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ENERGY EFFICIENT BUILDING DESIGN LEGAL BASIS

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Abstract. Nowadays there are passed many EU directives and documents aimed to stimulate development of renewable energy resources and reduction of energy demand in living houses. On another hand, energy efficient buildings in legal acts are described very broadly and their parameters vary in wide range. There are no unified methodology to evaluate building energy demand at its design and pre-operation (energy performance certification) stages as well. The analysis on comparison of legal methodologies for evaluation of building energy demand and building energy performance is made by the authors and presented in this paper. Imperfections of technical regulations and possible improvements are presented here as well.

Keywords: energy efficiency, energy efficient building, energy demand, sustainability, construction technical regulations.

1. Introduction

Under Baltic Sea Region 2007-2013 programme "LONGLIFE" project is established to develop the concept and prototype of energy efficient multi-storey residential building (Ruckert et al. 2010). It is set that annual energy demand of "LONGLIFE" house should not exceed 40 kWh per square meter of heated area (excluding the consumption by individual equipment of user). 30% of the demand should be covered from renewable resources and by year 2050 this amount should increase up to 100 %. (Ruckert *et al.* 2010). These requirements well correspond to the newest Directive 2010/31/EU of the European Parliament and of the Council of 19 May 2010 on the energy performance of buildings (recast). The EPBD recast now requests that Member States shall ensure that minimum energy performance requirements for buildings are set "with a view to achieving cost-optimal levels". "The cost-optimal level shall lie within the range of performance levels where the cost benefit analysis calculated over the estimated economic lifecycle is positive."

Apart of exceptional thermal properties attractiveness of low-energy building depends on various local circumstances. One of them is heat source reliability and convenience. The mission of "LONGLIFE" programme is to promote erection of low-energy sustainable residential buildings by exposing their advantages and attracting attention of public opinion and construction companies. The task is not to explore effectiveness of particular energy saving remedy. The task is to find economically and energy efficiency viable solution of residential buildings suitable for repetition in Baltic States climate and at the state of economy.

Blocks of flats possess specific features compared to one family houses: 1) tens of times higher power demand, 2) often it is built as a single unit, 3) their position and heat source highly depends on built environment. Thereby, focus is made on integrating, accessibility and reliability of solutions.

It is told in previous as well as in the latest version of Directive 2010/31/EU that methodology on evaluation of energy demand should be unified. In this case it should be pointed that there are two Construction Technical Regulations allowing evaluation of energy performance of buildings in Lithuania. STR 2.09.04:2008 "Power of heating system. Heat demand for heating" is intended to calculate energy demand of buildings. Another one STR 2.01.09:2005 "Energy Performance of Buildings. Certification of Energy Performance of Buildings" is set to evaluate energy efficiency of buildings. The regulations are prepared in accordance with European standards EN 12831:2003, EN 832:1998/AC:2002, EN ISO 13790:2004, however some amendments are made; this development raises an issue of regulations mentioned above compatibility. Quality of both Regulations is of crucial importance for construction of energy-efficient buildings analysis and comparison of methodologies.

2. Research object

Nowadays under the logical deed of building lifecycle the regulation STR 2.09.04:2008 should be applied for a house in its design stage. Later a building should be certified in pre-operation stage using STR 2.01.09:2005. The same building data (Tables 1-4) were applied for both methodologies of energy demand evaluation.

Table 1. Climate. Mean monthly air temperature (STR 2.09.04:2008)

Locality	Month											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Vilnius	-5,5	-4,5	-0,1	6,4	13,3	16,7	18,0	17,0	12,3	7,2	1,9	-2,2

Table 2. General building data

Length, m	Width, m	Height, m	Internal volume, m^3	Living area, m^2	Staircase area, m^2	Total heated area, m^2	Occupancy, persons	Location
33,2	16,2	14	5197	1648	144	1792	58	Vilnius

Table 3. Thermal envelope characteristics

Component/ Parameter	Description	Area, m^2	U-value, W/m^2K	Length, m
Walls		853,20	0,12	
Windows:	South/East	320	0,8	
	South/West	50	0,8	
	North/East	-	-	
	North/West	160	0,8	
Roof		537,84	0,12	
1st level floors		537,84	0,12	
Entrance doors		5,28	0,7	
Linear Thermal bridges	Windows, doors, roof, basement			1019,2
	House corners			56

Table 4. Building services

Heating system	Hot water system	Solar collectors area, m^2	Ventilation system	Ventilation fan power, W	Ventilation fan efficiency	Heated area, m^2
Individual gas boiler, hydronic water heating system with automatic control	Individual gas boiler and solar collectors, hot water storage tank	85	Mechanical ventilation with heat recovery	350	0,75	1792,00

Coefficient of total solar radiation energy permeability g = 0,48. All flats are equipped with individual heat recovery air handling units, annual heat recovery thermal efficiency is equal to 0,75, mechanical ventilation air change rate n_{mech}= 0,5 h^{-1}, infiltration air change rate n_{inf} = 0,15h^{-1}.

Architectural and technical solution of building was designed in accordance with Construction Technical Regulation STR 2.02.01:2004 „Residential buildings“ and guidelines of LONGLIFE multi-storey apartment house (Ruckert *et al*. 2010).

In the research if the same building data is applied for both technical regulations STR 2.02.09:2005 and STR2.09.04:2008 it is logical to expect coincidence of the results. This assumption is going to be examined in next chapter.

3. Comparative analysis of the results

The aim of heat demand and energy performance calculations was not only to find figures but also to reveal shortages in existing Building Codes or other documents concerning energy efficient residential building design.

Heat demand is calculated strongly in accordance with Construction Technical Regulation STR2.09.04:2008 and STR 2.02.09:2005 and reference documents mentioned in those Codes as EN 12831:2003, EN 832:1998/AC:2002, EN ISO 13790:2004 except taking into account expected number of residents. Heat demand calculation in 2.09.04:2008 is based on monthly method, in STR 2.02.09:2005 are used mean values and simplifications. The results are presented in table 5.

Table 5. Comparison of calculated heat gains and losses by STR 2.01.09:2005 and STR 2.09.04:2008

No.	Description	Losses / Gains, W/m^{2}K*year	
		STR 2.01.09:2005	STR 2.09.04:2008
1.	External walls	-5,85*	-5,58
2.	Roof	-3,69*	-3,34
3.	1st level floor	-2,73*	-2,34
4.	Windows	-24,24*	-22,71
5.	Entrance doors	-0,21*	-0,31
6.	Linear thermal bridges	-5,47*	-6,02
7.	Entrance door opening losses	-1,05	-3,46
8.	Ventilation heat losses	-6,01	-7,62
10.	Air infiltration	-35,68*	-13,72
11.	External (solar) gains	28,51*	17,38
12.	Internal gains	15,48	17,90
13.	Hot water preparation	-26,67*	-27,2
14.	Total losses	-111,6	-92,3
15.	Total gains	43,99	35,28
16.	Heat demand (incl. evaluation of heating system efficiency**)	-71,11	-57,02
17.	Heat gain from solar collectors for hot water preparation***	14,2	14,2
18.	**End-use heat demand**	**-56,91**	**-42,82**

Electricity consumption by individual equipment is not included in the results.
* The parameters are calculated using NRG-SERT programme package.
** Applicable for STR 2.01.09:2005 only.
***Construction Technical Regulations do not mention calculations of energy gains from renewable energy resources.

There are some parameters in Table 5 whose results vary significantly (pos. 7, 10, and 11). In total these discrepancies differ approximately 21 % for total heat losses (pos. 14), 25 % for total heat gains (pos. 15) and 33 % for overall heat demand (pos. 18). This fact forces to deepen in the regulations to find variances in methods of energy losses and gains evaluation.

To find first differences there is no need to go deep inside. The heating season time span of 220 days (when outside temp. <10°C) and average outside temperature 0,6°C is stated in STR2.01.09:2005 while 225 days with 0,2°C is written in STR2.09.04:2008.

Generally it can be stated that in regulation "Energy performance of buildings" (STR2.01.09:2005) a simplified calculation methods rather refer to average statistical data and various coefficients than to accurate parameters of particular building. Meanwhile the regulation "Capacity of heating system" (STR2.09.04:2008) basically concentrates on precise evaluation of a researched building characteristics.

The formulas for calculation of air infiltration (pos. 10) represent different understanding in the regulations of what destines these losses. In STR2.01.09:2005 the main parameter determining air infiltration flow is area of windows and doors while in STR2.09.04:2008 these are infiltration air change rate (depends on climate and location conditions) and internal volume of a building. This could probably explain why the results vary so much. Mathematically it could be possible to minimise greatly losses in first regulation by decrease of total amount of windows but it would just show imperfection of calculation method. Meanwhile it wouldn't significantly change the result of the second regulation.

Discrepancies happen while evaluation of solar gains through transparent parts of building envelope as well (pos. 11). Even calculation algorithms differ in compared regulations, their principle to determine sun energy inflow inside the building is pretty the same. The simplified method of calculation stated in STR 2.01.09:2005 where the multiplier to evaluate window frame and other shadings in the formula is placed. Anyway comparing to a precise calculation of STR 2.09.04:2008 based on monthly solar gain calculation the mentioned multiplier is not precise enough.

Pretty the same situation happened while calculating entrance door opening losses (pos. 7). More precise algorithm of STR 2.09.04:2008 determined more accurate result and shown imperfect value of multiplier in algorithm of STR 2.01.09:2005.

Separately it is worth to be mentioned method of heat calculation for domestic hot water as there are no any guidelines in both Regulations. Solar energy input estimation is based on three year field measurements near Kaunas (120 km SW from Vilnius). Measurements revealed that solar plate collectors have produced 400 kWh/m^2 per year of heat for hot water preparation (Suksteris, 2007). In case of optimal maintenance (regular cleaning from dust and snow) and optimal placing heat production may be up to 520 kWh/m^2 per year. Collectors would be placed on the roof of LONGLIFE building; thus they will not be cleaned regularly.

Monthly run of delivered heat from 78 m^2 solar collectors is shown on the Fig 1.

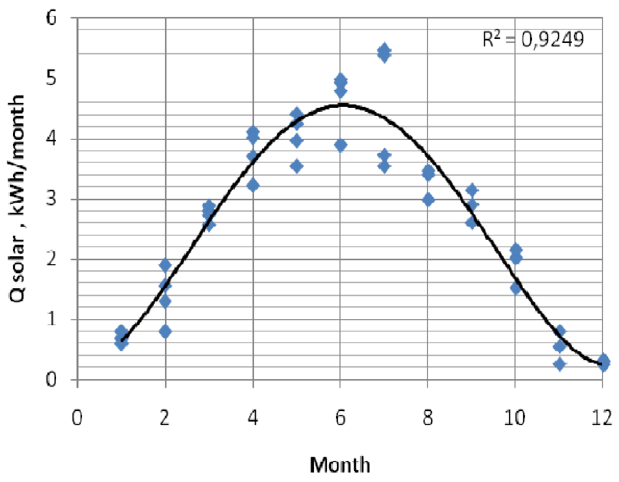

Fig 1. Monthly run of delivered heat in years 2004-2007 (Suksteris, 2007)

Surface of solar collectors is assuming that their heat production covers heat demand in June-July (Fig 2). Part of heat that is lost in hot water delivery system depends on system type. Preliminary, monthly heat loss could be up to 33%, then design area of solar collector is 85 m^2. Exact value of heat loss may be found after the system was constructed. Piping heat loss is not included as heat gain in Table 5.

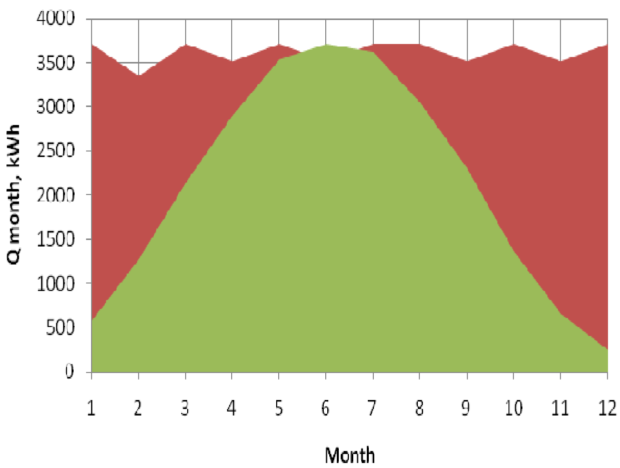

Fig 2. Monthly heat demand for domestic hot water and heat supplied by solar collectors. *Background – monthly heat demand, central cone – heat supplied by solar collectors*

The comparison of presented technical regulations has pointed the need of their improvements and unification.

Nowadays the same house in certification stage will probably show worse energy performance values than it was expected under energy demand calculations in building design phase. For accurate markings of this statement analogous researches should be applied for more examples of multi-storey residential houses.

4. Discussions

Lithuanian Building Codes are tailored having in mind residential buildings which specific annual heat consumption for heating and ventilation near 100 kWh/m^2a and more. The terms "energy-efficient", "low-energy building", etc., are not mentioned in the Regulations at all.

The aftermath of this is lack of data for low-energy building design:

- Outdoor air design temperatures come from 50 years old SSSR Regulations data. Design temperature for heating is defined as the point below which temperature lasts not more than 220 hrs (it corresponds to 2,5% of year hours), actual duration of the temperature equal or lower than design temperature is 0,4%.
- Use of renewable energy sources is not foreseen, except general statements.
- Extracted ventilation air heat recovery is mentioned however left for customer's decision.
- Length of thermal bridges and heat transmission coefficient of thermal bridges defined in accordance with Regulations are presumably much bigger than in low-energy buildings thanks more careful design of latter.
- Details that are of minor importance in the case of energy wasting buildings become essential in energy balance of energy effective ones, e.g. infiltration heat loss through the external doors of staircase calculation is based on presumption that staircase manhole to the roof is open during heating season or cracked.
- Selection of energy sources is based on traditional fuel burning boilers or electricity. There are no strictly defined requirements to use renewable energy sources. Direct use of solar heat is well investigated for domestic hot water preparation and as solar heating; solar collectors of acceptable costs are well developed. Solar collectors may cover more than half of heat for hot water preparation; however this is not reflected in norms.
- Solar radiation through windows covers substantial part of transmission heat loss. Weak point of large windows is increased solar radiation in summer resulting in non-comfortable indoor climate and heat loss in winter, however integrated approach is absent in norms.
- No thermal parameters of energy efficient windows are given in the Regulations; value of internal heat gain is subject for discussion; "passive" measures for decrease of solar radiation at summer time are not described in researched construction technical regulations.

Strictly speaking the design and construction of energy-effective residential building might be done more efficiently, consuming less time if some good practice recommendations exist. Reduction or increase of any parameter influences other ones; final result is not clear. Naturally, in the case of LONGLIFE building all accessible examples of energy efficient building were analysed, conclusions were drawn however absence of milestones substantially aggravated design process.

The calculation reveals that specific annual heat demand for heating, ventilation and domestic hot water preparation in multi-storey residential house in Baltic States' climate may be less than 40 kWh/m^2 per year without special efforts; also up to 2/5 of heat annual losses may be compensated by internal and solar heat gains. Further lessening of heat demand needs more sophisticated heat saving improvements and more knowledge on the behaviour of residents. (Spiekman, 2010; Wellmer, 2008), eg., Baltic States' residents are accustomed to have a bath in a flat, not a shower, many of them believe that a house must be energy–efficient by itself without any care of, etc.

Building design and construction includes many actors; every of them present its own view. In many cases architect's opinion does not coincide with HVAC engineer's suggestions. It is evident that the best energy saving results may be achieved by compromise; however without authoritative recommendations it is not evident whose opinion is preferable.

5. Conclusions

The comparable analysis of construction technical regulations pointed the necessity of their upgrade. The calculation algorithms of regulations are based on experience of past decade inefficient building design with unacceptable assumption of huge energy demand.

It is urgent to fulfil the requirement of Directive 2010/31/EU to unify methodology on evaluation of energy performance of buildings in the whole territory of European Union. Performed research pointed that Lithuanian norms even based on European standards are not unified.

Even the same building data was used for both calculation methods they resulted with different building energy demand. Discrepancy for total energy losses equals to 21%, gains – 25% and 33% in end-use energy demand. This means the house will probably be certified as worse energy performance class than it was expected under energy demand calculations in building design phase.

The definite parameters for description of energy efficient houses should be stated in technical regulations and other kind of legal acts. These should also contain effective and obligatory guidelines for expansive application to renewable energy resources while meeting house energy needs.

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