STOCHASTIC PRINCIPLES IN ENERGY DEMAND CALCULATIONS

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Summary

Paper deals with the use of the energy performance calculations for qualified discussion on building energy policy as well as for support of design process. The stochastic approach allowing the calculation of large amount of combination of input data in one step is presented. Example 1 identifies an energy saving potential by preparing of refurbishment of apartment buildings. Example 2 shows the combination of energy demand calculations with overall costs. Such prognosis can be advantageously used in the discussions about setting of energy related requirements at cost-optimum level.

Keywords: energy demand of buildings, space heating, stochastic methods, integrated design process, energy policy, cost optimum

1 Introduction

Previous studies [1, 2] presented possibilities of using the energy demand calculations based on stochastic approach. In general, such calculations can be used in a very effective way for overall assessments, for setting of targets and policy making. Software allowing user friendly operation together with quickly delivered and understandable results can become a very strong instrument during whole design process, as a real design supporting tool. Thus, the necessary decisions during the design of particular building can be advantageously based not only on personal experience, intuition and comparisons with other projects.

2 Calculation procedure and input data

The core model remains in all studied cases identical, based on standard procedure [3]. The calculations using steady state monthly method are repeated automatically for large amount of combination of input data (typically several hundred up to thousands). Stochastic principles for selection of input data and for expression of the results are used.

In general, all input data can be set in different modes:

- exact value, if available,
- reference to standard or legislative requirements (upper limit or lower limit, as interval),
- realistic default values created automatically within the software tool.

The results are expressed in the form of statistic evaluation of all calculations done for generated data sets (overall distribution, minimum and maximum for 90 % of results, mean value, probability of reaching usual targets). A sensitivity analysis describing the importance of input data in both, positive and negative direction, respectively can be used for "fine--tuning" in the next step of the building design.

3 Examples

3.1 Example 1

The stochastic method was used to analyze an energy saving potential of refurbishment of middle size apartment buildings. This set of virtual buildings is characterized by simple cubic form, built volume in the range 5.000 m^3–8.000 m^3 and 4 to 8 floors. The compactness level varies in the range 1,0–1,2.

Compactness level is defined here as the ratio of the area of vertical part of building envelope to its possible minimum for given geometry. The dimensions are created automatically within the given parameters for each round of calculation. Fenestration ratio is considered for each façade orientation as follows: S 35 %, W 25 %, E 25 %, N 20 %. The exact number of inhabitants is considered indirect as 35 m^2/person.

The stochastic space heat demand calculation was performed for the existing stage and for different levels of refurbishment (Tab. 1) in 1.000 plausible combinations in each case. The results are presented at Fig. 1 and Tab. 2. For information about energy demand reduction potential per building and energy demand per occupants see Tab. 3. Such values can be used in strategic planning e.g. at city or regional level. For the first two refurbishment strategies (envelope upgraded to today's requirements or recommendations, respectively [4]) natural ventilation is expected. Mechanical ventilation with heat recovery is planned for higher levels of refurbishment. Level 04 contains components suitable for passive house. Only the level 05 expects the change of layers in floor slab (mostly very costly and complicated operation). The generated geometry of the overall sample of buildings is characterized by mean value of A/V (surface area/volume) 0,37 m^{-1} and mean value of the floor area 1.980 m^2.

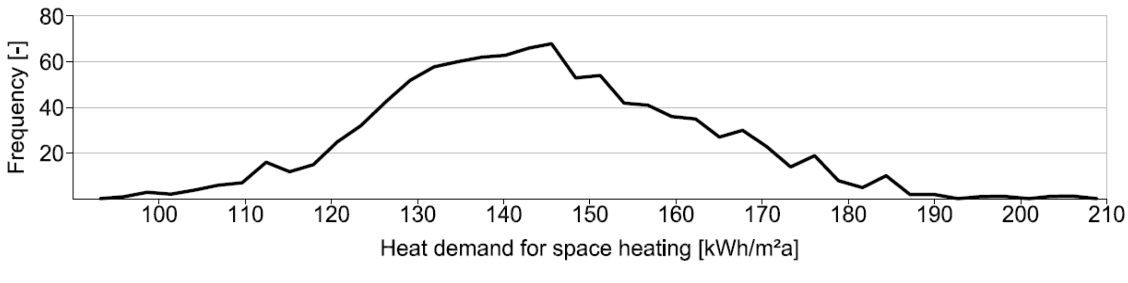


Fig. 1 *Space heat demand for set of buildings in Example 1 (existing stage)*

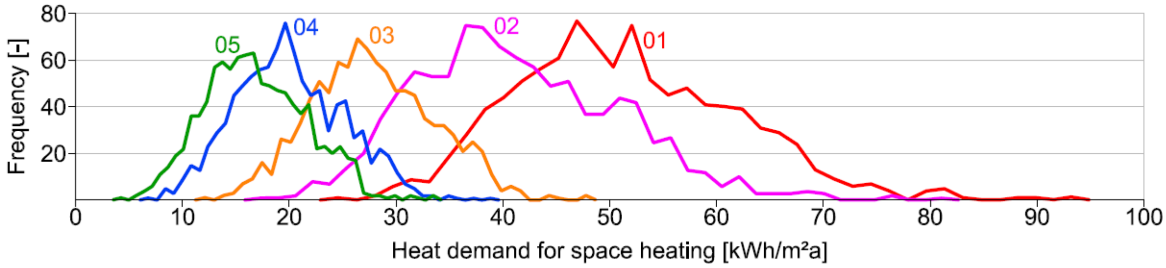


Fig. 2 Space heat demand for set of buildings in Example 1 – different refurbishment level

Tab. 1 Basic data on energy quality of virtual apartment building in Example 1

Altern.	Thermal transmittance U [W/(m^{2}K)]				Efficiency of heat recovery [%]
	Wall	Window	Roof	Floor	
Exist.	1,40	2,5	1,0	2,0	0
01	0,30	1,5	0,24	2,0	0
02	0,25	1,2	0,16	2,0	0
03	0,25	1,2	0,16	2,0	70
04	0,20	0,9	0,10	2,0	70
05	0,20	0,9	0,10	0,45	70

Tab. 2 Summarized results for Example 1

Altern.	Mean value of thermal transmittance U_{em} [W/(m^{2}K)]	Heat demand for space heating [kWh/(m^{2}a)]			Probability of reaching targets of 50 kWh/(m^{2}a) [%]
		Mean	95 % of values		
			above	below	
Exist.	1,42	145	118	176	0
01	0,56	52	37	70	45
02	0,48	42	28	58	78
03	0,48	28	19	38	100
04	0,39	20	13	29	100 (passive by 14 %)
05	0,35	17	10	25	100 (passive by 35 %)

Tab. 3 Space heat demand and potential for its reduction evaluated from mean values for whole building in Example 1

	Exist.	01	02	03	04	05
Space heat demand per capita [MWh/(pers.a)]	5,5	2,0	1,6	1,1	0,8	0,6
Reduction of space heating demand [MWh/a]	----	177	194	222	237	244

3.2 Example 2

The energy demand expressed in primary energy (non-renewable part) for middle size apartment building [2] was studied here together with overall costs in the life cycle period. For random selected combination of input parameters being in the range according to tab. 4 and tab. 5 the calculations were performed for 3000 combinations divided in 3 groups according to building quality.

The investment costs correspond to today’s practice in the country considering their increase for more advanced technologies. Moreover, the randomized fluctuation of investment costs was considered in the range +/-10 %, regardless to the level of technical solution. A period of 30 years of operation was taken into account [5]).

Energy prices consider the situation in 2011 with increasing 4 % from year to year. Results are expressed graphically as a function of primary energy (non-renewable part) and overall costs for natural gas as main energy carrier (Fig. 3). The overlapping “clouds“ illustrate that there is no significant difference among the building quality group in the overall costs. A very significant overlapping of the results is visible if the biomass heating in combination with solar thermal system was used. In such case the auxiliary energy and artificial lighting play the most important role, only little affected by building quality.

The overall results will change only slightly if other price scenarios are used (Fig. 4), simulating the situation in “cheaper” and “more expensive” regions regarding the investment costs by setting identical energy prices. By changing of prognosis for energy price development one can discuss if the “cost optimum” remains at the same level (Fig. 5).

Tab. 4 *Range of basic input data in example 2*

Parameter	**Unit**	**Lower bound**	**Upper bound**
Volume	m^3	5000	8000
Floor number	–	4	8
Occupancy	Pers/flat	2	4
Flat area	m^2/flat	40	100
n_{50} – air-tightness	1/h	0,50	4,00
Windows g – value	–	0,35	0,60
Energy for hot water	kWh/(Pers.a)	350	750
Efficiency of lighting device	lm/W	10	65

Tab. 5 *Range of thermal transmittance and heat recovery for three group of building quality in example 2*

Group	**Thermal transmittance U [W/(m²K)]**					**Efficiency of Heat recovery efficiency [%]**
	Wall	**Floor**	**Roof**	**Window**	**Thermal bridges (overall)**	
G3	0,20–0,36	0,30–0,45	0,20–0,24	1,10–1,70	0,05–0,10	0
G2	0,15–0,20	0,18–0,30	0,15–0,20	0,85–1,10	0,02–0,05	0,70–0,85
G1	0,10–0,15	0,12–0,18	0,08–0,15	0,70–0,85	0,00–0,02	0,70–0,85

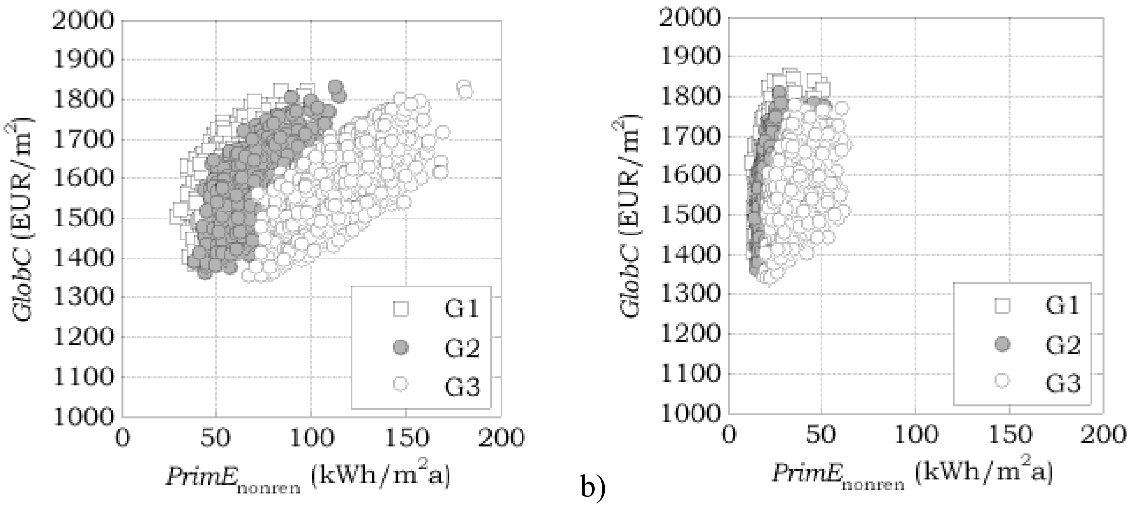
4 Concluding remarks

The stochastic approach in energy demand calculations can create a very good base for really competent discussions. One can see large amount of results in the same moment, the overall tendencies and sensitivity to different parameters. Such methods can be widely used as design supporting tool starting from the beginning of the process. Nevertheless, it should be noted that all energy demand calculations are prognosis only, based on expected building use in the future.

For such purposes a specific a web application for residential buildings was developed [6]. It calculates 1.000 plausible combinations of input data sets in approx. 90 second and sends back a corresponding protocol with the results and statistic evaluation.

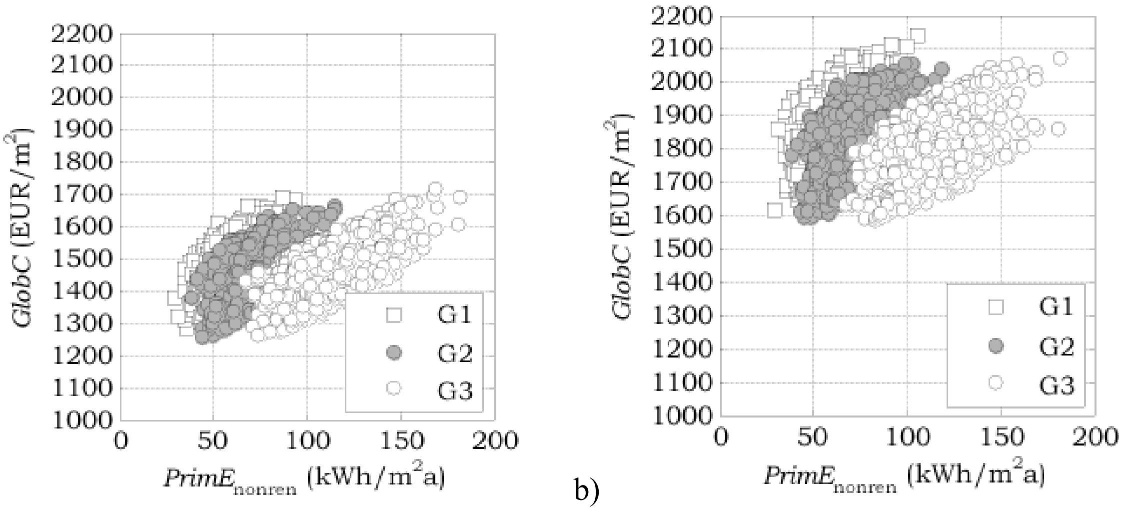
The combination with overall cost calculation could bring valuable results. Quite large un-certainties are connected to the setting of investment costs and energy development scenarios. Having in mind this fact the results can be used for studying overall tendencies. Of course, the better the information about costs are the better the quality of overall results can be.

The method described here can be subject of further development to be relevant for other building typologies and for other climatic conditions, respectively.



a) b)

Fig. 3 *Study on relation primary energy (non renewable part) and total costs for apartment buildings with different energy carriers. a) Case A – Heating and hot water: natural gas, b) Case B – Heating: biomass (wooden pellets), hot water: solar thermal system + 50 % support by biomass. In both cases auxiliary energy and artificial lighting: conventional electricity*



a) b)

Fig. 4 *Study on relation primary energy (non renewable part) and total costs for apartment buildings for case A in Fig.3, identical energy costs a) Investment costs at 90 % level, b) Investment costs at 120 %*

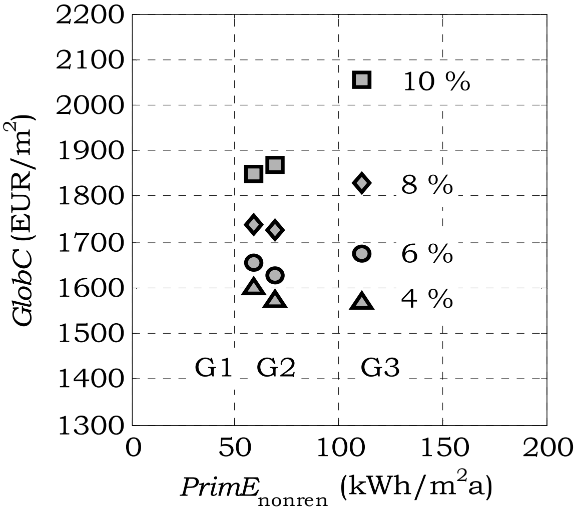


Fig. 5 *Study on relation primary energy (non renewable part) and total costs for apartment buildings for case A in Fig. 3 with different energy costs development scenarios for median values*

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