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DYNAMIC ENERGY SIMULATION OF NZEB BLOCK OF FLATS TO BE BUILT IN KIEV

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The study presented in this article comes from the business venture of a Ukrainian construction company to create buildings in Kiev with high energy performance and at a competitive cost compared to the highly energy efficient buildings throughout the area. As known, the political contingencies between Russia and Ukraine are imposing a drastic reduction in the use of natural gas. Moreover, Ukraine is a big producer of high quality wood at competitive prices.

Based on these considerations, a study for the design of an NZEB building was carried out, which uses raw material linked to the territory, that is wood, thus eliminating the use of natural gas. Furthermore, this study offers plant solutions suitable to cold climates.

The aim of this article is to show the valuable contribution given by the dynamic energy simulation in order to calculate the variations in annual energy consumption and operating costs of the studied building depending on different building enclosures and system features.

The economic comparison between different solutions in terms of Life Cycle Cost, over a period of twenty years has allowed us to identify the optimal mix of technologies and materials and has oriented the investor decisions.

The goals achieved are relevant: elimination of the use of natural gas and drastic reduction of CO_2 emissions due both to the low carbon footprint of the used materials and to the use of renewable energy

1. INTRODUCTION

The work described in this article was carried out to assist a Ukrainian company in constructing a NZEB in Kiev. The study compared two possible design solutions: a traditional and an alternative.

Using the dynamic energy simulation, we calculated the savings based on the expected usage modes. We also implemented in the model a photovoltaic system for electricity generation in such a way to obtain an NZEB.

2. DESRIPTION OF THE MODEL

The building under construction is for residential use. The total air-conditioned area is about 800 m^2. The used constructive typology is a wooden structure, well insulated (U=0,15W/m^{2}K) with windows consisting of low emission triple glazing and wood frame.

Based on the architectural concept, we created a numerical model of the building, which reproduces the behavior under dynamic conditions of operation.

The numerical model was realized according to ASHRAE regulations; in particular, we used The EnergyPlus calculation engine developed by the Department of Energy of the United States of America. We created room use profiles, based on the expected use of the building and the expected behavior of the occupants, and we set an hourly weather file of Kiev.

To model the photovoltaic system, we used typical values of common commercial products in polycrystalline silicon modules. The receiving surface is equal to 90% of the total covered area. The cell efficiency is 14.2%, equivalent to 16.7% less 15% to take into account the decrease in performance of the panel over the years (25 years). The inverter efficiency is equal to 90%.

The first HVAC modeled configuration is a traditional type. It has a hot water radiator system supplied by a gas-condensing boiler and a trial-split air conditioner system for each apartment. There is no controlled mechanical ventilation system. However, we fixed a minimum air exchange equal to 0,3vol/h necessary to ensure the thermo hygrometric comfort.

The second HVAC is a water-water heat pump system coupled with a geothermal borehole exchange system (aka GSHP). To enable the heating and the cooling of the rooms, we chose a chilled beam system with an average water temperature of 17°C in cooling mode and an average water temperature of 35°C in heating mode. This solution is possible by delegating the task to meet the thermal load due to the envelope to the chilled beam and the thermal load due to the ventilation of the mechanical ventilation system, which provides an air exchange of 0,3vol/h. The system also provides a heat recovery of 70%. The treated air reaches the beam at a temperature of 16°C in summer and of 20°C in winter.

3. ANALYSIS OF THE RESULTS

The comparative evaluation between the two system types emphasized, as expected, the elimination of the use of natural gas against an increase of electricity consumption. We converted the fuel consumption due to the kitchenette from gas to electricity induction with a conversion factor equal to 0,54 [1]. Table I shows the results of the simulation for the two cases; you can see a saving of natural gas of about 34,4 MWh against an increase of electricity consumption of about 6,3 MWh.

Table I

Energy consumptions of the building in kWh

Use	Energy	Case 1	Case2	Diff.
Equipment	Electricity	8.682	11.730	+3.048
Equipment	Natural gas	5.644	0	-5.644
Lighting	Electricity	5.817	5.817	0
Fans	Electricity	54	246	+192
Pumps	Electricity	160	795	+635
Air-cond.	Natural gas	28.710	0	-28.710
Air-cond.	Electricity	231	2.686	+2.455
Total	Electricity	14.944	21.274	+6.330
Total	Natural gas	34.354	0	-34.354

In order to highlight the different behavior of the two HVAC systems, Figure 1 and Figure 2 show the profiles of energy consumption during a typical winter day for the two studied cases. You notice a drastic reduction in consumption due to the use of GSHP system.

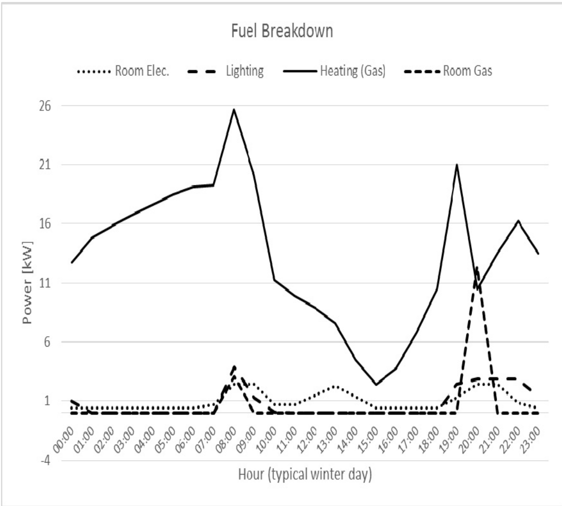

Figure 1. Winter day, case 1

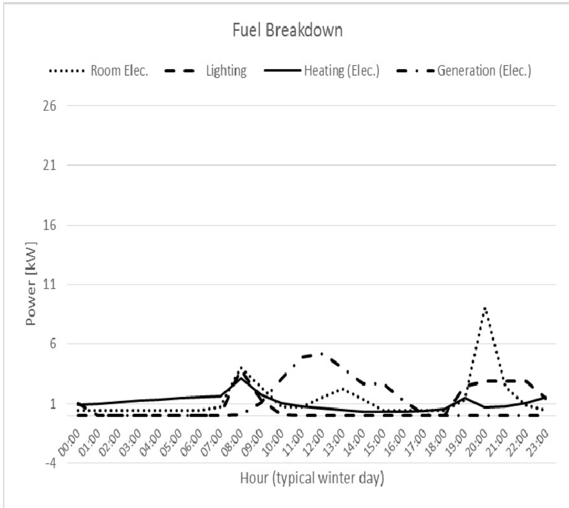

Figure 2 .Winter day, case 2

Once the electricity used was defined, we included in the model a photovoltaic system for electricity production. We sized the system to meet the whole electricity needs in a year. The simulation showed that 160 m^2 of photovoltaic panels were sufficient to compensate for the electricity consumed from the building, The electricity generation calculated with the energy simulation is around 22,7MWh. In Figure 2, you can see the contribution in terms of energy generated by the PV system.

3. ECONOMIC EVALUATION

The cost evaluation of HVAC systems was made based on a pre-sizing according to the maximum needed thermal power obtained from the calculations: 27 kW for the traditional system and 18 kW for the alternative one. Recovery heat of mechanical ventilation reduces heat loses. Costs are approximate, taken from list prices we requested from suppliers. A precise cost can be estimated only as a result of an executive project:

- Cost of traditional HVAC system[1]: **90.809€**.
- Cost of alternative HVAC system [2]: **93.000€**.

The cost of the alternative HVAC system is only **2.191€** higher than that of the traditional system. In order to make a comparison between both systems, we identified, through the simulation, the annual energy needs of the two configurations, in terms of electricity and gas equal to **321€** (see Table II).

[1] Prices, including installation, taken from the list prices of building works in Italy.
[2] Prices provided by estimates requested to Italian suppliers and installation firms.

Table II

Comparison of operating cost

	En. (Gas)	Cost (Gas)	En. (Elec.)	Cost (Elec.)	Total En. Cost
	[kWh]	[€]	[kWh]	[€]	[€]
Case 1	34.354	1.271,10	14.944	2.244,60	3.512,70
Case 2	0	0,00	21.274	3.191,10	3.191,10
Diff.					-321,60

For the definition of the costs (Table II), we considered the cost of electricity and gas equal to 0,15 €/kWh and 0,4 €/m^3 respectively, and the conversion factor between thermal kWh and m^3 of gas equal to 10,81.

The NPV (Net Present Value) and the Pay Back Period calculation will help the investor to choose the best solution. The analysis considered the following aspects: cost of money, general inflation, and inflation of energy products. However, given the political current Ukrainian instability, these parameters fluctuate from day to day. Please note that the price of gas increased by 280% and inflation by 106% in recent months. The cost of money currently exceeds 25%. Using these values, we would get the following data over 10 years: Pay Back Period of three years, NPV of almost 275.000€.

Using the values that existed a few years ago, that is cost money of 15%, general inflation of 7%, and inflation of energy products of 10, the investment could be paid off in just six years. The NPV after 10 years would be positive and equal to about 3.009€.

If we wanted to reach a NZEB configuration, it would be necessary to produce on-site, via a PV system, an amount of electricity sufficient to meet the total energy needs of the building which is equal to **21.274 kWh/year** (annual saving of **3.191€**). The initial investment for installing the PV system is about 40.000€. The total investment is then of **42.191€** with annual savings of **3.191€**. Adopting the NZEB configuration, we would save 34.354 kWh of natural gas consumption, that is 3.172 m^3, and get a building with zero CO_2 emissions.

Using the values that existed a few years ago the investment is paid off in 9 years with a NPV of about 10.300 € after 10 year. If we used the current economic Ukrainian parameters, the Pay Back Period would be of only 2 years. So, we expect an intermediate value.

CONCLUSIONS

A NZEB drastically reduces the energy consumption for air conditioning. In the studied situation, the efficient envelope, the window solar shading system, the treatment of the air with heat recovery, and the use of the GSHP system lead to a building energy consumption of only 5 kWh/year per m^2. Consequently, the electrical consumption due to lighting and equipment became preponderant, coming to a total consumption of about 27 kWh/year per m^2. The high consumption of electricity can be met by a photovoltaic system. Today, given the impressive trends in energy costs, interventions of energy efficiency are much more cost effective and can offer a viable alternative of investment for the economy of Ukraine.

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ДИНАМИЧЕСКОЕ МОДЕЛИРОВАНИЕ ЖИЛОГО ДОМА «НОЛЬ ЭНЕРГИИ», КОТОРЫЙ ПРЕДПОЛАГАЕТСЯ ПОСТРОИТЬ В КИЕВЕ

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Исследование, представленное в этой статье посвящено созданию в Киеве здания высокой энергетической эффективности и по конкурентной цене, по сравнению с существующими зданими. Как известно, политические условия между Россией и Украиной навязывают резкое сокращение использования природного газа. При этом в Украине имеются крупные запасы высококачественной древесины по конкурентоспособным ценам.

Исходя из этих соображений, было проведено исследование по разработке зданий «нуль энергии» (NZEB) которые использует в качестве основного конструктивного материала дерево, тем самым устраняя использование природного газа при производстве конструкций. Кроме того, это исследование предлагает использование древесных пород, пригодных для холодного климата.

Целью этой статьи является иллюстрация возможностей динамического моделирования для расчёта зависимости годового потребления энергии и эксплуатационных расходов изучаемого здания от использования различных строительных конструкций и функций системы.

Экономическое сравнение между различными решениями в 20-летнем жизненном цикле здания позволило нам определить оптимальное сочетание технологий и материалов и дать рекомендации инвесторам.

Цели, достигнутые в результате исследования актуальны – устранение использования природного газа и резкое сокращение выбросов CO_2 как за счет низкого углеродного следа используемых материалов, так и использования возобновляемых источников энергии.

ДИНАМІЧНЕ МОДЕЛЮВАННЯ ЖИТЛОВОГО БУДИНКУ «НУЛЬ ЕНЕРГІЇ», ЯКИЙ ПЕРЕДБАЧАЄТЬСЯ ПОБУДУВАТИ В КИЄВІ

Мауріціо Ландольфі, Даніеле Ді Джорджіо

Дослідження, представлене в цій статті присвячено створенню в Києві будівлі високої енергетичної ефективності і за конкурентною ціною, в порівнянні з існуючими будівлями. Як відомо, політичні умови між Росією і Україною нав'язують різке скорочення використання природного газу. При цьому в Україні є великі запаси високоякісної деревини за конкурентоспроможними цінами.

Виходячи з цих міркувань, було проведено дослідження з розробці будівель «нуль енергії» (NZEB) які використовують в якості основного конструктивного матеріалу дерево, тим самим усуваючи використання природного газу при виробництві конструкцій. Крім того, це дослідження пропонує використання деревних порід, придатних для холодного клімату.

Метою цієї статті є ілюстрація можливостей динамічного моделювання для розрахунку залежності річного споживання енергії та експлуатаційних витрат досліджуваного будівлі від використання різних будівельних конструкцій і функцій системи.

Економічне порівняння між різними рішеннями в 20-річному життєвому циклі будівлі дозволило нам визначити оптимальне поєднання технологій і матеріалів і дати рекомендації інвесторам.

Мети, досягнуті в результаті дослідження актуальні – усунення використання природного газу та різке скорочення викидів CO_2 як за рахунок низького вуглецевого сліду використовуваних матеріалів, так і використання поновлюваних джерел енергії.