

# Energy and comfort advice for consumers designing their own house : a connection between iBuild and IWCS

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# Energy and comfort advice for consumers designing their own house

## A connection between iBuild and IWCS

Rona Vreenegeer<sup>1</sup>, Jan Hensen<sup>1</sup>, Bauke de Vries<sup>2</sup>, Peter Bonsma<sup>3</sup>, Luc Soethout<sup>4</sup>

<sup>1</sup> Building Physics and Systems, <sup>2</sup> Design Systems  
Faculty of Architecture, Building and Planning  
Technische Universiteit Eindhoven

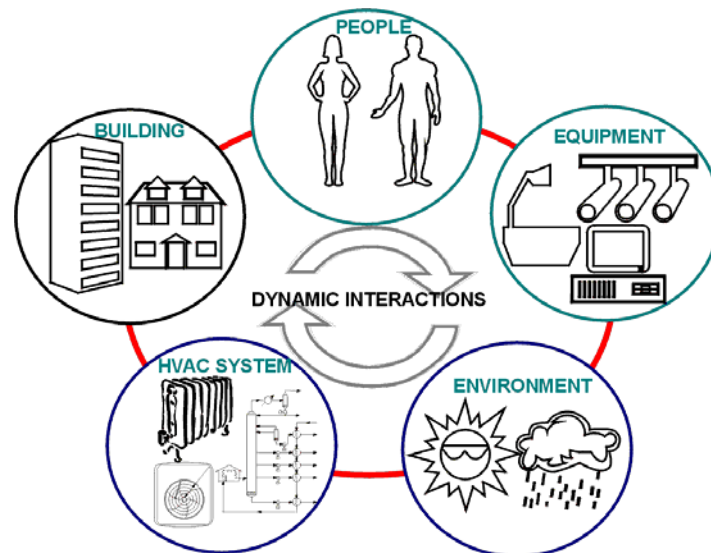
<sup>3</sup> Building Process Innovation, <sup>4</sup> Indoor Environment, Building Physics and Energy  
TNO Built Environment and Geosciences, Delft

### 1. Introduction

In the (Dutch) construction industry relatively little attention is paid to low-energy and comfortable housing. It is often limited to prescribed rules by the government. For low-energy and comfortable solutions beyond the minimum legal requirements in one's own home, someone almost has to be an environmental 'enthusiast'. Many people don't realise that a sustainable building offers besides environmental benefits also other important qualities such as improved health and comfort. Especially the last aspects are important for consumers. Therefore people should be informed about these 'extra' benefits of low-energy and comfortable building during for example the designing or buying process. On the one hand people get a more comfortable house (and life) and on the other hand it is positive for the environment and the future population. This paper introduces a project which aims to develop a consumer design support system which is based on combining an architectural design support system with building performance prediction software.

### Building performance simulation

Computer modeling and simulation is a powerful technology for addressing interacting architectural, mechanical, and civil engineering issues in buildings. Building performance simulation can help in reducing emission of greenhouse gasses and in providing substantial improvements in fuel consumption and comfort levels, by treating buildings and the systems which service them as complete optimized entities and not as the sum of a number of separately designed and optimized sub-systems or components. It is only by taking into account dynamic interactions, as indicated in Figure 1, that a complete understanding of building behavior can be obtained.



**Figure 1: Dynamic interacting sub-systems in a building context**

For more than a quarter of a century, building performance simulation programs have been developed to undertake non-trivial building (design) analysis and appraisals (Kusuda 2001). The techniques of building performance simulation are undergoing rapid change. Dramatic improvements in computing power, algorithms, and physical data make it possible to simulate physical processes at levels of detail and time scales that were not feasible only a few years ago. Although contemporary programs (for an overview see e.g. DOE 2003) are able to deliver an impressive array of performance assessments (see e.g. Augenbroe and Hensen 2004, Hensen and Nakahara 2001, Hong et al. 2000), there are many barriers to their routine application in practice, mainly, in the areas of quality assurance, task sharing in program development and program interoperability (see e.g. Augenbroe and Eastman 1998, Bazjanac and Crawley 1999, Blis 2002, Bloor and Owen 1995, Crawley and Lawrie 1997, Eastman 1999), and because the use is mainly restricted to the final stages of the overall building design process.

Although it is evident that the impact of design decisions is greatest in earlier design phases, building performance simulation is rarely used at all for supporting early design phase tasks such as feasibility studies and conceptual design evaluations. (De Wilde, 2004). The main applications of building simulation in current building design projects are code compliance checking and thermal load calculations for sizing of heating and air-conditioning systems; in other words: analysis (of a single solution) rather than (multiple variant) design oriented (e.g. Altavilla et al. 2004).

Our research aims to address some of these issues. The ultimate goal is to provide integrated design and operation tools, knowledge and procedures which lead to innovative, elegant and simple building designs with (a) a balanced attention to the value systems of the building occupier, building owner and the environment, (b) a better quality, (c) a shorter design time, and (d) lower life-cycle costs.

### **Consumer design support**

The building market is slowly shifting from mass building to consumer based building. This means people have more influence in the shape and attributes of their future house. Consumer based building could appear in the form of participation in the design process or even making the design by themselves. Designing your own home sounds great, but is not an easy job for

everyone. Especially the inexperienced consumer could use some support in the design process. For example virtual reality to give a good view of the future house, cost information and energy and comfort advice. Designing a large window may look great in virtual reality, but also has some consequences like a large energy loss. When people know this in advance, the design of the house would probably be different. Virtual reality, cost information and energy and comfort advice during the design process must help the consumer to make well-considered design decisions in order to prevent disappointment about the final result.

## Research objectives

The *iBuild* concept (developed by TNO Built Environment and Geosciences in association with European Design Centre and Willems van de Brink Architects) offers consumers the possibility to design their own house with a view of reducing construction costs. The software allows inexperienced consumers to design their future house. With the help of 2D- and 3D-views and virtual reality (to walk through the design), consumers get a good idea of how the future house will look like. The consumer designs the façades and interior of the future house just by dragging a certain building part like a window, door or interior wall into the façade (2D) or interior design (2D and 3D).

Besides giving a good idea of how the future house will look like, *iBuild* wants to offer energy and comfort advice during the design process. This could for example be a simulation to show the daylight impact or a calculation to show a score for energy use.

One of the solutions to support consumers during the design process is a connection between *iBuild* and an existing energy and comfort advice program. In the research, described in this paper, the possibilities of a connection between the existing advice program *IWCS* (also developed by TNO) and *iBuild* is analyzed. *IWCS* stands for ‘Integrale WoonComfortScan’ which loosely translated means integrated home comfort scan. Figure 2 is a visual presentation of the connection between *iBuild* and the *IWCS*.

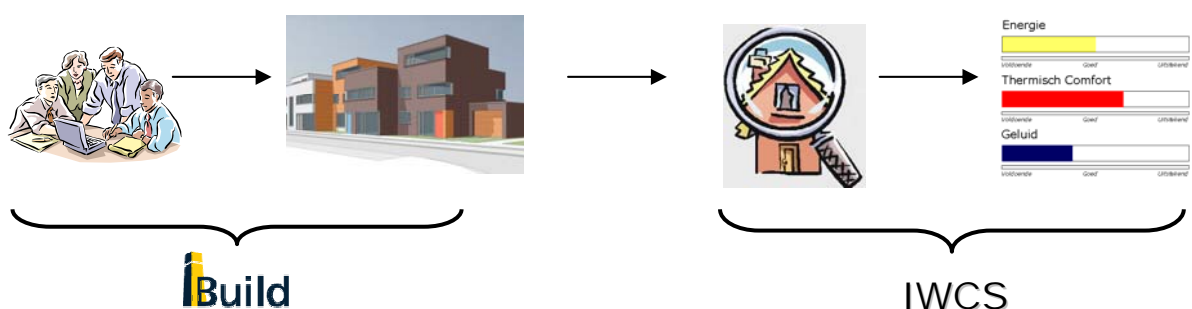


Figure 2: Connection between *iBuild* and *IWCS*

## 2. Research methods

The research presented in this paper comprises a literature search and prototype implementation and testing as elaborated in the following.

### Literature search

A literature search was carried out to determine which calculations are needed to generate that kind of results which will support the consumers during the design process. This research occupies not all the possible energy and comfort aspects, but only the aspects energy, thermal comfort and air quality. The number of studied aspects is limited because of the short period of time available for this research. The aspects energy, thermal comfort and air quality are chosen due to own interest and the strong relationship between them. One of these three aspects couldn't be studied without the knowledge of the others. For example the energy use could be zero when the thermal comfort and air quality isn't taken into account.

The literature search was to find out what each of the three aspects mean (what is thermal comfort?), which parts of the aspects are important for the consumers to know and which building restrictions apply.

## Prototyping

The connection between *iBuild* and the *IWCS* is made with the knowledge of these existing (prototype) programs. An architect delivers a basic design for *iBuild* which the consumers can transform in their own 'perfect' house. This can be done within the guidelines of the architect and the building restrictions of the government and the local authority. To guarantee a reasonable price, *iBuild* has a direct connection with the product database of suppliers of building parts such as, windows, doors, kitchens and interior walls. When designing his house, a consumer can directly choose building components from the manufactures, guaranteeing that his design can actually be built. Such a connection improves the building processes and communication, eventually leading to lower costs.

On the technical part, *iBuild* consists of a model that describes how the design information is stored. Such a model is called an *Express* model and is in this case an IFC *Express* model. IFC stands for Industry Foundation Classes and is a standard for the storage of geometrical data, relations between spaces and properties of the building elements. This standard is supported by many CAD applications. This means that a house design made with *iBuild* can be opened (and edited) in those CAD applications. Therefore a connection between the *IWCS* and *iBuild* can in principle also be used by users of CAD applications to calculate energy and comfort scores of their designs.

The *IWCS* program supports advisors in evaluating the status of an existing house with respect to energy use, thermal comfort, indoor air quality, noise and moisture problems and giving an integral advice for improvement on these aspects. The calculations are at building level and are designed to have an advice available in a couple of hours. The *IWCS* also consists of an *Express* model which describes how the information is stored.

In order to make the connection between *iBuild* and the *IWCS* three aspects had to be dealt with. At first the calculations of the *IWCS* needed to be updated. The calculations behind the *IWCS* are based on building restrictions of the government for existing houses and are simplified with respect to input requirements, i.e. based on observation rather than detailed design information. Because with *iBuild*, new houses are designed, the building restrictions for new houses need to be applied. And, since detailed design information is available, the simplified calculations could be made more accurate. Besides that, the original *IWCS* calculations are applied at building level whereas the geometrical data from *iBuild* are at room level. The question was whether the calculations behind the *IWCS* needed to be fitted to apply at room level or that the geometrical data from *iBuild* needed to be transformed to apply at building level to fit the

*IWCS* calculations. Of course, this decision also depends on the required accuracy of the calculations.

Secondly the update of the calculations behind the *IWCS* caused a change in the kind and detail of data that's needed for the calculations. This also applies for the calculated output data. Because of the different data, the *IWCS* program needed to be updated. The earlier mentioned *Express* model of the *IWCS* is no longer valid and needs to be changed to make a connection between *iBuild* and the *IWCS* possible and to be applicable for new houses.

The last problem consisted of the actual connection between *iBuild* and the *IWCS* and the programming of the new calculations. The data from a final design in *iBuild* needs to serve as input for the calculations and, vice versa, the energy and comfort results need to serve as input for *iBuild*. Since both models do not have the same structure, the connection is made through a mapping between the *Express* models of both programs. This mapping tells which data from *iBuild* needs to be connected with the data needed for the *IWCS*. For example *iBuild* generates the length and height of a wall and these need to be connected with the area data of a wall in the *IWCS* (with the knowledge  $\text{area} = \text{length} * \text{height}$ ).

In many applications, connections between drawing programs and building physics calculations already exist. But the connection is generally made with the use of one model which describes how the data must be stored. And this often means that the drawing or the calculations model has been adapted to fit in the other. Both *iBuild* and the *IWCS* consist of such a describing model, called an *Express* model. In this research these models are kept separate, that way each model is made after fundamental research.

### 3. Results

#### Performance requirements

The information of the literature research leads to a list of calculations to determine values for a good advice. The list of calculations could be seen as a guideline. Some of the needed values are defined with simple calculations and others are defined with complex simulations to determine a right value. Thereby not all the defined calculations could be programmed. Some of them are replaced with other calculations to give a global value. In the future these simplified calculations could be exchanged with more accurate calculations or a complex simulation. In the following text the aspects energy, thermal comfort and air quality are explained and a table shows the concerned indicators and calculation methods.

Since the energy crisis in 1973, energy saving played an important role in the Dutch construction industry. In the beginning energy saving meant mainly preventing heat loss by raising the thermal resistance and the air tightness of the house. Nowadays the building restrictions of the government prescribe a certain energy performance which a house has to satisfy. Consumers could be interested in the energy performance of a house because energy saving also means money saving. Important aspects for the energy performance are thermal isolation, air tightness, design of installations and the use of sustainable energy sources. All these aspects are taken into account in the energy performance coefficient (EPC). Other values that could give an indication of the energy performance are the Energy-Index (EI), which is comparable to the EPC but applicable for existing houses, and the energy use ( $Q_e$ ) for heating. The calculation of the energy use for heating takes a lot of important aspects not into account. Figure 3 shows a list of possible values and matching calculation methods for a good advice to the customers in the field of energy. After fundamental and scientific research, the conclusion is

that the EPC value is preferred for a good advice. The calculation of the EPC value is simplified to make programming possible in the short time available for this research.

### Energy Performance

PI	Value presentation	Calculation method	Demanded/Aligned value
<i>EPC</i> [-]	<i>Single value per house</i>	<i>EPN 2001, NEN 5128</i>	<i>EPC ≤ 1,0</i>
<i>EI</i> [-]	<i>Single value per house</i>	<i>Rekenmodel EPA</i>	<i>n/a</i>
<i>Q<sub>e</sub>/Q<sub>wb</sub></i> [kWh]	<i>Single value per heating season</i>	<i>ISSO publicatie 16</i>	<i>n/a</i>

Figure 3: indicators energy performance

Thermal comfort is not an easy term to explain, a commonly used definition is: “That condition of mind which expresses satisfaction with the thermal environment”. A definition which many people agree with, but which is also difficult to translate into physical parameters. The experience of thermal comfort depends, in addition to the interior climate (temperature, draught, cold feet), on the activity level and the clothing a person is wearing. When the heat balance of a person and its environment is disrupted, he will feel uncomfortable. Thermal comfort can be divided in global and local comfort. Global comfort is related to the total environment of the user, but not directly related to the user, whereas local comfort deals with the direct influence on the user himself, for example draught near a window, asymmetrical radiation or a vertical temperature gradient. In the first place it is important for the consumers to know whether the global thermal interior environment is comfortable.

Values that could give an indication of the global comfort are operative temperature  $T_{o}$ , which is the average of the air- and radiance temperature, PMV and the PPD. The PMV describes the general opinion of a group of people about the thermal comfort. And the PPD, which is related to the PMV, describes the percentage of dissatisfied people about the thermal comfort. Figure 4 shows a list of the indicators and matching calculation methods in the field of global comfort. After fundamental and scientific research could be concluded that the PMV and PPD values are preferred. There has to be noted that the calculation of the PMV and PPD values are made with a couple of assumptions to make programming in a short time frame possible. In the future these assumptions, for example the clothing level, can be made more accurate. For the global comfort in the summer the indicator GTO (weighted exceeding hours of a certain temperature) is preferred.

### Global thermal comfort

Aspect	PI	Value presentation	Calculation method	Demanded/Aligned value
Global TC	$T_o$ [°C]	Average per hour	n/a	n/a
Global TC	PMV [-]	% appearance PMV < -0,5 en PMV > +0,5	Fanger	Max. 10% of the time
Global TC	PPD [%]	% appearance PPD > 10%	Fanger	Max. 10% of the time
Summer TC	GTO [hours]	Hours per summer	Rgd	Max. 20 hours > 28 °C Max. 100 hours > 25 °C (offices!)

PMV and PPD  
(assumptions)  
GTO

Figure 4: Indicators for global (whole body) thermal comfort

Besides global thermal comfort, local comfort is of concern. Research in the field of interior environment problems and health effects (Platform Binnenmilieu 2004) showed among other things that draught is one of the main complaints in houses and is therefore useful to take into account. Draught can arise near large windows with poor thermal insulation, because of radiance asymmetry or because of a large velocity of cold dropping air. A possible indicator for draught is the predicted percentage of dissatisfied due to draught (PD). Another local discomfort that could be relevant for the consumers to know is the vertical temperature gradient. This temperature difference appears in situations with a cold floor (poor thermal insulation) and/or a hot ceiling (heating installation). However, the relevance for new houses is limited, since building restrictions prescribe severe thermal floor insulation to prevent energy loss and heating installations in the ceiling are very rare. Figure 5 shows a list of the indicators and matching calculation methods in the field of local comfort. After fundamental and scientific research could be concluded that the PD value is preferred. To make programming possible in a short time frame, the single PD value is chosen.



### Local thermal comfort

Aspect	PI	Value presentation	Calculation method	Demanded/Aligned value
<i>Draught</i>	<i>PD</i> [%]	% appearance <i>PD</i> > 15%	<i>Fanger &amp; Christensen</i> (1986)	Max. 10% of the time
<i>Draught</i>	<i>PD</i> [%]	Single value	<i>ISSO researchrapport 5</i>	< 15%
<i>Vert. ΔT</i>	<i>T<sub>vloer</sub></i> [°C]	Average per hour	n/a	19 – 26 °C

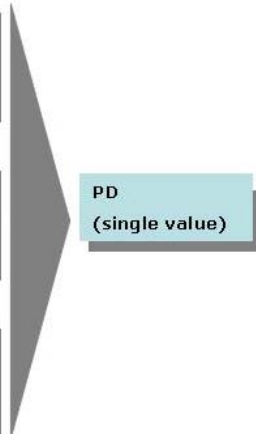


Figure 5: Indicators for local comfort

After the energy crisis in 1973, the indoor air quality became a problem. To prevent heat loss, the air tightness of houses increased, mainly by closing openings at cracks and joints. However, the ventilation of many houses took, besides the installed facilities, place through such cracks and joints. By closing these openings, the ventilation rate decreased. This caused poor ventilation and polluted indoor air. The indoor air quality is of high importance because we spend most of the time inside. Ventilation provides a building with fresh air (oxygen) and removes smell, combustion gases, smoke, dust and vapour. Therefore, the provisions for infiltration and ventilation are important to guarantee the required minimum level of fresh air.

Indicators for the quality of the indoor air could be the pollution intensity and ventilation rate. Other important aspects are the type of ventilation and the amount of possible adjustments. Figure 6 shows a list of the indicators and matching calculation methods in the field of indoor air quality. After fundamental and scientific research could be concluded that the air velocity in a room, the ventilation, infiltration and pollution rate are preferred. The air velocity is needed for other calculations like the local thermal comfort. In this stage the indicators can't be programmed and will be omitted. The infiltration and ventilation rate can be calculated, based on the available provisions in the house, however the pollution rate is more complicated. It depends on the material use in the building and the emission rate of volatile components from these materials, which is often difficult to quantify.

## Air quality

Aspect	PI	Value presentation	Calculation method	Demanded/Aligned value
Air velocity	$v$ [m/s]	Average per hour per zone/node	- Zone: AFN simulation - Node: CFD simulation	< 0,15 m/s
Ventilation rate	$V_c$ [dm <sup>3</sup> /s]	Average per hour	n/a	Function depending
Infiltration rate	$q_{v10}$ [dm <sup>3</sup> /s]	Average per hour	- Global - Richtlijnen NEN 5128 - Advanced	< 200 dm <sup>3</sup> /s
Polution	Concentration [mg/m <sup>3</sup> ]	per certain time period	n/a	Polution depending

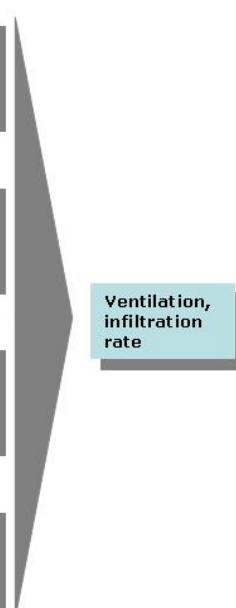


Figure 6: Indicators for indoor air quality

## Prototype design and implementation

This phase of the research project consists of several steps:

- Requirements of the evaluation tools, based on the literature review
- Redesign and adaptation of the *IWCS* to meet the requirements
- Coupling between *iBuild* and the adapted *IWCS*
- Programming of the new *IWCS* calculations

These steps are described below in more detail.

The connection between *iBuild* and the *IWCS* is made in a couple of steps. These steps are discussed in the following text. Figure 7 gives an impression of the technical consequence of this connection.

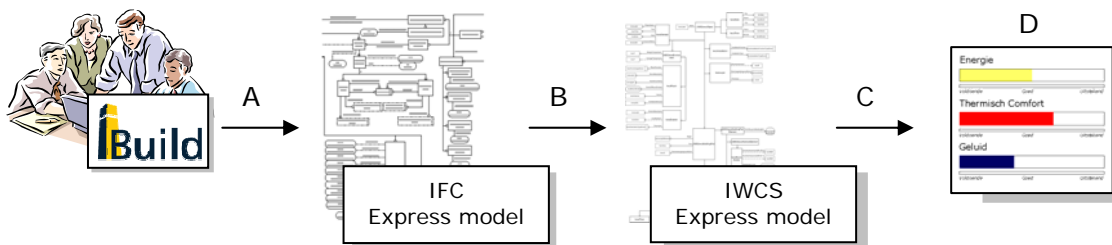


Figure 7: Schematic of the connection

The first step (A) consists of the storage of the house design made by the consumer according to the IFC standard. This step is integrated in the *iBuild* program and implies that the house design

of the consumer can be opened and/or edited in CAD applications which support IFC. Step A is not a part of this research.

Step B describes a mapping between the two *Express* models. As mentioned before, this mapping prescribes which data from *iBuild* needs to be connected with the data needed for the *IWCS*. For example *iBuild* generates the length and height of a wall and these need to be connected with the area data of a wall in the *IWCS* (with the knowledge  $\text{area} = \text{length} * \text{height}$ ). Vice versa, mapping prescribes how the results of the calculations in the *IWCS* are transferred to the *iBuild* model. Both mappings are part of the research and are made with the language (Express-X) specially made for the connection between *Express* models.

Step C is the mechanism to get the information from the *IWCS* model into the calculation modules of the *IWCS*. Since the *IWCS* does not have a native interface to read from and to write to Express models, such an interface is provided by the program EDM (2005) and the program language C. This language can be coupled easily to the *IWCS* modules, providing the data in the model to the internal algorithms of the modules. For example the model consists of a wall with a certain thermal resistance. This value is read from the model and used for the calculation of the thermal transmittance.

Step D consists of the programmed calculations. The calculations are programmed in the C language. The data needed for the calculations is, as mentioned before, picked from the *IWCS* model. The results of the calculations in the *IWCS* modules are transferred back to *iBuild* in the reversed way, using the same Express models.

## 4. Discussion

Discussion of building performance simulation normally includes validation and verification. Validation concerns mostly whether “the model” is implemented correctly, whereas verification is about whether the correct model has been implemented. In the current case, the latter can be read to mean whether it is any good for the prospective users.

### Validation

In this stage of the research, the connection between *iBuild* and the *IWCS* is working. The first (simple) calculations can be made with the use of information from a drawing made in *iBuild*. But it is still very much work in progress. The connection could be seen as a thin line between *iBuild* and the *IWCS* which will be thickened with the extension of calculations. Eventually, all the calculations as mentioned before will be programmed. This extension will have effects on the programmed calculations, the *IWCS Express* model and the connection between the *Express* models. The (simple) calculations which are performed still need to be tested to find out if the results correspond with the reality.

### Utilization

The building physical calculations in the field of energy, thermal comfort and air quality can be made without the interference of the consumer, according to their house design. But the results of the calculations still have to be transformed in a score per analysis aspect. The presentation of the scores is highly important for a good understanding. More research is necessary to find a good visual presentation of these scores. Such a presentation can help the consumers during the design process. The question is in which stage the consumers need to be able to check the energy and comfort results, and how often such an analysis is required. Is it only once at the end of the

design, in order to have a final check on the energy and comfort status, or repeatedly from the beginning? In the latter case, the results of the basic design are visible and these results change according to the design decisions made by the consumers. To make an active use of the advice possible, the advice should be available in the earliest stage of the design process.

The coupling as developed in this project is not only useful in the context of a design session with consumers. It can also be used by professionals, like architects, to get support from evaluation modules during the design. Designs made in 3D with a CAD application which supports IFC are suitable for a connection with the *IWCS* calculations. A designer is asked to insert just once certain values, for example the thermal transmittance, which are normally introduced by *iBuild*. This makes intermediate testing of a design possible. The final design of an architect is often sent to a consultant, which performs building physical calculations, to verify the design. This is quite expensive and can lead to suboptimal solutions, since the architect aims for a final design to be certain fulfilling the energy performance requirement without having feedback during his design. Intermediate testing of a design gives the architect more design freedom and more certainty of the final design fulfilling the energy performance requirement. When in the future the calculations are extended and more accurate, the connection is even more useful. The question arises in which phase of the design process it should be possible for the designers to generate energy and comfort results. Energy and comfort results should be available in the earliest stage of the design process. And it has to be distinct for the designer when enough information is available and the *IWCS* calculations can be executed.

*iBuild* generates all the information needed for the *IWCS* calculations. It enriches the IFC *Express* model with certain (material) properties which cannot be automatically be generated from the drawing, for example the thermal transmittance of a construction. When a designer uses the *iBuild* – *IWCS* connection, he has to enrich the IFC *Express* model by himself. The question is, whether the designer has the disposal of enough knowledge to insert this (technical) information. When a certain value is inserted wrong, will it be noticed by the designer with almost no experience in the field of building physical calculations?

## 5. Conclusion

The information generated from *iBuild* can be used to perform the (new) *IWCS* calculations to provide information of the design in the field of energy, thermal comfort and indoor air quality. The connection between *iBuild* and the *IWCS* makes it possible to generate these results without the interference of the consumers. The coupling is also applicable for professional designers like architects for intermediate testing of the design. A 3D-drawing of the design made in a CAD application which supports IFC can provide a large part of the information needed for the *IWCS* calculations.

Before the connection between *iBuild* and the *IWCS* is useful for the support of consumers, more research is needed. The results of the calculations need to be transformed in certain scores. And the visual presentation of these scores needs to be understandable for the consumers. A test among consumers designing their future house could show the actual usefulness of the offered energy and comfort advice. Also in the field of the support of designers, more research is needed. Especially in the field of enriching the IFC *Express* model. When a designer has almost no experience with building physics, a mistake in the inserted information stands little change of being noticed. Research can find out whether the support of the designer needs to be extended.

The results of the calculations have to be tested to find out if the results correspond with the reality. In the future the calculations can be extended or replaced with more advanced ones for more accurate results.

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