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AUTOCERT: A web-based approach for heating demand calculations for Building Performance Evaluation and Optimization

Ulrich Pont, Stefan Glawischnig, Ardeshir Mahdavi
Department of Building Physics and Building Ecology
Karlsplatz 13/4, A-1040 Vienna, Austria
Corresponding Email-Address: bpi@tuwien.ac.at

ABSTRACT

In most European countries the thermal performance of buildings must be specified in terms of energy certificates. These involve, amongst other things, the calculation of buildings' heating demand. However, architects and planners tend to use heating demand calculations obtained from energy certification tools to evaluate the impact of design alternatives on buildings' thermal performance. Typical existing calculations tools do not effectively support automated parametric change of input data. Manual change of input data might be a time-consuming and error-prone process. This circumstance motivated the present contribution: A simple annual standard calculation method was analysed and redesigned to be used in a web-based environment. The resulting tool can accept input data arrays (consisting of a starting-point, an end-point and a step-width value for constitutive input variables) and compute the heating demand for the resulting variants. Therefore, planners can explore the implications of variable ranges of various design features (e.g., percentage of glazing in the façade, U-values of the building’s constitutive elements) for the magnitude of heating demand. The present contribution describes the structure of the tool. Moreover, ongoing work is described that addresses the algorithmic cost of calculation of all variants and potential solutions involving, for example, the use of genetic algorithms.

KEYWORDS: multivariable analysis, energy performance, heating demand

1 INTRODUCTION

As widely known, buildings contribute to more than 40% of total energy according to the European Commission (EU 2005). Therefore, a number of regulations have been issued at a worldwide (Kyoto 1997), European (EU 2002, EU 2010), and national (OIB 2011a, OIB 2011b, OENORM 2014) level to promote energy efficiency in the building sector. Unfortunately, the identification of feasible efficiency-increasing measures is not a trivial task, given the complexity of buildings, their users and users’ behaviour, and surrounding parameters (e.g. microclimate on the building site) and the associated uncertainties (Augenbroe 2010). In practice, building performance (e.g., heating demand, cooling demand, indoor air quality) is supposed to be specified via IT-based calculation of pertinent indicators. However, to compare variations in design (e.g., different glazing sizes and types in a building’s façade) in view of their impact on performance indicators, planners need effective tools. Currently, most tools do not support automated parametric change of input variables. Thus, planners are forced to change these input variables manually. Repetitive manual change of input data is not only time-consuming and error-prone, it also does not guarantee the identification of optimal designs.

To address this problem, we utilized a rather simple calculation method for annual heating demand of buildings (compare OIB1999a) as the engine for a web-based environment for automated, parametric, repetitive derivation of key performance indicators (AUTOCERT). The underlying annual calculation scheme was published as an excel-tool (OIB 1999b) for planers and was the standard performance proof mandated by the departments of building regulations in several Austrian states between 1999 and 2007. However, with the implementation of EN 13790 (CEN 2008), annual calculation methods were considered to be outdated, and thus replaced by monthly methods (OIB 2007a, 2007b, 2011a and 2011b). Nonetheless, for the purposes of the present study, we deploy the annual calculation method, given its simplicity and computational efficiency.

Although a number of attempts toward web-based tools for performance evaluation and planning supporting has been published in the past few years, few offer the option of parametric input change. Most of the online energy calculators (e.g., energyglobe 2014) are limited in geometry and data entry and do not offer parametric evaluation as well. The Semergy environment (Semergy 2014), a very ambitious approach toward incorporating semantic web technologies in energy evaluation and optimization, offers a certain capability in variation of input data. However, parametric explorations in Semergy are not based on incremental variation of a generic variable, but utilize instead specific searchable building products from the world wide web. With regard to communication scheme, we decided to use XML, which we consider a promising option, even though rarely deployed in the web today.

2 METHODOLOGY

2.1 Calculation method

The annual single-zone calculation method used in this contribution is based on the guidelines of the Austrian Institute of Building Technology (OIB 1999). It is a simple accounting method based on the general heat balance equitation (1). The Heating Demand Q_H is derived from Transmission (Q_T) and Ventilation Losses (Q_V) as well as internal (Occupancy, Lighting, Equipment; Q_i) and solar gains (Q_S). Gains are reduced by the utility factor η. Equations 2 to 5 show how the different terms of this simple balance equation are calculated.

$$Q_H = (Q_T + Q_V) - \eta \cdot (Q_i + Q_S) \tag{1}$$

$$Q_T = 0.024 \cdot (Le + Lu + Lg + L\psi + L\chi) \cdot HDD \tag{2}$$

$$Q_V = 0.024 \cdot 0.33 \cdot n \cdot V_n \cdot HDD \tag{3}$$

$$Q_i = 0.024 \cdot q_i \cdot BGF_B \cdot HD \tag{4}$$

$$Q_S = \sum \left(I_j \cdot A_{gj} \cdot f_{sj} \cdot g_{wj} \right) \tag{5}$$

Table 1 provides an overview of the input information for equations 2 to 5. Note that only a subset of these variables can be changed by the planners. For instance, solar radiation, heating degree days, and heating days are fixed for a location. Moreover, internal gains are a function of the building’s function. Variables that are parametrically changed in this study are highlighted with an asterisk in table 1.

Table 1: Input data for the adopted calculation method. Variables with an asterisk (*) are used for parametric input variation.

Q_T Transmission Losses	**Q_V** Ventilation Losses	**Q_i** Internal Gains	**Q_S** Solar Gains
*U-Values, Area and Adjacencies of all exothermic building parts of the building envelope (for calculation of L_g, L_e, L_u)	*Net Volume (V_n)	*Heated Gross Area (BGFB)	Cumulated annual solar radiation for each orientation j (I_j)
Thermal Bridge Evaluation or Approximation (for calculation of L_ψ $L\chi$)	*Ventilation Rate (n)	Internal heat source output (q_i)	*Area and Shading factors for glazing (A_{gj}, f_{sj})
Heating Degree Days (HDD)	Heating Degree Days (HDD)	Heating Days (HD)	*Effective g-values of glazing (g_{wj})

2.2 Parametric data variation

In planning of new and refurbished buildings, multiple options with regard to geometry, materials, and technical systems (e.g. mechanical ventilation systems) can be considered. These options determine the input information for the calculation method (for instance U-Values, percentage of glazing, etc.). Given the very large number of different material and product combinations for building parts, it becomes obvious that input information for thermal properties alone can assume a wide range of values. Therefore, the following approach for parametric change of input was chosen to allow an expedient assessment of options: For each variable open to parametric change, the planer determines three values: A start value, a step width, and an end value.

After a first calculation (using the start value), the corresponding variable is increased (or decreased) by the step width, and the calculation is repeated until the end value is processed. Figure 1 illustrates this process. Optimization tasks usually utilize more than one variable. Therefore, this scheme (start value, step width, end value) is executed for all variables (see Figure 2). Obviously, computational load increases exponentially with the increase in the number of variables. The well-known problem of increasing algorithmic cost (Puntigam and Reiter 2013) will be countered at this level of realisation with a simple limitation of step-width size and repetitions. More sophisticated optimization options (genetic algorithms or meta-heuristics) shall be pursued in future efforts.

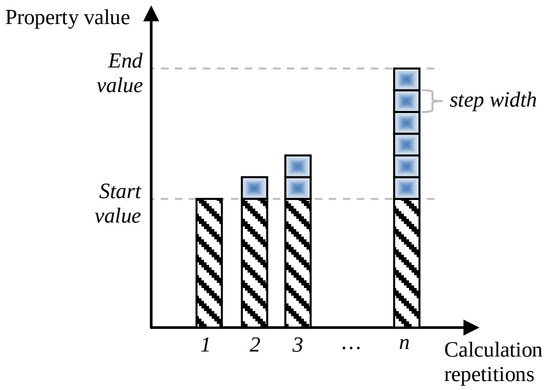


Figure 1: Scheme for start value, step width, and end value pertaining to one variable

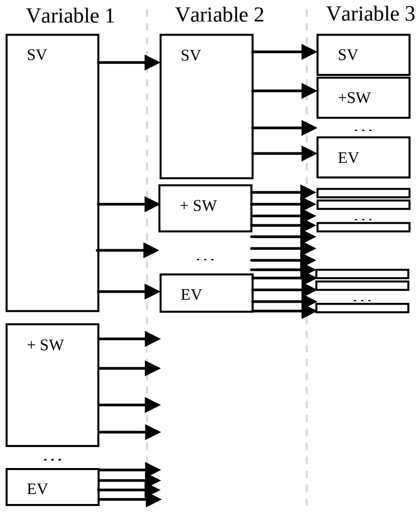


Figure 2: recursive repetition of calculation (three variables); SV… start value, +SW…plus step width; EV…end value

2.3 Technical implementation

A XML building model is utilized to derive the input parameters for the annual heating demand calculation method. As shown in Figure xxx, an abstract *Building* encapsulates a *Building Schema* and a *Building Object.* The *Building Schema* defines reusable *Building Parts* with corresponding physical properties. These are transparency, neighbouring elements, type, id, U-value and g-value. For example, a *Building Part* could look as followed:

```
<buildingSchema>
        <buildingPart transparent="true" touchesElement="2" id="1" type="simpleWindow">
            <uvalue start="1.1" step="0.25" end="1.7"></uvalue>
            <gvalue start="0.3" step="0.1" end="0.7"></gvalue>
        </buildingPart>
</buildingSchema>
```

Each *Building Object* describes the exact structure of the sample building. For each building the heated gross floor area, the heated volume, heating days, ventilation, and internal gains are specified. Each *Building Object* consists of one or more *Building Elements* that specify gross area and orientation. A building element (for instance a wall) consists of *Building Parts* that are defined in the schema definition. The building object's *Building Parts* simply refer to the corresponding schema definition via a unique reference id and specify the respective area in either percent or square meters.

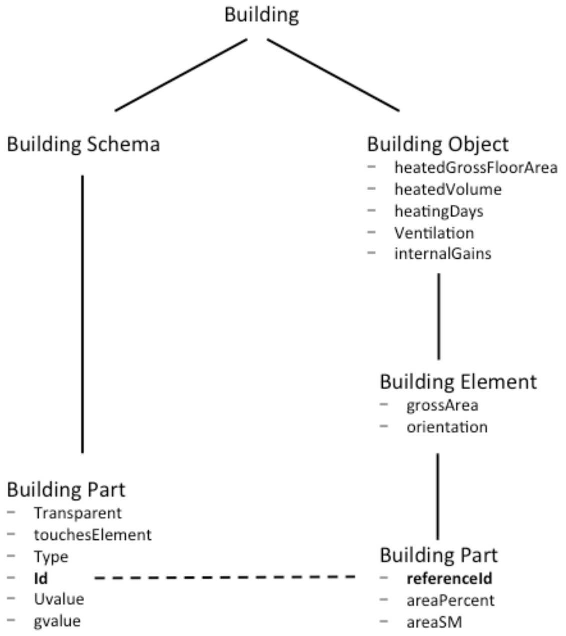


Figure 3: XML building schema elements and attributes.

The reason to develop a distinct, not standard compliant building model lies primarily in the complexity of IFC definitions that causes large file sizes, overhead code and the corresponding resource needs to validate the model. Unlike IFC models, the proposed XML model facilitates validation as it defines a strictly hierarchical schema. Each model is validated for consistency before the optimization process is started.

3 RESULTS AND TEST RUN

3.1 Developed Application

As Figure 4 shows, a simple web-client offers the possibility to upload the XML building model to a server. The backend consists of a model validator module that confirms the model consistency in compliance with the XML building schema. Consistent models are analysed by the application core module that parses the XML model and extracts all needed parameters. The optimization module implements the standard optimization algorithm. The extracted parameters are iteratively adjusted within the specified boundaries to identify solutions that minimize the heating demand. The most suited results are presented to the user via a simple pdf report that can be downloaded from a webpage.

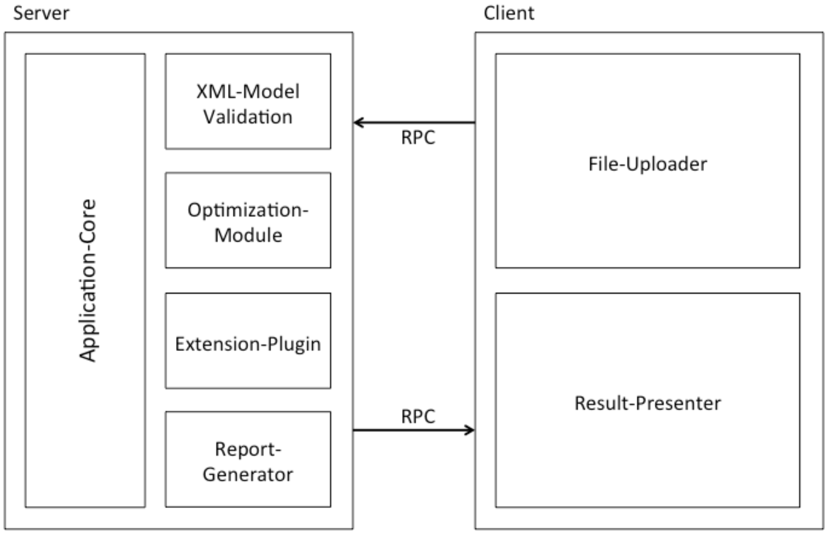
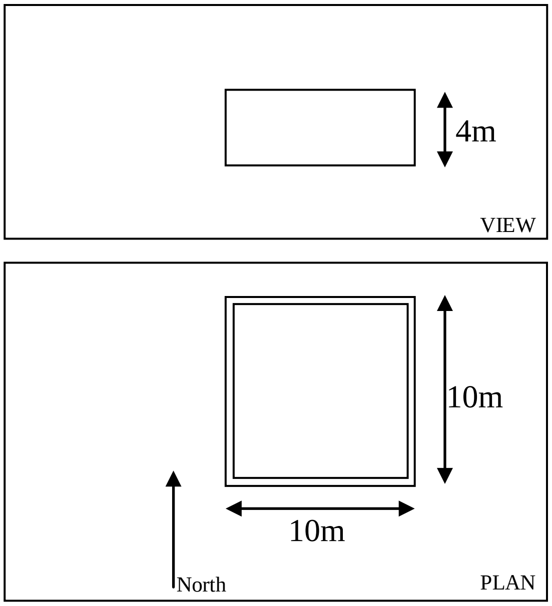


Figure 4: Proposed application design.

3.2 Test run Example

To test the implementation, we defined a simple free standing (no external obstructions) single-storey reference building (10 by 10 m, height 4 m) in Vienna (see Figure 5). Main constitutive building components are: floor slab to ground, external wall, façade glazing and flat roof. The objective of design optimization is in this case to identify the percentage of glazing of the façade (= windows in external wall) as well as the U-values of external walls and windows that would minimize annual heating demand. This task would be rather difficult to handle manually. Using AUTOCERT, first the variables subject to optimization (percentage of glazing in the façade, U-values of the windows and walls) and the associated start and end values (together with step width) are defined (see Figure 5), resulting, in this case, in 672 (21×8×4) combinations.



Input Data (parametrically changed)

	Starting Point	Step Width	Threshold	Unit
U-Value Wall	0.15	0.05	0.30	$W.m^{-2}.K^{-1}$
U-Value Windows	1.25	0.05	1.60	$W.m^{-2}.K^{-1}$
Percentage of Windows in Facade	40	1	60	%

Input Data (constant)

U-Value Roof	0.3	$W.m^{-2}.K^{-1}$
U-Value Floor	0.3	$W.m^{-2}.K^{-1}$
Ventilation Rate n	0.4	h^{-1}
Internal heat flow qi	3.75	$W.m^{-2}$
Heating Days HD	208	d
Heating Degree Days	3235	K.d
g-Value glazing	0.70	-

Figure 5: Geometry and key data for the sample building

Table 2 shows the combinations resulting in the lowest and highest heating demand Q_H, solar gain Q_S and transmission loss Q_T. Note that Q_i and Q_V are constant in all calculations. Figure 6 depicts the result space (heating demand) as a function of percentage of glazing, and highlights the highest and lowest values of heating demand, transmission losses and solar gains. These results suggest that in the present case the selection of the thermal properties of the building envelope components has a major impact on the indicator value (heating demand).

Table 2: Input data for the described calculation method. Variables with an asterisk (*) will be used for parametrical input variation.

Case	**Percentage of glazing** [%]	**U-Value Wall** [$W.m^{-2}.K^{-1}$]	**U-Value Glazing** [$W.m^{-2}.K^{-1}$]	**QH Heating Demand** [$kWh.a^{-1}$]	**QT Trans-mission Losses** [$kWh.a^{-1}$]	**QV Ventilation Losses** [$kWh.a^{-1}$]	**Qi Internal Gains** [$kWh.a^{-1}$]	**QS Solar Gains** [$kWh.a^{-1}$]
Lowest Heating demand	60%	0.15	1.25	**4384**	12391	3280	1836	9451
Highest Heating demand	60%	0.30	1.60	**7738**	15745			9451
Lowest Solar Gain	40%	0.15-0.30	1.25-1.60	4384-7738	9658-12516			**6301**
Highest Solar Gain	60%	0.15-0.30	1.25-1.60	4801-7659	12391-15745			**9451**
Lowest Transmission Losses	40%	0.15	1.25	4801	**9658**			6301
Highest Transmission Losses	60%	0.3	1.6	7738	**15745**			9451

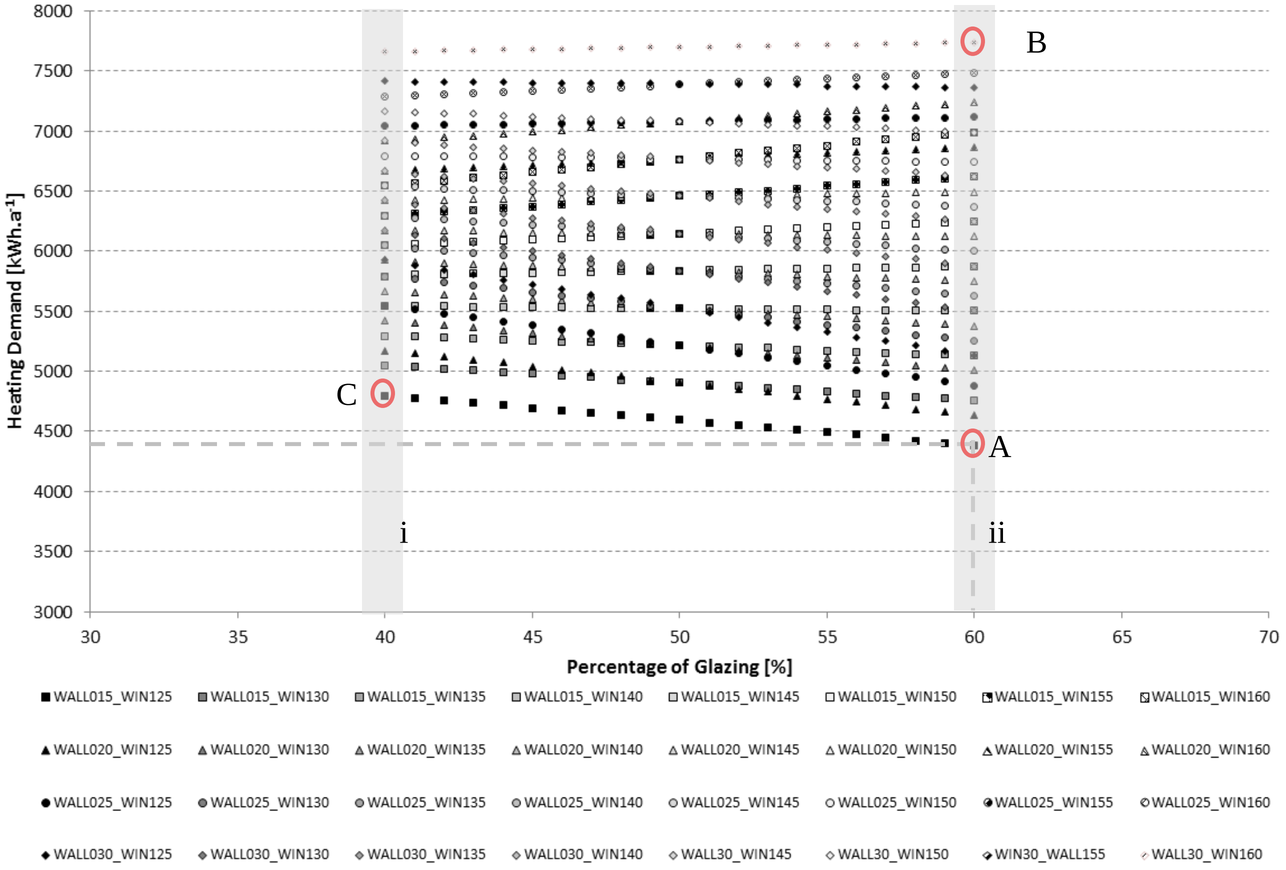


Figure 5: Result space of the illustrative test run. Highlighted are solutions for lowest (A) and highest (B) heating demand, lowest (area i) and highest (area ii) solar gains, lowest (C) and highest (A) transmission losses.

4 CONCLUSION AND FUTURE RESEARCH

The present contribution reported on ongoing efforts toward developing a web-based building performance evaluation tool that incorporates a simple XML building representation and is capable of automated input parameter variation. Future efforts in this domain will focus on:

- Integration of more advanced heat balance calculation methods as well as optimization tools (e.g., GenOpt 2014).
- Extending the XML-based model to improve flexibility in handling complex geometries
- Conducting a feasibility analysis on IFC-based (and other BIM-compliant) input models and potential integration of these in the presented approach.

REFERENCES

Augenbroe, G. 2010. Can simulation reveal how buildings really behave? Keynote-Lecture; BauSim 2010; 22.-24. September 2010; Vienna University of Technology.

CEN 2008: DIN EN ISO 13790:2008-09, Energy performance of buildings - Calculation of energy use for space heating and cooling (ISO 13790:2008); European Committee for Standardization

Energyglobe 2014 http://www.energyglobe.com/de_AT/; last visited: 29th January 2014

EU 2002: Directive 2002/91/EC of the European parliamant and of the council of 16 December 2002 on the energy performance of buildings. 2002; http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2003:001:0065:0071:EN:PDF; last visited: 29th January 2014.

EU 2010: Directive 2010/31/EU of the Europeam parliament and of the council of 19 May 2010 on the energy performance of buildings (recast). 2010; http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2010:153:0013:0035:EN:PDF; last visited: 29th January 2014.

GenOpt 2014: http://simulationresearch.lbl.gov/GO/; lats visited: 29th January 2014

Kyoto 1997.: The Kyoto Protocol to the United Nations Framework Convention on Climate Change(UNFCCC) 1997 http://unfccc.int/resource/docs/convkp/kpger.pdf; last visited: 29th. January 2014

OENORM n.d.: OENORM B 8110 (parts 1 – 7, different years): Wärmeschutz im Hochbau; Österreichisches Institut für Normung, Wien;

OIB 1999a: Leitfaden für die Berechnung von Energiekennzahlen; März 1999 Nummer OIB-382-010/99; Österreichisches Institut für Bautechnik; http://www.oib.or.at/Leitfaden2.doc; last visited: 29th January 2014

OIB 1999b: Excel-Tool; OIB-Programm für die Berechnung von Energiekennzahlen, Version hwb02f; Österreichisches Institut für Bautechnik, 1999;

OIB 2007a: OIB-Richtlinie 6: Energieeinsparung und Wärmeschutz, Oktober 2007; Österreichisches Institut für Bautechnik; 2007;

OIB 2007b: Energietechnisches Verhalten von Gebäuden, Oktober 2007; Österreichisches Institut für Bautechnik; 2007;

OIB 2011a: OIB-Richtlinie 6: Energieeinsparung und Wärmeschutz, Oktober 2011; Österreichisches Institut für Bautechnik; 2011; http://www.oib.or.at/RL6_061011.pdf

OIB 2011b: Energietechnisches Verhalten von Gebäuden, Oktober 2011; Österreichisches Institut für Bautechnik; 2011; http://www.oib.or.at/LF6_301211%20Revision.pdf

Puntigam, F. and Reiter, M. 2013 Skriptum zu Programmkonstruktion (185.A02 Grundlagen der Programmkonstruktuion und 183.592 Programmierpraxis) im Wintersemester 2013/14; Fakultät für Informatik, Technische Universität Wien, 2013

Semergy 2014: http://www.semergy.net; last visited: 29th January 2014