APPLICATION OF SPECIFIC MODELS IN A GENERAL SIMULATION TOOL

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ABSTRACT

The dynamic building simulation software IDA Indoor Climate and Energy v. 4.0 (IDA ICE, see www.equa.se) offers a standard level with fast input for general simulation projects, an advanced level for more flexible modelling, and a developer's level with open code and editable models for specific problems. This enables that numerical investigations of non-standard systems within a whole-building context can be achieved at low costs. This paper presents three real case applications performed in the scope of a consultancy service.

INTRODUCTION

To be practical, a building simulation tool has to be detailed and simple, accurate and fast, flexible and fault-tolerant. Even though use of high quality building simulation in the planning process has a proven positive impact, few software distributors succeeds in reaching a broad user base. Mostly, their products address either the academic community, being detailed, accurate and (hopefully) flexible, or, the commercial world, being simple, fast and fault-tolerant.

The Centre for Integral Building Technology at Lucerne University acts as an intermediary between engineering research and commercial service providers in the field of building services. For more than 10 years, IDA ICE has been used for education, research and commercial services, and the reason for this is the flexibility provided through the different user levels found in this software.

CASE 1: NATURAL VENTILATION OF A CLASS ROOM

A Swiss engineering company developed their own natural ventilation concept for schoolhouses in Luxembourg. The classrooms have predominantly surfaces that are thermally well coupled with the construction mass. They are ventilated by controlled window sashes and heated by heating devices situated towards the building core. To demonstrate the functionality of the system, the dynamic thermal behaviour of a classroom, its heating unit and its adjacent walls during natural ventilation between the lessons were investigated.

Proportional controllers control the radiators, and due to the inertia of the thermostats and the radiators, the system reacts with a certain delay. Usually, this effect is not taken into account when performing building simulations. However, thanks to the open simulation environment found in IDA ICE a more advanced and hence realistic model can be created. In IDA ICE, the general system is built up using the standard level (Figure 1), while the finalization of the model with the time delay is built up in the advanced level, where the variables of the individual components are visually linked (Figure 2).
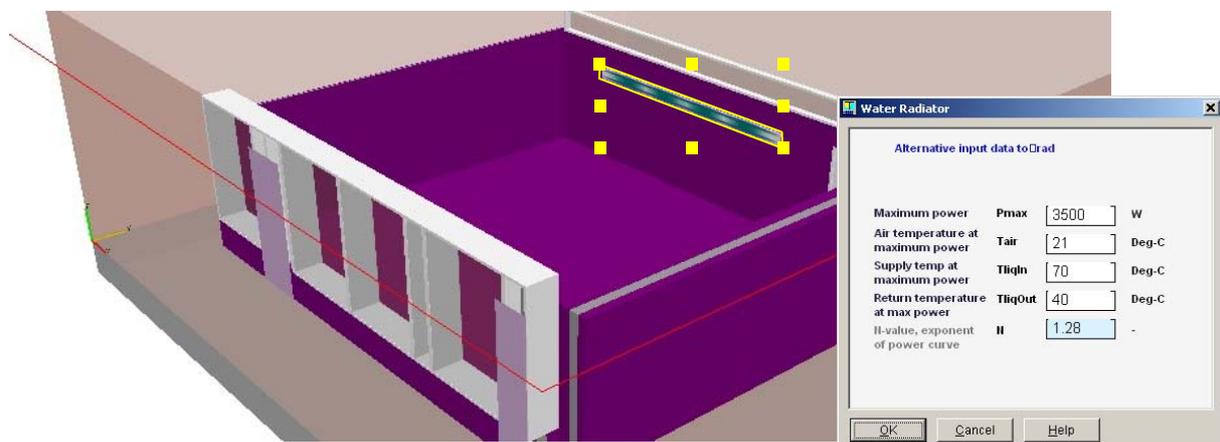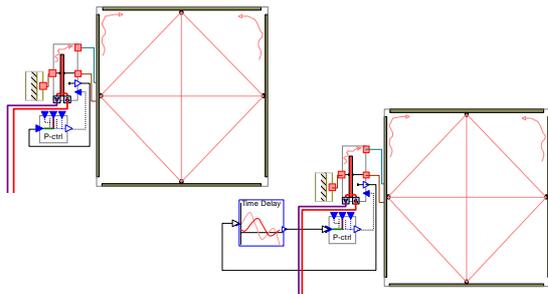

Figure 1 Input of radiator in standard level

Figure 2 Radiator in advanced model
above: generated automatically
below: adding of delay model

Results

For more details, see Meier et al., 2009. As the time steps in IDA ICE are adaptive, the time resolution of the results is fine enough to show how the walls emit their buffered heat (Figure 3). Oversizing of the heating units can therefore be avoided.

The influence of the delayed temperature signal can be seen in Figure 4. Due to the increased reaction time of the system, the heat from the radiators is given to the zone with a delay. This leads to a bigger room temperature drop during the breaks, to longer operation time of the radiators and to a slight temperature overshooting after the breaks.
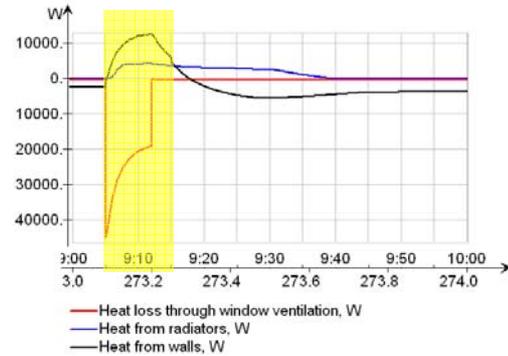

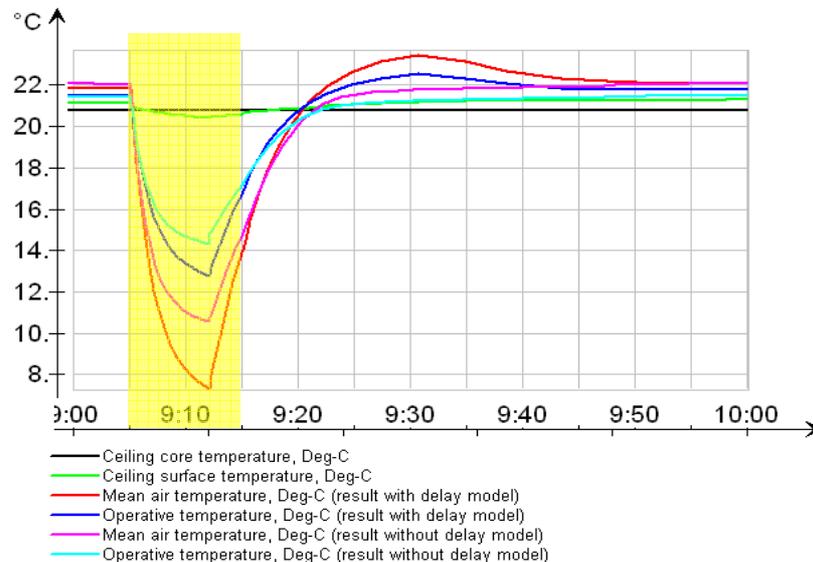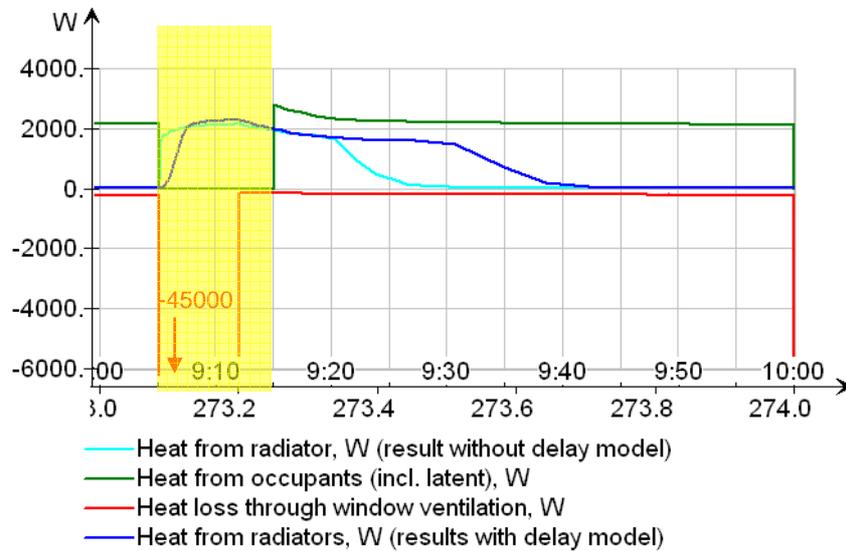*Figure 3 Simulated heat flows during a break*

Figure 4 Influence of time delay for thermostat signal

CASE 2: MOISTURE CONTROL IN A LOW ENERGY HOUSE

The mechanical ventilation of low energy houses can lead to dry air during the winter period due to the high air exchange rate. For a single-family house, different strategies (CO_2 or humidity control with different sensor positions vs. moisture recovery) to counteract this phenomenon were compared with respect to air humidity.
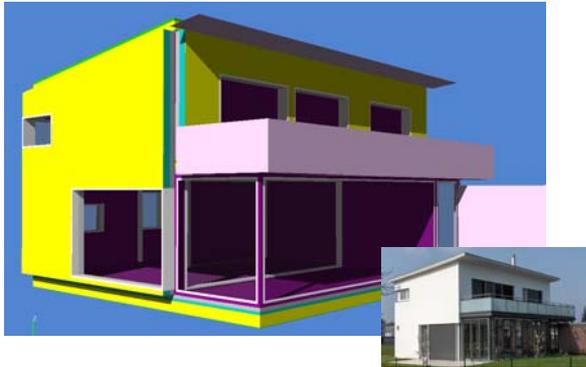

Figure 5 Simulation model (standard level) and photograph of the investigated single family house
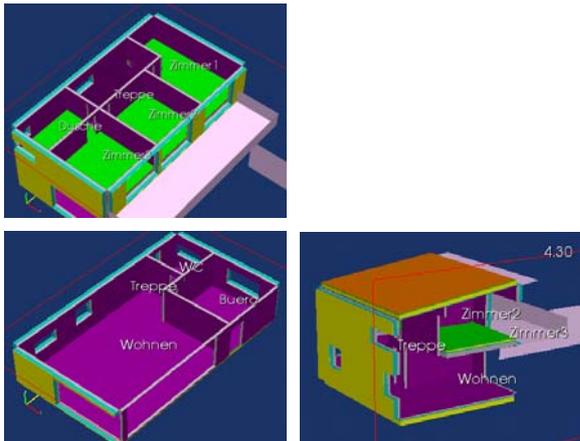

Figure 6 Standard level simulation model

The results are of course highly sensitive to internal loads (humidity production). Therefore, two user profiles were compared: (a) 4 persons with high presence, and (b) 2 persons with low presence. It is relevant to take the penetration and storage of humidity into the wall constructions into account. Again, this effect is usually not taken into account when performing building simulations. However, the IDA ICE wall model can be edited and extended with equations for humidity transport and storage (Kurnitski et al., 2000). In the developer level, this is achieved by directly writing the differential equations in either Modelica or in the Neutral Model Format (NMF) (Figure 7).

$$\frac{\partial w}{\partial t} = -\frac{\partial g}{\partial x}$$

```
EQUATIONS
   FOR i=1, n
       w'[i] = (gD[i] + gC[i])/(a*l[i])
   END_FOR;

VARIABLES
/* type   name   description    */
Factor   w[n]   "Moisture content [kg/m3]"
HumFlow  gC[n]  "Convective hum.flow diff. [kg/s]"
HumFlow  gD[n]  "Diffusive hum.flow diff. [kg/s]"

MODEL_PARAMETERS
/* type  name  description    */
INT      n     "Number of wall layers"

PARAMETERS
/* type  name  description    */
Length   l[n]  "Layer thickness [m]"
Area     a     "Wall area [m2]"
```

Figure 7 Equation for moisture balance and related NMF model code (developer level)

The advanced level allows to define any control strategy, such as air volume rate proportional to CO_2 concentration (Figure 8).
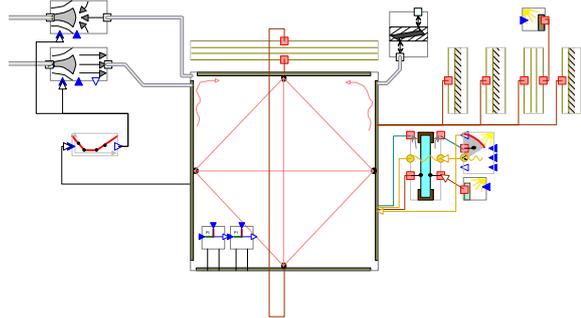

Figure 8 CO_2 control defined in the advanced level

Results

For more details, see Moosberger et al., 2008. Figure 9 shows the relevance of the humidity transport and storage equations for the daily peaks of relative air humidity. The results turn out differently for high and low humidity production (Figures 10 and 11). The optimized ventilation control strategy proves to be very project specific.
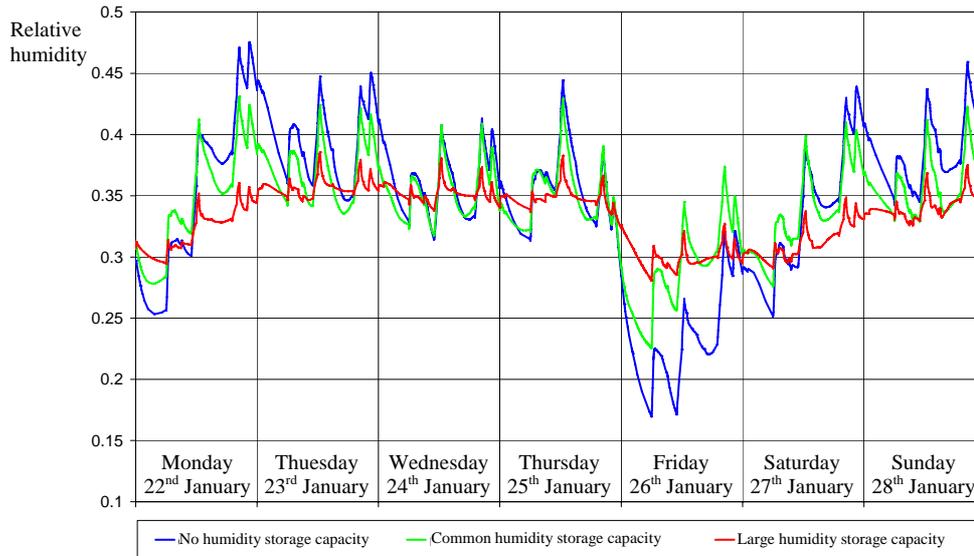
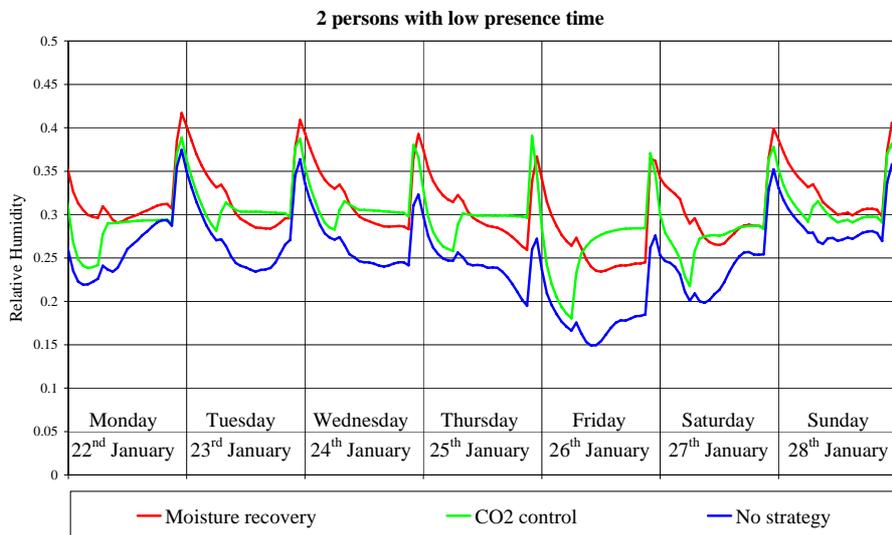*Figure 9 Influence of the equations for humidity transport and storage*

2 persons with low presence time

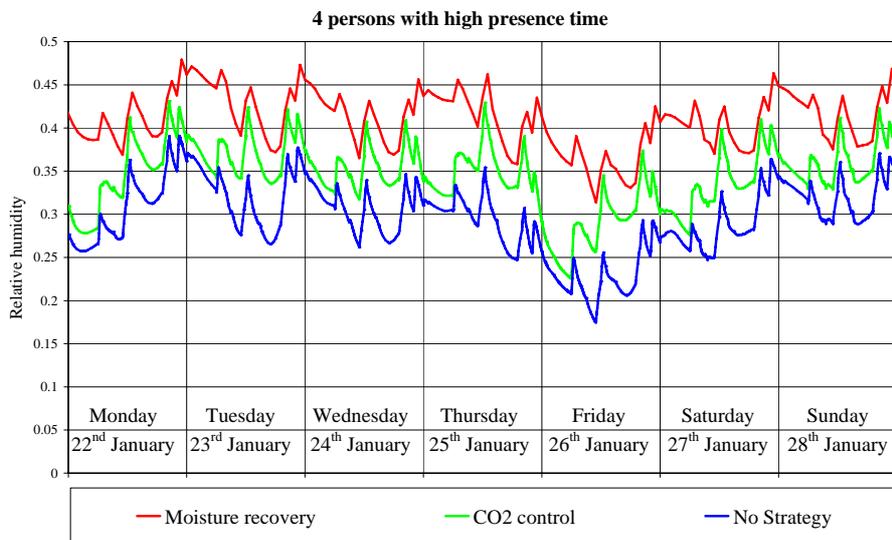*Figure 10 Comparison of strategies for low moisture production*

4 persons with high presence time

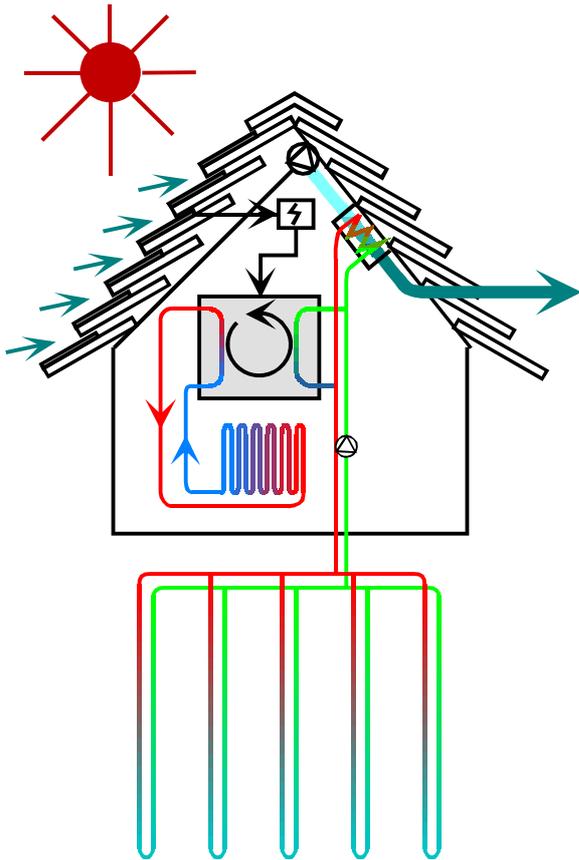*Figure 11 Comparison of strategies for high moisture production*

CASE 3: PV/T AND BOREHOLES

The ground around the borehole field of a geothermal heat pump system will be cooled down year by year. To investigate the potential of ground heat recovery with help of waste heat of photovoltaic (PV) modules during the summer period, a reference residential building system (Figure 12) was simulated. Results for the two cases with and without heat recovery were compared. The model of the building was built in IDA ICE, using the standard level. The heat generation and storage models were built using the advanced level (Figure 13 / Kropf, 2003), and the components for this were generated in the developer level, using NMF.
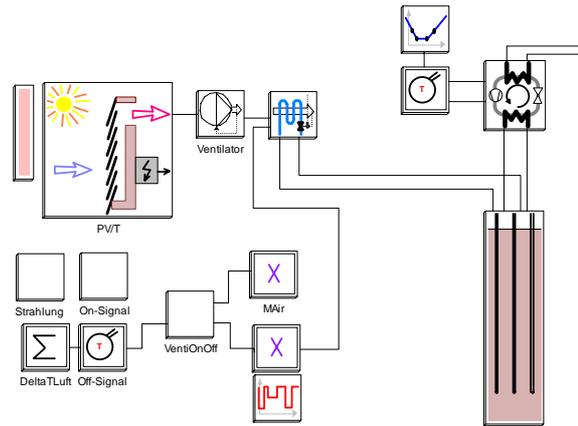

Figure 12 System to be simulated

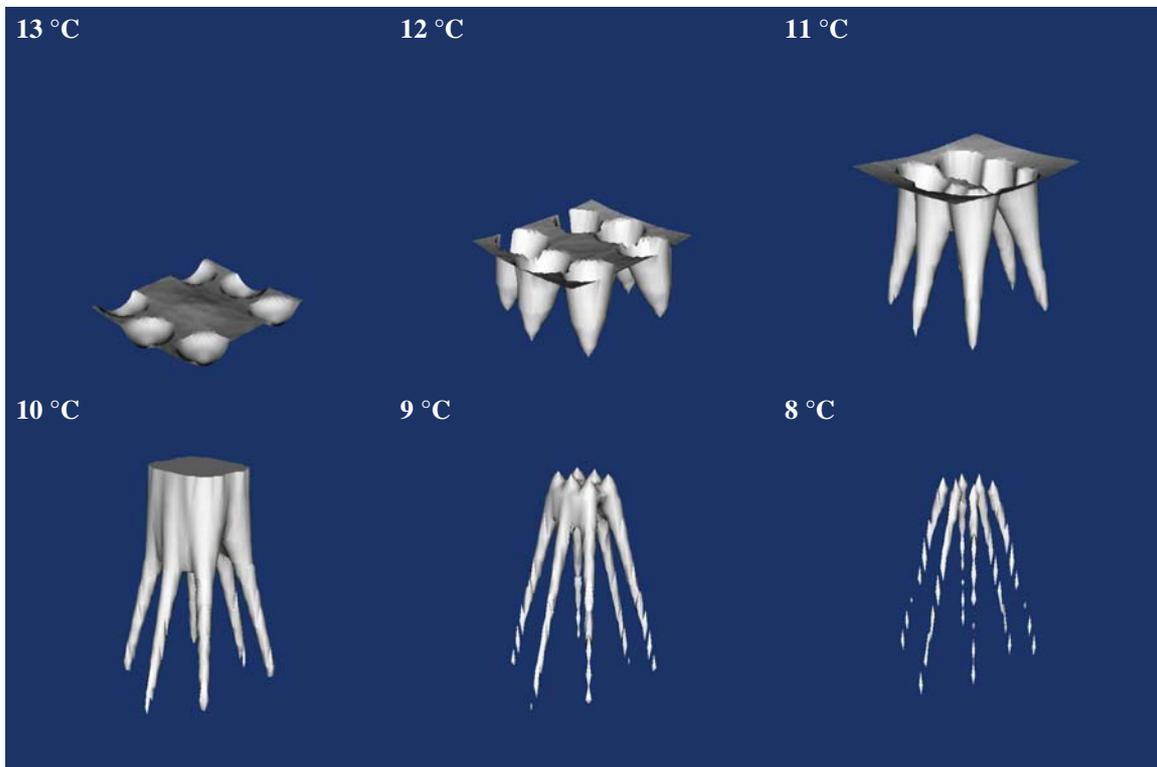*Figure 13 Advanced level: Linked NMF models*

Figure 14 3D result visualisation: Isotherms around the borehole field during discharging of ground.

Results

For more details, see Kropf, 2003. With the help of 3D visualisation, the results can be checked for plausibility (Figure 14). To illustrate the year by year shift of the borehole temperature, the monthly average for July and January of each year are compared (Figure 15). Table 1 shows the potential of electricity saving due to ground heat recovery with PV waste heat.
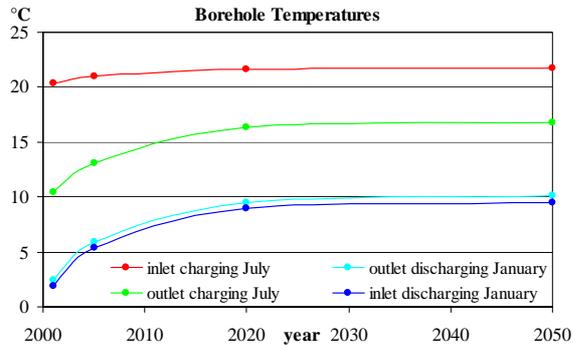

Figure 15 Borehole temperatures during 50 years of system operation

Table 1 Electricity need of heat pump

without PV waste heat	514 kWh
1st year with PV waste heat	488 kWh
5th year with PV waste heat	408 kWh
20th year with PV waste heat	396 kWh

CONCLUSION

The presented examples show the benefit of using a general simulation tool like IDA ICE. Its support for different user levels allows convenient and efficient modelling of general building systems, as well as detailed modelling and accurate investigations of complex systems.

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