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Achieving Deep Energy Retrofit in Latvian Public Building - Simulation Study

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Abstract

During the last few decades an increased attention has been directed towards reduction of building energy use. This paper presents results of a simulation study to achieve deep energy retrofit in a five story dormitory of about 3825 m^2, located in Latvian capital Riga. Simulation was carried out within the framework of Annex 61 "Business and Technical Concepts for Deep Energy Retrofit of Public Buildings" of program "Energy Conservation in Buildings and Communities" by International Energy Agency. A software "Riuska" was used for comfort and energy simulation. Following scenarios have been used in modelling: Scenario 1 (baseline) represents the pre-1980 standard to describe the building envelope and systems before renovation. Scenario 2 (base case) is the country specific "business as usual" retrofit to meet requirements of minimum current national standards. Scenario 3 is related to application of core energy technology bundles to achieve approximately 50% energy use reduction against the baseline (scenario 1). Scenario 4 targets to achieve a current national "dream energy standard". Energy improvement measures for scenarios 2 to 3 focused on the reduction of transmission and infiltration losses through insulation of building envelope and replacement of windows. These measures are one of the most frequently implemented ones in Latvian public buildings, where most energy is used for heating. Building's energy need for space heating was 143 kWh/($m^2 \cdot a$) before renovation as for scenario 1 (pre-1980 standard) and has been reduced in the scenario 4 ("dream energy scenario") to 27 kWh/($m^2 \cdot a$).

Keywords - Deep energy retrofit, energy use, public buildings

1. Introduction

During the last few decades an increased attention has been directed towards reduction of building energy use. High and constantly growing energy prices together with the growing concerns about the global climate change have made many governments worldwide set more stringent targets on energy consumption of buildings. One such example is the European Union's introduced Energy Performance of Buildings Directive [1] and the Energy Efficiency Directive [2] which focus on energy performance certification, financing renovations as well as on setting energy targets, e.g. for all new buildings to be nearly zero energy buildings (nZEB) by 2020.

The substantial part (about 60%) of the existing building stock (non-residential excl. industrial) in the European Union is comprised of buildings constructed before 1975 [3]. These buildings can be characterized by very poor energy performance contributing greatly to high energy use of the building sector in general. Despite the great effort put into applying "know-how" knowledge regarding energy efficiency in old building stock, results from the typical retrofit projects show only 10-20% reduction in energy use.

Results from numerous studies conducted all over the world show great potential in achieving energy savings of 50% and even more after renovation of residential and public buildings. Moreover, approaching the passive house standard or zero energy building status can be achieved in a cost effective way. In these studies hundreds of individual energy efficiency measures were identified attributable to e.g. building envelope, heating, ventilating and air conditioning (HVAC) systems, energy production and generation systems, building internal processes including occupant behaviour [4]. Bundling of individual measures together can greatly reduce energy use for a smaller investment, leading to a shorter payback time as indicated by studies of [5, 6, 7, 8].

This paper presents results of a simulation study to achieve deep energy retrofit (DER) in a Latvian public building. Simulation was carried out within the framework of Annex 61 "Business and Technical Concepts for Deep Energy Retrofit of Public Buildings" of program "Energy Conservation in Buildings and Communities" by International Energy Agency [9].

2. Methodology

The modelling project was a five story dormitory building located in Riga, Latvia. A building model used for comfort and energy simulation with software "Riuska" is presented in Fig. 1.

Fig. 1 Building model used in simulation

The modelling building represents the design, construction system and energy performance typical for most of the buildings constructed in Latvia during 60's and 70's. Buildings were typically composed of precast concrete panels without additional insulation. District heating system was a primary source of energy for heating and domestic hot water. Buildings had one-pipe radiator heating systems. Control of individual room temperature was impossible since radiators were not equipped with special thermostats. Room temperature for the entire building was therefore regulated in heat substations based on outdoor temperatures. Premises were ventilated by means of a natural ventilation with openable two-pane windows in wooden frames. Kitchens were normally equipped with a ventilation hood.

Details concerning the layout of the modelling building are listed in Table 1.

Table 1. Characterization of the modelling building

Number of floors	Five
Net area, m^2	~3825
Heated area, m^2	~3400
Number of apartments	80
Usage of building	Dormitory

Following scenarios were simulated:

- Scenario 1 (baseline) represents the pre-1980 standard to describe the building envelope and systems before renovation.
- Scenario 2 (base case) is the country specific "business as usual" retrofit to meet requirements of minimum current national standards.
- Scenario 3 is related to application of core energy technology bundles to achieve approximately 50% energy use reduction against the baseline (scenario 1).
- Scenario 4 targets to achieve a current national "dream energy standard" (nZEB within scope of this study).

The energy simulation was based on climatic data collected in Riga (World Meteorological Organization number 26422) during the period of years 1961-1990. This also corresponds to the national weather data given in Table 2.

Table 2. Mean monthly air temperatures

Month	Jan	Feb	Mar	Apr	May	Jun
Air temperature, °C	-2.1	-2.7	0.7	7.0	12.3	15.4
Month	Jul	Aug	Sep	Oct	Nov	Dec
Air temperature, °C	19.0	17.8	12.9	7.4	2.8	-0.6

Table 3 illustrates assumptions that were used in simulation. This input data has been constant for all four simulation scenarios.

Table 3. Simulation input data

Heating set-points, °C	
Bathrooms	25
Bedrooms	18
Kitchens	18
Other rooms	18
Heat gains (human occupancy + electrical appliances), W/m²	
Kitchen	
07.00-17.00	8.0
17.00-23.00	20.0
23.00-07.00	2.0
Bedroom	
Weekdays	
07.00-17.00	1.0
17.00-23.00	1.0
23.00-07.00	6.0
Weekends	
07.00-17.00	2.0
17.00-23.00	4.0
23.00-07.00	6.0
Lighting, W/m²	
Kitchen	
07.00-17.00	3.6
17.00-23.00	9.0
23.00-07.00	0.9
Bedroom	
07.00-17.00	0.0
17.00-23.00	4.5
23.00-07.00	0.0
HVAC equipment	
Natural ventilation/ infiltration schedule (scenarios 1, 2 and 3)	24 hours every day
Air handling unit operation schedule (scenario 4)	24 hours every day

3. Results and discussion

Most important simulation parameters incl. heat transmission coefficients (U-values) for building envelope elements defined through modelling of four scenarios are presented in Table 4.

Table 4. Most important building parameters of scenarios 1 to 4

	Scen. 1 (baseline)	Scen. 2 (base case)	Scen. 3 (50% energy use reduction against the baseline)	Scen. 4 ("dream energy standard")
	U-value, W/(m²·K)			
Wall	1.20	0.19	0.19	0.19
Roof	1.25	0.16	0.16	0.16
Slab	0.69	0.16	0.16	0.16
Windows	2.61 (g=0.61)	1.37 (g=0.51)	1.37 (g=0.51)	1.21 (g=0.38)
	Thermal bridges, W/(m·K)			
Window perimeter	0.40	0.11		
External wall-Roof	0.30	0.11		
External wall-internal slab	0.40	0.11		
External wall - ground slab	0.30	0.11		
External wall - External wall	0.20	0.11		
	Ventilation and infiltration			
Ventilation type	Natural			Mechanical
Building air tightness, [m³/(h·m²)] @ 50Pa	-	-	-	1.50
Average infiltration rate, ACH	0.70	0.50	0.60	0.028
Average ventilation rate, ACH				1.00

Energy improvement measures for scenarios 2 to 3 focused on the reduction of transmission and infiltration losses through insulation of building envelope and replacement of windows. These measures are one of the most frequently implemented ones in Latvian public buildings, where most energy is used for heating (3451 heating degree days in Latvia at base temperature of +17°C). Approximately 50% energy use reduction against the baseline can be achieved by implementing "business as usual" retrofit to meet requirements of minimum current national standards. To further reduce energy use to approach the nZEB requirement, additional reduction of U-value for windows was necessary by changing two-pane windows to even more energy efficient three-pane ones. Additionally, in scenario 4 solar collectors were introduced along with the mechanical ventilation system with heat recovery efficiency of 75% and specific fan power of 1.50 kW/(m³/s).

Results concerning the energy performance for four scenarios, expressed in site energy demand is given in Fig. 2.

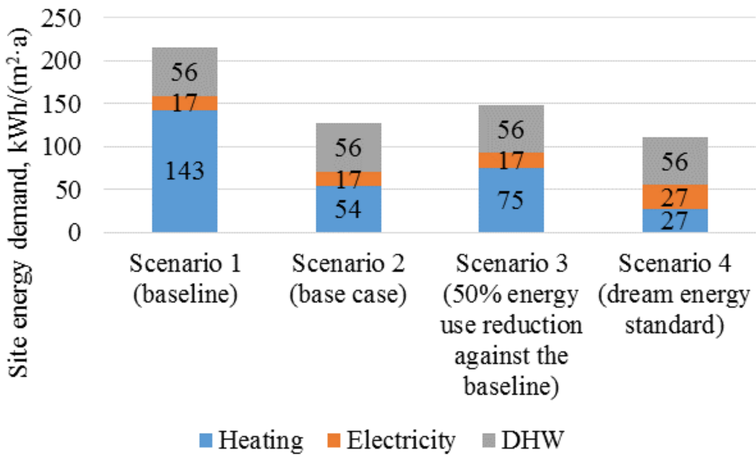

Fig. 2 Site energy demand for Latvian building model

Building's energy need for space heating was 143 kWh/(m²·a) before renovation as for scenario 1 (pre-1980 standard) and has been reduced in the scenario 4 ("dream energy scenario") to 27 kWh/(m²·a).

Introduction of mechanical ventilation system in scenario 4 is accompanied with increase in electricity necessary for operation of ventilation fans compared to scenario 2 with natural ventilation only. Site energy demand for heating included both space heating and ventilation air heating, calculated with heat recovery. Site energy demand for heating is greater for scenario 3 compared to scenario 2 due to greater average infiltration rate, i.e. 0.5 and 0.6 air changes per hour for scenarios 2 and 3 respectively.

Results concerning the energy performance for all four scenarios, expressed in source energy demand is provided in Fig. 3.

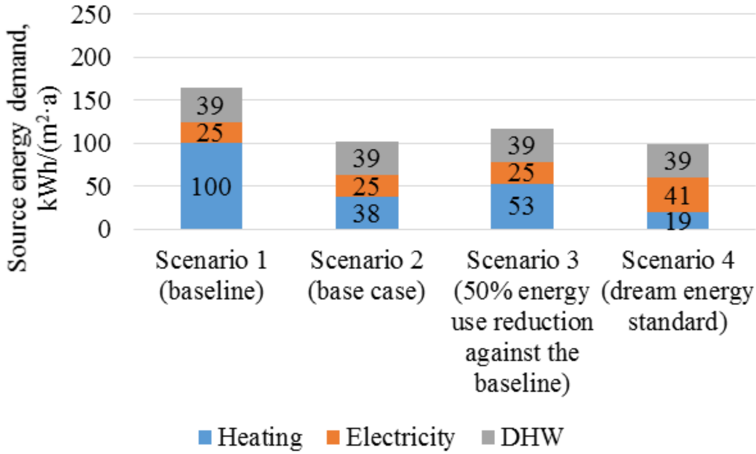

Fig. 3 Source energy demand for Latvian building model

Conversion from site to source energy was done using following primary energy factors: 0.7 for district heating and 1.5 for electricity. District heating in Latvian capital Riga comes from combined heat and power (CHP) plants, where mainly biomass and natural gas is used. This is the reason why source energy demand is consequently lower compared to site energy demand. Electricity is produced both at CHPs and hydroelectric power plants. Energy performance value of about 100 kWh/(m^2·a) was achieved in scenario 4 as for “dream energy standard”.

4. Conclusions

This paper presents results of the simulation study to achieve deep energy retrofit in a Latvian public building - five story dormitory. Energy improvement measures for scenarios 2 to 3 focused mainly on the reduction of transmission and infiltration losses through insulation of building envelope and replacement of windows. These measures are one of the most frequently implemented ones in Latvian public buildings, where most energy is used for heating. This allowed about 50% energy demand reduction against the baseline to be achieved by implementing “business as usual” retrofit to meet requirements of minimum current national standards. To further reduce energy use to approach the nZEB requirement, additional reduction of U-value for windows was necessary by changing two-pane windows to even more energy efficient three-pane ones. In addition, solar panels and mechanical ventilation with heat recovery of 75% and specific fan power of 1.50 kW/(m^3/s) were introduced in scenario 4 to approach the nZEB requirement. By using these measures it was possible to reduce building's total energy need for space heating from 143 kWh/($m^2 \cdot a$) before renovation to 27 kWh/($m^2 \cdot a$) in the scenario 4 ("dream energy scenario").

Acknowledgment

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