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3X4 – EASY SPECIFICATION OF TECHNICAL INSTALLATIONS IN BUILDING ENERGY CALCULATION SOFTWARE

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ABSTRACT

The paper describes a strategy of how to implement technical installations (heating, domestic hot water and ventilation) in a building energy calculation application in an effective and userfriendly manner. Technical installations are designed using a 3x4 matrix (3 columns for the different technical systems; 4 rows for the system parts: generation (E), storage (S), distribution (V) and emission (Ü)). The 12 parts specified individually with information related to one specific part provided on-screen at any time, enhance the user friendliness substantially.

The entire system layout is updated on a continuing basis, showing possible conflicts (e.g. if a storage tank does not fit with a certain type of boiler).

The building energy calculation application, BuildDesk Expert - Energy Design, supports building designers in complying with the energy part of national building codes.

INTRODUCTION

Systems for heating, domestic hot water and ventilation are important parts of the energy balance of a building. The main reason for this is due to the fact that poor performing technical installations can completely ruin the energy performance of a rather well insulated building.

Traditionally, energy performance of buildings included the thermal performance of the building envelope limiting the thermal transmittance (U-value) or thermal resistance (R-value) of components (floor, walls, windows and roof). Inclusion of the performance of technical installations has only been performed in European countries in recent years, e.g. Germany in 2001 (EnEV, 2001) and Denmark in 2005 (EBST, 2005). Other European countries, like the Netherlands, included such technical installations as early as 1995 (NEN, 1995).

Figure 1 shows the development of energy performance calculation methods, which has been the case in most European countries.

Figure 1 Development of energy performance calculation methods

A major driver in integrating technical installations in building energy performance calculations is the EPBD, European Energy Performance of Buildings Directive (EPBD, 2002), which is currently under mandatory implementation in all countries in the European Union. The EPBD states that buildings should be measured on their energy performance including technical installations. This requires a revision of most European building regulations.

The revision of the national building regulations requires building designers to use specialized software to calculate the energy performance of building designs. Prior to the implementation of the EPBD, most European countries had thermal requirements to the individual components of a building. By calculating U-values (or R-values) for single components, it could be determined whether a design matched the requirements or not. With the EPBD such an easy approach is no longer possible. As the entire building performance has to be evaluated and reported on one (or very few) numbers or indices, software for handling both thermal performance of building envelope and the effect of technical installations on the thermal performance is needed.

Software for calculating thermal performance of buildings, including technical installations, exists in abundance. The U.S. Department of Energy maintains a list including many of such (DOE, 2005a) with DOE-2/VisualDOE (DOE, 2005b and AEC,

2004) and EnergyPlus/DesignBuilder (Crawly et al., 2004 and DesignBuilder 2005) which are well-known examples of such tools. Numerous studies like (Sullivan, 1998) and (Henninger and Witte, 2004) have confirmed the accuracy of calculating such tools.

Besides sole calculation accuracy of an application, two other items are of interest to a building designer.

- The application should have an easy-to-understand user interface, making it easy to perform necessary calculations.

- As several options are normally investigated, it should be easy to exchange one set of technical installations etc. with alternatives.

Many building energy calculation applications offer hour-by-hour calculation of temperature and energy flow, which is needed when working with innovative designs or innovative components. For a typical building design (e.g. standard detached houses, blocks of flats etc. which are built in thousands or ten-thousands), hour-by-hour simulations will be too advanced as the building energy code deals with energy consumption of the building on an annual or monthly basis.

ENERGY DESIGN APPLICATION

To support building designers in their work, a suite of building energy calculation applications, named BuildDesk Energy Design, has been developed. The suite consists of an application for calculating R- and U-values of components (named BuildDesk U), an application for calculating the energy performance of buildings (named BuildDesk Expert) as well as specialist modules for calculating retrofittings. All applications are nationally adapted so that calculations can be performed according to the individual national energy code requirements. Currently, applications exist for Germany, the Netherlands and the United Kingdom with more to follow.

Demonstration versions of the applications, which offer a 30-day trial period, are available from national BuildDesk web-sites. Links to national websites and building energy applications are found at http://www.builddesk.com.

Figure 2 shows the layout of the German BuildDesk Expert - Energy Design application, where a building design is calculated. The application offers a graphical input assistant which, in four to eight screens with a complexity equivalent to that of the screen shot in Figure 2, enables the user to calculate the energy performance of a building in an efficient way. The screens include input of:

- Shape of roof, floor plan and basement

- Dimensions and type of walls and floors

- Dimensions, pitch and type of roof

- Dormers and windows

- Technical installations (Domestic Hot Water, Space Heating and Ventilation)

The graphical input assistant assumes all exterior walls in a building are made of identical components, the floor place is rectangular, L- or T-shaped, and the building has a uniform temperature across the entire space (except for an unheated basement or unheated attic). It is expected that 80% of all buildings may be calculated based solely on this graphical assistant.

For a building of moderate complexity, these four to eight steps of the graphical assistant can be completed in less than 15 minutes using predefined components and technical installations provided by the BuildDesk Expert - Energy Design program. Later on it is possible to change e.g. wall types, modify the geometry to match the exact design or add the effect of thermal bridges. It is also possible to create own components, window types and technical installation systems.

Another option is to implement geometrical data from CAD, either by working with BuildDesk Expert in parallel to Autodesk Architectural Desktop 3.3 transferring data back and forth between the two applications, or by importing geometrical data written in a DXF-file, the de facto standard for transferring drawings between CAD systems.

Building Energy Calculation Results

Based on the input of geometrical data, components and types of technical installations in the building design, the energy performance of the building design is calculated.

The results calculated depend on the building code requirements of the country-specific software in which the calculation is performed. The main results of the German applications are the average heat loss coefficient of the building envelope and the annual gross energy requirement including all items of the pre-EPBD shown in Figure 1.

The results may be sent as PDF-files or printed on paper and formatted according to the requirements of the country in question.

TECHNICAL INSTALLATIONS

As technical installations have a strong influence on the energy performance of a building, they should of course also be included and described in a building energy calculation application. The level of detail of the technical installations should be equivalent to that of the building envelope, components, geometry etc. Furthermore, when looking at applications for

calculating the energy performance of buildings, one should distinguish between design tools for calculating annual energy consumption and tools for hour-by-hour calculation of temperature and heat flow. Of these, the latter may require much more information on the dynamic nature of the technical installations (among these, the schedule of the technical installations).

Technical installations in BuildDesk application

The BuildDesk Expert – Energy Design application calculates according to the national standards. As standards differ from country to country, so does the calculation principles in the applications for the Netherlands and Germany.

This paper deals strictly with the German BuildDesk Energy Design application as a special module for technical installations has been developed and integrated in this application.

The technical installation module is based on equations and data supplied by the German standard on "Energy efficiency of heating and ventilation systems in buildings", (DIN 4701-10, 2003). What is new in this application is not equations or data, as these are already known and published, but the way the technical installations of a building are created and may be edited, i.e. the user-interface of this specific part of the application.

The first data to be provided to the technical installation module in the BuildDesk Expert Energy Design application is the expected annual heating demand (per m^2/building) and the area of the building. For each of the three technical installations parts (domestic hot water, space heating and ventilation) a number of system build-ups are possible as shown in the following

Domestic hot water:

- None
- One system per building
- One system per dwelling
- Decentralised (at each hot water tap)

Space heating:

- Water based
- Electricity-based with directly heating
- Electricity-based with heat storage

Ventilation:

- None
- Central exhaust ventilation (one outlet / project)

- Centrally balanced ventilation (one inlet/outlet / project)
- De-centrally balanced ventilation (several inlets/outlets / project)

Once the basic system type for domestic hot water, space heating and ventilation has been identified using dropdown menus, the more detailed specification is initiated. Figure 3 shows the technical installation design matrix of BuildDesk Expert once the basic system type for the technical installations has been decided.

Exact specification of technical installations

Details on the technical installations are specified by activating each of the 12 icons in the technical installation design matrix. The icons represent generation (E), storage (S), distribution (V) and emission (Ü) as well as the use of domestic hot water ("Trinkwasser"), space heating ("Heizung") and ventilation ("Lüftung"). In practice, only 10 icons are operable as storage in a ventilation system does not make any sense and taps in a domestic hot water system cannot be changed from a standard value.

By activating of one of the icons, a specification screen is provided. Figure 4 shows the layout of a specification screen when implementing generation device(s) of a domestic hot water system.
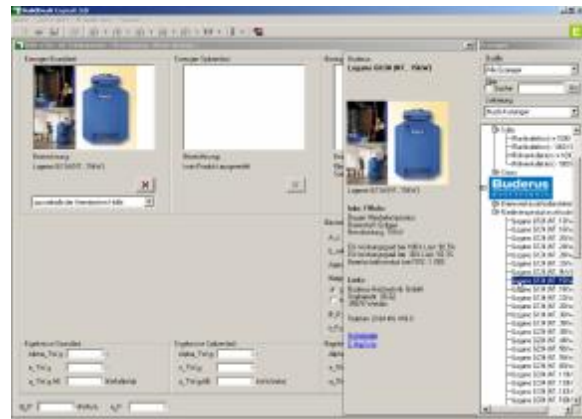

Figure 4 Detailed implementation of a gas boiler and a solar collector as the energy source in a domestic hot water system. Besides generic (non-manufacturer specific) components, the software provides catalogues of gas boilers etc. from manufacturers.

Once suitable components have been identified in the catalogue, the generation of the domestic hot water (using boiler, solar collector, heat pump, electricity etc.) will be specified. The user can then move on to other parts of the technical installations, such as defining heat storage, possible circulation of water, radiator/convector-heating or floor heating system, heat exchanger in the ventilation system etc. It is possible to define the parts in detail, specifying type

of equipment, controls etc. for all parts of the technical installations.

A possible technical installation system may look like the one visualized in Figure 5. The system shown in Figure 5 is a combined gas boiler/solar collector with a storage tank and hot water circulation for domestic hot water, an identical boiler and floor heating system for space heating and a balanced ventilation system with a heat exchanger and heat pump.

It should be noted that, even though two boilers are shown in Figure 5, only one is installed in the actual building. Once a boiler is defined either for the domestic hot water or the space heating, the BuildDesk Expert application asks if the boiler is also to be used to heat the other types of water.

Another thing to be noted in Figure 5 is that the space heating system does not have a storage tank of its own. Instead the storage tank of the domestic hot water is used as storage for domestic hot water. If needed, an extra storage tank (only to be used by the space heating system) may be installed.
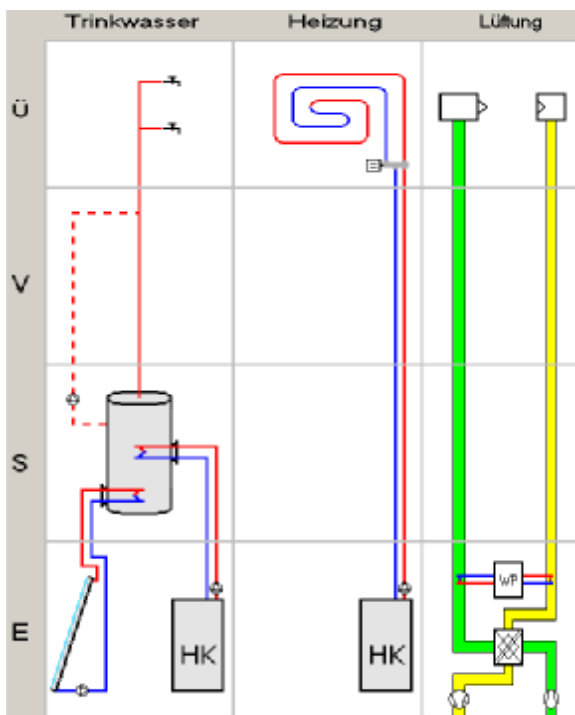

Figure 5 A possible system of technical installations in BuildDesk Expert. The system includes a combined gas boiler (HK) and solar collector, a storage tank, floor heating and a balanced ventilation system with heat exchange and heat pump.

The technical installations may then be saved in a database and utilized in a building design – either a design currently being made or for future projects.

Checks of logic

Besides containing information on the physical properties of a specific component (e.g. efficiency and peak load), the built-in catalogue also contains information on the usage of the specific component. This means that the application secures that a storage tank is not inserted instead of a boiler etc. Figure 5 illustrates a correct and an incorrect implementation of a component in the field where solar collectors are implemented.
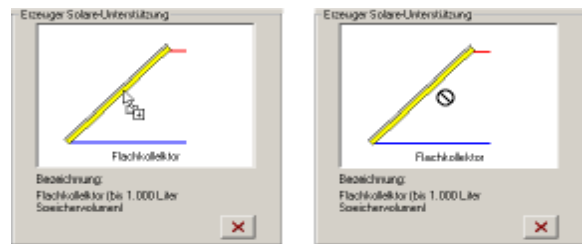

Figure 6 On the left side, a solar collector is correctly placed in the field for solar collectors (the cursor has a small plus showing a correct implementation). On the right side, a boiler is attempted instead of a solar collector. The cursor changes to a "forbid" sign, signaling that a boiler cannot be inserted here.

Other checks of logic concern the combination of different parts in a system. Figure 7 shows two examples marked in orange of inconsistencies in the technical installation system.
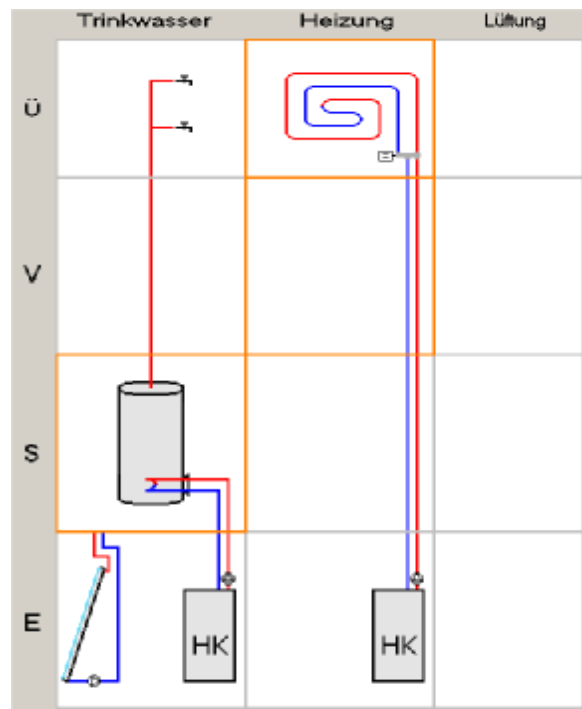

Figure 7 Checks of logic in application shows inconsistencies (storage and floor heating system)

By examining the technical installation system shown in Figure 7, one inconsistency is evident. The heat generating unit(s) of the domestic hot water is a gas boiler and a solar collector, but the storage tank is of a kind which is only suitable for a gas boiler system without a solar collector. It requires either another storage tank or the removal of the solar collector to solve this inconsistency.

The defects in the modeling of the floor heating system are not evident based on the graphical representation of the system. The software has a context sensitive help system which offers guidance on the "defects" of the technical installation system. Throughout the application, the values are initially on the safe side (highest possible energy demand), and requires an action from the user to confirm other settings. As default, the supply/return temperature of the floor heating system is $90^{\circ}C/70^{\circ}C$ which is too high in a floor heating system. By lowering the supply/return temperature to $35^{\circ}C/28^{\circ}C$ the issue is solved.

A COMPLETE ENERGY CALCULATION

Once a technical installation system has been created with the 3x4 matrix, the energy performance of the entire building design may be assessed. Options are either to take advantage of the graphical assistant (which lets you model the geometry of most single family houses within 10-15 minutes) or to enter all surfaces one-by-one in a detailed way (if the floor plan of a building cannot be described using simple geometrical shapes). To support the construction of the model, built-in catalogues are available containing the 200+ most used components (exterior and interior walls, floors, roofs and windows).

Once the geometry of the building design is modeled (including structural elements, windows, dormers etc.), the technical installations are attached to the model. The annual primary energy demand, average U-value and other vital numbers describing the energy efficiency of the building are then calculated according to the national regulations.

The flow through the step-by-step graphical assistant, including implementation of a defined system of technical installations is shown in Figure 8.

Having completed the model in the graphical assistant, the user can change the model individually. Items which may be changed include, but are not limited to, the following:

- Expected air-tightness of building envelope

- Thermal bridges, thereby lowering a penalty enforced on the average U-value of the building envelope

- Adding surfaces (if a building includes two roof systems, half of the original system

could be removed and a new system could be inserted instead)

- Removing surfaces (in case of terraced houses, two surfaces are adiabatic, and should not be included in the calculations)

- Change of boundary conditions (another option when working with terraced houses with adiabatic surfaces)

- Change of components (if a building design had three masonry walls and a wooden wall, the graphical assistant would be completed by implementing masonry walls on all four sides, and the single wall would be changed afterwards)

FUTURE DEVELOPMENT

Although BuildDesk Expert - Energy Design is already an advanced tool, the development of the calculation standards in Germany pushes the development even further. Due to the EPBD (2002), cooling and fixed lighting is to be included in energy calculations for all non-domestic buildings. This will come into force no later than 4 January 2006.

2006 will also bring a new member into the BuildDesk Energy Design family. A Bestandsenergiepass (energy labeling of buildings) application based on the BuildDesk Expert programme recently underwent a successful field test together with a number of other building energy applications.

CONCLUSION

In this paper an application for calculating the energy performance of buildings was presented. The main focus was on the design and functionality of the part of the application in which systems of technical installations are designed.

The application offers an intuitive user interface combined with catalogues of a large number of boilers, hot water storage tank and ventilation parts. These items, combined with calculations which are in line with the latest national codes and standards, ensure results of a high quality (the BuildDesk Expert - Energy Design application is DIN certified in accordance with DIN CERTCO (2002).

By following the creation of a system of technical installations such a system is easily integrated into a building design, and offers a calculation of the annual primary energy demand of a building in accordance with the national building codes and the European Energy Performance of Buildings Directive (EPBD, 2002).

As the user interface of the application is easy to understand aimed at both architects and engineers,

the goal of this application is to increase architects' knowledge on energy design of buildings, and to improve the communication between architects and engineers during the design phase.

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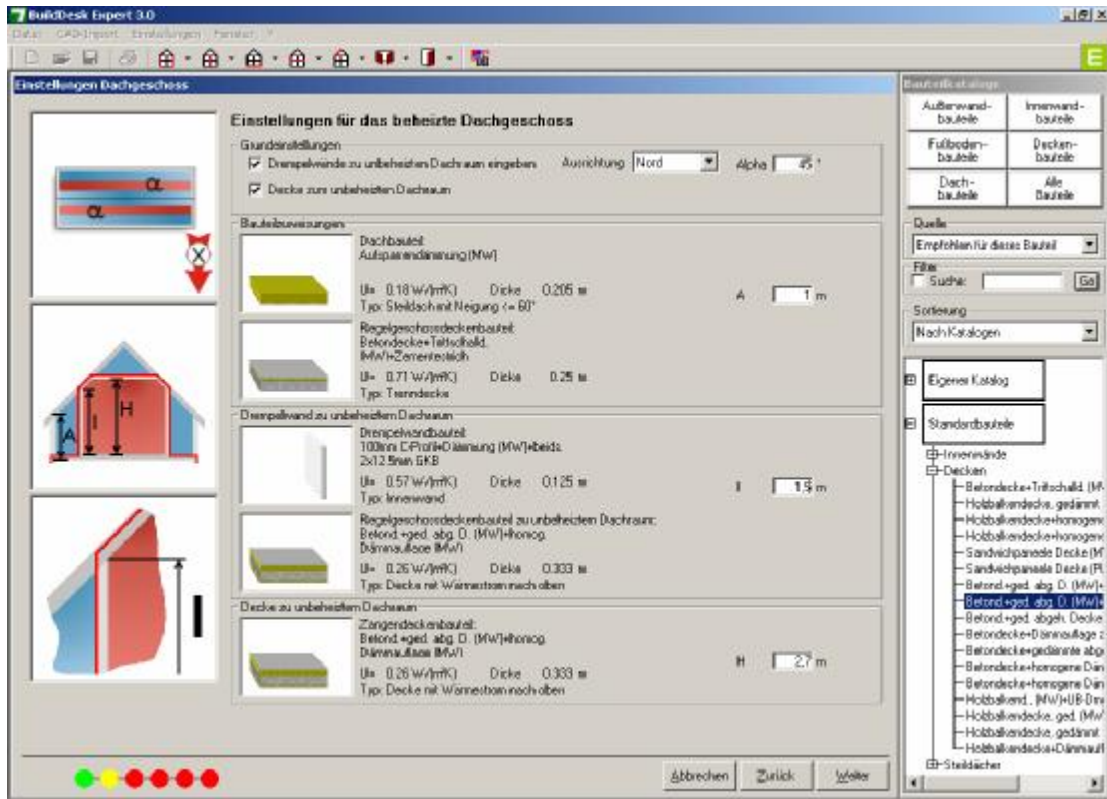
Figure 2 Layout of BuildDesk Expert - Energy Design application. Components for roofs are easily implemented into the design by drag-and-drop
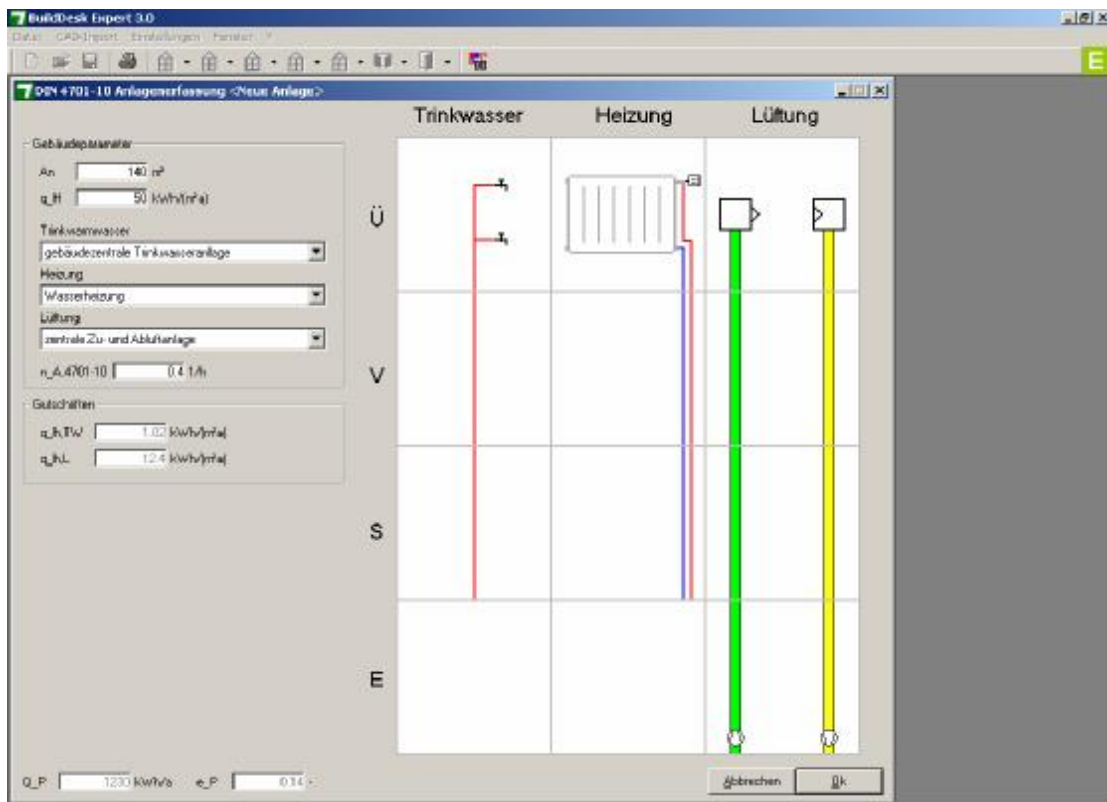

Figure 3 Layout of the technical installations designer in BuildDesk Expert - Energy Design application. Components are further specified by clicking on the appropriate box of the 3x4 matrix.
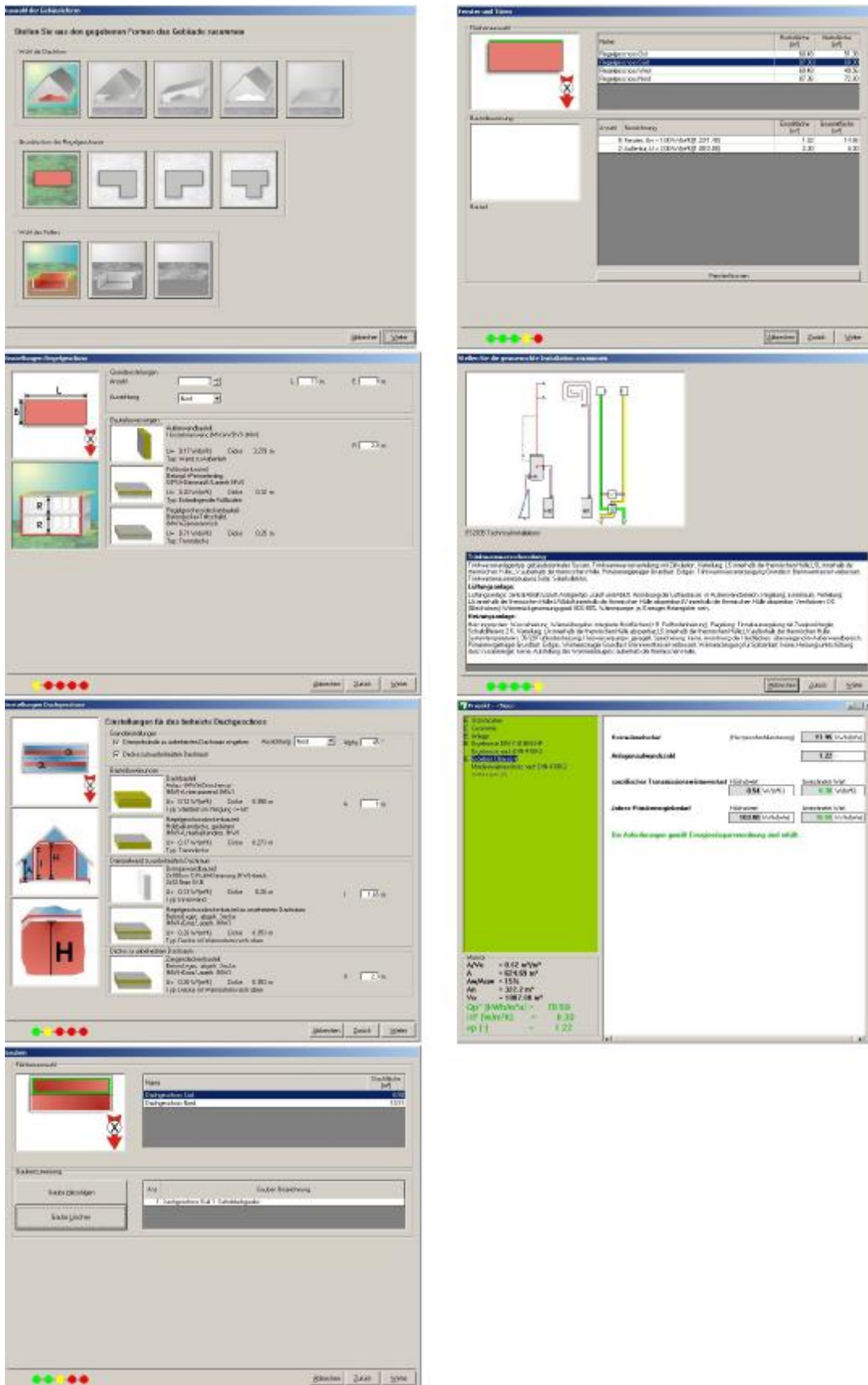
Figure 8 Overview of the different steps to be completed to perform an energy calculation of a typical building using the BuildDesk Expert Energy Design application. The left column shows the first four steps (shape, floor plan, roof and dormer); the right column shows the last three steps (windows, technical installations and results). The model may then be edited individually further on from here