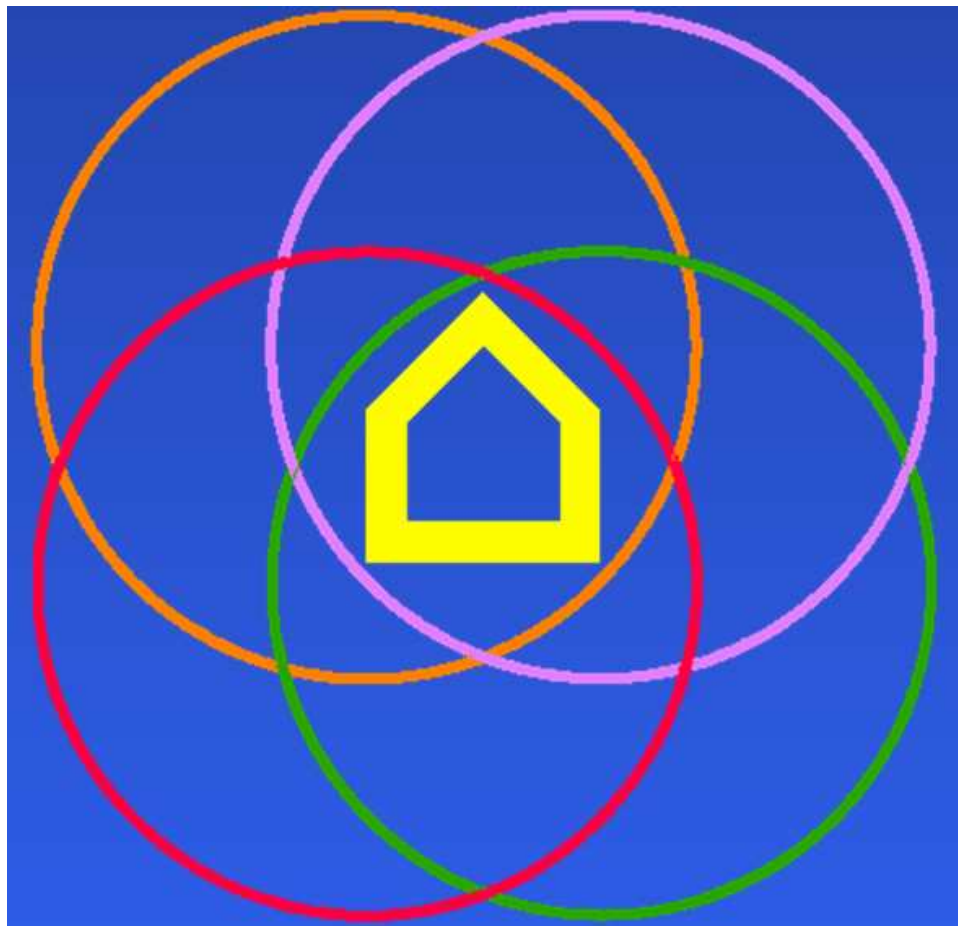


Method for Integrated design



By
Steffen Petersen, PhD candidate
and
professor Svend Svendsen
BYG.DTU
September 2007

Index

1	Introduction.....	3
2	Method for integrated design.....	4
2.1	Step 1: Establishing design goals.....	5
2.2	Step 2: Establishing design proposals for rooms and sections	7
2.3	Step 3: Generating proposals for total building designs	12
2.4	Step 4: Selection and optimisation of final building design	13
	Appendix.....	15

1 Introduction

A steadily growing awareness about the importance of the environment has increased the demand for sustainable development. This leads to an increasing pressure on building developers and designers to produce buildings with a high level of environmental performance. Chief amongst environmental loads from buildings is the consumption of energy from fossil fuels. More than 40% of the total energy consumption in the EU is related to buildings, which also mean that this is an area with significant potential for economic savings. The growing demand for sustainable development is reflected in regulatory performance requirements. In the EU, the Energy Performance of Buildings Directive (EPBD) is introduced as a regulatory initiative to improve the energy performance of buildings. The key objective in EPBD is to ensure that the energy performance of a new building is considered as a whole, rather than on an elemental basis. EPBD lays down requirements to a methodology for calculation of the energy performance of a building, together with a demand for a national minimum requirement for energy performance of a new building. Each country in the EU must then individually develop national calculation methods based on EPBD and set a minimum requirement for energy consumption.

Within the EPBD framework, a regulatory for performance-based requirements in terms of indoor environment prEN 15251 is to be implemented in the EU member countries ultimo 2007. The standard specifies how to establish indoor environmental input parameters for building system design and energy performance calculations. Furthermore, the standard specifies different categories of criteria for the quality of the indoor environment, which may have a significant influence on the energy demand.

As a consequence of the development described above, energy performance and indoor environment have become decisive design parameters in the process of building design. In this relation, it is important to understand that energy performance and indoor environment are in many cases dependent of each other. Many design decisions affect both energy performance and the indoor environment, and it may be hard for building designers to establish an overview of the consequences of their design decisions in terms of energy performance and indoor environment, and even harder to handle any overstepping of building performance demands. These facts call for new methods and tools to integrate energy performance and indoor environment in the building design process.

These notes present such an integrated design method. The method is considered a part of a total integrated design process where other building-related performance issues such as adaptability, flexibility and safety also are included in a suitable organisational and managerial context.

2 Method for integrated design

Many current building design approaches is not very efficient in terms of designing buildings with high energy performance and good indoor environment. These issues are often handled as sub problems rather than a part of the total solution. The traditional handling of these sub problems is to evaluate the random generated design geometries, which leads to either acceptance of the solution, rejection of the solution or expensive sub optimisation of the design. However, the risk of rejection and/or expensive sub optimisation is distinct, thus also the risk of wasting valuable time.

The proposed integrated design method is focusing on the identification of possible designs which fulfil predefined performance demands in terms of energy performance and indoor environment (design goals) prior to the actual building form giving. The main difference compared to more traditional approaches is that instead of rejecting and/or make expensive sub optimising of random building designs, this design method provides the building designers with a certain space of solutions. This space of solutions is not controlling the design process – it is merely a statement of the boundary conditions (like the chalking of a tennis court) in which all possible design decisions are possible.

The space of solutions is used to generate several possible designs of room geometries and sections which, because of the space of solutions, will fulfil the predefined design goals. Now the actual form giving of the building can start: the designer selects from the predefined rooms/sections and merge them in to suggestions for overall building geometries. The integrated design process described in simple steps is:

Steps in the integrated design process	Key persons
Step 1: Establishing design goals	Building owner, design facilitator
Step 2: Establishing design proposals for room and sections	Building owner, design facilitator
Step 3: Generating proposals for total building designs	Architects, experts, design facilitator
Step 4: Selection and optimisation of final building design	Building owner, design facilitator, experts

This process is managed by a so-called design facilitator who, together with the building owner, is the main actor in the integrated building design process. The design facilitator is helping the building owner throughout the building design process. The design facilitator helps establish explicit design goals, create the space of solutions and the design proposals. The design facilitator has access to a pool of competences (a team of experts) from which he/she can find relevant expert knowledge and help on any issues throughout the initial stages of the design process (step 1 and 2). When the design proposals are ready architects, construction engineers and other relevant competences are compiling a number of total building designs from which a final building design is selected.

In the following sections, the four steps of the integrated design process will be described more in details.

2.1 Step 1: Establishing design goals

The first step in the integrated design process is to set up design goals for the specific building. Design goals should be set up based on the building owner's ideas and wishes, which often contain some superior design goals/wishes such as type of building and the number of people using the building. It is the task of the design facilitator to explicitly outline the demands and wishes from the building owner in a way that the content and scope of the task is clear when presented to other participant of the building design team. The initial step (step 1) is therefore to define concrete design goals through series of performance demands. The design facilitator may involve different experts to help establish the design goals. It is important to outline, that anyone who is involved in this phase of the integrated design process should be in 'possibility-mode' – and certainly not 'solution-mode'.

Essentially, the process of setting up design goals should end up with a number of typical and/or repeated room typologies, e.g. single offices or open space offices, and set design goals regarding energy performance and indoor environment formulated as performance-based requirements. These design goals are to be fulfilled in the overall design in order to be successful in the eyes of the building owner. Therefore design goals are the decisive parameters in the design process and all design decisions should be evaluated with respect to these. No details should be described or decided on in this phase.

In the following, a schedule for obtaining and reporting the design goals is presented. The main idea is to suggest a standard process for the gathering information which is needed to state the design goals, and to have a structured way of reporting them. The suggested process is to use the schedule in Table 1. The schedule is filled out by the design facilitator together with the building owner. Throughout the process of establishing design goals, the design facilitator may use the core team for expert assistance and advice. The design goals should be considered as minimum demands and the filled out schedule work as outer limits for the further design process: every design decision is measured with respect to stated design goals.

The schedule comes with guidelines for each of cell of the schedule. These are found in appendix. Furthermore the appendix contains an example of a complete schedule for a dormitory apartment house for student couples.

Table 1: Schedule for reporting design goals

1 Type of Building		
1.1 Type		
1.2 Image		
1.3 Floors		
1.4 Site Information	1.4.1 Geographical location	
	1.4.2 Size of site	
	1.4.3 Shadows from surroundings	
2 Use of Building		
2.1 Occupants		
2.2 Number of occupants		
2.3 Space required	2.3.1 Room types	
	2.3.2 Size of rooms	
	2.3.3 Facilities required besides the main rooms	
2.4 Interactions between rooms		
2.5 Flexibility		
2.6 Special equipment required		
2.7 Working hours		
3 Indoor Environment: [fill in room type and size x/y/z]		
3.1 Thermal comfort	Class I, II or III:	
3.2 Lighting		
3.3 Air quality		
3.4 Acoustics		
3.5 Operational comfort		
3 Indoor Environment: [fill in room type and size x/y/z]		
3.1 Thermal comfort	Class I, II or III:	
3.2 Lighting		
3.3 Air quality		
3.4 Acoustics		
3.5 Operational comfort		
4 Energy consumption		
4.1 Energy Frame / Energy Class		
5 Safety		

2.2 Step 2: Establishing design proposals for rooms and sections

The design of a building is a process consisting of a number of design decisions which in the end defines a final building design. The outer boundaries of these design decisions are regulatory demands from building authorities combined with wishes and demands from the owner of the building project and there may be physical restrictions of the building site – all which is considered and handled in step 1 of the integrated design process. All alternative designs which fulfil these outer limits are in principle possible solutions. The task of step 2 in this integrated design method is to identify the solutions which fulfil the established design goals.

The possible solutions are found through parameter analysis which identifies constellations of performance-decisive parameters which fulfils the design goals. The output of this process is sketches of a suitable amount of room geometries and building sections which can be used to compose total building designs.

2.2.1 Parameter analysis and space of solutions

Current design approaches tend to be based on so-called ‘trial and error’ analysis, where building designs are generated and then assessed in terms of energy performance and indoor environment. The result of the assessment shows whether the specific design fulfils or does not fulfil the established design goals. The distinct risk for rejection of proposed building designs is a distinct risk of wasting time and resources. Furthermore, the results of the trial and error analysis tends to be non-transparent, meaning that causes of any performance overstepping are hard to identify and does not provide any information about how to avoid and/or eliminate these oversteppings.

Instead of using time and resources assessing random architectural building designs, this integrated design method suggests that a space of solutions is established. Space of solutions is the creation of boundary conditions for architectural design with respect to the initial defined design goals from step 1. It is based on parameter analysis of performance-decisive design parameters of the single rooms of the building. These parameters are shown in Table 2.

Table 2 Performance-decisive parameters of a room in a building

Geometry	Comments
Room depth	Internal measure
Room width	Internal measure
Room height	Internal measure
Overhang and side fins	
Building components	Comments
Window	Defined by U-value, g and L_T , and the placement and size of the window
U-value of opaque constructions	
Thermal capacity of constructions	The thermal mass of the building itself.
Thermal capacity of interior	Other thermal mass besides the building itself, like furniture.
Systems	Comments
Internal loads	People load and load from equipment.
Lighting	Internal heat load due to lighting.
Ventilation	Infiltration, natural/mechanical air change, heat exchanger efficiency.
<i>Controls</i>	
Set points summer	Depend on design goals in terms of indoor environment.
Set points winter	Depend on design goals in terms of indoor environment.
Energy data	Comments
COP heating	Coefficient of performance of the heating system
COP cooling	Coefficient of performance of the cooling system
Solar water heating	Amount of kWh/year heat generated from solar power
Photovoltaic	Amount of kWh/year electricity generated from solar power
SFP	Specific fan power for mech. ventilation system
Installations	Energy use for e.g. pumps and other building services
Hot water consumption	The amount of hot water used in the building.

Space of solutions is generated at room level. The procedure of establishing a space of solutions is as follows:

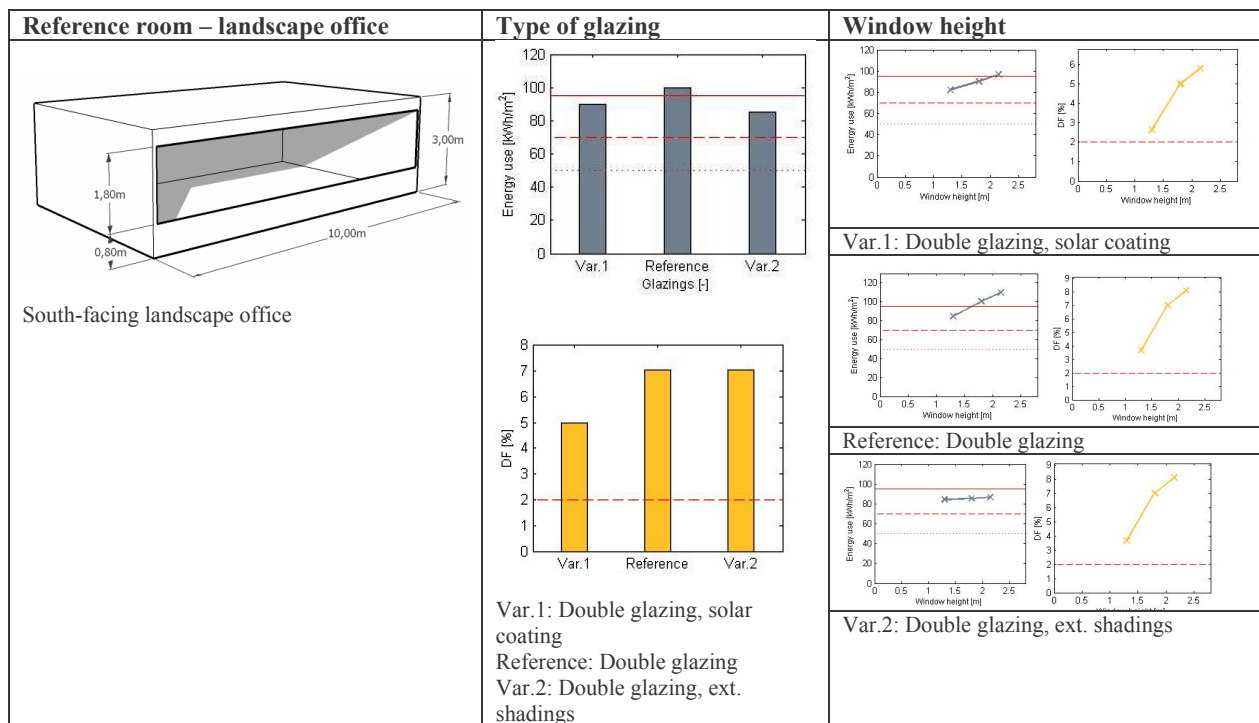
1. A reference of the room to be analysed is established based on the output from step 1. The reference is described in terms of the performance-decisive parameters of Table 2.
2. The reference is implemented in the tool iDbuild¹ together with the design goals for the indoor environment. iDbuild is a tool for parameter variations which is the main essence in the concept space of solutions: the parameter variations gives an overview of the consequences of any design decision in terms of energy performance and indoor environment and creates the dynamic boundary conditions of the space of solutions.

¹ iDbuild is an abbreviation of ‘integrated design of energy efficient buildings’.

A parameter variation is based on the reference value of a performance-decisive parameter and two variations of this: a lower value and a higher value. Designers may pick whatever performance-decisive parameter is found relevant to vary. It is important to pin out that the designer should be in a “possibility-mode”, not a “solution-mode”. The solution mode starts in step 3 of this method.

At present time, iDbuild only applies for office building with single sided offices, class rooms and alike, meaning that there can be only one window in the simulation model. Furthermore only buildings of simple shapes, like quadrangular shape, can be evaluated. A description of the program and how to use it is found within the program folder. An example of a space of solutions for a landscape office is shown in Table 3. The graphs to the right of the drawing of the reference room geometry are output data from iDbuild.

Table 3: This table contains two parameter variations; the type of glass/sun screen and the variation of window height for all 3 types of glazing. The room fulfils thermal and air quality class I (prEN 15251). The space of solutions illustrate that if the energy design goal is to reach the energy frame, the window height has certain restrictions dependent on the window component. Other parameter variations can, at will, be added to the space of solutions.



The purpose of the space of solutions (like in Table 3) is to show the relations between performance-decisive parameters, and the energy performance and indoor environment. This is very important to building designers: it gives them a chance to create an overview of the consequences of changing a performance-decisive parameter and at the same time shows the relative influence of the single or combined performance-decisive parameter in terms of the design goals. Based on this overview the designers are now able to perform transparent ‘consequence-conscious design decisions’ which does not conflict with the design goals. The designers may now go in to ‘solution-mode’ and use the space of solutions as a flexible platform for design decisions to create numerous design proposals for all room typologies established in step 1.

2.2.2 Design proposals – room level

When space of solutions is established the design facilitator, maybe with help from other experts, starts to generate a number of alternative design proposals for the different rooms in the building. The setup of a design proposal starts with no design decision, meaning that the space of solutions is completely open. As design decisions are made, the design proposal takes more and more form with increasing constraints on other design decisions as a consequence. One design decision is almost certain to exclude a number of other design decisions which were there before the design decision was made. Realisations like this may occur during the use of the space of solutions. But instead of just rejecting design decisions which exceeds the design goals, the integrated design process allows the designers to adjust either the design goals or to make other design decisions which compensates for the exceeding of the design goals. The designer may also go back to step 2 and add more parameter variations to the space of solutions which might compensate. Compensations may even be found in another room type of the building (this is discussed in section 2.2.3). It is only when no adjustments or compensations are possible that the design decision is rejected.

How to use the space of solutions depends on the creativity of the designer. The space of solutions does not dictate a solution; it merely shows the consequences of any design decision. An example of how to use the space of solutions is shown in the box below.

Example: Using the space of solutions

Problem:

A design decision allocates a large glazing area to the design, leading to excessive overheating and thus overstepping of the energy demand. Is the design rejected or are compensations possible?

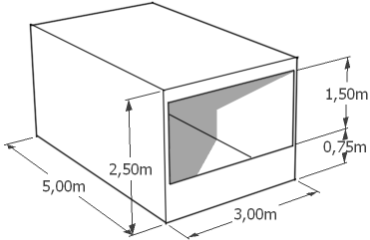
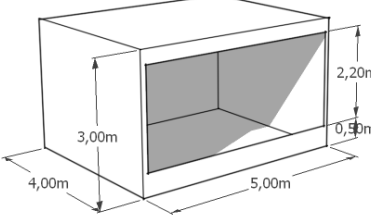
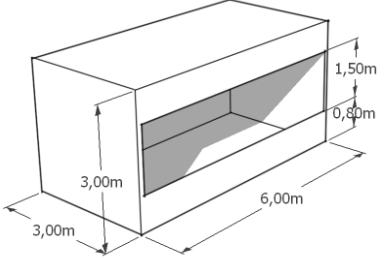
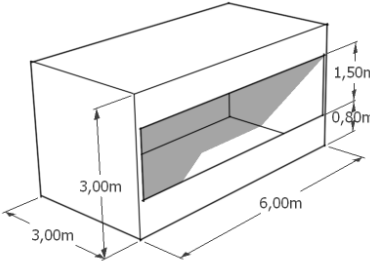
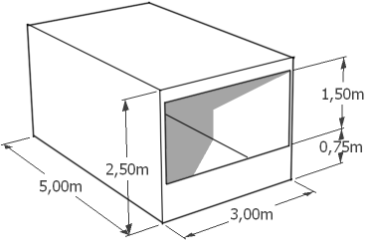
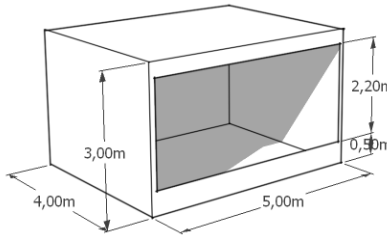
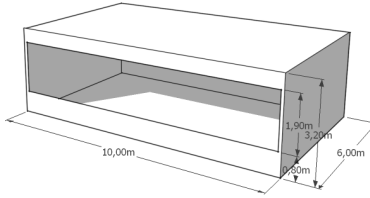
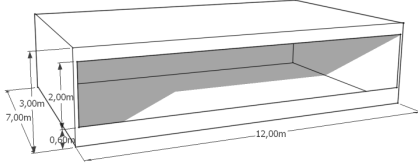
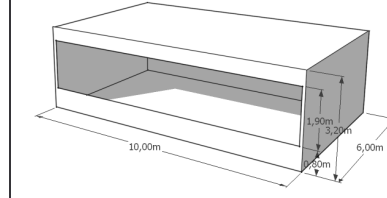
Solution:

Other parameter variation from the space of solutions shows a possibility for compensation. Certain external solar shading + a certain amount of night ventilation is compensating for the overstepping. The design now fulfils the design goal and is a valid design proposal.

In the above example, it is important to point out that the direct summing up the gains/losses in energy consumption and changes in indoor environment from different parameter variations in order to evaluate the influence of more than one parameter is usually not possible. Different parameters may interact with each other and essentially has to be assessed in a holistic perspective. The result will be very or somewhat different from the simple summing of the two separate measures. However, even though the summing results do not provide the correct energy consumption or indoor environment of a room (at least in terms of building simulations) it might give an indication of the “correct” result. In order to end up with more correct results in the generation of solutions, the design decisions based on the parameter variations should be put together in iDbuild simulation, hence getting more realistic results.

When a valid design proposal is established, it should be presented graphically. Usually the orientation of a room in a building is very important to its performance. Therefore it is suggested to establish a number of rooms which are fulfilling the design goals depending on the orientation as shown in Table 4.

Table 4: Rooms which are fulfilling the design goals depending on the orientation

2-person Office		
<i>South</i>	<i>North</i>	<i>East /west</i>
		
ID: Room1.1	ID: Room2.1	ID: Room3.1
		
ID: Room1.2	ID: Room2.2	ID: Room3.2
Landscape office		
<i>South</i>	<i>North</i>	<i>East /west</i>
		
ID: Room1.3	ID: Room2.3	ID: Room3.3

The graphical presentation of the possible room designs is to be presented to the rest of the design team and is the basis for the form giving of the entire building.

2.2.3 Design proposals – sectional views

When a number of possible room designs are established it is recommended to produce a number of possible building sections. The possible building sectional views have two purposes:

1. A help in the composition of total building designs (step 3). The sectional views may be a valuable help in the composition of the total building design. They can be used directly in the total building design or as illustrative examples.
2. Identification of possible compensation of oversteppings on room level in terms of energy consumption through total energy performances of sectional views. A single room design might not fulfil the design goal regarding energy performance. But by combining such a room with room designs, which have an energy performance lower than the

design goal, the total combination may end up having an area-weighted total energy performance which fulfils the design goal.

Suggestions for sectional views should, as the possible room designs, be presented graphically. As for the room designs, it is suggested to present a number of sectional views depending on the orientation, e.g. as shown in Table 5.

Table 5: Sectional views depending on the orientation

North/south sections			East/west sections		
Room2.1 (North)	Hallway (1.5 m)	Room1.2 (South)	2x Room3.2 (East)	Hallway (1.5 m)	Room3.3 (West)

The graphical presentation of the possible sectional views is to be presented to the rest of the design team and is the basis/help for the form giving of the entire building.

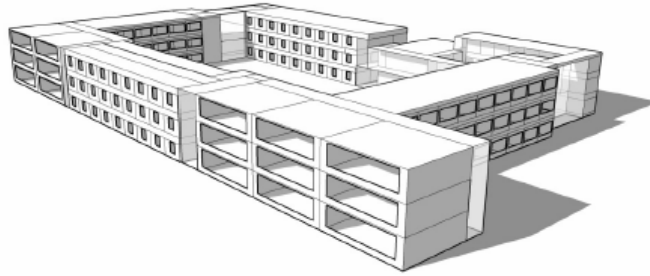
2.3 Step 3: Generating proposals for total building designs

The third step in the integrated design process is to combine design proposals of rooms and sectional views in to total building design proposals. The key person in this part of the process is the architect. The design facilitator presents the design proposals (rooms and sectional views) to the architect. The architect may, together with relevant experts, then freely combine the design proposals in to a number of total building designs which meets the established design goals from step 1 of the process. An analogy is that the architect is equipped with a number of toy bricks (like Lego blocks) with certain properties and constraints (the orientation of the block could be a constraint). These blocks can be combined in different ways into total building designs.

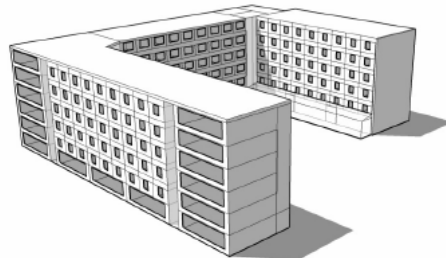
A total building design also includes considerations regarding constructional systems, HVAC routes, fire safety and other issues which is relevant on total building level.

If the overall form giving of the building is based on the room and section design proposals, the total building design will fulfil the design goals. A need for minor adjustments of the room and section design proposals may occur due to architectural considerations. It is then job of the design facilitator to assist the architect and, if possible, mend the space of solutions and design proposals. Furthermore, the team of various experts may also be asked to assist in the process. The sketches below are three examples of how proposed room and section designs are put together into total building designs. The two proposals are based on the same “pool” of design proposals.

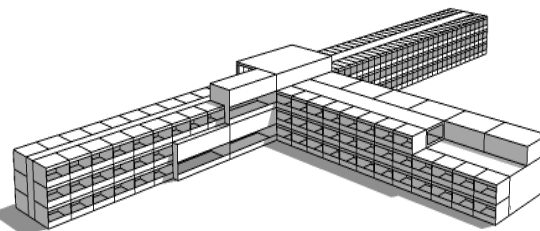
Design proposals for a university building with single offices, 2-person offices and different class rooms and auditoriums



Proposal 1



Proposal 2



Proposal 3

2.4 Step 4: Selection and optimisation of final building design

A number of total building design proposals are established in step 3. However, only a single total building design is to be built: one final building design has to be selected from the proposed designs for detailed design.

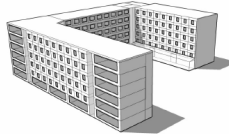
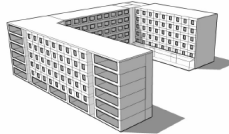

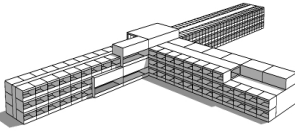

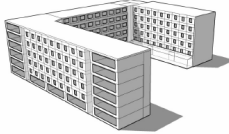
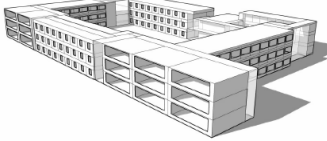
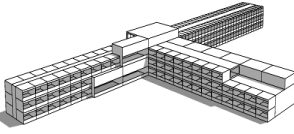
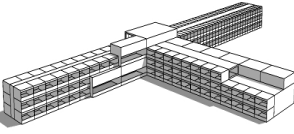
All of the proposed total building designs initially are fulfilling the design goals in terms of needed space, indoor environment and energy consumption. The only distinctions between them are:

1. Marginal differences in energy and indoor environment performance
2. The initial cost and/or total economy
3. The perception of architectural quality.

The building designs should be ranked within the three categories above. Unless one of the building designs is standing out e.g. with three top scores in each of the categories, the final building design must be found in a trade-off between marginal differences in energy and indoor environment performance, initial cost and/or total economy and architectural quality.

The set up of trade-offs is based mainly on the opinion of the building owner. If the building owner wants the initial and/or total economy to be low rather than marginal better indoor environment and architectural quality, then the trade-off is clear: solutions which is cheaper is more preferable than marginal better indoor environment (design goals are still fulfilled).

In the example below, the three building designs from step 3 are ranked in the three categories above. Proposal 2 is selected for detailed design based on the trade-off priority.

Rank	Energy and indoor environment performance	Initial cost and/or total economy	Architectural quality
1			
2			
3			

Appendix

1 Type of Building

1.1 Type

Determine what the building objective is; dwelling, company, institution, hotel etc.

1.2 Image

Describe whether the building should signal any specific image to the surroundings. It can be an objective that the building has a publicity or branding value for itself, the owner or other partners involved in the construction of the building. This could be architectural, characteristics or other distinctive features.

1.3 Floors

Number of levels in the building; single or multi-story building.

1.4 Site Information

Calculations on the indoor climate are very dependent upon the site location. Similar buildings located in e.g. Copenhagen and Cairo have very different circumstances to obtain a good indoor environment.

In Building Calc the site information is used to ensure that the right weather-files are used to evaluate the indoor climate in the building. Some simulation tools have many different location possibilities, other just a few.

1.4.1 Geographical location

Determine where the building site is situated; country, city, etc.

If there is a city- or district plan for the area setting up limitation for the building, it is important to research the issue and maintain the plan.

1.4.2 Size of site

Number of square meters on the site. Dimensions of the ground plan e.g. is the site rectangular, squared or triangular. Dimensions in the three dimensional plan e.g. are the site flat, inclining or undulating.

1.4.3 Shadows from surroundings

The level of shadows falling on the building from surrounding buildings or vegetation, are determined in the shadow factor. Whether a building are situated alone on a plane field highly exposed for the sun and wind or in a city among other buildings which covers the building by shadows most of the time makes a significant difference in the evaluation on the indoor climate.

2 Use of Building

The information about the occupants determined in this section will be useful when analyses of the indoor environment are performed. In Building Calc information on the volume of the room, heat load from occupants and electronics, working hours are required to evaluate e.g. PPD and number of overheated hours in the building. More information on PPD is found in the section regarding thermal comfort.

2.1 Occupants

Determine the type of occupants; e.g. children, adults, senior citizens etc. or a mixture.

2.2 Number of occupants

Determine the number of occupants in the building.

2.3 Space Required

2.3.1 Room types

Determine which room types primarily are required by the occupants. E.g. open-plan offices, classrooms, study facilities etc.

2.3.2 Size of rooms

Investigate if there is legislation on the square meters required pr. occupant, e.g. kindergarten and classrooms. If not, determine how many square meters is estimated to be needed.

2.3.3 Facilities required besides the main rooms

Beside the primary type of rooms in the building, decide whether other types of rooms are required, e.g. changing rooms, locker rooms, canteen, lecture hall, etc.

2.4 Interactions between rooms

There may be several considerations necessary to respect when thinking about the location of the rooms. E.g. students vs. professors at a university, how close it is desirable for the employees in an office to be seated (will they socialize too much or will too many conflicts arise) or are there special wishes to create a very creative environment for the users. Another consideration is how a pantry or toilet facilities are located in order to avoid disturbance of people not using the facilities.

2.5 Flexibility

In some buildings, e.g. offices, there is a wish to be able to re-arrange rooms, e.g. create large meeting rooms or small offices. When working in project groups it is convenient to be able to arrange the office sizes according to the project groups. The desired flexibility must be discussed.

2.6 Special equipment required

Amount of heat-generating electronic equipment in the building. E.g. number of computers in a classroom or in an open-plan office.

2.7 Working hours

Describe an average day or week. E.g. office work mainly in the daytime five days a week, a school used only half days five days a week, nursing home used around the clock seven days a week etc.

3 Indoor Environment

The requirements for the indoor environment should be in accordance with the European Standard prEN15251 (2006)², which specifies the indoor environment parameters influencing the energy performance of buildings. Further reading on the parameters described here and in prEN15251, is listed in prEN15251 (Normative References).

The standard utilises four categories classifying the indoor environment:

- I. High level of expectation and is recommended for spaces occupied by very sensitive and fragile persons with special requirements like disabled, sick, very young children and elderly persons
- II. Normal level of expectation and should be used for new buildings and renovations
- III. An acceptable, moderate level of expectation and may be used for existing buildings
- IV. Values outside the criteria for the above categories. This category should only be accepted for a limited part of the year.

² Indoor Environmental Input Parameters for Design and Assessment of Energy Performance of Buildings -- Addressing Indoor Air Quality, Thermal Environment, Lighting and Acoustics, CEN/TC156 WG12, 2006-07-31

The productivity of the occupants is often related to their well-being, which the building owner should take into consideration when setting up the requirements for the indoor environment.

It may be necessary to fill out section 3 of the schedule several times, depending on how different demands there are for the indoor environment in the room types required in the building. The empty schedule contains space for two different room types.

3.1 Thermal Comfort

Overall the thermal comfort can be determined from the Predicted Percentage of Dissatisfied (PPD) or Predicted Mean Vote (PMV), since these two considers the following parameters, which are influencing the thermal environment. The program BuildingCalc calculates the two indices. BuildingCalc needs information on temperature, clothing and activity level. The PMV or PPD is used to place the thermal environment in class I, II or III. The following explains the parameters involved in the indices.

Operational Temperature [°C]

When talking about thermal comfort attention should be paid to the season. During summer time occupants may be wearing lighter clothes than in winter, and thus require higher room temperature. Temperature categories exist for both summer and winter. Annex A in EN15251:2006 contains information on acceptable indoor temperatures. Danish legislation determines the design temperatures as 20°C indoors and -12°C outdoors (Danish Building Code and SBI 213).

Besides the operational temperature, the temperature difference between e.g. neck and ankles, radiant asymmetry, etc. are of importance to the thermal comfort. More information on local (dis)comfort is found in CEN Standard CR 1752:1998.

Relative Humidity [%]

Relative Humidity (RH) is important since too high RH may cause microbial growth and too low RH can cause mucous membrane irritations. RH between 20% and 70% would normally not have an impact on the thermal sensation and air quality of a room. For ordinary use of buildings the RH classifications as described in EN 15251, Annex B3 may be used.

Air Velocity [m/s]

The air velocity is closely related to draught. The Draught Rating can be calculated according to CEN Standard CR 1752:1998 (Section A.2.4.3 Draught), however, the risk of draught is also considered when calculating the PPD and PMV.

Clothing [clo]

The clothing of the occupants is important for thermal comfort and can be described in the unit clo. The clo-value of occupants can be found from from CEN Standard CR 1752:1998 (Table D.2 and D.3) or the values used in the example in Table A.3 in EN 15251 may be used, i.e. 1 clo (winter) and 0.5 clo (summer).

Activity [met]

The difference in activity level is crucial for the comfort temperature. Different types of work require different activity levels. From CEN Standard CR 1752:1998 (Table D.1) typical metabolic rates are found, alternatively the activity levels in Table A.3 in EN 15251 may be used, e.g. 1.2 met for sedentary work or 1.4 met for work in a kindergarten.

3.2 Lighting

3.2.1 Illumination [lux]

The adequate maintained luminance at work areas must be provided, when possible daylight should be utilised (cf. the following paragraph on Daylight Factor). Required task illuminance is defined and detailed in EN 12464-1 and in Table D.1 in Annex D of EN 15251:2006, e.g. 500 lux at the work area of a single or open plan office.

3.2.2 Daylight Factor [%]

According to the Danish Working Environment Authority it is recommended to have a Daylight Factor (DF) of at least 2 %. The DF is the ratio between the illumination in the point on the work plane and the illumination outdoors on a horizontal plane, illuminated by a full sky hemisphere.

In the prEN 15251:2005 there were classes for illumination and for the daylight factor. Since they have been removed in the 2006 version, the values in the following schedule may be used to categorise and evaluate the light (they are as they appeared in prEn 15251:2005).

Illumination Class	Category A	Category B	Category C
	The work task is well-visible, visual comfort is good, the lighting can be personally adjusted and gives a very good representation of colours.	The work task is well-visible, the visual comfort is good and the lighting gives a good representation of colours	The workdays is visible, visual comfort is moderate
Daylight factor (at centre of room)	5 %	3 %	1 %

3.3 Air Quality

In order to maintain good air quality indoors ventilation is necessary. Lack of fresh air can have many severe impacts and impact on the performance of occupants. Ventilation depends on occupancy (odour etc.), activities (smoking, cleaning, cooking etc.), pollution from equipment (printers etc.) and emissions from furniture and building materials.

In EN 15251 it is possible to design for different categories of indoor air quality. The methods described in Annex B can be used, e.g. according to Table B3. In Table B3 the required airflow per person for each category is stated together with the necessary airflow per m² depending on the pollution level of the building. It should then be decided upon whether the building will be built from low emitting material and equipped with low polluting materials.

Further, the Danish Building Code sets requirements for minimum ventilation rates. The relevant section in the Danish Building Code is 6.3 (the Building Code is in Danish).

When utilising BuildingCalc the infiltration should be stated as well. Infiltration will add to the ventilation rate, but is usually very low, especially in new, low energy buildings.

3.4 Acoustics

Especially when designing ventilation systems the noise must be considered.

Outdoor noise should be considered when windows are used for venting. The outdoor noise level should not exceed the desired category.

3.5 Operational Comfort

The operational comfort includes information on whether the occupants should be able to adjust installation, e.g. temperature controlling installations, ability to open windows, blinds etc.

For the occupant's comfort the control of e.g. windows is important. Windows allow for venting, furthermore view from the windows is important. Control of blinds is important not only due to the occupant's feeling of control, but also in order to be able to avoid glare problems, e.g. on the monitor. However, to avoid overheating automatic control of blinds and windows is required, since occupants will react only when it is too late.

4 Energy Consumption

4.1 Energy Classes

The total energy consumption for heating, hot water, cooling, ventilation and lighting in the building must not exceed the requirements described in the Danish building code. Lighting only applies for offices, schools and institutions.

The requirements in the building codes ensure a limit of the society's energy consumption for dwellings, offices, institution etc. Energy consumption in buildings belongs to one of the largest groups of energy consumption together with transportation. Energy use in building can be reduced and the legislation is therefore tightened – both to ensure continuous development of building technologies and to ensure that buildings are constructed in a reasonable way considering energy consumption and economy.

In Addendum 12 to the Danish building code from 1995, the requirements for apartment houses, dormitories and hotels and for offices, schools and institutions are described. In Addendum 09 to the Danish building code from 1998, the requirements for one-family houses are described. Furthermore, see the following table for the energy frames.

For each type of building described in the Danish building code, there are three different energy classes. One describes the maximum energy consumed in the building on regular basis; these requirements must always be met. In addition "Low energy building class 1" and "Low energy building class 2" describes two classes with more strict requirements for the energy consumption. The two low energy classes furthermore serves as the minimum requirements for maximum requirements in future building codes.

In the draft for the building code for 2008 a new energy class, "Low energy class 3", is introduced. Class 3 introduces new strict requirements for office buildings.

It should be decided in which of the above mentioned categories the building project should be placed.

Energy frame	Annual kWh / m ² heated floor area
Dwellings, dormitories, hotels etc.	$70 + \frac{2200}{A}$
Offices, Schools, Institutions and other buildings not covered by the above	$95 + \frac{2200}{A}$
Low energy class 3 (only applicable for the category above)	$70 + \frac{1600}{A}$
Low energy class 2	$50 + \frac{1600}{A}$
Low energy class 1	$35 + \frac{1100}{A}$

5 Safety

Safety requirements must be considered. Often considerations are done when choosing materials and planning the room distribution, e.g. in relation to fire protection. It is important to have sufficient escape routes, fire hoses etc. In certain buildings, e.g. chemical factories, the safety requirements demand special attention. It is often necessary to consult experts when dealing with safety and security issues.

Appendix 1 – Example of Complete Schedule

1 Type of Building		
1.1 Type	<i>Apartment house for dwelling purposes</i>	
1.2 Image	<i>Sustainable building</i>	
1.3 Floors	<i>Eight storied</i>	
1.4 Site Information	1.4.1 Geographical location	<i>Ørestaden, Denmark. Expanded area of Copenhagen city, no district plan</i>
	1.4.2 Size of site	<i>3500m², 100m x 35m, flat area.</i>
	1.4.3 Shadows from surroundings	<i>New building site, so far no shades from surroundings.</i>
2 Use of Building		
2.1 Occupants	<i>Students, 20-30 years old</i>	
2.2 Number of occupants	<i>256</i>	
2.3 Space required	2.3.1 Room types	<i>Two rooms-dormitory apartments with kitchen and bathroom</i>
	2.3.2 Size of rooms	<i>Estimated 60 m² per apartment.</i>
	2.3.3 Facilities required besides the main rooms	<i>Laundry facilities and bicycle storage in the basement.</i>
2.4 Interactions between rooms	<i>-</i>	
2.5 Flexibility	<i>-</i>	
2.6 Special equipment required	<i>Normal conditions</i>	
2.7 Working hours	<i>Around the clock</i>	
3 Indoor Environment: Bed- and living room (4/5/2.5)		
3.1 Thermal comfort	<i>Class I, II or III: II (winter: 20-25°C and summer: 23-26°C)</i>	
3.2 Lighting	<i>Estimated 500 lux at working desk and 200 lux room illuminance.</i>	
3.3 Air quality	<i>Class II (PPD 20%, 7 l/s pr. person, low polluting building 0.7 l/s, m²)</i>	
3.4 Acoustics	<i>-</i>	
3.5 Operational comfort	<i>Full flexibility</i>	
3 Indoor Environment: kitchen (8/4/2.5) and bathroom (3/4/2.5)		
3.1 Thermal comfort	<i>Class I, II or III: III (winter: 18-25°C and summer: 22-27°C)</i>	
3.2 Lighting	<i>Estimated 500 lux at working desk and 200 lux room illuminance.</i>	
3.3 Air quality	<i>Class III (14 l/s in kitchen, 10 l/s bathroom)</i>	
3.4 Acoustics	<i>-</i>	
3.5 Operational comfort	<i>Full flexibility</i>	
4 Energy consumption		
4.1 Energy Frame / Energy Class	<i>Low energy class I</i>	
5 Safety		
<i>No special requirements</i>		