EIC Visualizer, an intuitive tool for coupled thermal, airflow and daylight simulations of residential buildings including energy balance of windows

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SUMMARY

The use of detailed building energy simulation tools is less common in the design of residential buildings than for non-residential buildings. Simple tools exist, but they rarely include detailed daylight and airflow models as offered by the detailed tools. The Energy and Indoor Climate Visualizer offers the detailed analyses necessary for holistic design of sustainable residential buildings while providing a fast, simple and intuitive user interface.

The simulation engine is based on the existing and validated tool IDA ICE, which provides a detailed coupled thermal and airflow model that calculates ventilation and infiltration airflows based on driving forces for each of the dynamic time-steps, as well as temperatures and energy flows.

The user interface is based on 7 tabs which guide the user through the simulation process. The results presentation is based on a single, printable report which summarises all main results on energy, air quality and thermal comfort. Ventilation flows through windows can be animated and temperatures can be investigated on a daily or weekly level. Temperatures are evaluated based on the comfort categories of EN 15251 which vary with the outdoor temperature for naturally ventilated buildings.

INTRODUCTION

Increased focus on energy performance of buildings makes building energy simulations ever more important. The simulation tools available to building designers have evolved to reflect this, and many tools exist that can determine the energy performance of buildings, each tool with its own individual focus.

Following the higher requirements for thermal performance of the building envelope, the heating demand of buildings is decreasing. Consequently, the proportion of energy used for ventilation, cooling and lighting of buildings has increased over the years. The introduction of the Energy Performance of Buildings Directive has led to a more holistic evaluation of the energy performance, taking most of the energy related parameters into account.

Most countries have their own de-facto standard tools, which are often general simulation tools applicable for many different building types. Essentially, this means that they are tailored for commercial buildings and require some experience or expertise to use. They can be used for residential buildings, but offer options that are not essential for residential building simulations.

Consequently, building simulation tools are not commonly used for design or renovation of single-family houses, as the professionals involved in the projects rarely have the background or expertise to use the general simulation tools.

Tools have been developed specifically for single-family houses [1, 2, 3], but using such tools is still not common practice in single-family house design. The existing tools are often without specific focus on the potentials of natural ventilation, solar shading and daylight.

Most existing residential buildings, as well as many new buildings, are naturally ventilated. To determine the optimal balance between indoor air quality and energy demand, detailed control options for natural ventilation are necessary. And the airflow models used in the tool must be based on opening characteristics and pressure balances rather than assuming constant "infiltration" airflows. Moreover, to take the energy savings potential from daylight into account in the electric lighting calculation, an accurate calculation of the daylight level in the building at a given time is necessary.

Apparently, the existing tools are either detailed, general tools requiring experienced users, or fast and easy-to-use, but without the detailed control options and models for daylight and airflow-thermal-coupling found in the detailed tools. The purpose of the Energy and Indoor Climate Visualizer is to fill this gap.

METHODS

Scope

The Energy and Indoor Climate Visualizer (EIC Visualizer) [4] has been developed to provide a simple and intuitive user interface, while providing a detailed coupled airflow and thermal model. It uses the IDA ICE 4.0 engine and is a custom implementation of IDA ICE by the developers of IDA ICE [5]. The input required to make a model of a building has been selected so that no specific building energy simulation experience is needed by the user. All other input settings are predefined.

The focus of the EIC Visualizer is windows, as sources of heat losses and gains, but also as sources of light and ventilation. It is flexible as it regards different types of panes in combination with different types of internal and external solar shading. It allows flexible control of both solar shading and natural ventilation. The EIC Visualizer uses a detailed coupled airflow and thermal model for ventilation, i.e. infiltration, mechanical ventilation and controlled natural ventilation.

It is the intention to make thermal simulations available to new users without building simulation experience: small architectural offices, single-family house contractors, installers, etc. Results can be analyzed based on a customizable results report which includes advice and guidance in the interpretation of the results presented. The EIC Visualizer is free for download on http://eic.velux.com.

Intuitive workflow

The navigation in the Energy and Indoor Climate Visualizer is based on seven tabs, which provide an overview of the steps to be taken to perform a simulation:

- Geometry
- Constructions
- Windows and doors
- Heating and cooling
- Light and ventilation
- Start simulation
- Results

The tabs guide the user through the simulation process and the tab structure makes is it clear where the user is in the simulation process and provides an intuitive workflow.

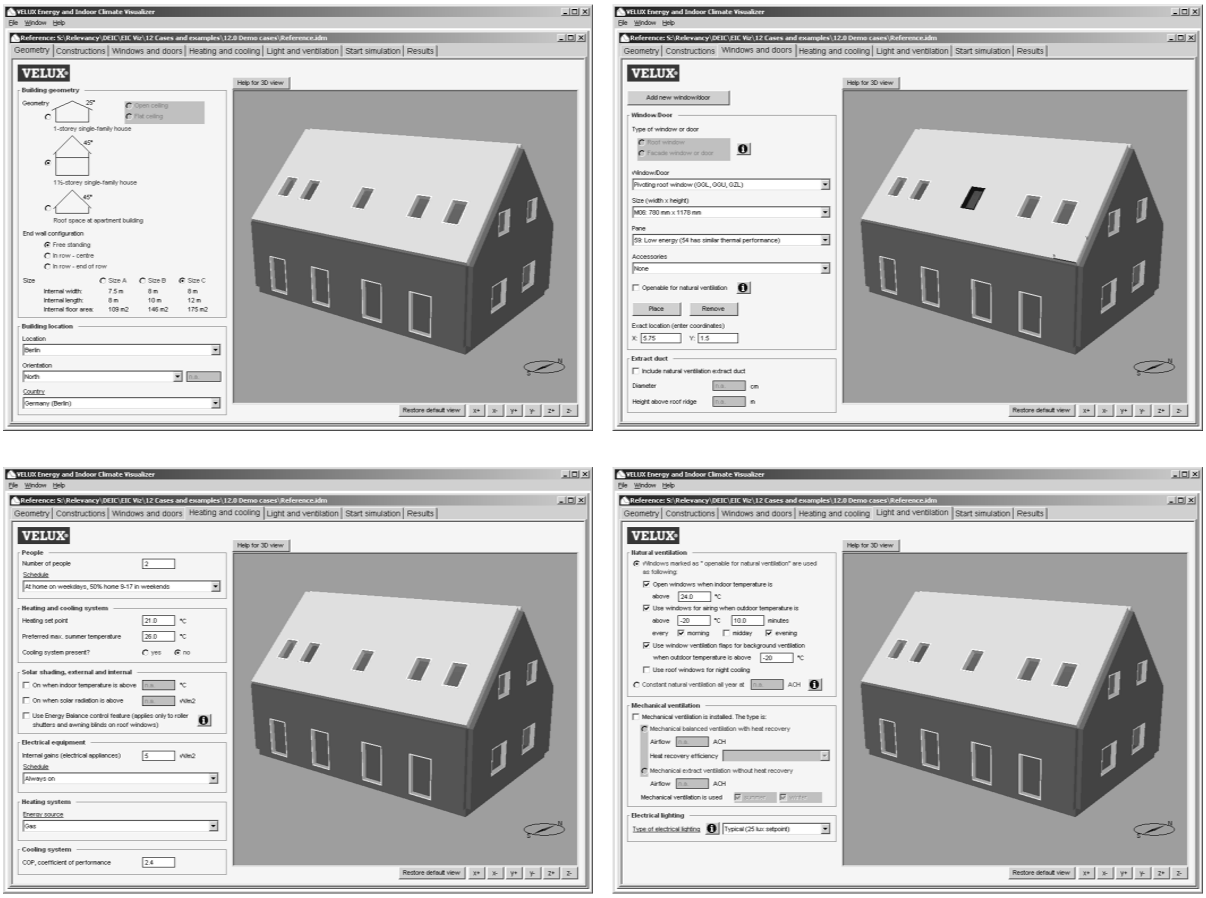

Figure 1. The user interface of the Energy and Indoor Climate Visualizer with the Geometry tab active (upper left), Windows and doors (upper right), Heating and cooling (lower left) and Light and ventilation tab (lower right)

Model implementation

A number of pre-defined house geometries are available. The construction of the roof, wall and floor can be selected from a list of pre-defined construction types, or the pre-defined construction types can be customized.

The airflow model used in the EIC Visualizer is a pressure driven model. Cracks in the building façade and windows are defined with regards to airflow characteristics. The result is a calculation of airflow that considers infiltration through the façade and controlled natural ventilation through windows as one, i.e. these two components constitute the airflow and thus the ventilation rate of the building. Windows are defined with a maximum openable area, and the opening is modulated up to this area according to the control options selected.

The controls for natural ventilation are designed to mimic typical use of windows as providers of natural ventilation. The following control options for natural ventilation are available and can be used individually or in combination:

- Open to maintain the indoor temperature below a specified set point
- Airing for a specified duration morning, midday or evening
- Use of ventilation flaps/vents for background ventilation
- Night cooling

The optical properties of windows are defined by τ_e, τ_v and g. EIC Visualizer relies on a database of measured values from a range of pane-shade combinations to correctly account for the combination of pane and shading device. The same standard attenuation as a function of incidence angle is applied to all pane-shade combinations.

The thermal properties of windows are defined by the U-value of the frame and the angle-dependent U-value of the pane. The Ψ-value between pane and frame is included, as well as the Ψ-value between frame and building envelope. If solar shading is active, the U-value is adjusted according to the measured thermal resistance of the shading.

The EIC Visualizer supports the concept of Dynamic Windows, where the solar transmittance and thermal resistance are optimized for the current time-of-day, season and climate, with the use of solar shading.

The electricity demand for electrical lighting is determined based on the amount of daylight entering the building as an average of the lux level on a working plane. The daylight model, calculates the target position of the direct light beam from each window. Each surface that is hit will then reflect diffusely. A radiosity model is applied to negotiate diffuse light exchange according to approximate view factors.

The default values for installed power of electric light include the effect of light fixtures. The control of electric light is based on a set point for the minimum light level. When the daylight level is below the set point, and when there is a need, electric light will be used to increase the light level towards the set point.

The EIC Visualizer is based on the IDA ICE 4.0 engine as a custom interface developed by EQUA. IDA ICE has been validated as part of several studies, including validation exercises as part of IEA task 34 [6], IEA task 22 [7], and IEA task 12 [8]. A validation against CIBSE TM 33 showed good agreement between IDA ICE and CIBSE TM 33 [9].

RESULTS

Presentation of results

Results can be accessed at two levels. At the advanced level it is possible to obtain the results expected from general simulation tools, i.e. customizable charts detailing the building energy balance, temperatures, airflows, etc. on hourly basis.

The standard level of accessing results is based on a printable results report, which provides an overview of the energy performance of the building. Users without building simulation experience can select to have additional advice and guidance included in the report, which will assist them in the interpretation of the results. The results report is divided into sections on Energy, Thermal comfort, Ventilation, and Light.

The report can be generated for one building or as a report which compares results for several buildings. The comparison report is particularly useful for case studies. Examples of results graphs are seen at Figure 2.

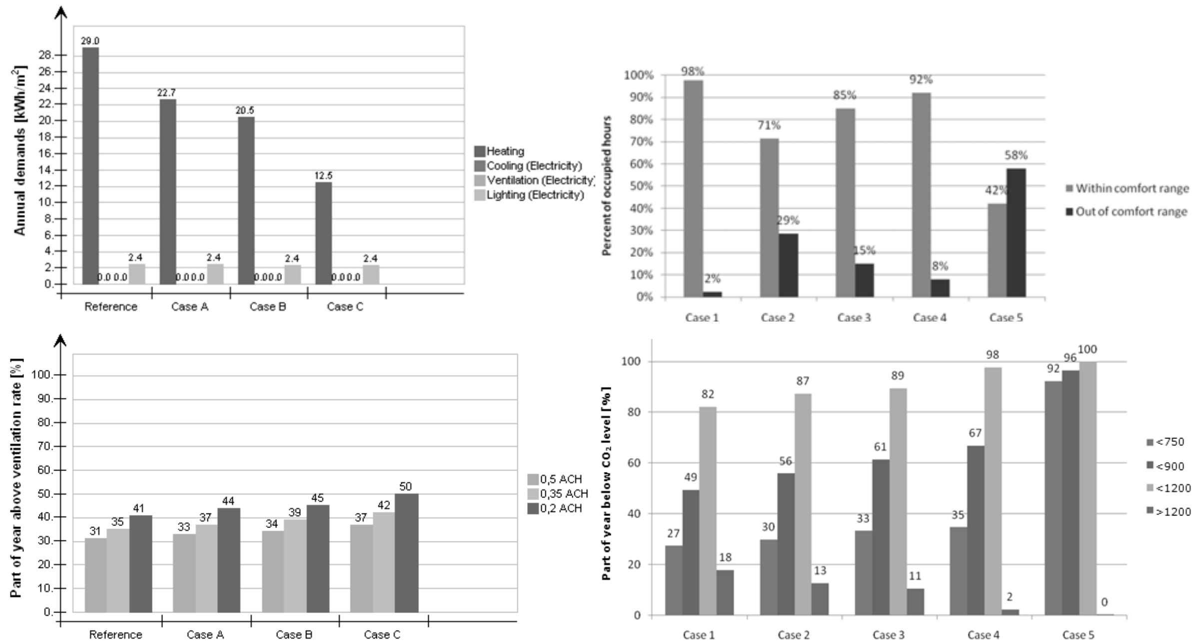

Figure 2. Results as presented in the comparison report. Energy demands (upper left), thermal comfort (upper right), ventilation rates (lower left) and CO_2 levels (lower right)

The thermal comfort results are given according to EN 15251 using the adaptive approach based on a running mean outdoor temperature [10]. This approach is implemented in the EIC Visualizer. Results within comfort categories I-III are categorized as “within comfort” range, while results within category IV are categorized as “outside comfort range”. Using the adaptive approach provides more meaningful results for naturally ventilated buildings than counting hours with a temperature above a specific threshold, especially in warm climates.

Operative temperatures can be displayed in a graph with the comfort range shown as a solid in the background for investigating of the thermal conditions on specific days or weeks, see Figure 3. The comfort range will change depending on outdoor temperature.

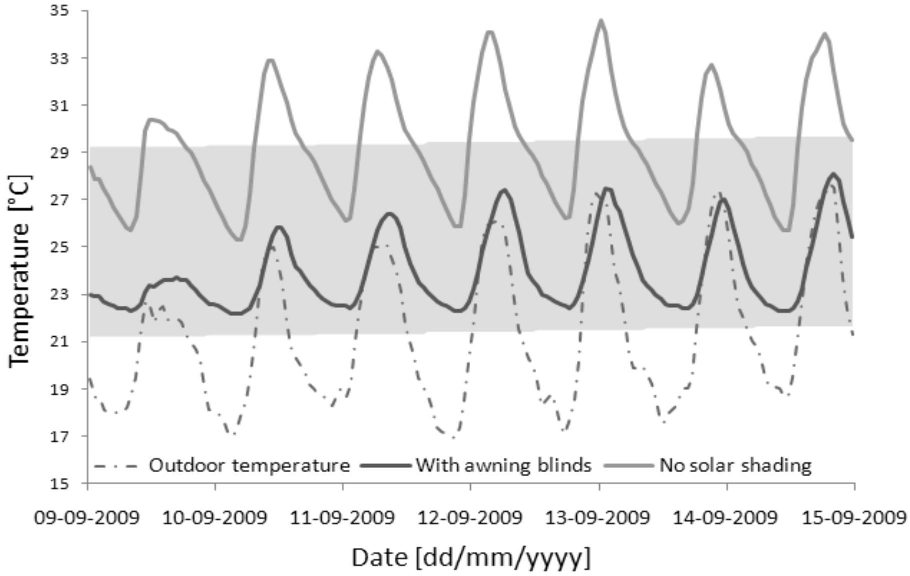

Figure 3. Presentation of operative temperature of the simulations with the comfort range (solid grey) based on running mean outdoor temperature.

Ventilation rates and CO_2-levels are used together to indicate the air quality of the house. Four categories of CO_2-levels are used, based on the levels proposed in EN 15251.

Natural ventilation flows through windows can be investigated through an annual animation. The airflows are visualised as coloured arrows with size and colour representing the flow magnitude, see Figure 4.

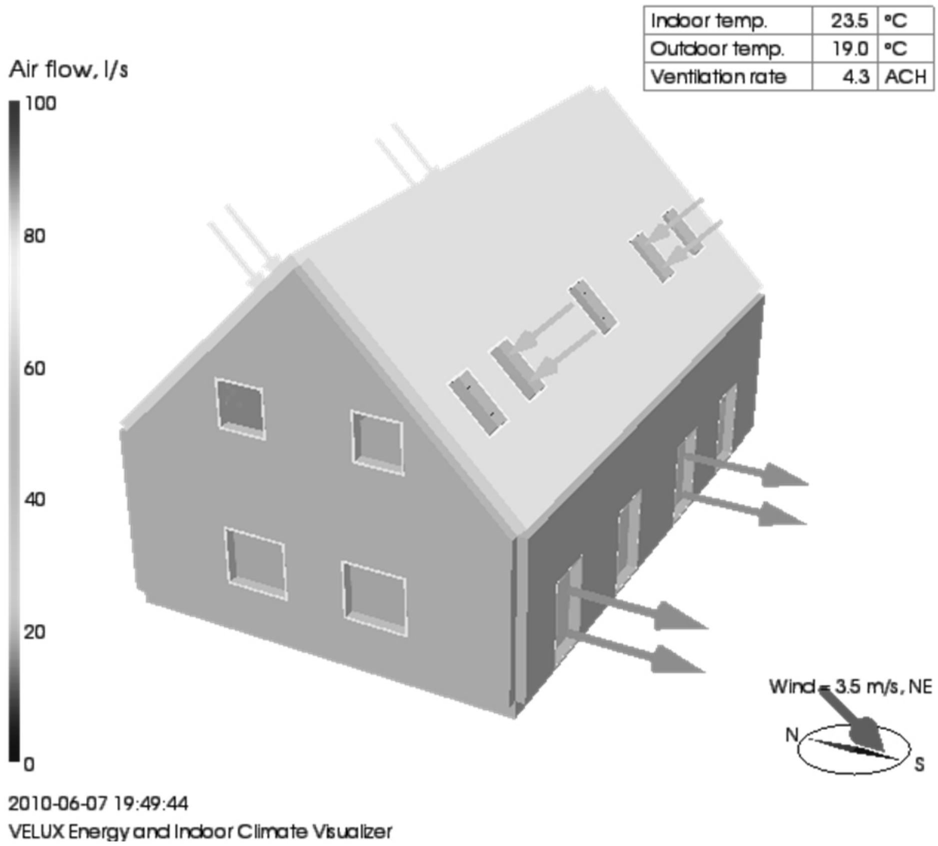

Figure 4. Animation of airflows through windows.

The animation is used to explore how the combination of ventilation controls and natural driving forces determine the magnitude and distribution of the airflows. It can be used to investigate stack effect, cross and single sided ventilation under different weather conditions during a year.

DISCUSSION

The Energy and Indoor Climate Visualizer has a fast and simple user interface. The EIC Visualizer is based on the validated IDA ICE 4.0 engine and allows detailed thermal, airflow and daylight modelling.

Understanding the standardised results report does not require simulation experience. The report summarizes the main results, and provides particularly insight in thermal comfort and natural ventilation. The adaptive approach of EN 15251 is used to evaluate thermal comfort in naturally ventilated buildings which provides a fair indication of thermal conditions, particularly in warm climates.

The EIC Visualizer can be used to design and evaluate sustainable residential buildings with a holistic approach to all elements of the energy balance and with particular focus on the effects of windows, solar shading and natural ventilation. The intuitive interface makes building performance simulations of residential buildings available to users without simulation expertise, which can expand the use of simulations for residential buildings. If used as part of an integrated design process with active involvement of the architect, this can lead to better building designs.

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