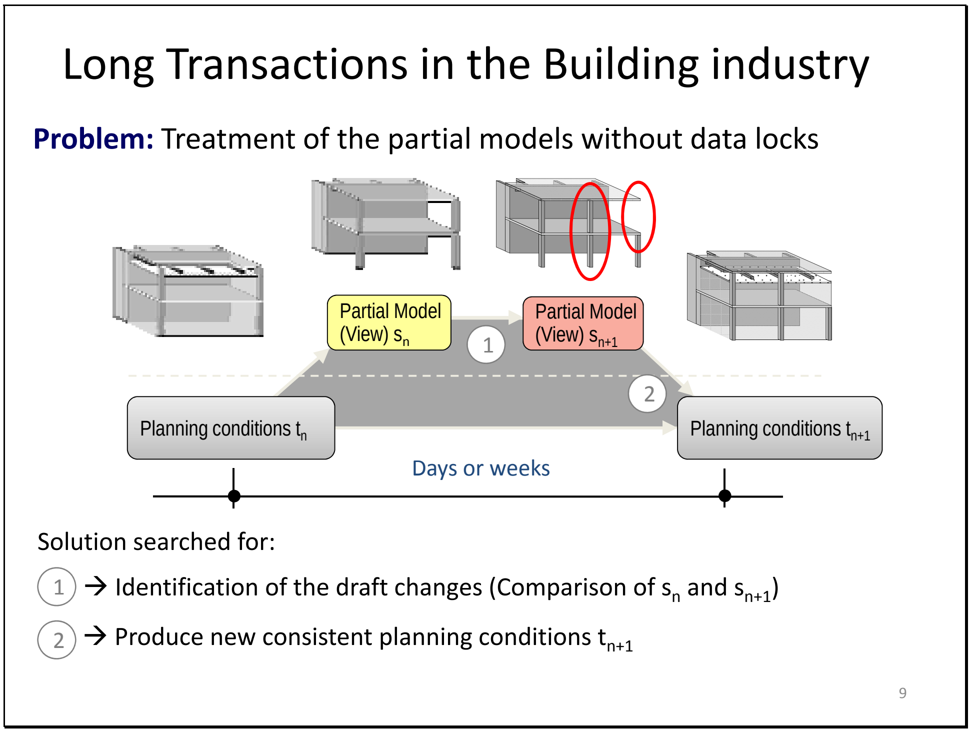
Normal data base systems are not applicable:

- Long transactions are not manageable

-Transactions are not pre-defined e.g. Draft activities are not formalised or only weakly formalised . The treatment takes place much more ad hoc depending upon needs.

7


General BIM based cooperative scenario
coordination point i
coordination point j
design session
designer 1,:Architecture
coordination
designer 2: structural engineering
persistent common data model i
persistent common data model j
check-out
check-in
temporary info
HKL, alternative 1
HKL, alternative 2
local consolidated design
8


Long Transactions in the Building industry
Problem: Treatment of the partial models without data locks
Partial Model (View) s_n
Partial Model (View) s_{n+1}
1
2
Planning conditions t_n
Planning conditions t_{n+1}
Days or weeks
Solution searched for:
1 → Identification of the draft changes (Comparison of s_n and s_{n+1})
2 → Produce new consistent planning conditions t_{n+1}
9

Methods of the product data management

PDM-methods for the general cooperative scenario

1) Extraction of the model view (filters)
2) *Model-Transformation*
3) *Consistency control (knowledge-based)*
4) *Model-Comparison*
5) *Model-Reintegration*
6) *Model-Unification*

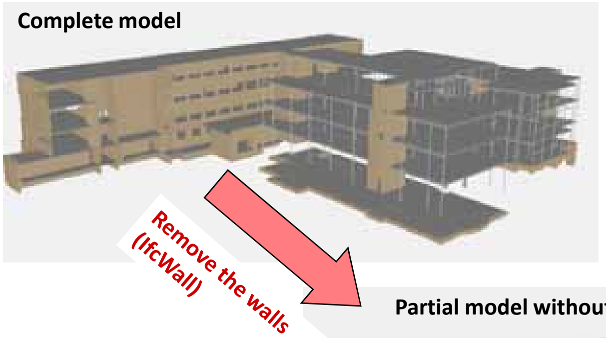
10

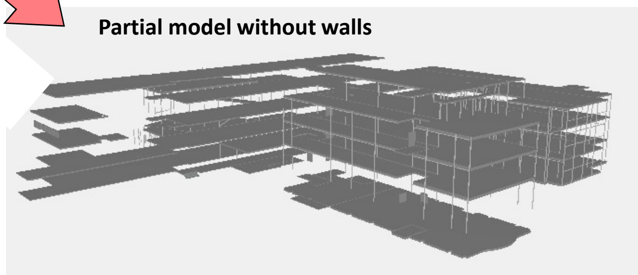
Problem

Generate a data view through filtering

11

Use of filter methods to IFC files

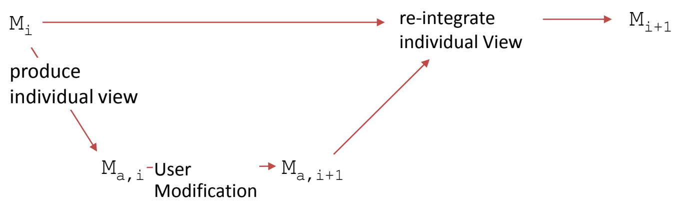




Note:
IFC is the Data structure of the building industry

12

1thTask in the information process

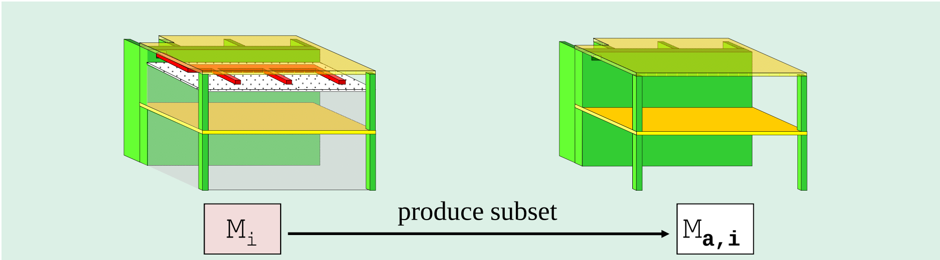


1) Avoid information loss

⇒ user-specific individual view, i.e. adaptable view

13

Extraction of the model view (filters)

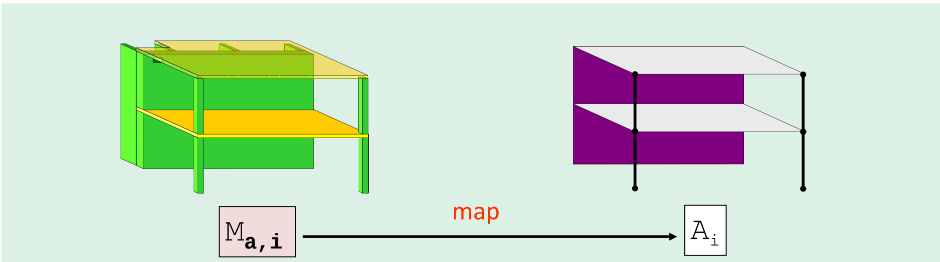


M_i produce subset

$M_{a,i}$

14

Model transformation



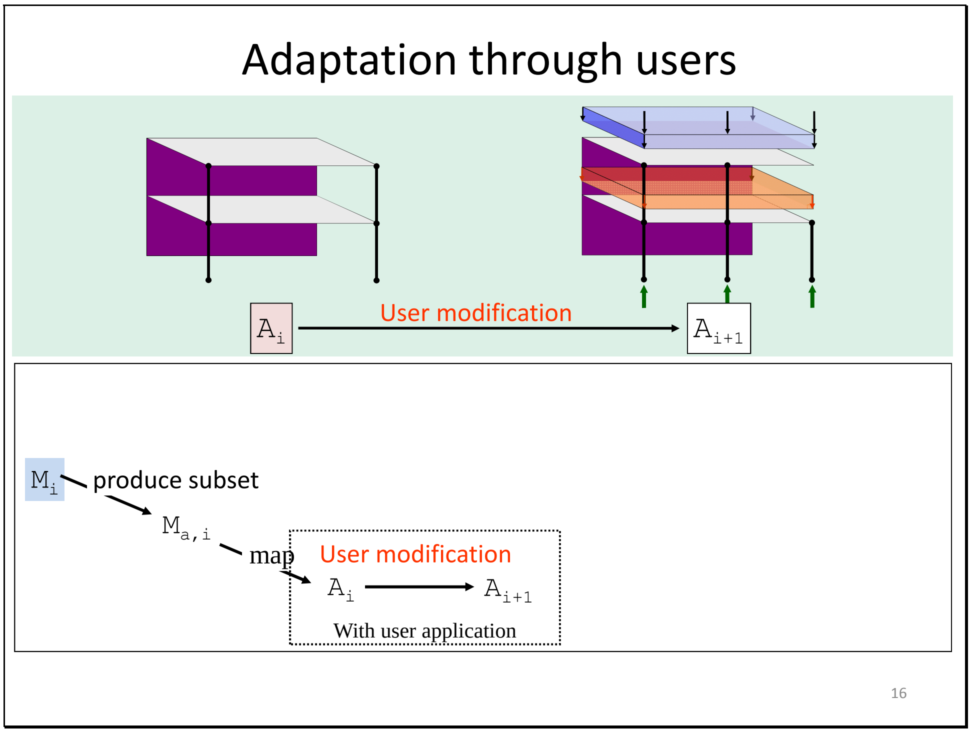
Transformation from the common to proprietary Model

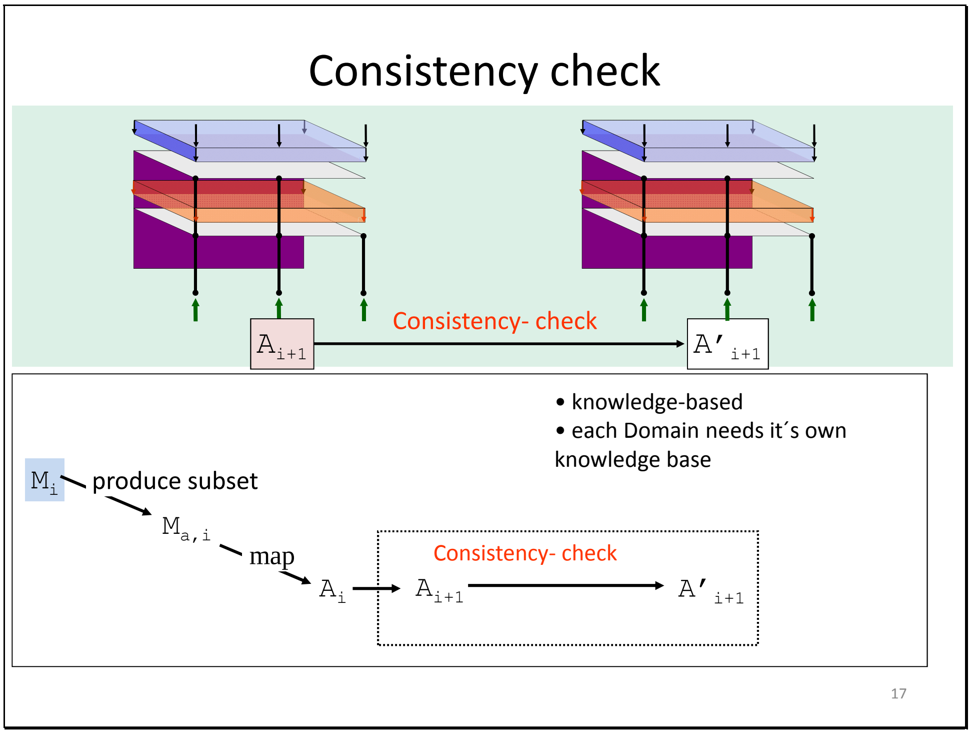
M_i produce subset

$M_{a,i}$ map =Interface of the Program

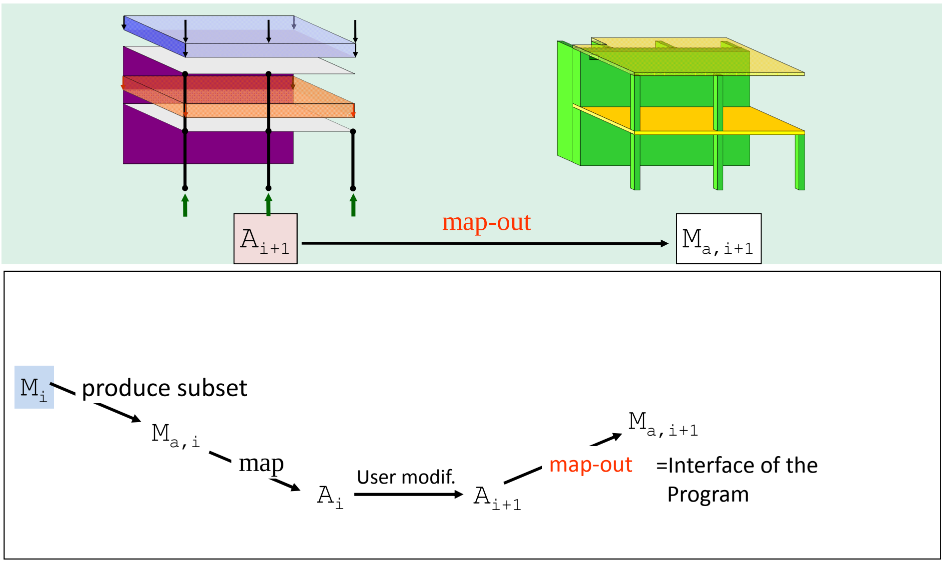
A_i

15


Adaptation through users
A
i
User modification
A
i+1
M
i
produce subset
M
a,i
map
User modification
A
i
A
i+1
With user application
16

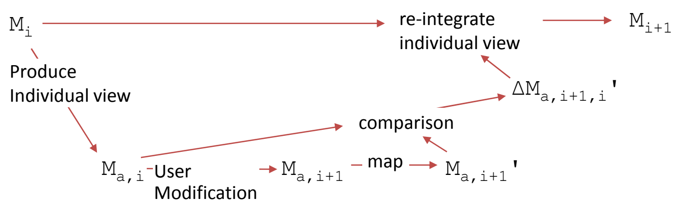

Consistency check
A
i+1
Consistency- check
A'
i+1
• knowledge-based
• each Domain needs it´s own knowledge base
M
i
produce subset
M
a,i
map
A
i
A
i+1
Consistency- check
A'
i+1
17

Inverse Model Transformation



18

2nd Task in the Information process

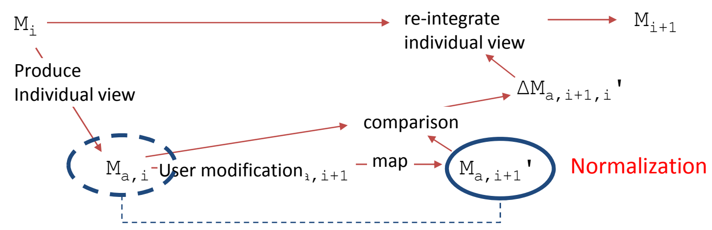


1) Avoid information loss
   ⇒ user-specific individual view, i.e. adaptable view

2) Recognize inconsistencies
   ⇒ pursue changes of draft, i.e. capture draft changes

19

2nd Task in the Information process

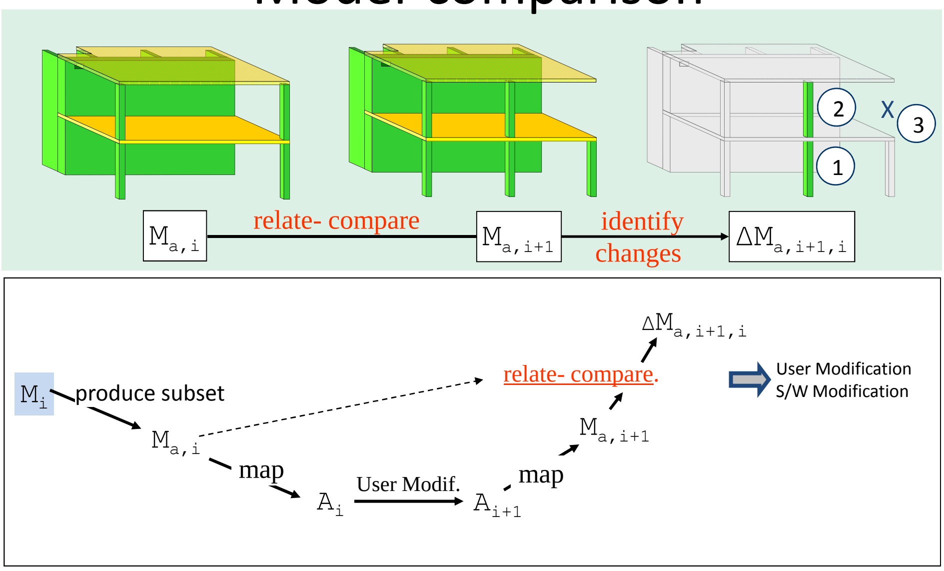


Normalization must minimize and/or identify the occurrence of unintentional, apparent changes. Apparent changes develop through:

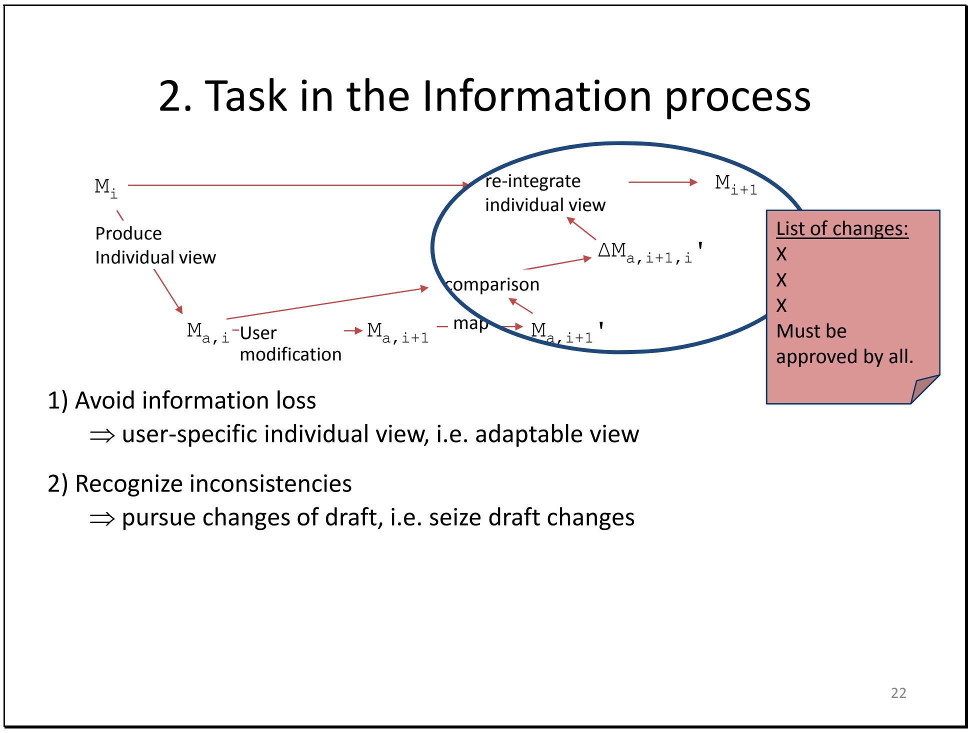
- Different quality of the program interfaces
- Representation and modeling variety in the IFC model
- Different planning parameters (e.g. kart. - Cylinder coord., different coord.-reference systems, units m - mm)

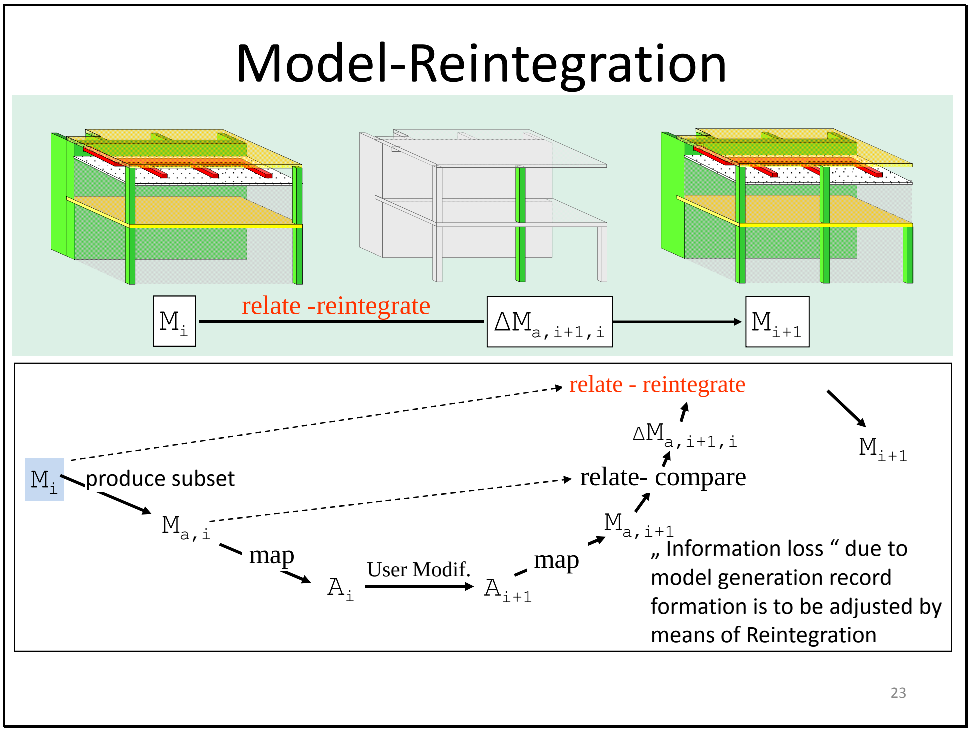
20

Model-comparison

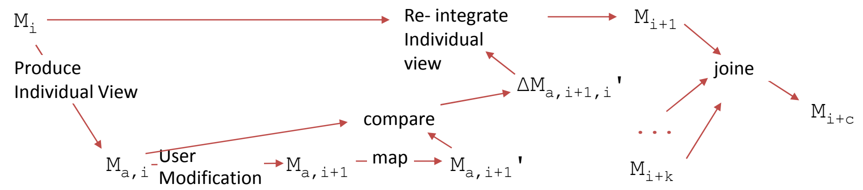


21


2. Task in the Information process
M_i
Produce
Individual view
M_a,i
User
modification
M_a,i+1
map
M_a,i+1'
comparison
ΔM_a,i+1,i'
re-integrate
individual view
M_i+1
List of changes:
X
X
X
Must be
approved by all.
1) Avoid information loss
⇒ user-specific individual view, i.e. adaptable view
2) Recognize inconsistencies
⇒ pursue changes of draft, i.e. seize draft changes
22


Model-Reintegration
M_i
relate -reintegrate
ΔM_a,i+1,i
M_i+1
relate - reintegrate
ΔM_a,i+1,i
M_i+1
M_i
produce subset
relate- compare
M_a,i
M_a,i+1
map
A_i
User Modif.
A_i+1
map
„Information loss " due to
model generation record
formation is to be adjusted by
means of Reintegration
23

3rd Task in the Information process



1) Avoid information loss
   ⇒ user-specific individual view, i.e. adaptable view

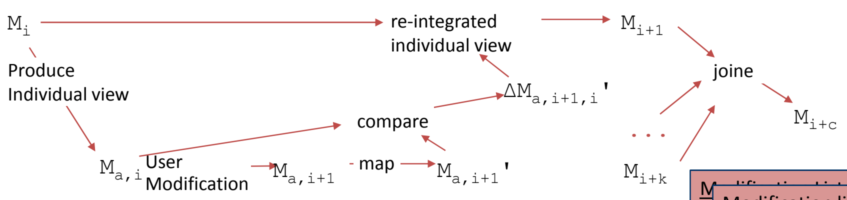
2) Recognize inconsistencies
   ⇒ pursue changes of draft, i.e. capture draft changes

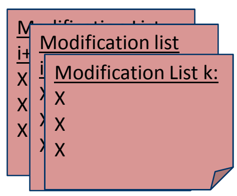
3) Synchronize particular, overlapping transactions, i.e. bring together all the parallel generated design changes

24

3rd Task in the Information process

All modification lists have to be compared mutually





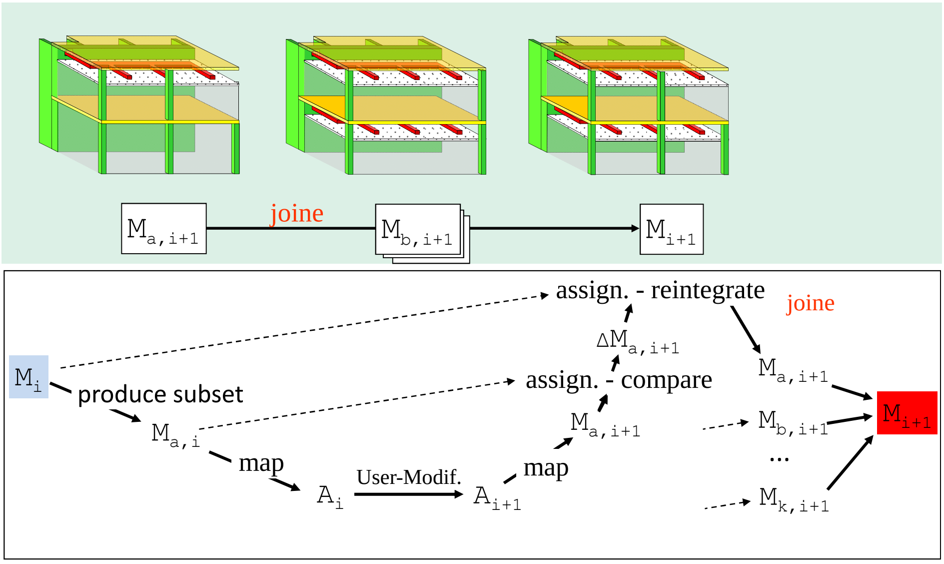
1) Avoid information loss
   ⇒ user-specific individual view, i.e. adaptable view

2) Recognize inconsistencies
   ⇒ pursue changes of draft, i.e. capture draft changes

3) Synchronize particular, overlapping transactions, i.e. bring together all the parallel generated design changes

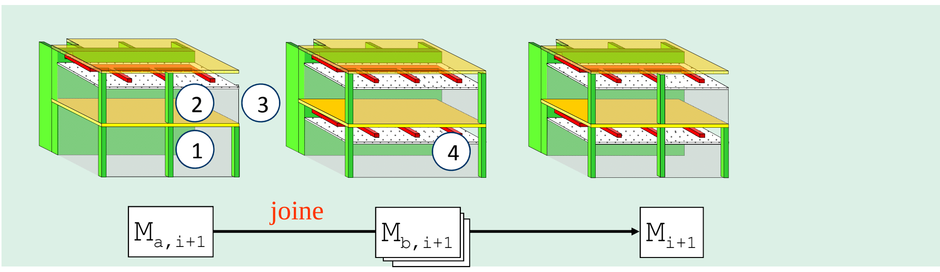
25

Model-Unification



26

Model-Unification



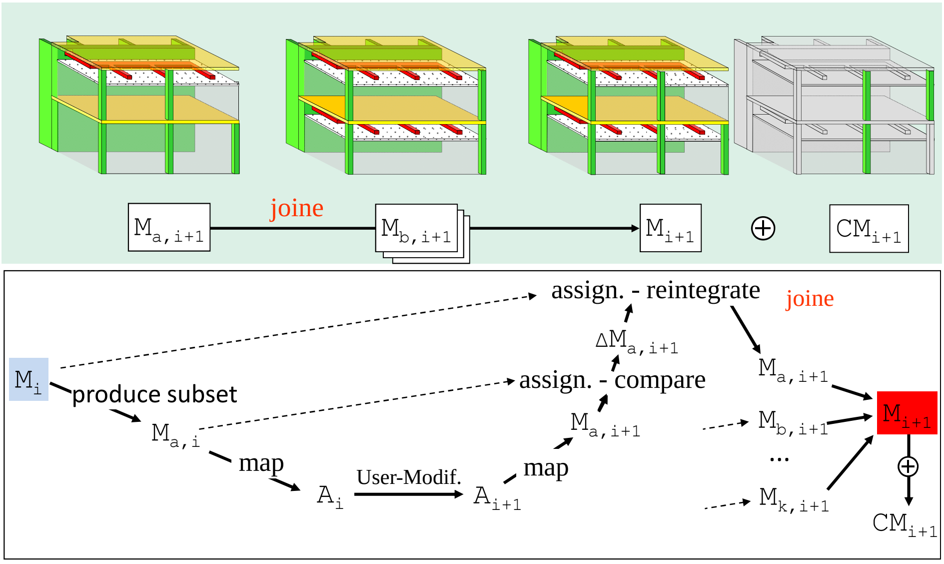
Conjoined planning modification :

- for more efficiency, if there are (planning)changes with technical conflict , they must be adjusted
- Without changes, alignment with all elements of the planning conditions are necessary (frequent > 1 Mio.)

→ 3 : 1 Mio. + 1 : 1 Mio. ➔ 4 Mio. Vgle. vs. ≤ 6 Vgle.

27

Model-Unification



28

Model- view

Problem:
Which walls are needed and when?

1) Which walls form an area?
   necessarily for:
   a) Cost calculation (Structural work-, development quantities)
   b) Energy computation
2) Which walls are a carrying element
   For wing unit computation the entire wall is needed d.h. individual walls are to be combined to a wall screen

→ Different perspectives (views) in model data , e.g.: due to more differently working on systems, system integration must be considered.

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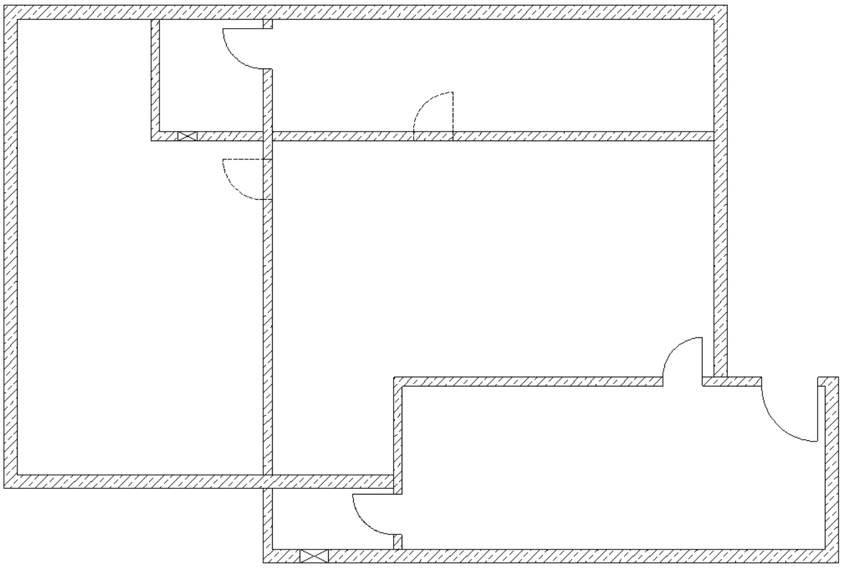
Area and wall allocation



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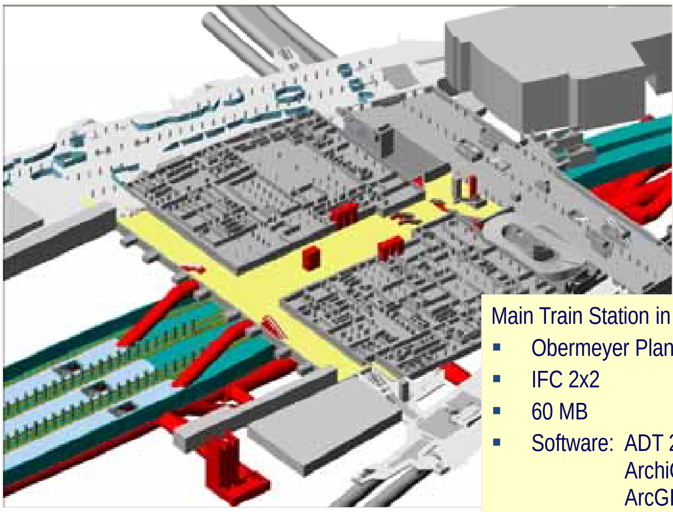
Example for Model based Design

Intergration of the Transrapid in the main station of München.

Background material for the bit of the design task

31

Application use of IFC

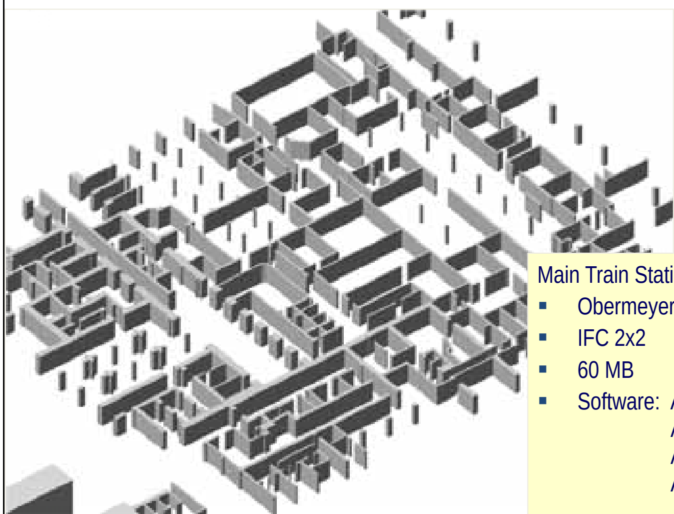


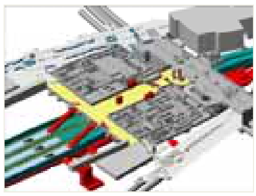
Main Train Station in München 2003

- Obermeyer Planen + Beraten, München
- IFC 2x2
- 60 MB
- Software: ADT 2004 (Autodesk)
  ArchiCAD 8 (Graphisoft)
  ArcGIS (ESRI)
  ALLPLAN (Nemetschek)

32

Application use of IFC





Main Train Station Walls , gray asset

Main Train Station München 2003

- Obermeyer Planen + Beraten, München
- IFC 2x2
- 60 MB
- Software: ADT 2004 (Autodesk)
  ArchiCAD 8 (Graphisoft)
  ArcGIS (ESRI)
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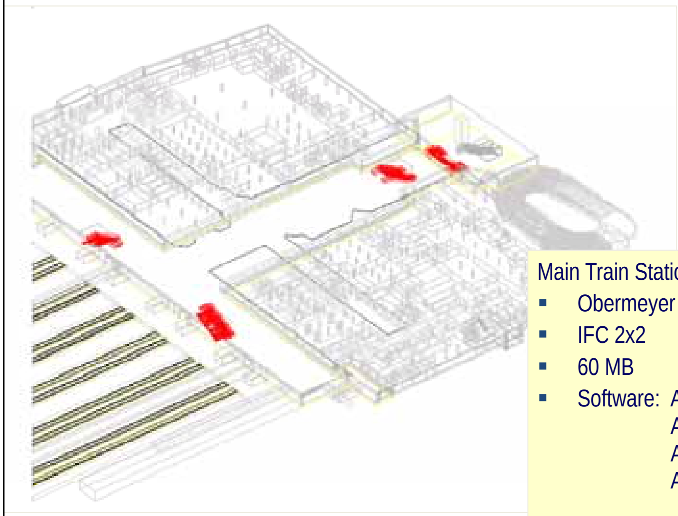
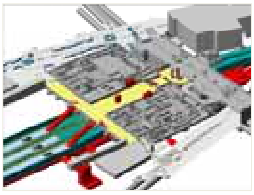
33

Application use of IFC





Main Train Station München 2003

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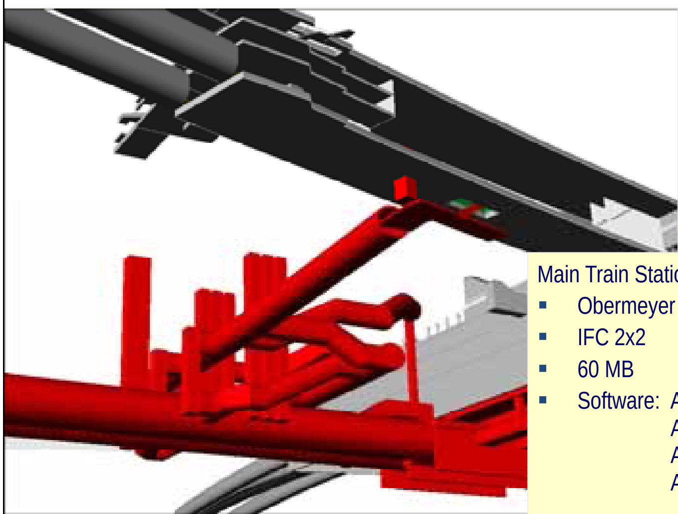
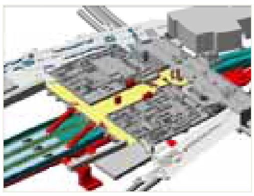
  ArchiCAD 8 (Graphisoft)
  ArcGIS (ESRI)
  ALLPLAN (Nemetschek)

Wired model Main Train Station

34

Application use of IFC





Main Train Station München 2003

- Obermeyer Planen + Beraten, München
- IFC 2x2
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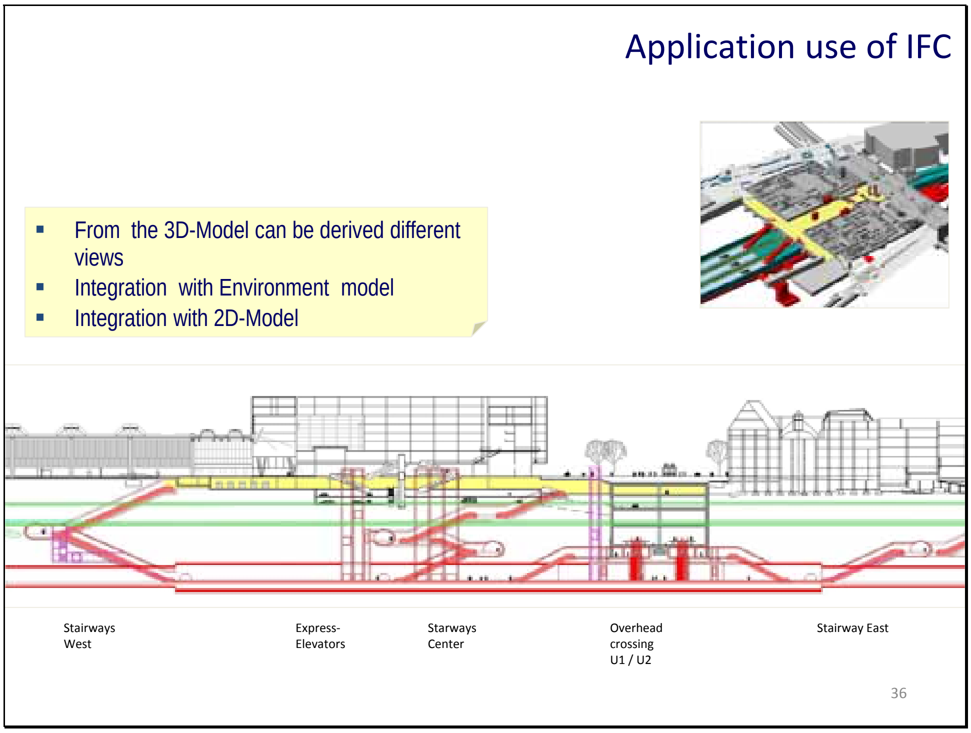
  ArcGIS (ESRI)
  ALLPLAN (Nemetschek)

Overhead crossing U4/U5

35



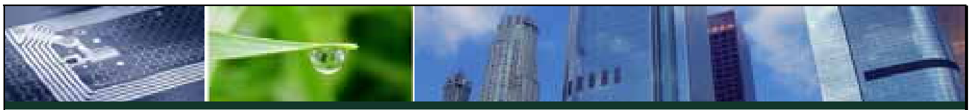
6.5 LECTURE M3L31

Short Outline

M3.L31 EE related BIM visualisation

- Visualisation methods and principles
- Visual model evaluation
- Model consistency checking
- Incorporating engineering rules with the model

Powerpoint Outline



Lesson example M3L31

Lecture Notes on energy Efficiency in Building Construction

Karsten Menzel- UCC

TECHNISCHE UNIVERSITÄT DRESDEN

1

Sources

- Information Technology in Architecture, Engineering and Construction
Dynamic Building Modelling Lecture 1 and Lecture 2 – ICT Euromaster Lectures
Autor: Ana Kosiel, Karsten Menzel

- Remark
This lecture is very practical oriented and therfore software product based in and to provide the student a very hand off lecture
The selected software product and software companies are not exclusive, but an arbitrary selection from construction software market, how this lecture mainly give a snapshot of the state of the sofware market

2

Content

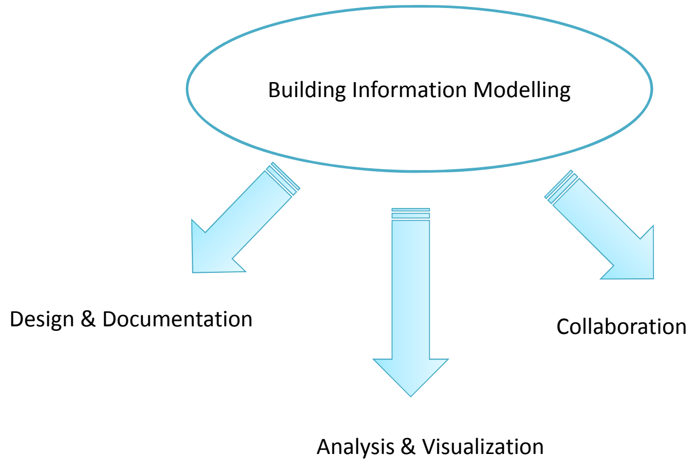
- BIM tools
- Open software tools, free software tools and license tools – pros, cons, challenges
- Fundamental ICT tools for BIM support (model parsers, model servers, model viewers, model checkers, general-purpose utilities, import/export utilities, embedded utilities and plug-ins)
- Specialised BIM tools for engineering design
- Interoperability of EE related design tools and BIM tools – overview, current state and development trends

3

Building Information Model
BIM models and manages graphics and information that allows the automatic generation of drawings and reports, design analysis, schedule simulation, facilities management, and more – ultimately enabling the building team to make better informed decisions.

BIM:
▪**Building - the entire lifecycle of the building is considered (design/build/operations)**
▪**Information - all information about the building and its lifecycle is included**
▪**Modelling - defining and simulating the building, its delivery, and operation using integrated tools**
BIM tools help to keep information co-ordinated, up-to-date and accessible in an integrated environment.

4



5

Design and Documentation

Demonstrated through the product part folie of Autodesk

➢**Autodesk Revit** group for improved multidiscipline coordination of architects' design vision, structural analysis and mechanical, electrical and plumbing design

- **Revit Architecture**
- **Revit Structure**
- **Revit MEP**

➢**AutoCAD group**

- **AutoCAD Civil 3D - the BIM solution for civil engineering, helps project** teams explore transportation, land development, and environmental projects digitally before they are built.
- **AutoCAD – for use with other BIM applications for drafting,** documentation, and 3D design
- **AutoCAD LT -** 2D drafting and detailing product

6

Analysis and Visualization

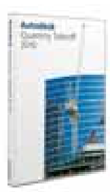
Autodesk Ecotect Analysis
• sustainable design analysis tool, providing a wide range of simulation and analysis functionality through desktop and web-service platforms
Autodesk Robot Structural Analysis Professional
• collaborative application that extends BIM for structural engineering with analysis capabilities for buildings, bridges, and civil and specialty structures.
Autodesk 3ds Max Design
• enables architects, designers, and visualization specialists to explore, evaluate, and communicate their ideas.
• delivers powerful lighting analysis technology, advanced rendering capabilities, and digital continuity with the AutoCAD family of products and the Revit® platform.

7

Analysis and Visualization

➢ **Autodesk Navisworks**
• advanced interference analysis and project simulation.
• combines and reviews 3D design data created in BIM applications (e.g. Revit-based products) with other design models regardless of file size or format

➢**Autodesk Quantity Takeoff**
• enables faster, easier, and more accurate cost estimating
• creates synchronized, comprehensive project views that combine important information from BIM tools such as Revit Architecture, Revit Structure, and Revit MEP together with geometry, images, and data from other tools.



8

Analysis and Visualization

➢**Autodesk Buzzsaw**
• Helps to centralize building design and construction-related documents, simplify communication, and streamline collaboration so projects can be successfully executed based on timely decision and accurate information.
• Provides secure, on-demand access to designs, documents, and information and automatically notifies project team members of changes and updates
• Provides project status, schedule, and budget information
➢**Autodesk Constructware**
• Provides an on-demand environment for construction project management and collaboration — connecting people, information, and processes so that projects can run smoothly to completion and beyond.
• Information can be accessed via a web browser

9

Dynamic simulation software

The most common software packages:
▪Virtual Environment from IES
▪ECOTECT
▪Bentley HEVACOMP
▪EnergyPlus

10

▪Virtual Environment from IES

IES VE offers a variety of ways to analyze design oriented building in a convincing environment. It uses a three dimensional (3D) geometric explanation of the building. It is considered to be a dynamic simulation software tool that is based on the principles of the mathematical models of building energy transfer procedures.
One of the principal features of IES is the possibility of importing the REVIT model.

IES can be used to perform **day lighting analysis** and available if the requirements of LEED EQ c8.1 Daylight and view will be met.
It can also perform a computational **fluid dynamic analysis** and predict the percentage of occupants that would be dissatisfied with thermal comfort in the proposed building.
It offers a **complete evaluation of system and building design** and can also be used to provide yearly building energy simulation models.

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▪Virtual Environment from IES

IES - Integrated suite of applications linked by a Common User Interface (CUI) and a single Integrated Data Model (IDM)

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▪Virtual Environment from IES

IES - ModelIT

- ➢creates 3d building geometry
- ➢building models can be generated from scratch
- ➢*dxf files can be attached*
- ➢direct connectivity with other CAD/BIM systems:
  - Google SketchUp plug-in
  - Revit plug-in
  - ArchiCAD plug-in
- ➢allows importing *gbXML and*
- ➢*GEM (geometry) files*

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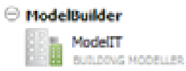
▪Virtual Environment from IES



IES - ModelIT

➢***DXF – Drawing Exchange Format***
CAD data file format for enabling data interoperability between AutoCAD and other programmes.

➢***gbXML – Green Building XML***
Green Building XML facilitate the transfer of building information stored in CAD building information models (e.g. Autodesk Revit, ECOTECT, Bentley Systems) to variety of engineering analysis tools

➢***XML – Extensible Markup Language***
Type of computer language that allows software programs to communicate information with little to no human interaction. It has textual data format.

➢***GEM – Graphical Environment Manager***
Vector image format. GEM metafile stores a sequence of GEM drawing instructions.

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▪Virtual Environment from IES

IES – APLocate & Weather data files

➢APLocate is the weather and site location editor for the programs CIBSE Heat Loss & Heat Gains (ApacheCalc), ASHRAE Heat Balance Method (ApacheLoads), ApacheSim, SunCast and Radiance

➢The design weather data is used to determine peak loads, and the simulation weather data is used for the full year simulation.

➢CIBSE Weather Files for VE Compliance - there is a total of 14 Weather Data Sets available.

➢Annual Climate files supported: .fwt (IES file format) and .epw (US Department of Energy file format)

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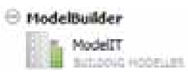
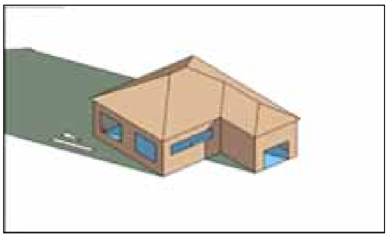
▪Virtual Environment from IES



IES – SunCast

Detailed sunpath analysis based on specified location

▪allow optimizing building orientation
▪allow shadow analysis
▪essential for proper solar systems design – solar collectors & PV modules
▪provide assistance with façade design
▪required for dynamic thermal analysis (heat gains and energy consumption)
▪asses impact of solar control devices
▪required for daylight analysis
▪allow sunpath images and video creation



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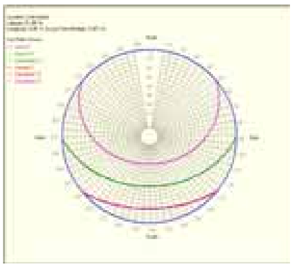
▪Virtual Environment from IES

INTEGRATED ENVIRONMENTAL SOLUTIONS

IES – Sunpath analysis

▪SunPath Diagram

Solar
Suncast
SOLAR SHADING ANALYSIS



17

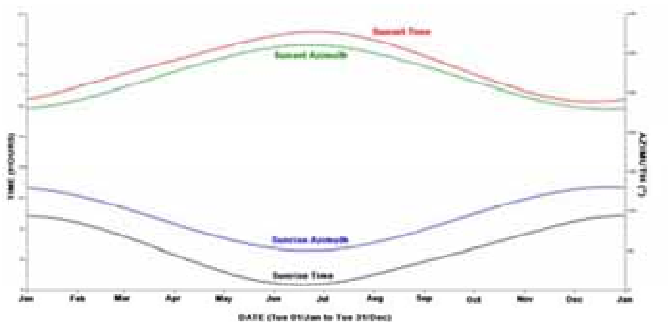
▪Virtual Environment from IES

INTEGRATED ENVIRONMENTAL SOLUTIONS

IES – Sunpath analysis

▪Sunrise/Sunset Times & Azimuths

Solar
Suncast
SOLAR SHADING ANALYSIS



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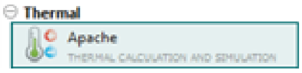
▪Virtual Environment from IES

IES – ApacheSim: Dynamic thermal analysis

➢Core of the IES <VE> suite for thermal analysis, which takes into account:
- solar shading and penetration (SunCast)
- HVAC systems and control (ApacheHVAC)
- natural ventilation and mixed mode systems (MacroFlo)

➢ApacheSim is based on first-principles models of heat transfer processes and is driven by real weather data.

➢ Application Areas:
- Thermal performance analysis
- Building fabric design
- Occupant comfort analysis
- Natural ventilation studies
- Façade analysis
- Energy consumption prediction
- Plant design and sizing
- Mixed-mode design
- Building Regulations
- Carbon emissions
- CFD boundary conditions

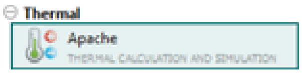


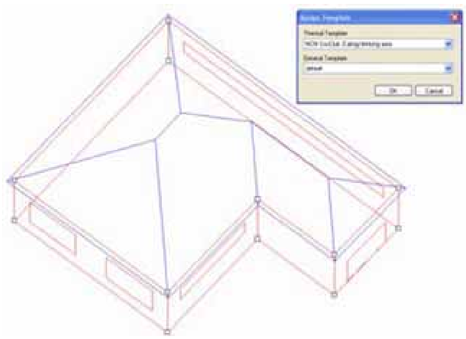
19

▪Virtual Environment from IES

IES – ApacheSim

▪Thermal Templates & Room data





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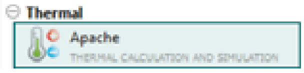
▪Virtual Environment from IES

IES – ApacheSim



▪Simulation Results:
- heating and cooling report
- results in tables and graphs
- min and max values & times
- range tests
- monthly totals

21

▪Virtual Environment from IES

IES – ApacheCalc: CIBSE loads calculations

➢ ApacheCalc performs heat loss and heat gain design calculations, using procedures laid down by the Chartered Institute of Building Services Engineers (CIBSE), to determine building heating and cooling loads.
➢ApacheCalc is used internationally where the CIBSE procedures are recognised.
➢ApacheCalc Methodology:
It uses the Integrated Data Model (IDM) generated within the IES <VE> with specified thermal properties and undertakes two principal calculations:

- Steady state heat loss calculations to predict the heating requirements for the building
- A heat gain calculation, based on the Admittance technique, to predict the building cooling requirements. The heat gain calculations can be performed for a selected design day of the week, and for a range of design months.

22

▪Virtual Environment from IES

INTEGRATED ENVIRONMENTAL SOLUTIONS

IES – HVAC application

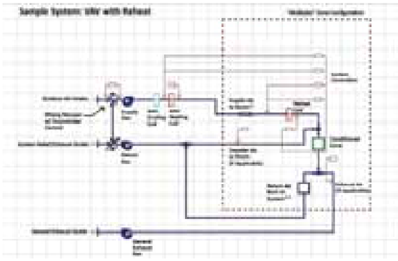
➢ApacheHVAC enables you to simulate heating, ventilation and air-conditioning systems. It uses a flexible component-based approach which enables you to assemble
systems on-screen as designed.

➢ApacheHVAC covers all common system types including VAV, CAV, fan-coil, VVT, displacement ventilation, hollow-core slab systems and under-floor heating.

➢ApacheHVAC is dynamically integrated with ApacheSim

➢The principal application areas for ApacheHVAC are:

- HVAC system design
- Component sizing
- HVAC control design
- Mixed mode system design
- Energy consumption prediction
- Carbon emissions
- Building Regulations
- CFD boundary conditions



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▪Virtual Environment from IES

INTEGRATED ENVIRONMENTAL SOLUTIONS

IES – HVAC application

➢ApacheHVAC Methodology:

• ApacheHVAC enables you to define HVAC plant components and controls schematically, with easy-to-use graphical tools for placing, moving, copying and deleting.

• ApacheHVAC components:

❖Heating and cooling coils
❖Fans and dampers
❖Mixing boxes and economisers
❖Steam and spray humidifiers
❖ Heat recovery
❖Duct heat loss
❖Room conditions
❖Radiators and chilled ceilings

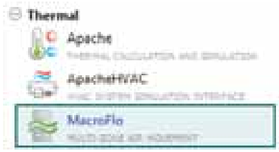
❖Direct-acting heaters and chilled beams
❖Controllers sensing temperature, humidity, enthalpy, flow rate or solar radiation
❖Controllers sensing the difference between
❖two variables
❖ On-off and proportional control
❖Cascaded control logic
❖Boilers, chillers and heat pumps, including
❖ancillary pump and fan consumptions

24

▪Virtual Environment from IES

IES – MacroFlo

•MacroFlo is a program for analysing infiltration and natural ventilation in buildings.
• It uses a zonal airflow model to calculate bulk air movement in and through the building, driven by wind and buoyancy induced pressures.
•The preparation of MacroFlo input data in the MacroFlo view consists of setting the air flow characteristics of openings in the building (windows, doors and holes).

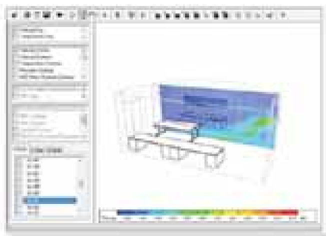


25

▪Virtual Environment from IES

IES – CFD simulations

<u>Computational Fluid Dynamics</u>
▪Detail simulation of fluid flow and heat transfer process within and around building spaces under specified boundary conditions (climate, internal energy sources, HVAC systems)
▪Mashing/volumetric grid is required. The finer the finite volume grid, the more accurate results but the longer the simulation will take.
▪CFD involves the following equations:
▪Momentum □ Energy
▪Mass continuity □ Turbulence
▪Scalar/Mass Fraction



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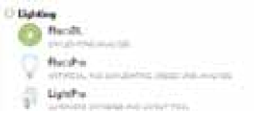
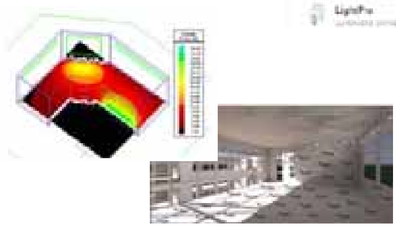
▪Virtual Environment from IES

INTEGRATED ENVIRONMENTAL SOLUTIONS

IES – Lighting design and analysis

Daylight
▪Artificial lighting
▪Radiance





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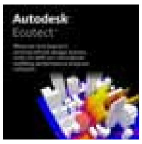
▪ECOTECT



Ecotect is considered to be the whole environmental design software and it features:

- ➢cost analysis
- ➢lighting
- ➢thermal
- ➢solar
- ➢interfaces for 3D modelling
- ➢DXF and 3DS files

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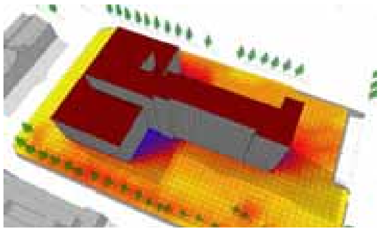
▪**ECOTECT**

Visual Impact helps you to analyze site projection angles, assess obstructions, calculate vertical sky components for any point or surface, and visualize the no-sky line in any space.

Solar Radiation analysis enables you to visualize incident solar radiation on windows and surfaces, showing differential incident solar radiation calculated over any period.



29

▪**HEVACOMP – Bentley Systems**

- ➢ building energy design, simulation and energy performance certification (U.K. Part L2, Australia section J, U.S. LEED program)
- ➢ Irish Part L compliance – Pro/Quick EP Cert or Design Database
- ➢ based on EnergyPlus analysis engine
- ➢ consists of 3 packages:
  - •Mechanical and Energy Modelling
  - •Electrical suite
  - •Part L and Energy Assessors

30

▪**HEVACOMP – Bentley Systems**

Hevacomp Mechanical and Energy Modelling

Includes:

•**Mechanical Designer V8*i* – *design*** software suite for quick Energy Performance Certificates (not ROI)

•**Simulator V8*i* – *building energy analysis***
using dynamic simulation with EnergyPlus that can quickly produce Energy Performance Certificates

•**Mechanical System Builder V8*i* – *CAD***
tools combined with Hevacomp Mechanical Designer's comprehensive load, pipe, and duct calculations

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▪**HEVACOMP – Bentley Systems**

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▪**HEVACOMP – Bentley Systems**

Hevacomp Mechanical and Energy Modelling

Mechanical Designer V8*i* – *design software suite*
▪simple model building application with DXF files and 3D visualization tools
▪work is carried out on one floor at a time with services connection points between floors.
▪building load and energy calculations
▪simple system layouts
▪system sizing (pipes, ducts, fans and pumps sizing and selection)
▪system types: heating, chilled water, ductwork, gas, hot water and cold water services
▪system isometric view

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▪**HEVACOMP – Bentley Systems**

Hevacomp Mechanical and Energy Modelling

➢**Mechanical System Builder V8*i* – *CAD tools combined with Hevacomp Mechanical***
Designer's comprehensive load, pipe, and duct calculations
▪Full functionality of the Mechanical Designer tool
▪Calculates air volumes for set-up rooms and allow selection and determining the number and layout of diffusers
▪Acoustic calculations available
▪Allow for automatic sizing & positioning of radiators
▪Complete cold and hot water system analysis
▪Systems are automatically recalculated and resized, when room data changes
▪Manufacturers' database for diffusers, radiators and heat emitters is available

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▪**HEVACOMP – Bentley Systems**

Hevacomp Mechanical and Energy Modelling
➢ **Simulator V8*i* –** building energy analysis using dynamic simulation with EnergyPlus
▪conform to ASHRAE standards 90.1
▪extensive weather databases
▪steady state calculations and complex simulations
▪LEED and UK Part L compliance
▪overheating calculations
▪part load efficiency curves for all plant equipment
▪passive design (controlled windows, natural and mechanical ventilation)
▪renewables (solar, wind and biomass)
▪gbXML friendly

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▪**EnergyPlus**

➢A stand-alone simulation program without a 'user friendly' graphical interface. The EnergyPlus reads input and writes output as text files.
➢Tools for Creating EnergyPlus Input Files or Running Parametric Simulations Software tools that were specifically designed to create EnergyPlus input files or run parametric simulations include Easy EnergyPlus, ECOTECT, EnergyPlugged, EP Geo, EP Sys, EP-Quick, IFCtoIDF, ESP-r, Green Building Studio, and jEPlus.
➢predicts precise comfort and temperature
➢calculates the cooling, heating and electrical response of a system
➢widely used in research laboratories, universities and engineering firms

Remark: Energy plus is public domain software, due to US law, because financied by US tax money

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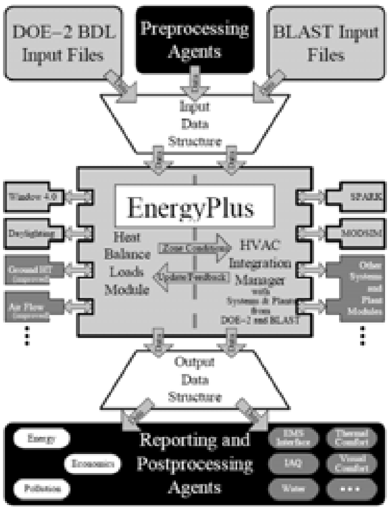
▪EnergyPlus

consist of 2 modules:

▪building simulation module
▪mass and heat balance module



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▪EnergyPlus

Main Features
➢simulation time steps of less than an hour
➢modular systems and plant integrated with:
•heat balance-based zone simulation
• multizone air flow
• thermal comfort
•HVAC
•water use
•natural ventilation
•photovoltaic systems
•construction cost estimation

• Evaporative Fluid Cooler
• Zone water-to-air heat pump (ZoneHVAC:WaterToAirHeatPump)
• Zone air dehumidifier (ZoneHVAC:Dehumidifier:DX)
• Plant Pressure Drop can be calculated
• Improved control of heat recovery in outside air systems during economizer operation

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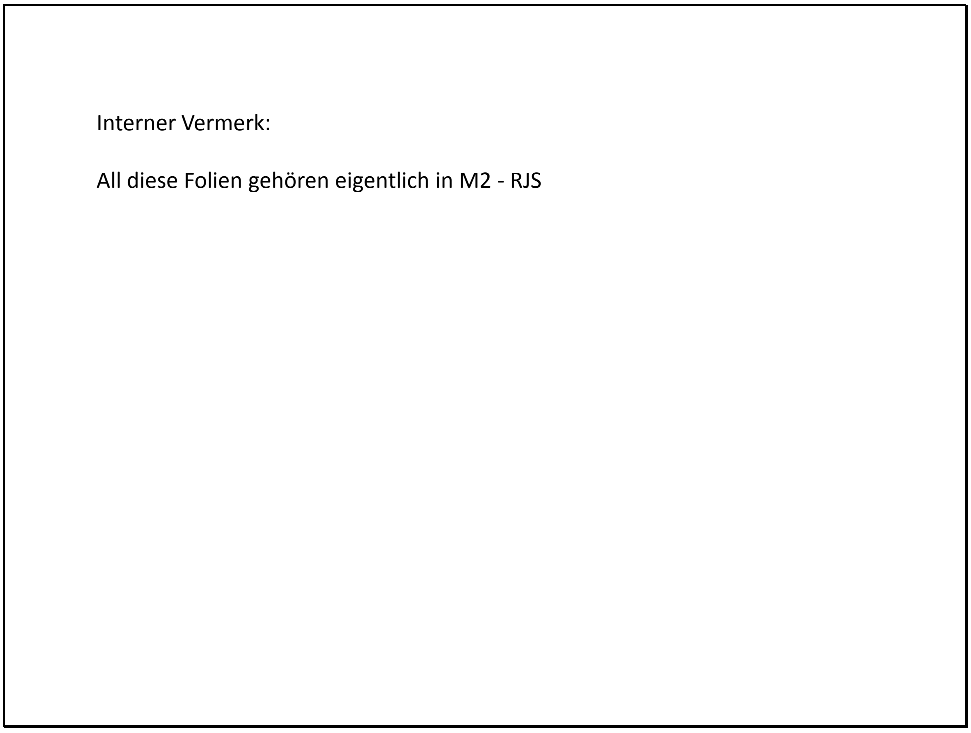
6.6 LECTURE M4L1

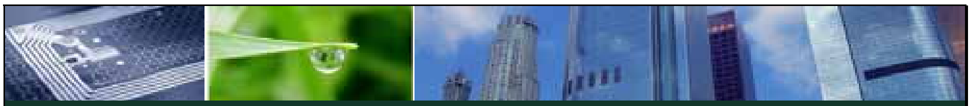
Short Outline

M4.L1 Introduction

- Motivation and objectives of the module, learning goals
- Principles of detailed EE design
- Overview of energy calculation and analysis methods
- Introduction to ICT tools for detailed EE design

Powerpoint Outline





Lesson example M4L1

Interner Vermerk:
All diese Folien gehören eigentlich in M2 - RJS

Lecture Notes on energy Efficiency in Building Construction

Karsten Menzel & Ana Kosiel- UCC

TECHNISCHE UNIVERSITÄT DRESDEN

1

Sources

- Module VE_LE_06:
Business models for Energy Management (EM)
Author: Karsten Menzel Lectures
- Information Technology in Architecture, Engineering and Construction
Dynamic Building Modelling Lecture 1 and Lecture 2
Autor: Ana Kosiel

2

Content

Introduction to Energy Efficient Design System

- **Motivation and objectives of the module, learning goals**
- Principles of detailed EE design
- Overview of energy calculation and analysis methods
- Introduction to ICT tools for detailed EE design

3

Objectives of the module

- To increase Professional productivity and innovation in the area of EE in buildings Design.
- To understand the practical application and utility of the software simulation techniques in engineering.
- To get acknowledge in the various simulation Design techniques .
- Have a overview of the Building Design procedure and the importance in the optimization of the techniques.
- To develop the capacity to efficiently use detailed computerized energy simulation programs.

4

Content

Introduction to Energy Efficient Design System

- Motivation and objectives of the module, learning goals
- **Principles of detailed EE design**
- Overview of energy calculation and analysis methods
- Introduction to ICT tools for detailed EE design

5

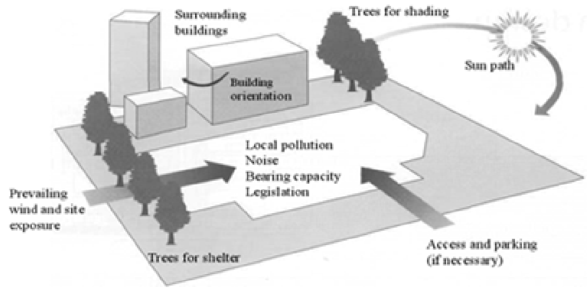
Principles of Energy Efficiency in Buildings Design

Energy Efficiency Design Principles:

- building and room orientation,
- size and shading of windows,
- roof and wall insulation,
- use of thermal mass (heat absorbing) materials inside the house,
- cross ventilation and draft proofing and use of breezes,
- landscaping, and
- energy-efficient appliances.

6

Principles of Energy Efficiency in Buildings Design
Building Orientation



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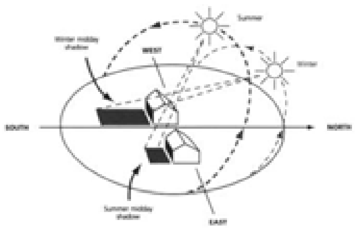
Principles of Energy Efficiency in Buildings Design
Building Orientation

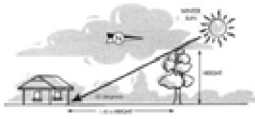


The low angle of the sun in winter allows the greater penetration of direct sunlight into buildings orientated and designed to allow this, while the higher angle of the sun in summer allows it to be excluded.

8

Principles of Energy Efficiency in Buildings Design
Building Orientation

➢Sun
Depending on the building orientation there are various aspects that should be considered:
- daylight
- winter time solar gains
- summer solar gains
- shading



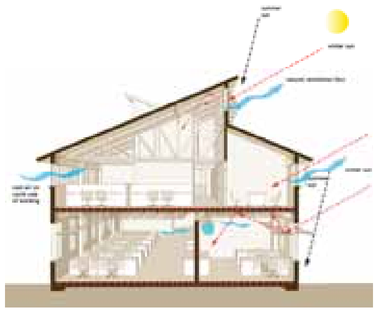
Computer modelling techniques allow tracing the path of the sun through the sky for each day of the year.

9

Principles of Energy Efficiency in Buildings Design
Building Orientation

➢ Wind

- enhance natural ventilation
- cooling breeze during summer months
- cross-ventilation
- taller buildings more affected
- energy generation
- increase infiltration



The local weather data files used in dynamic modelling include wind data for each specified location.

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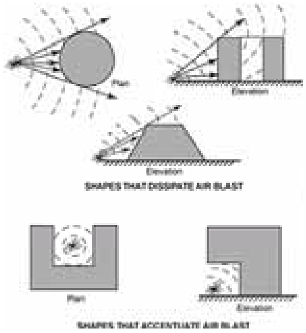
Principles of Energy Efficiency in Buildings Design

Building Orientation

Building Shape considerations:

- minimize heat losses and gains through external constructions – high volume of floor space to external surfaces (deep plan buildings)
- maximize daylight via increased glazing areas and minimized depth of the buildings
- space for renewables (wind turbines, solar panels, etc)



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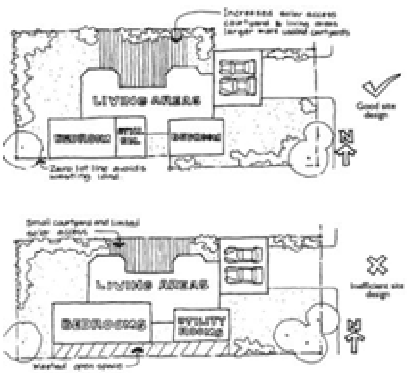
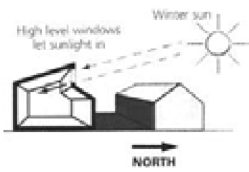
Principles of Energy Efficiency in Buildings Design

Orientation, size and shading of windows,



Indoor and outdoor living and entertainment areas and primary work areas should be orientated, in order to optimize solar access.



skylights or upper level windows and in some circumstances translucent roofs and
glass bricks should be used to improve solar and natural light access

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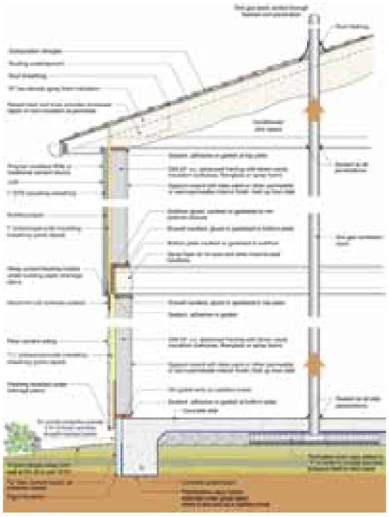
Principles of Energy Efficiency in Buildings Design
Envelope and Façade Design

- Testing various scenarios of building constructions and materials used
- U values - optimisation of insulation
- Heat and moisture movement within
the building fabric
- Air tightness
- Thermal mass effectiveness



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Principles of Energy Efficiency in Buildings Design
Envelope and Façade Design

- Glazing – area and glass performance
- Shading - solar control performance
- Double and triple façades
- Operable windows – location, size, obstructions

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Content

Introduction to Energy Efficient Design System

- Motivation and objectives of the module, learning goals
- Principles of detailed EE design
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Energy Calculation and Analysis Methods

Building Information Modelling include form, behaviour and relations of parts and assemblies of a Building:

- Geometric information directly relates to the building form in three dimensions.
- Semantic information describes the properties of components such as u-values of walls.
- Topological information captures the dependencies of components.

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Energy Calculation and Analysis Methods

Building information models have to be distinguished between:
- ➢proprietary models established by software companies and
- ➢open,non-proprietary models such as the Industry Foundation Classes (IFC)

The IFC data model is already used by a number of CAD tools as an export and import option.
Besides the generic models, software companies have developed their own internal models to feed their CAD and BIM software. These models differ in their structure and capabilities to establish a consistent model.

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Energy Calculation and Analysis Methods

Physical calculation models calculate precisely the detailed tasks as well as energy consumption (zone loads, daylighting and solar, multizone airflow, etc)
Many expert tools using engineering physical calculation models are available (TRNSYS , IES Virtual Environment or EnergyPlus). Necessary information input to run expert simulations is extensive, so is knowledge to perform and interpret the simulation results.

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Energy Calculation and Analysis Methods

Statistic calculation models are simplified models for the estimation of total the energy demand, heating or lighting energy demand.
Regulations such as the German Energy Savings Regulation EnEV or the Swiss Minergie use statistical calculation models for mandatory application in the building process.

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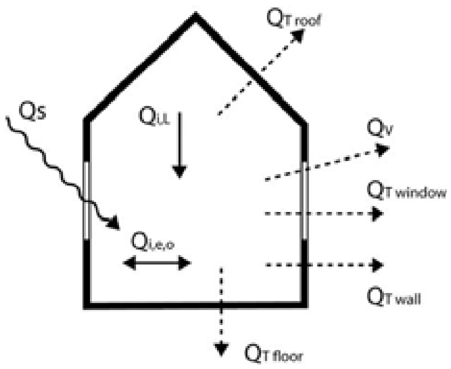
Energy Analysis



To be operated to maintain user comfort and functionality, a building needs a defined amount of energy that has to be supplied. In order to estimate the amount of energy that is needed, an energy balance has to be set up.

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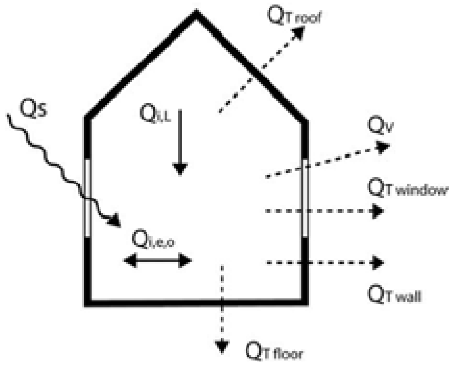
Energy Analysis



Six key performance indices are calculated to display the energy performance of the building:
- Transmission heat losses of the envelope
- Ventilation heat losses
- Solar heat gains through windows
- Internal heat gains
- Specific lighting power/lighting power
- Resulting heat demand

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Introduction to Energy Efficient Design System

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Energy Profiling

Energy profiling, in the built environment, involves an analysis of the actual or predicted energy performance of buildings and/or an analysis of the embodied energy within the materials and methods used to construct buildings. The ultimate aim of this analysis is to improve energy performance and in this way improve the energy efficiency of the built environment

- Energy profiling usually involves comparisons between actual or predicted energy use and some type of benchmark or model intended to indicate regulatory requirements, average energy consumption or best practice
- An improvement in energy efficiency is regarded as any action undertaken by a producer or a consumer of energy products that reduces energy use per unit of output, without affecting the level of service provided

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Energy Profiling - INTRODUCTION

- Focus of Energy Profiling
- The focus of energy profiling can be individual buildings, building types, organisations or localities.
- Energy efficiency improvements can be considered at all stages of the various fuel cycles. Greater energy efficiency can be brought about through hardware improvements, such as technological enhancements; software changes, such as improved energy management and better operational practices; or a combination of both
- Energy profiling often involves calculations of both energy consumption and related carbon dioxide (CO_2) emissions.
- This new regulatory environment combined with rising energy prices is stimulating a new interest in the role of energy profiling in optimising energy performance during the whole life cycle of both domestic and commercial buildings.

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Energy Profiling - INTRODUCTION

- <u>How is energy profiling applied?</u>
- The Traditional Approach

Traditionally two types of energy profiling are used in different phases of a buildings lifecycle. These can be:

1. *Design-phase energy profiling*
2. *Operational-phase energy profiling*

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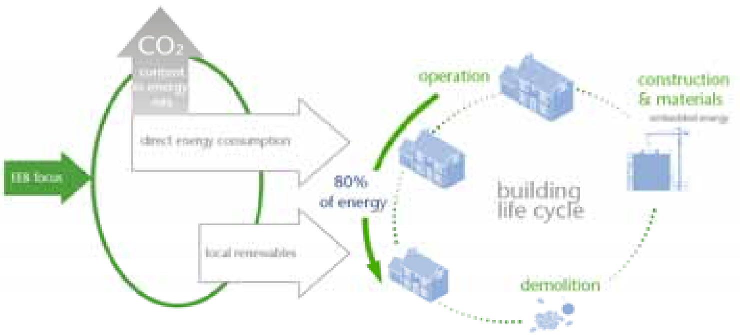
Energy Efficiency Building Design



Energy Profiling - INTRODUCTION

1. Design-phase energy profiling

- It usually involves building energy simulations. It is conducted by design professionals (project team members, assisted by energy consultants) using building design and energy analysis software tools to analyse the energy performance of their designs.
- For example, the energy performance feedback provided by whole building energy analysis tools allows designers to assure equipment is properly sized for the design conditions of a given building and that the part-load performance of the building subsystems are optimised to provide a comfortable environment with the lowest possible energy costs .
- Design phase energy profiling could also include calculations of the embodied energy within the products and methods used in the construction of buildings, although this type of energy profiling in buildings is very poorly represented in current preconstruction energy analysis.

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Energy Profiling - INTRODUCTION

2. Operational-phase energy profiling

- Ideally operational-phase energy profiling is based on the actual energy consumption of the building or buildings under examination.
- It is used to analyse buildings energy demand and illustrate measures that building managers, owners or occupiers can use to improve energy efficiency within the running of those buildings on a daily basis.
- Much of the energy analysis for the operational phase of a buildings life cycle has been sporadic (irregular), typically working from historical metered data and focusing on bulk energy assessment.
- This level of information leaves many possibilities for the reduction of heavily energy intensive energy consuming practices in both commercial and domestic buildings unknown

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- New technologies for Energy Profiling

Advances in the sophistication of computing technologies and real-time monitoring and metering technologies, combined with a reduction in their cost, offer the possibility of improving the operational energy performance information supplied to the managers, owners and occupiers of buildings.

- These technologies are enabling a rapid growth in the sophistication of energy profiling and encouraging an expansion of use of building management systems (BMS) which incorporate building energy management systems (BEMS).

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- BEMS (Building Energy Management Systems) – Operational Phase
- BEMS are control systems for individual buildings or groups of buildings that use computers and microprocessors for monitoring, data storage and communication.
- BEMS can be centrally located and communicate over telephone or Internet links with remote buildings having 'outstations' so that one energy manager can manage many buildings remotely.
- With energy meters and temperature, occupancy and lighting sensors connected to a BEMS, faults can be detected manually or using automated fault detection software helping to avoid energy waste.
- With the advent of inexpensive, wireless sensors and advances in information technology, extensive monitoring via the Internet is possible

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- BIM (Building Information Modelling) - Design Phase

- Advances in computing technologies are also facilitating improved techniques within the design phase energy profiling facilitated by the use of BIM tools which allow the creation and use of coordinated, internally consistent, computable information about a building project in design and construction (Digital Drafting Systems)

- In principal the models developed by BIM could be used to improve the energy efficiency of the built environment by assessing both the predicted energy performance of buildings and the energy embodied in the materials and methods used in construction

- In the absence of accurate data obtained from actual buildings in operation, designers rely on estimate values to feed in the data about loads, air flows, or heat transfer in order to carry out energy simulations

32

- Optimum Energy Profiling

- It is suggested that BEMs can be integrated with the building energy analysis software tools traditionally used in the design phase of buildings to enable BIMs to act as a data source which can be compared against actual building energy performance

- It would enable building managers, consumers and owners to accurately visualise both the measured and predicted energy performance of a building.

- This approach will enable energy profiling to be used to optimise the energy performance of the built environment rather than merely improve that performance

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- <u>Building Energy Simulation Software (Introduction)</u>

- Software tools used to assess energy performance in building design is practical in nature

- Some attempts are being made towards the quantification of the energy embodied in building materials, as well as the energy used during the construction process, most of the tools used for lifecycle analyses (LCA) are general and not designed for the built environment.

- There are very few exceptions, where energy performance is to be addressed in the complete lifecycle of the building

- Currently LCA tools are not widely used in energy efficient building design. Energy simulation tools are little used for designing buildings and even fewer projects include LCA

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➢ <u>Limitations of current building energy simulation tools</u>

- Poor interoperability means most still depend on the user entering large amounts of data, which represents a barrier to integrating these tools in the different stages of the building lifecycle

- The amount of time that it is necessary to dedicate to enter data in the energy analysis programs is repeatedly mentioned by researchers as one of the main obstacles to be overcome

- The time dedicated to process and re-create the geometry generated with a BIM authoring tool to conform with the format required by an energy analysis software amounts to up to 50% of the time a project team dedicates to perform an energy simulation. These issues have led to the infrequent application of comprehensive design phase energy profiling by design professionals

- Energy simulation tools are also limited when it comes to assessing the impact of occupant behaviour

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- It has been shown that the major sources of uncertainties in the use of energy simulation tools are related to proper evaluation of lighting, appliances/equipment and occupancy schedules
- All of these factors relate to occupant behaviour: An issue which is particularly problematic in buildings "where the air conditioning equipment are mainly unitary systems (window-type air conditioners and split systems) [which] can significantly affect the energy consumption profile, making its forecasting more difficult or inaccurate
- A lack of accurate, ready-to-use data also hinders the integration of energy simulation software in the conceptual design stages of building production
- In the absence of accurate data obtained from actual buildings in operation, designers rely on estimate values to feed in the data about loads, air flows, or heat transfer in order to carry out energy simulations. This is why it is suggested that the information from BMS can be integrated with the building energy analysis software tools to enable BIMs to act as a data source
- There is a need for the development and validation of a new approach to the integration of simulation and real time data capturing sensors. However for this to be achieved BIM tools also have to be integrated with energy simulation software

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- Building Information Modelling (BIM)
- Building information modelling (BIM) tools are used to generate graphics and information about building components which demonstrate the entire construction planning, project costing, lifecycle costing, etc
- Ideally the building information models produced by BIM tools would enable users to identify potential problems during early stages of a project, reduce the design errors, save cost and time and accurately predict the energy consumption during the lifecycle of the building.
- Revit, Bentley Architecture, ArchiCAD and Digital Project are some of the BIM software used for planning or drafting purposes. While the technologies such as IES, DesignBuilder and Riuska, are energy evaluation software, which offer the potential to inform building information models enabling them to act as data

  source which can be compared against actual building energy performance.

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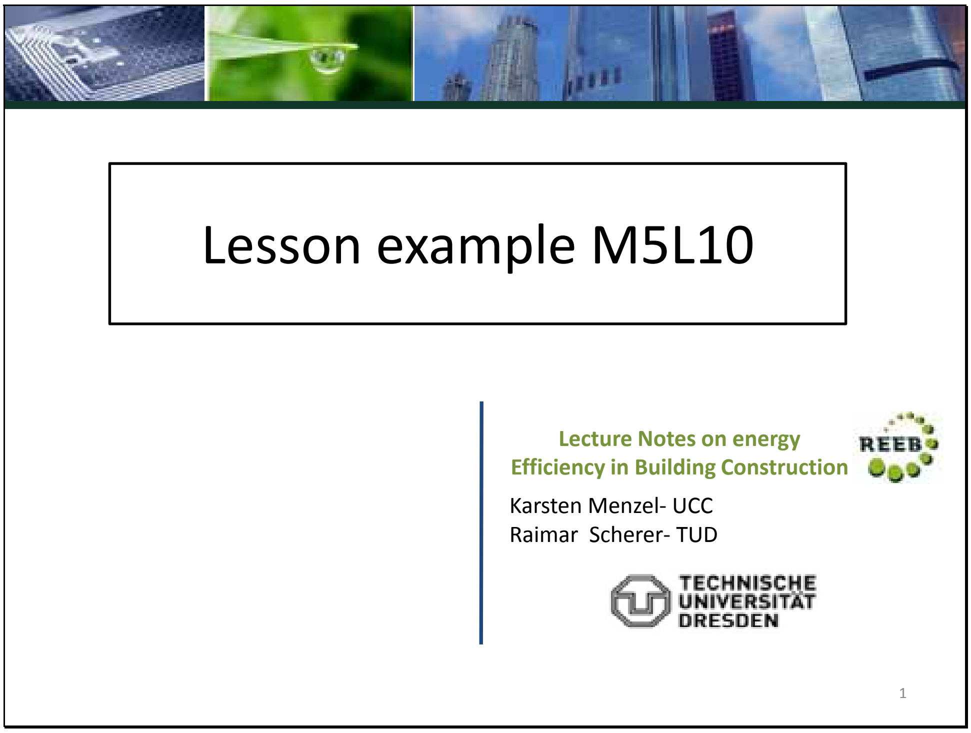
6.7 LECTURE M5L10

Short Outline

M5.L10 Basic principles of building automation and management systems (BAMS)

- Types of building automation and management systems and their relationship
  with EE building operation control
- Principal hard- and software architecture
- Basic BAMS components (sensors, datapoints, bus controllers, gateways etc.)
- Integration and interoperability challenges – state-of-the-art and R&D roadmap and trends

Powerpoint Outline



Sources

- Information Technology in Architecture, Engineering and Construction

BAMS structure by Karsten Menzel

- Building Wireless Sensor Networks
  http://www.mwrf.com/Articles/Index.cfm?Ad=1&ArticleID=11071

2

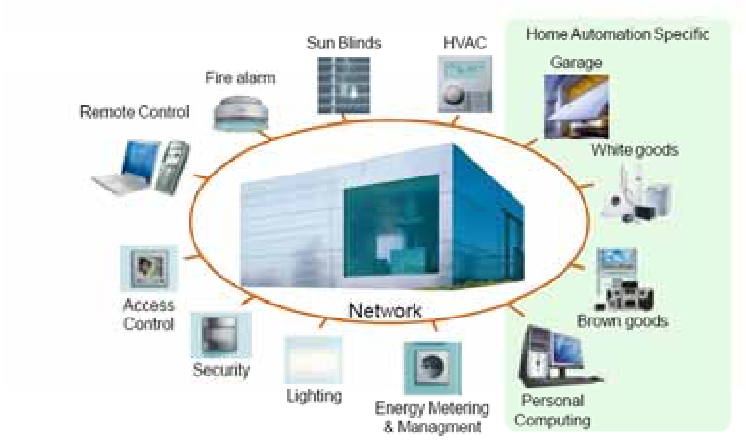
D 5.32 Lecture Notes on EE in BC

Module 5 Lesson 10 Description content

- **M5.L10 Basic principles of building automation & management systems (BAMS)**
  - **Types of Building automation & management systems & their relationship with EE building operation control**
  - Principal hard-and software architecture
  - Basic BAMS components
  - Integration & interoperability challenges –state-of the-art and R&D roadmap and Trends

3

SMARTHOMES–Home Automation Systems



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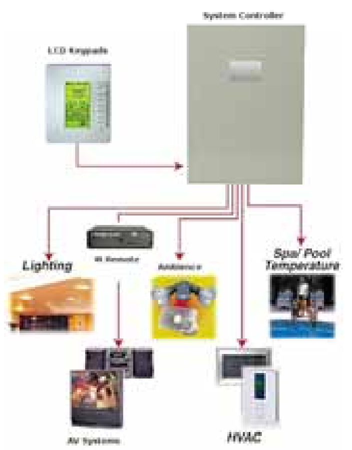
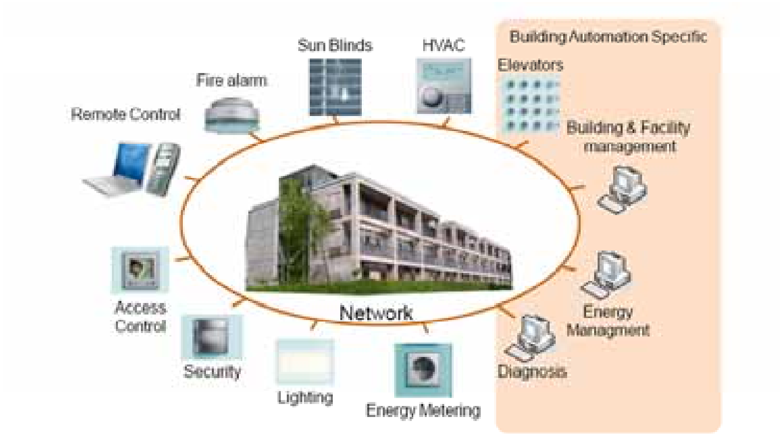
Building Management System (BMS)



Computer-based control system
that controls and monitors the building's
mechanical and electrical equipment:

- Ventilation
- Lighting
- Power systems
- Fire systems and,
- Security Systems.

BUILDING AUTOMATION SYSTEMS



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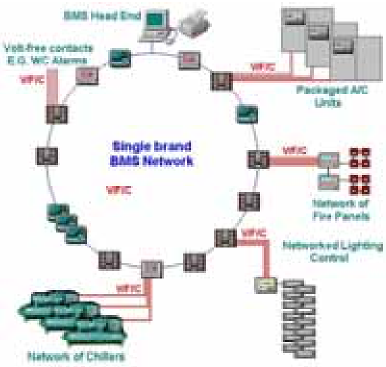
Objective & Functions of BMS



- •**Automate the mechanical and electrical services** facilities of the buildings for a comfortable environment.
- •**Manage the environment within the building**
- •**Control temperature, carbon dioxide levels and humidity**
- •**Control heating and cooling**
- •**Monitor the level of human-generated CO2**

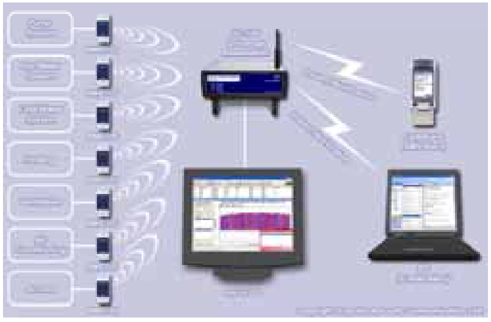
A BMS system comprises:

- **Power systems**
- **Illumination system**
- **Electric power control system**
- **HVAC systems Security and Observation system**
- **Fire alarm system**
- **Lifts, elevators,**
- **Plumbing system**
- **Burglar alarms**
- **Trace heating and other engineering systems.**

7

BMS & control optimatization

The level of control of BMS depends on:
•the information received from its sensors
•the way in which its programs respond to that information.
•BMS may offer a precise degree of control to its environment,
•it may alarm on conditions that can't meet specification
•It may warn of individual items of plant failure.



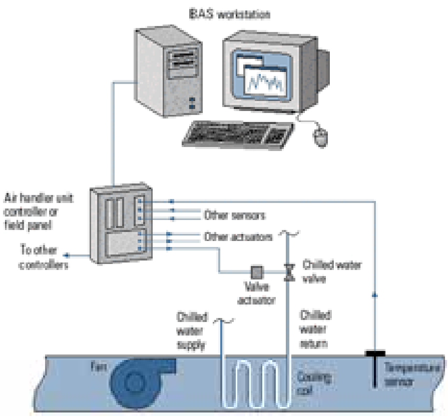
8

Building Automation System (BAS)

BAS use computer-based monitoring to coordinate, organize and optimize building control sub-systems such as security, fire/life safety, elevators, etc.

Common applications include :

- **Equipment scheduling**
- **Optimum start/stop**
- **Operator adjustment**
- **Monitoring**
- **Alarm reporting**



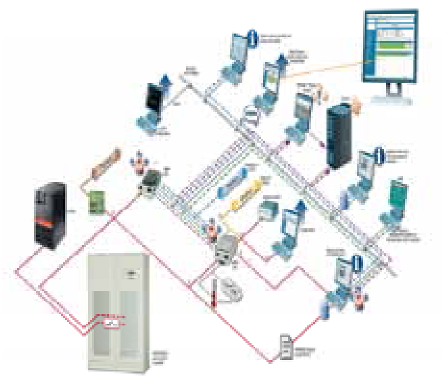
9

BAS Function: BAS controllers designed to operate as stand-alone controllers With its own program with the ability to communicate to other Direct Digital Control (DDC) building automation controllers.

BAS Objectives:

•set up schedules of operation for the equipment & systems
•optimal start with adaptive learning (compare space temperature, outside air conditions, and equipment capabilities)
•monitor energy (meter electric, gas, water, steam, hot water, chilled water, and fuel oil services).
•BAS control algorithms
•send alarms via email, pager, or telephone to alert developing problems and system failures.
•BAS set up to bill tenants for energy usage.
•communications abilities to be integrated with other building automation control systems & TCP/IP.

BAS Related to control optimisation



The BAS electronic processing in combination with dedicated sensing apparatus is design to control the operation of the building systems which regulates its functions in the building spaces, the BAS activities will develop as a result to controlled spaces.

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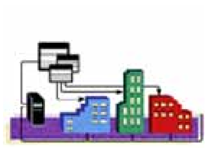
Integrated Building Automation System (IBAS)

This system provides a productive and cost-effective environment through interrelationships and optimization of its four basic elements:

1)Building structure
2) Building systems
3) Building services
4) Building management



Characteristics of IBAS form a fundamental level of an IBAS building:

- •Environmental conservation
- •Space utilization and flexibility
- •Life cycle costing - operation and maintenance
- •Human comfort
- •Working Efficiency
- •Safety - fire, earthquake, disaster and structure etc.
- •Culture
- •High Technology

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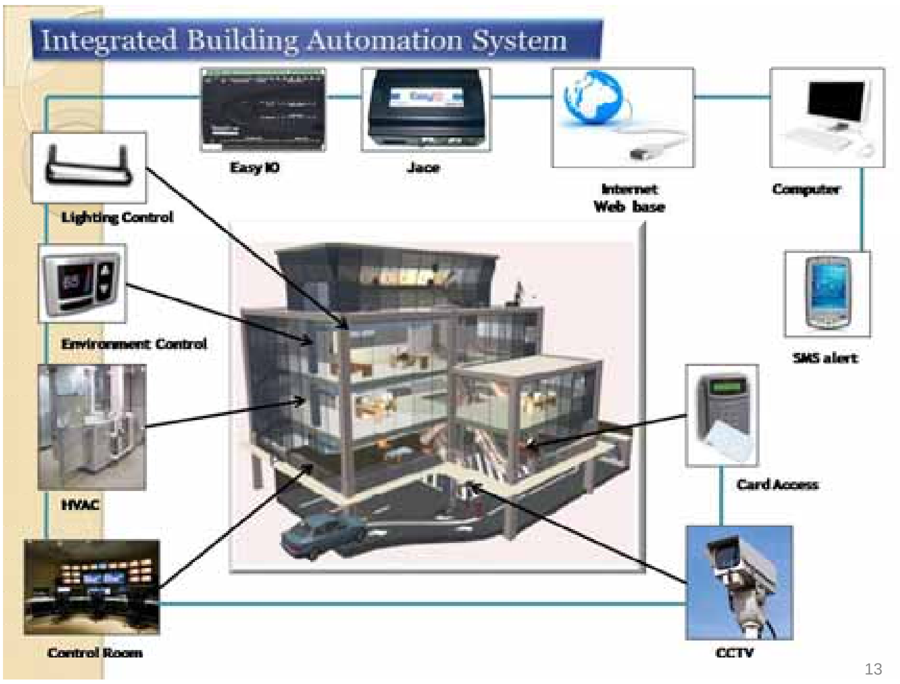

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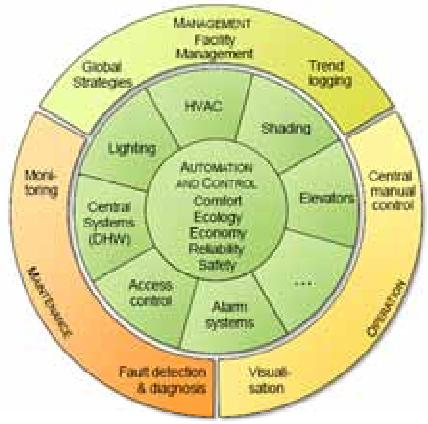
FUNCTIONALITY OF BUILDING AUTOMATION SYSTEMS

Interaction processes :

Maintenance
Operation
Management

in the core activity of
Automation & Control
to operate the BAS systems



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D 5.32 Lecture Notes on EE in BC
Module 5 Lesson 10 Description content

- **M5.L10 Basic principles of building automation & management systems (BAMS)**
  - Types of Building automation & management systems & their relationship with EE building operation control
  - **Principal hard-and software architecture**
  - Basic BAMS components
  - Integration & interoperability challenges –state-of the-art and R&D roadmap and Trends

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BAMS architecture

Operator Interfaces comprising PC-based workstations;

Communications network with BACnet/IP connection to the UNSW BACS VLAN network;

Controllers with inputs and outputs (I/O) for controlling central plant and air handling systems with customable control sequences, data collection (metering/trending);

Application Specific Controllers with inputs and outputs (I/O) for controlling packaged systems, unitary equipment & terminal units.

BAMS architecture :Hardware

The basic Hardware architecture consists of:
- Network control units (NCUs)
- Network expansion units (NEUs)
- Operator workstations (OWSs)
- Local Area Network (LAN)
- N2 Bus
- Application Specific Controllers (ASCs)

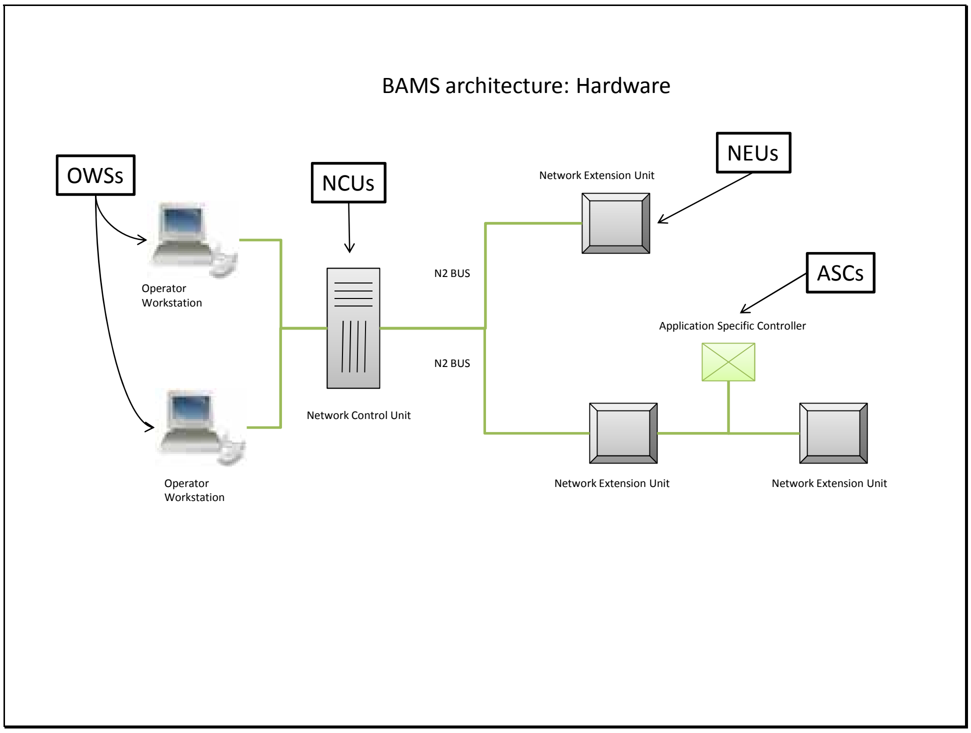
BAMS architecture :Hardware

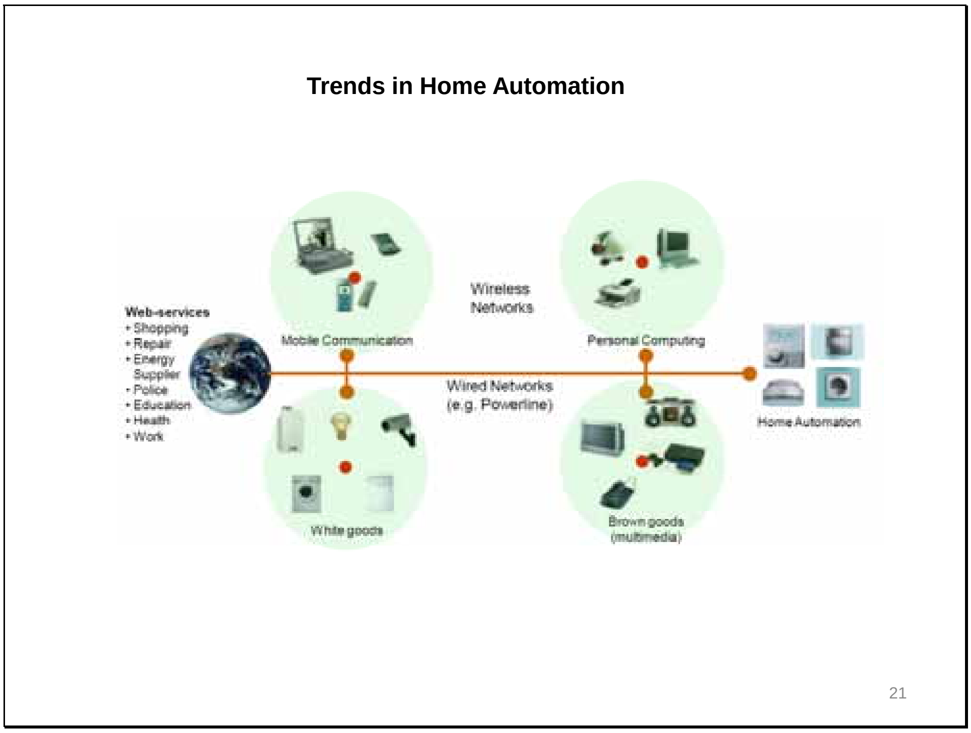
➢Network control units (NCUs): Multiple programmable control panels, each NCU manages a physical area within the building. The NCU is the heart of the network and it has free access to all other NCUs & ASCs. Can directly control central plant equipment and provide standalone control capability for HVAC, fire management, access control and lighting control wherever they are needed, giving maximum fault tolerance and reliability.
➢Network expansion units (NEUs): remote panels that can enhance the capacity of the NCU & can directly control central plant equipment.
➢Operator workstations (OWSs): usually a standard personal computer.
➢The N1 Local Area Network (LAN): high speed communication network to communicate each OWSs.
➢N2 Bus: secondary communication network which communicates ASCs and NEUs with the NCUs.

BAMS architecture :Hardware

➢Family of Application Specific Controllers (ASCs): delegate to management of smaller air handlers, heat pumps, lighting circuits and other building services systems.
Standalone ASCs include:

- Air handling unit controller (AHU)
- Intelligent lighting controller (ILC)
- Variable air volume box controller (VAV)
- Unitary equipment controller (UNT)
- Intelligent access controller (IAC)
- Intelligent fire controller (IFC)


BAMS architecture: Hardware
OWSs
NCUs
NEUs
ASCs
Network Extension Unit
Operator Workstation
N2 BUS
Application Specific Controller
N2 BUS
Network Control Unit
Operator Workstation
Network Extension Unit
Network Extension Unit


Trends in Home Automation
Wireless Networks
Web-services
• Shopping
• Repair
• Energy Supplier
• Police
• Education
• Health
• Work
Mobile Communication
Personal Computing
Wired Networks (e.g. Powerline)
Home Automation
White goods
Brown goods (multimedia)
21

BASIC BACS STRUCTURE

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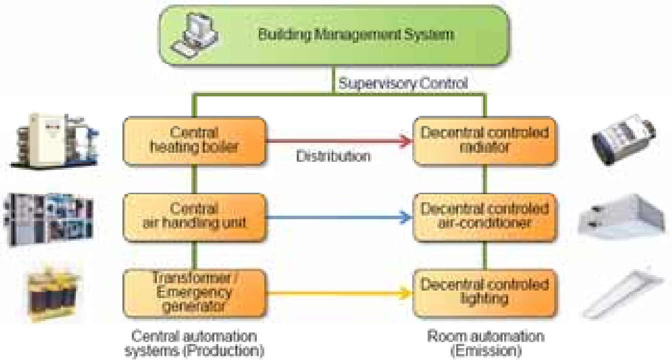
BASIC BACS STRUCTURE



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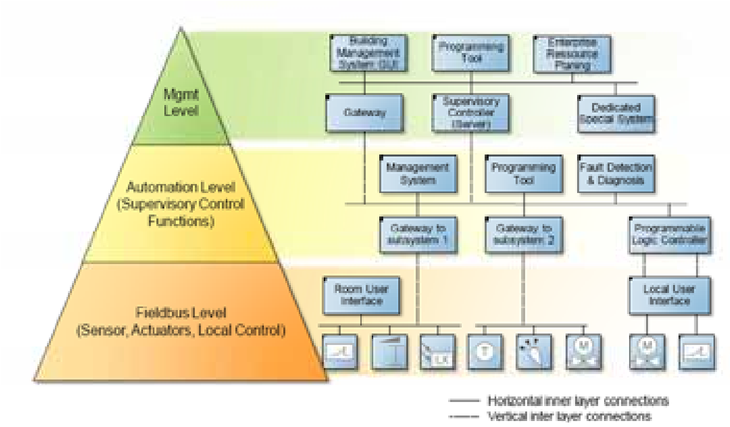
THE AUTOMATION HIERARCHY



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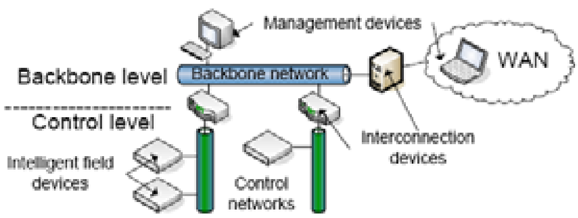
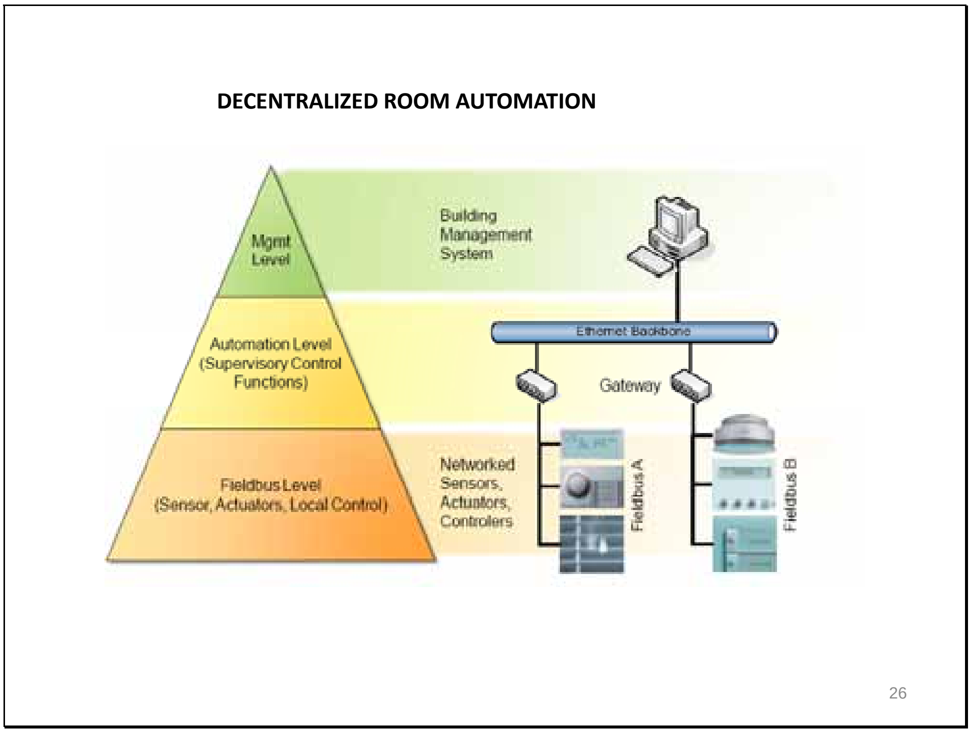
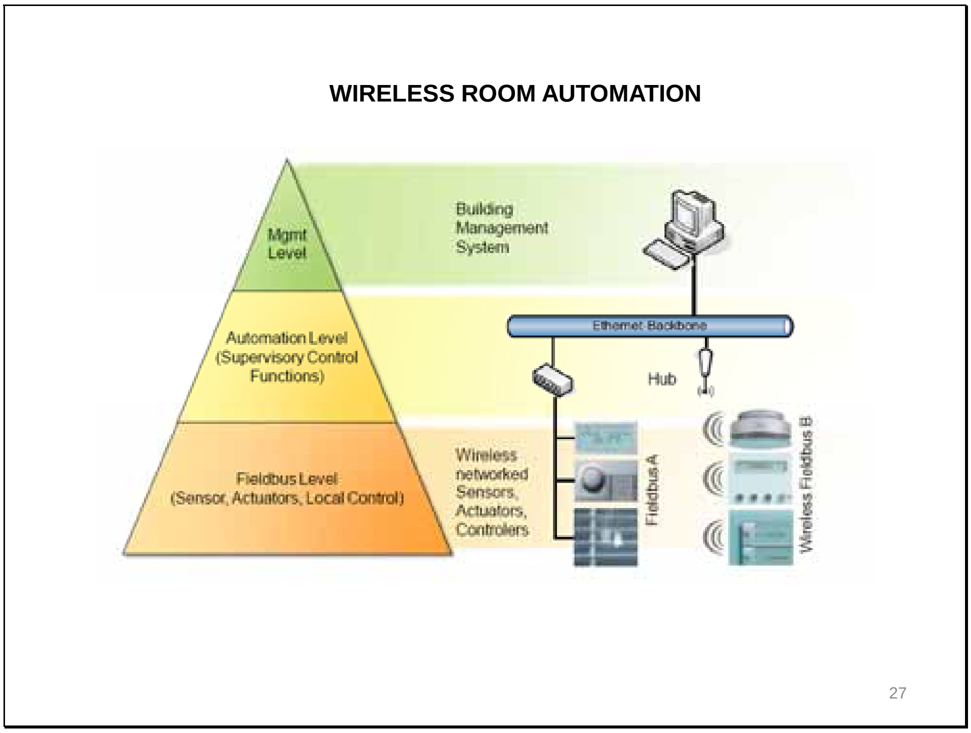
THE NEW AUTOMATION HIERARCHY



25


DECENTRALIZED ROOM AUTOMATION
Mgmt Level
Automation Level (Supervisory Control Functions)
Fieldbus Level (Sensor, Actuators, Local Control)
Building Management System
Ethernet Backbone
Gateway
Networked Sensors, Actuators, Controlers
Fieldbus A
Fieldbus B
26


WIRELESS ROOM AUTOMATION
Mgmt Level
Automation Level (Supervisory Control Functions)
Fieldbus Level (Sensor, Actuators, Local Control)
Building Management System
Ethernet Backbone
Hub
Wireless networked Sensors, Actuators, Controlers
Fieldbus A
Wireless Fieldbus B
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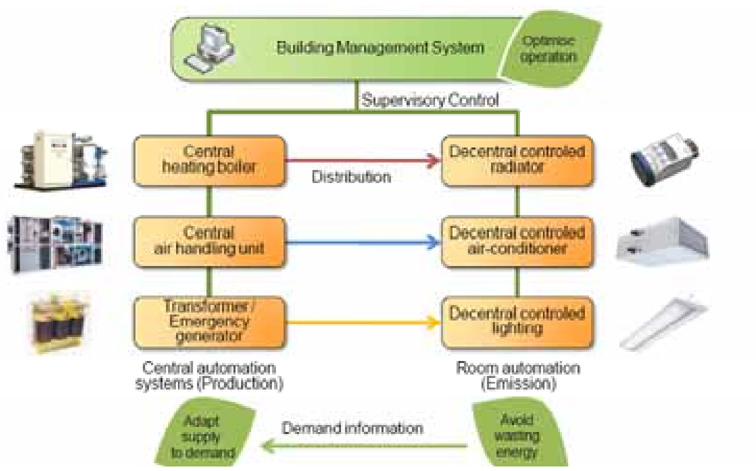
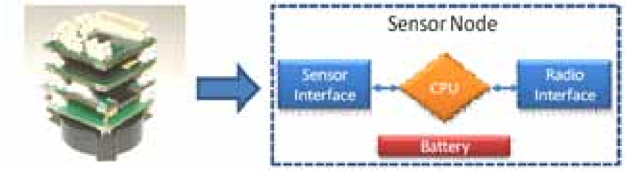
BAMS CONTROL STRUCTURE



Wireless Sensors
Wireless sensors can be developed to detect and measure various parameters such as temperature, humidity and water/gas/electricity meter readings.
A sensor node in a network(mote) mainly consists of 3 components:
- the sensor interface which actually measures the physical attributes like humidity level,
- the radio interface which communicates with other motes and
- the CPU which performs computations and transfers information between the two components



Tyndall 25mm wireless sensor module with components.

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Wireless Sensor Network
Wireless Sensor Network (WSN) is a wireless network consisting of spatially distributed autonomous devices using sensors that allow the physical environment to be monitored at high resolution. These sensors (motes), are installed in particular locations or can be sprayed in a particular zone to gather information such as temperature, humidity, CO2 level, etc.
Sensors are not powerful. The real functionality of sensors comes with wireless sensor networks when these tiny sensors start communicating with each other through wireless protocols.
WSN can shuffle the information collected through thousand of sensors and transfer it to the public internet and or a local area network. Finally, the information is collected in the data warehouse where it is analysed.

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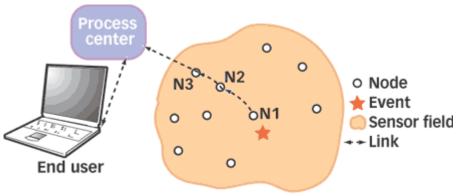
Wireless sensor networks (WSNs)

Wireless sensor networks (WSNs) offer great promise for information capture and processing in both commercial and military applications. Successful system design and deployment includes understanding RF channel characteristics, and the choice of modulation scheme on power consumption. Such factors ultimately determine the available range and data rate of a WSN, as well as cost and battery lifetime.



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WSNs Devices

WSNs employ a large number of miniature autonomous devices known as sensor nodes to form the network without the aid of any established infrastructure. In a wireless sensor system, the individual nodes are capable of sensing their environments, processing the information locally, or sending it to one or more collection points through a wireless link. Each node has a short-range transmission due to low RF transmit power. Short-range transmission minimizes the possibility of the transmitted signals being eavesdropped; it helps in prolonging the lifetime of the battery. In some sensor system applications, the nodes are hard to reach and it is impossible to replace their batteries. In other applications, the nodes must operate without battery replacement for a long time. Such conditions make the system power consumption a very crucial parameter.
WSNs use ad hoc topology because of its ease of deployment, and decreased dependence on infrastructure. Although WSNs use ad-hoc architecture, this architecture is different from the conventional wireless ad hoc networks. The performance of a WSN depends significantly on the characteristics of the sensor node.

Network technology

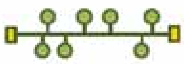
Several main network topologies are currently used in standard installations. The topology of a network refers to the configuration of cables, computers, and other peripherals.

▪**Bus topology** Also know as linear, ethernet or backbone topology, this consists of a main run of cable (backbone) with terminators at each end, all nodes (file server or servers, workstations and peripherals) are connected to the linear cable. It is usually limited to small businesses.
▪**Star topology** Star topology is designed with each node connected directly to a central hub. The hub packages data together and communicates with its nodes and other nodes on the network through their hubs. It is easy to install and configure.
▪**Star bus (tree) topology** This is probably the most common network topology in use today. It combines elements of the star and bus topologies to create a versatile and expandable network environment.

TOPOLOGY

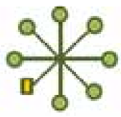
Line topology

- All devices are connected by a single cable. Short stubs are allowed



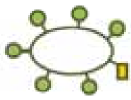
Star topology

- All devices are connected to a central point



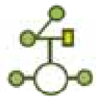
Ring topology

- All devices are connected by a cable in a loop for higher reliability



Free topology

- The devices can be connected in any way



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WSN TECHNOLOGIES IN BACS

ZIGBEE / IEEE 802.15.4

- Open communication standard of the IEEE und ZigBee Alliance
- Wants to be a big player and has potential as IEEE standard

Z-WAVE

- Proprietary technology developed by Zensys and the Z-Wave Alliance
- Well established in American market

ENOCEAN

- Proprietary technology developed by EnOcean GmbH (Siemens Spin-off)
- Biggest player in Europe
- Innovative energy harvesting

KNX RF

- Open standard by the KNX Association (Siemens lead)
- Part of KNX standard ISO/IEC 14543
- Longest in the market but no relevant sharte

SCATTERWEB

- Developed by Free University Berlin and spin-off as ScatterWeb GmbH
- Not very common, but interesting approach

NANONET

- Developed by Nanotron, Berlin
- Novelist with an interesting

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BMS Control & Automation nets

•C-Bus(protocol)
•Universal Powerline Bus
•Konnex
•Lonworks
•X10
•ONE-NET
•EIB
•EHS
•BatiBUS
•ZigBee
•EnOcean
•SCS BUS- OpenWebNet

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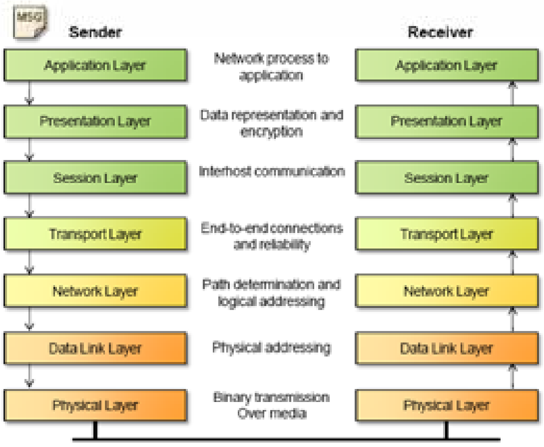
OPEN SYSTEM INTERCONNECTION REFERENCE MODEL (OSI MODEL)



- Each layer builds only upon services of its lower layer
- Each layer may add information to the message for the receiver
- Messages are created at application layer
- The transmission happens on physical layer

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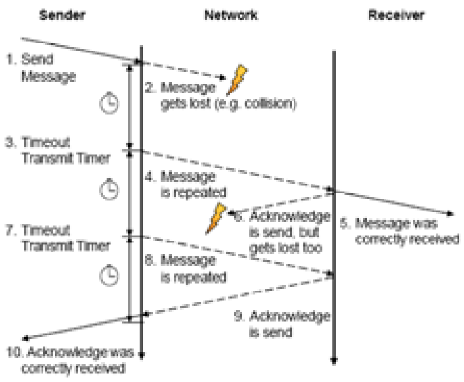
TRANSPORT LAYER RELIABILITY EXAMPLE ACKNOWLEDGED MESSAGE



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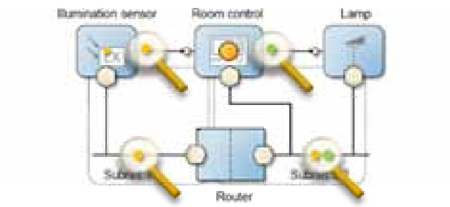
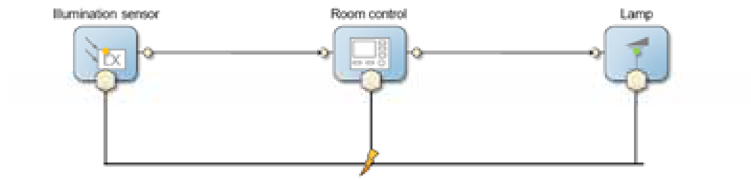
ROUTING IN THE NETWORK



COLLISIONS IN NETWORKS



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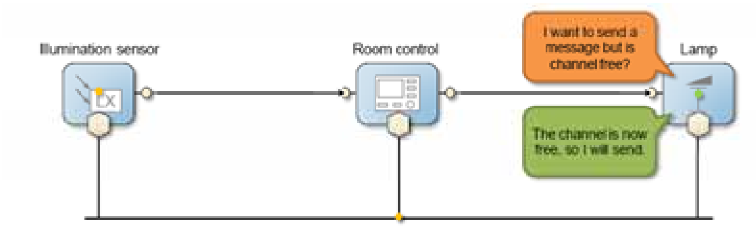
CARRIER SENSE MULTIPLE ACCESS



Listen before talking

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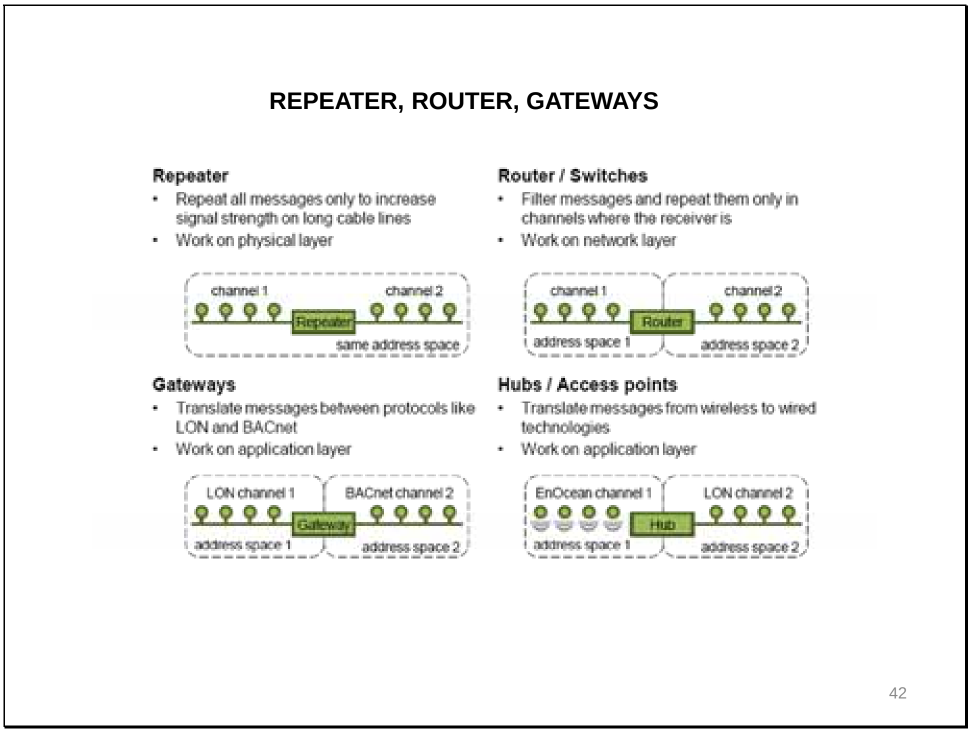
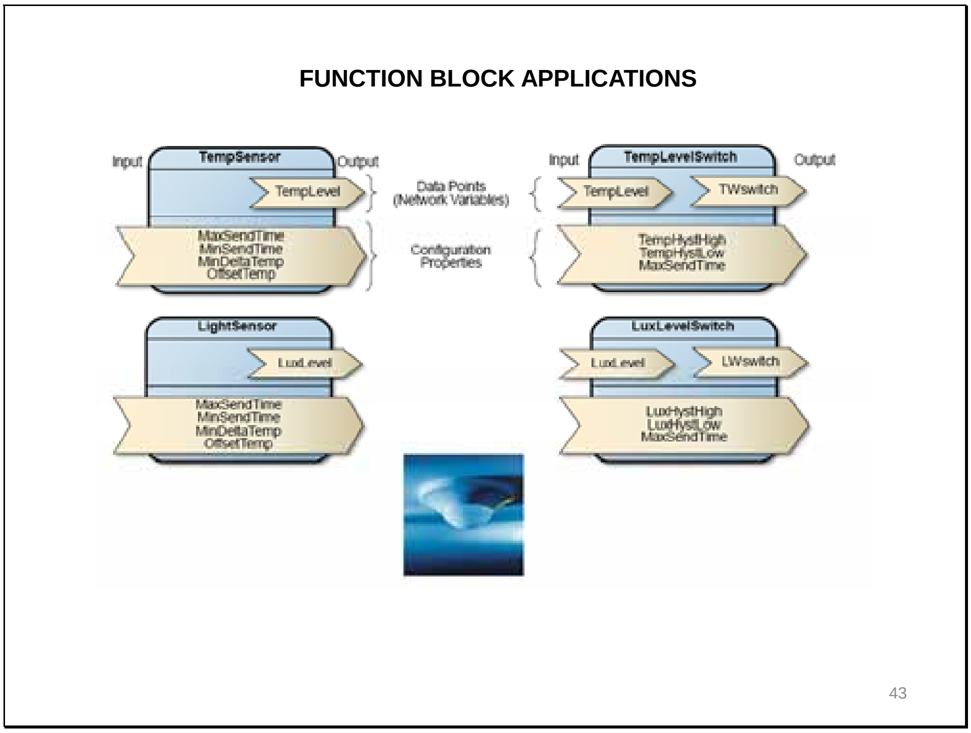
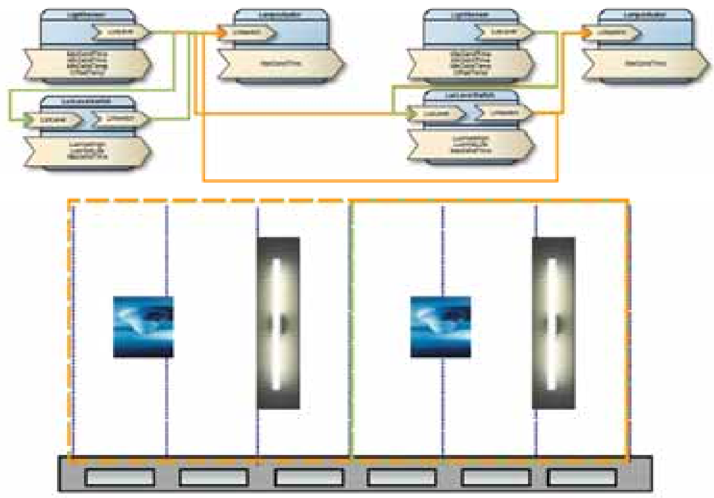

REPEATER, ROUTER, GATEWAYS
Repeater
• Repeat all messages only to increase signal strength on long cable lines
• Work on physical layer
channel 1
channel 2
Repeater
same address space
Router / Switches
• Filter messages and repeat them only in channels where the receiver is
• Work on network layer
channel 1
channel 2
Router
address space 1
address space 2
Gateways
• Translate messages between protocols like LON and BACnet
• Work on application layer
LON channel 1
BACnet channel 2
Gateway
address space 1
address space 2
Hubs / Access points
• Translate messages from wireless to wired technologies
• Work on application layer
EnOcean channel 1
LON channel 2
Hub
address space 1
address space 2
42


FUNCTION BLOCK APPLICATIONS
Input
TempSensor
Output
TempLevel
MaxSendTime
MinSendTime
MinDeltaTemp
OffsetTemp
Data Points
(Network Variables)
Configuration
Properties
Input
TempLevelSwitch
Output
TempLevel
TWswitch
TempHystHigh
TempHystLow
MaxSendTime
LightSensor
LuxLevel
MaxSendTime
MinSendTime
MinDeltaTemp
OffsetTemp
LuxLevelSwitch
LuxLevel
LWswitch
LuxHystHigh
LuxHystLow
MaxSendTime
43

USING BINDINGS FOR FLEXIBLE SPACE USAGE



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  - Basic BAMS components
  - **Integration & interoperability challenges –state-of the-art and R&D roadmap and Trends**

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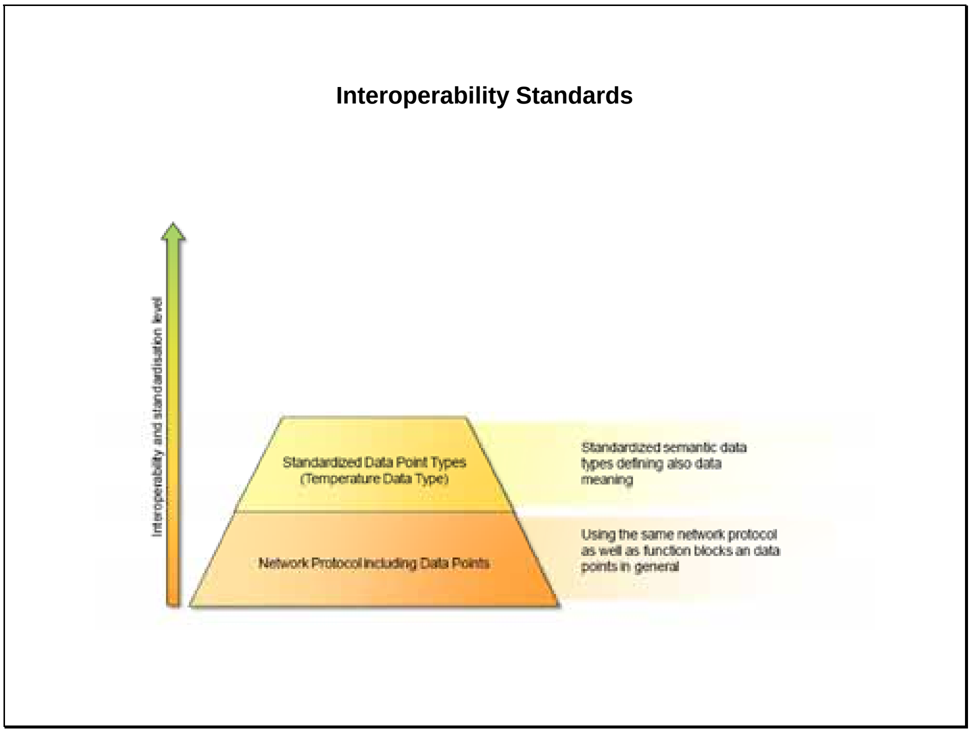
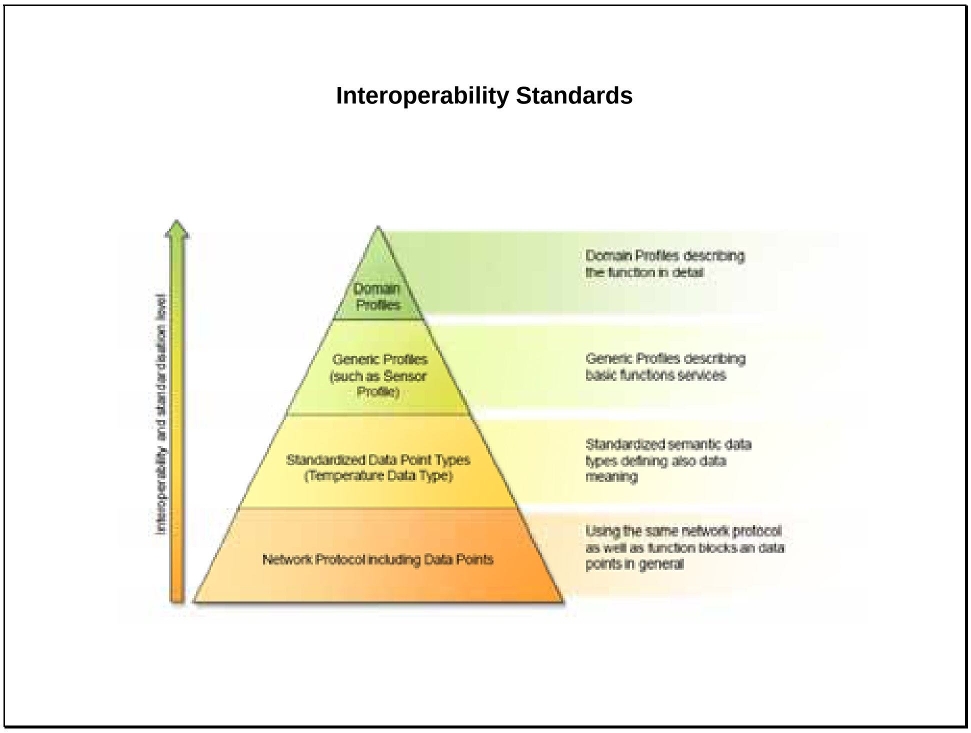
Why Interoperability?

- Many SMEs dominate the market with an incomplete product portfolio
- Investors and building operators want vendor-independent installations to be flexible with service contracts and be able to replace a after years even if the manufacture doesn‘t offers it any more
- Devices from different manufactures have to function together in one system.

Interoperability

	Compatible	Interconnectable	Interworkable	Interoperable	Interchangeable
Dynamic behaviours					equal
Application function				equal	equal
Meaning of variables				equal	equal
Definition of variables			equal	equal	equal
Access to variable		equal	equal	equal	equal
Protocol mapping		equal	equal	equal	equal
Protocol (layer 1-7)	equal	equal	equal	equal	equal

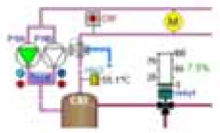

Interoperability Standards
Interoperability and standardisation level
Standardized Data Point Types (Temperature Data Type)
Network Protocol including Data Points
Standardized semantic data types defining also data meaning
Using the same network protocol as well as function blocks an data points in general


Interoperability Standards
Interoperability and standardisation level
Domain Profiles
Generic Profiles (such as Sensor Profile)
Standardized Data Point Types (Temperature Data Type)
Network Protocol including Data Points
Domain Profiles describing the function in detail
Generic Profiles describing basic functions services
Standardized semantic data types defining also data meaning
Using the same network protocol as well as function blocks an data points in general

FUNCTIONALITY OF A BUILDING MANAGEMENT SYSTEM

Visualisation

- Visualising the current system status



Control

- Providing modifying supervisory control actions

Historical data storage

- Logs historicals data for later analysis

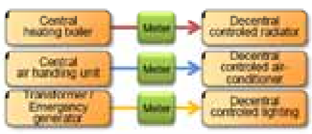
Fault Detection & Diagnosis

- Detects faults in the system and creates alarms
- Diagnosis reasons for detected faults

ENERGY MANAGEMENT

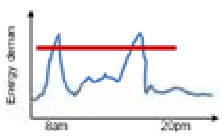
Monitoring Energy Consumption

- Monitoring and comparing the energy consumption to old data



Limiting Peak Deman

- Avoiding peaks in energy consumption



Visualize Energy Consumption

- Visualising the building energy consumption creates user awareness

OPTIMISATION

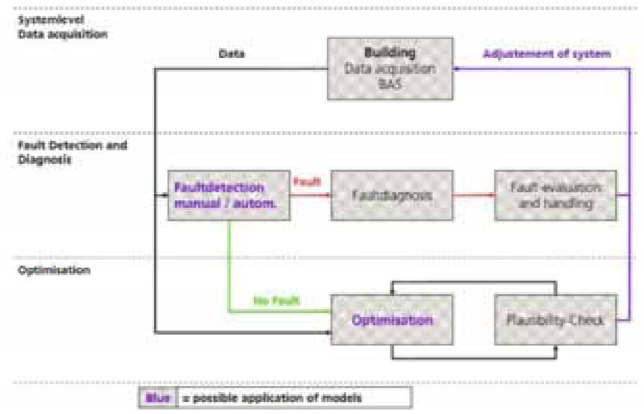
Goal:

- Optimising energy efficiency and comfort under consideration of conditions (weather, person occupancy, comfort profiles)

Approach:

- Optimise schedules and optimal start / stop not only to occupancy but also due to personal comfort preferences
- Optimal device usage (e.g. if the building has a geothermal and gas heating system prefer the one with the better energy efficiency)
- Predict the building behaviour in the near future to decide about optimal control strategies by : Simulating based on recent measures or predictions (weather) or by extrapolated measurements using predictive models (auto-regression models).

SUMMARY MODEL-BASED APPROACHES



7. CONCLUSIONS

E-learning enables better knowledge dissemination for better understanding and spreading of the energy efficiency subject. The challenge is to create a work environment community that allows participants to learn, adapt, share and respond.

The presented lecture design covers the teaching system methodology and the learning basis of the structured e-learning lessons, which aims to stimulate the energy efficiency solution applied to building design, with the application of technology to achieve better learning outcomes and a more cost-efficient way of bringing the learning environment to learners.

8. ACKNOWLEDGEMENTS

The REEB Consortium would like to acknowledge the financial support of the European Commission under the IST programme.

9. REFERENCES

Ackermann J. (ed.): *Handbuch DDS-CAD SHK*, © Data Design Systems GmbH, 2009, 314 p.

AIA, Rick Rundell: *BIM and Green Building Studio (1-2-3 Revit Tutorial)*, Cadalyst Online Journal, 2008. http://www.cadalyst.com/aec/bim-and-green-building-studio-1-2-3-revit-tutorial-3755

Autodesk: *Autodesk® Green Building Studio*, http://usa.autodesk.com/adsk/servlet/pc/index?id=11179508&siteID=123112

Autodesk: *Autodesk® Revit MEP*, http://usa.autodesk.com/adsk/servlet/pc/index?siteID=123112&id=6861034

Autodesk: *Revit MEP 2010 User's Guide*, http://docs.autodesk.com/RVTMPJ/2010/ENU/Revit%20MEP%202010%20Users%20Guide/RME/index.html

BuildingOnline: *Autodesk Green Building Studio Adds More Than a Million Global Weather Locations*, 2008. http://www.buildingonline.com/news/viewnews.pl?id=8813

BuildingSMART: *IFC Specification: IFC2x Edition 3 Technical Corrigendum 1* (IFC2x3-TC1), © BuildingSMART International, 2007 http://www.iai-tech.org/products/ifc_specification/ifc-releases

Data Design Systems: DDS-CAD Leistungsbeschreibung, http://www.dds-cad.de/103x10x0.xhtml pdf: http://www.dds-cad.de/files/web1.ddsv.de/downloads/PDF-Datein/DDS-CAD%20Leistungsbeschreibung.pdf

Design Builder Software Ltd.: *Designer Builder User Manual*, 2006, 388 p.

DOE: *EnergyPlus Energy Simulation Software: Documentation*, © U.S. Dept. Of Energy, http://apps1.eere.energy.gov/buildings/energyplus/documentation.cfm

Dürr U.: *GAMMA Instabus ® - Energieeinsparrungskonzepte mit Beleuchtungssteuerung/-regelung*, Lecture Notes, TU Dresden, 2008, © Siemens AG 2008, 40 p.

EC - Directorate General for Education and Culture: *ECTS Users' Guide, European Credit Transfer and Accumulation System and Diploma Supplement.*

GARD Analytics & University of Illinois: *Lecture Notes on Energy Plus*, © U.S.D.O.E. 2002-2003.

Grunewald J.: *Vorlesung DELPHIN4 und CHAMPS*, Lecture Notes, TU Dresden, 2008, 64 p.

Hadley S. W., McDonald J. M., Ally M., Tomlinson J., Simpson M. & Miller W.: *Emerging Energy-Efficient Technologies in Buildings: Technology Characterizations for Energy Modeling*, DOE Report ORNL/TM-2004/63, US Dept. of Energy Information Bridge, 2004, 55 p. http://www.osti.gov/bridge

Hannus M. (ed.): *REEB: Vision for ICT supported Energy Efficiency in Construction*, EU Project ICT-2007.6.3 REEB, Deliverable D4.1, 2009.

Hannus M. (ed.): *REEB: Strategic Research Roadmap for ICT-supported Energy Efficiency in Construction*, EU Project ICT-2007.6.3 REEB, Deliverable D4.2, 2009.

Hui S. C. M.: *Web-based Learning for Building Energy Efficiency- A Capacity Building Tool.*

Katranuschkov P.: *A Mapping Language for Concurrent Engineering Processes*, Report #1 of the Institute of Construction Informatics, TU Dresden, 2001, ISBN 3-86005-280-2.

Kiviniemi A., Rekola M., Belloni K., Kojima J., Koppinen T., Mäkeläinen T., Kulusjärvi H. & Heitanen J.: *Senate Properties - BIM Requirements 2007, vol. 1-9*, © VTT Technical Research Centre of Finland, 2007.

Mahdavi A.: *Lecture Notes in Building Science and Technology – Core Courses*, TU Vienna, 2009. http://www.tuwien.ac.at/lehre/masterstudien/architektur/masterstudium_building_science_and_technology/curriculum/core_courses/

Mayes T. & De Freitas, S.: *Review of e-learning theories, frameworks and models - JISC e-Learning Models Desk Study.*

Meinhold U.: *Architektonische Konzepte von energieoptimierten Gebäuden*, Lecture Notes, TU Dresden, 2008, 61 p.

Olof Granlund: *Company Web Pages*, http://www.granlund.fi/granlund_eng/frameset_suunnittelu.htm

Packham I., McNulty N., Vanderstockt Y. & Byrne M.: *Intelligent Control of Energy – A Reality for Building Management Systems*, in: Rafiq Y., de Wilde P. & Borthwick M. (Eds.) ICE08 – Proc. 15th workshop of the European Group for Intelligent Computing in Engineering (EG-ICE), Plymouth, UK, 2008, pp. 390-401.

Ploennigs, Joern: *Lecture in IT for Energy in Buildings Energy Efficiency Standards for Building Automation and Control Systems*, TU Dresden, Institute for Applied Computer Science

Roloff J.: *Bauklimatik für Architekten – Grundlagen der Bauklimatik 1 & 2*, 11th Ed., Lecture Notes, TU Dresden, 2006, 145 p.

Sathyanarayanan,V.: *Research Analyst Integrated Building Automation Systems – An Effective tool to reduce operating costs*, 2003 http://buildingtechnologies.frost.com/prod/servlet/market-insight-top.pag?docid=SBHR-5M5JJC&ctxixpLink=FcmCtx45&ctxixpLabel=FcmCtx46

Scherer R. J.: *Modellbasiertes Arbeiten*, Lecture Notes, MSc Module WP4-70, TU Dresden, 2008.

Scherer R. J.: *Management Information Systems*, Lecture Notes, MSc Study in Rehabilitation Engineering, TU Dresden, 2008.

Scherer R. & Katranuschkov P.: *Bauinformatik: Vertiefte Grundlagen*, Lecture Notes, MSc Module WP3-13, TU Dresden, 2008.

Schein, J.: *An information model for building automation systems*; National Institute of Standards and Technology, 100 Bureau Drive, MS 8631, Building 226, Room B122, Gaithersburg, MD 20899–8631, United States- 27 June 2005.

Schlueter A. & Thesseling F.: *Building Information Model Based Energy/Exergy Performance Assessment in Early Design Stages*, Automation in Construction 18(2), Elsevier B. V., 2008, pp. 153-163.

Weise M. & Liebich T.: *IFC Implementation Guide for Definition of Space Boundaries for Energy Analysis*, EU Integrated Project InPro, IP 026716-2, 2008, 27 p.

Wolfgang kastner, Georg Neugschwandtner, Stefan Soucek, and h. Michael Newman: *Communication Systems for Building Automation and Control*

Wolfgang Granzer, Wolfgang Kastner, Georg Neugschwandtner and Fritz Praus: *A Modular Architecture for Building Automation Systems*; Vienna University of Technology, Inst. of Computer Aided Automation, Automation Systems Group. Treitlstraße 1-3, A-1040 Vienna, Austria {wgranzer, k, gn, fpraus}@auto.tuwien.ac.at