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Research paper

Analysis of climate change and its potential influence on energy performance of building and indoor temperatures Part 2: Energy and thermal simulation

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Abstract: The subject of this paper is the analysis of possible influence of climate change on the energy performance of building and indoor temperatures. The model is based on the Maison Air et Lumière house, which concept was developed as part of the Model Homo 2020 project. It was a low-energy, single family, detached house. The model was divided into three thermal zones and developed by using SketchUp software. The analysis of the climate change was made on the example of the city in Poland – Kielce and described in the first part of the paper. Dynamic calculations of the building model were performed by using the TRNSYS software. The calculations were made for three different scenarios relating to existing technical systems: ventilation, ventilation + heating, ventilation + heating + cooling. Annual energy consumption and rooms air temperature changes were estimated for each variant. The results showed higher risk of summer discomfort and change in energy balance of building what indicates the need to use the cooling system in the future during the summer to reduce the discomfort of overheating. In the variant without the cooling system, the percentage of time with an indoor temperature above 27°C increased from 23.7% to 44.2% in zone 2. The energy demand for heating was reduced by 23.4% compared to the current climate, and the energy consumption for cooling (with the cooling option) increased significantly by 232% compared to the current demand. Summarizing, research indicates that with global warming, the energy demand for heating will decrease and the cooling demand will increase significantly in order to maintain the required user comfort.

Keywords: climate change, energy efficiency, thermal comfort, low energy building, energy simulation

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1. Introduction

In the first part of the paper the problem of climate change was analyzed and possible scenarios presented. All of them show that outdoor temperature will increase in the following years. The Representative Concentration Pathway 8.5 (RCP8.5 – represents possible, additional radiative forcing of 4.5 W/m^2 in 2100) scenario presents a vision much more dangerous for the natural environment and buildings than the Representative Concentration Pathway 4.5 (RCP4.5 – represents possible, additional radiative forcing of 4.5 W/m^2 in 2100) scenario. According to the RCP4.5 scenario, the average monthly temperature will increase for each month of the year. Depending from the years the temperature will increase in the range from 1.9 K to 2.9 K for 2065 and from 2.2 K to 3.3 K for 2090. The RCP8.5 scenario presents a vision much more dangerous for the climate and buildings than the RCP4.5 scenario. For the years 2065 and 2090 the monthly average temperatures are higher by around 40% compared to the RCP4.5.

However, it might be seen that the values of relative humidity do not change significantly during the winter months, i.e. December, January, February, while during the summer months these changes are easily visible. The biggest difference can be noticed in July, where most probably over the next 50 years relative humidity will drop by about 5% for RCP4.5 and 8% for RCP8.5. Nevertheless there are no major changes noticeable in the level of solar radiation or wind speed.

It can be expected that change of the climate will have influence on buildings construction, performance, and indoor conditions. Newly designed and constructed buildings as well as renovated should consider the occurrence (from year to year) of higher outdoor temperature and increase of heat gains during the summer. The second part of the paper tries to answer the question how the climate change will impact on the energy consumption and comfort of use. Similar analysis were conducted in European countries [18, 23] as well as on other continents [21]. To check the possible influence dynamic calculations of single family building model were carried out using the TRNSYS software [22]. The input data were based on calculated, future climate parameters for analyzed scenarios (described in part I [1]). Climate parameters like outdoor air temperature and relative humidity were modified according to the studied scenarios. The energy performance and indoor air temperature was compered in regard to base case. This allowed to determine possible the scale of change. The obtained results of simulation and comparative analysis can help in selection of appropriate solutions optimizing and neutralizing the negative impact of climate change on the indoor environment and energy performance of the building.

2. Modelling methodology

TRNSYS is an extremely flexible modeling software used to simulate the energy performance of buildings use of technical systems [2]. The software not only focuses on the systems but can equally well be used to model other dynamic phenomena, e.g. thermal comfort parameters. TRNSYS is made up of two parts. The first is an engine that reads and processes the input file, iteratively solves the system, determines convergence, and plots system variables. The second part is an extensive library of components, each of which models the performance of one part of the system. Calculations were made for the entire year with an hourly step. They take into account the thermal properties of building elements including heat capacity. The partitions that have accumulated heat during the summer give it back in the fall as outside temperatures drop down.

External files constituting the input data for the simulation were:

- climate data for the city of Kielce saved in the .epw format for the current climate and for the RCP4.5 and RCP8.5 scenarios for years 2035 and 2065. In order to simulate the comfort of using the building, parameters including monthly average values of temperature and relative humidity of the outside air, wind speed and solar radiation were taken into account.
- the developed model of Maison Air et Lumière building in TRNBuild software [19], which is an integral TRNSYS tool.

As a result of the simulation, the output data were obtained in the form of text files containing:

- hourly indoor air temperatures for the entire year, used to assess indoor parameters,
- monthly energy consumption values for energy performance analysis.

3. Building model

The model of Maison Air et Lumière single-family building was chosen for the simulation. The concept was developed as part of the Homo 2020 project [20]. For the purposes of simulation and analyzes, it has been assumed that the building is located in Kielce. The basic assumption of the authors of the project was to balance energy consumption with comfort of using. The design is based on the modular architectural concept with a gable roof. It can be adapted to different variants depending on the location, orientation and the way of using. House architecture increases its ability to capture sunlight (the window to floor ratio is 1:3) and makes it more energy efficient [3]. The building has a heated area of 130 m^2 and was founded on a concrete foundation slab insulated from the ground. It was divided into three thermal zones: 1 – ground floor, 2 – ground floor with entresol and 3 – attic. Well-insulated external walls have wooden frame structure of. The values of the heat transfer coefficients U for external and internal partitions were given in Table 1.

For the RCP4.5 and RCP8.5 climate scenarios, 3 steps simulations were performed (Table 2). In the first step, only ventilation was working (at 0.5 air exchanges per hour), in the second, ventilation and heating (set min indoor air temperature was 20°C), while in the third step cooling system was added (set max indoor air temperature was 26°C).

A scenario with ventilation only without heating is shown to reflect how a building would behave without heating and cooling. Energy consumption is divided into heating, ventilation and cooling. In order to maintain the same variants, the same division was used for the comfort assessment.

Table 1. Heat transfer coefficient for building partitions

Partition	Heat transfer coefficient U [W/(m^2·K)]
External ceiling	0.172
Internal wall	0.397
External wall	0.114
Roof	0.092
Slab on ground	0.093

Table 2. Simulation variants

<table>
<tr><th rowspan="2">Step no.</th><th colspan="5">Scenarios</th></tr>
<tr><th>Current climate</th><th>RCP4.5 2035</th><th>RCP8.5 2035</th><th>RCP4.5 2065</th><th>RCP8.5 2065</th></tr>
<tr><td>1</td><td colspan="5">Ventilation 0.5 [1/h]</td></tr>
<tr><td>2</td><td colspan="5">Ventilation 0.5 [1/h] and Heating [min. 20°C]</td></tr>
<tr><td>3</td><td colspan="5">Ventilation 0.5 [1/h] and Heating [min. 20°C] and Cooling [max. 26°C]</td></tr>
</table>

4. Calculation results – indoor operative temperature

The indoor operative temperature is an important parameter affecting the physiological and mental conditions of users, as well as their work efficiency and level of activity [4, 5]. Operative temperature is a simplified measure of human thermal comfort derived from air temperature, mean radiant temperature and air speed. It is influenced by many variables regarding the environment [6] and the building structure itself [7]. In order to check the influence of climate change on the operative temperature simulations were performed in TRNSYS 17. As a result, temperatures for 8760 hours per year were obtained for the three zones of the building. The level of comfort was assessed in accordance with standard (obligatory before the research was conducted) PN-EN 15251:2012 regarding the criteria of the indoor environment and available studies [8]. The calculated values of the operative temperature were compared with the minimum values for the heating season and the maximum values for the cooling season.

The thermal comfort categories refer to the following classes:

- Class I – rooms with high requirements, recommended for very sensitive people (disabled, young children, the elderly), operative temperature ≥ 21.0°C in the heating season, operative temperature ≤ 25.5°C in the cooling season,
- Class II – rooms with normal requirements (new and modernized buildings), operative temperature ≥ 20.0°C in the heating season, operative temperature ≤ 26.0°C in the cooling season,
- Class III – rooms with an acceptable level of requirements (existing buildings), operative temperature ≥ 18.0°C in the heating season, operative temperature ≤ 27.0°C in the cooling season,

- Class IV – values outside the range of the above categories hereinafter referred as discomfort.

Simulation results were compared with the criteria for thermal comfort of rooms and in this way the percentage share of given operative temperature values in the ranges of classes I, II, III and IV presented in the analysis as discomfort was determined.

The results were presented collectively for the whole year, but also broken down into:

- heating season, which was assumed to last from October 1st to March 31,
- the cooling season, which was assumed to last from April 1 to September 30.

4.1. Step 1 – only ventilation

The buildings' comfort of using is significantly affected by the ventilation system throughout the year [9]. In first step, the thermal comfort for a building with only ventilation switched on was analyzed. The heat gains were considering heat gains from sun, electrical devices, lighting and from users of the facility.

For each thermal zone (Table 3), the percentage share for individual comfort classes in relation to the whole year was presented.

Table 3. Percentage division of zone's comfort classes for step 1

	Ventilation							
	Current climate							
	Heating season				Cooling season			
	Class I	Class II	Class III	Discomfort	Class I	Class II	Class III	Discomfort
Thermal zone 1 – ground floor	0.0%	0.0%	0.4%	99.6%	16.1%	8.3%	19.6%	56.0%
Thermal zone 2 – ground floor with entresol	0.0%	0.0%	0.3%	99.7%	22.5%	8.2%	15.5%	53.8%
Thermal zone 3 – attic	0.0%	0.0%	0.2%	99.8%	35.7%	8.8%	16.3%	39.2%
	RCP4.5 2035							
	Heating season				Cooling season			
	Class I	Class II	Class III	Discomfort	Class I	Class II	Class III	Discomfort
Thermal zone 1 – ground floor	0.0%	0.0%	0.4%	99.6%	28.8%	9.7%	19.6%	41.9%
Thermal zone 2 – ground floor with entresol	0.0%	0.0%	1.3%	98.5%	22.9%	7.6%	13.1%	56.4%
Thermal zone 3 – attic	0.0%	0.0%	0.4%	99.6%	32.8%	9.5%	17.3%	40.4%

Continued on next page

Table 3 – *Continued from previous page*

	RCP8.5 2035							
	Heating season				Cooling season			
	Class I	Class II	Class III	Discomfort	Class I	Class II	Class III	Discomfort
Thermal zone 1 – ground floor	0.0%	0.0%	0.0%	100.0%	17.8%	8.0%	19.2%	55.0%
Thermal zone 2 – ground floor with entresol	0.0%	0.5%	1.1%	98.4%	23.9%	8.2%	14.4%	53.5%
Thermal zone 3 – attic	0.0%	0.0%	0.0%	100.0%	23.8%	10.2%	19.6%	46.4%
	RCP4.5 2065							
	Heating season				Cooling season			
	Class I	Class II	Class III	Discomfort	Class I	Class II	Class III	Discomfort
Thermal zone 1 – ground floor	0.0%	0.0%	0.4%	99.6%	32.0%	13.0%	20.4%	34.6%
Thermal zone 2 – ground floor with entresol	0.5%	0.9%	2.2%	96.4%	21.2%	7.2%	11.1%	60.5%
Thermal zone 3 – attic	0.0%	0.0%	0.4%	99.6%	31.7%	9.3%	9.9%	49.1%
	RCP8.5 2065							
	Heating season				Cooling season			
	Class I	Class II	Class III	Discomfort	Class I	Class II	Class III	Discomfort
Thermal zone 1 – ground floor	0.0%	0.0%	0.5%	99.5%	34.7%	15.0%	22.5%	27.8%
Thermal zone 2 – ground floor with entresol	1.0%	1.1%	2.8%	95.1%	21.4%	6.6%	11.4%	60.6%
Thermal zone 3 – attic	0.0%	0.0%	0.5%	99.5%	31.3%	5.9%	10.5%	52.3%

As expected for a building located in Kielce with only ventilation turned on, very high discomfort was visible. Such variant (without heating and cooling) was used to show better the influence of climate change. It was found that in parallel with global warming, there was an increase in discomfort during the cooling season (summer season) in thermal zone 3, where discomfort increased from 39.1% for the current climate to 52.3% for the RCP8.5 scenario for 2065 and in thermal zone 2, where discomfort increased from 53.8% for the current climate to 60.6% for the RCP8.5 scenario for 2065. In thermal zone 1, on the other hand, discomfort dropped from 56.0% to 27.8%. Almost 100% discomfort was noted during the heating season, which is due to the lack of heating.

4.2. Step 2 – ventilation and heating

The heating system significantly affects the comfort of the building's use using, especially during the winter [10, 11]. In this step, the thermal comfort was analyzed for a building with ventilation and heating system switched on. The set indoor air temperature was 20°C.

The chart (Fig. 1) shows the breakdown of the operative temperature during the year in relation to the ambient temperature for thermal zone 3. The chart also includes the comfort criteria for classes I, II and III. All points that are outside the comfort range determine the discomfort for the simulated building model. The criteria of thermal comfort are regulated by the PN-EN 15251 standard on indoor environmental criteria. The design values for the indoor temperature (operating temperature) given there have been limited by the minimum values for the heating season and the maximum values for the cooling season. For each thermal zone (Table 4), the percentage share for individual comfort classes in relation to the whole year was presented.

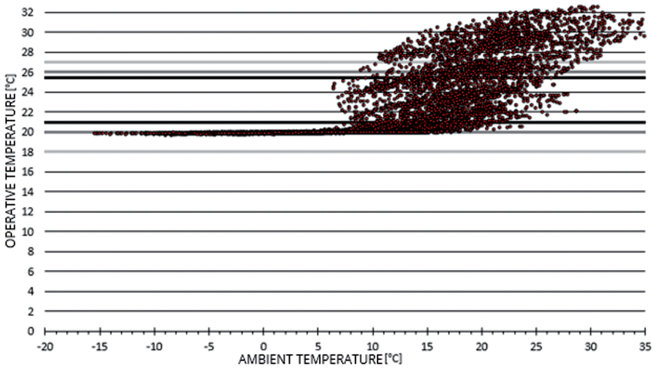

Fig. 1. Dependence of the operative temperature on the ambient temperature

Table 4. Percentage division of zone's comfort classes for step 2

	Ventilation and Heating							
	Current climate							
	Heating season				Cooling season			
	Class I	Class II	Class III	Discomfort	Class I	Class II	Class III	Discomfort
Thermal zone 1 – ground floor	0.0%	0.2%	99.8%	0.0%	17.5%	40.7%	41.8%	0.0%
Thermal zone 2 – ground floor with entresol	3.0%	7.3%	89.7%	0.0%	33.6%	18.5%	24.2%	23.7%
Thermal zone 3 – attic	0.0%	3.5%	96.5%	0.0%	43.6%	26.1%	27.7%	2.6%

Continued on next page

Table 4 – *Continued from previous page*

	RCP4.5 2035							
	Heating season				Cooling season			
	Class I	Class II	Class III	Discomfort	Class I	Class II	Class III	Discomfort
Thermal zone – ground floor	0.0%	0.6%	99.4%	0.0%	30.6%	36.5%	32.9%	0.0%
Thermal zone 2 – ground floor with entresol	3.5%	8.8%	87.7%	0.0%	31.5%	14.5%	17.9%	36.1%
Thermal zone 3 – attic	0.1%	5.0%	94.9%	0.0%	38.2%	24.5%	23.2%	14.1%
	RCP8.5 2035							
	Heating season				Cooling season			
	Class I	Class II	Class III	Discomfort	Class I	Class II	Class III	Discomfort
Thermal zone 1 – ground floor	0.0%	0.7%	99.3%	0.0%	33.5%	34.4%	32.1%	0.0%
Thermal zone 2 – ground floor with entresol	3.7%	8.8%	87.5%	0.0%	31.2%	14.8%	17.5%	36.5%
Thermal zone 3 – attic	0.0%	5.3%	94.7%	0.0%	37.2%	23.6%	21.5%	17.7%
	RCP4.5 2065							
	Heating season				Cooling season			
	Class I	Class II	Class III	Discomfort	Class I	Class II	Class III	Discomfort
Thermal zone 1 – ground floor	0.0%	0.7%	99.3%	0.0%	33.5%	34.4%	32.1%	0.0%
Thermal zone 2 – ground floor with entresol	5.1%	9.0%	85.9%	0.0%	28.4%	13.7%	16.1%	41.8%
Thermal zone 3 – attic	0.2%	6.5%	93.3%	0.0%	36.2%	20.8%	18.8%	24.2%
	RCP8.5 2065							
	Heating season				Cooling season			
	Class I	Class II	Class III	Discomfort	Class I	Class II	Class III	Discomfort
Thermal zone 1 – ground floor	0.0%	1.9%	98.1%	0.0%	38.1%	30.5%	31.2%	0.2%
Thermal zone 2 – ground floor with entresol	5.2%	9.7%	85.1%	0.0%	27.9%	13.1%	14.8%	44.2%
Thermal zone 3 – attic	0.4%	7.3%	92.3%	0.0%	34.6%	17.6%	18.8%	29.0%

A significant decrease in discomfort percentage was noted comparing to step 1, discomfort was not observed for each scenario only in thermal zone 1, while the highest discomfort occurs in thermal zone 2. It is worth to note that along with global warming discomfort increases due to too high operative temperature in rooms in the cooling season. Comparing the current climate and worst scenario RCP8.5 in year 2065, discomfort during the cooling season increased:

- from 2.6% (116 hours) to 29% (1272 hours) in thermal zone 3,
- from 23.7% (1043 hours) to 44,2% (1940 hours) in thermal zone 2.

Although the heating system was on the indoor thermal conditions were during the most of the time in III class not in II (normal requirements). The reason was the set indoor air temperature equal to 20°C by which the operative temperature is around 19.7°C so slightly below requirements for II class. In the next step it was decided to additionally use a cooling system in the summer.

4.3. Step 3 – ventilation and heating and cooling

Using of air conditioning system is not common in single family buildings in Poland. However, due to the increases of temperatures in the summer months and the desire to maintain comfort in of using the rooms [12], more and more residents are deciding to install cooling systems.

In this step, the thermal comfort was analyzed for a building with ventilation, heating and cooling system working. The maximum indoor air temperature was set to 26°C. The simulations take into account heat gains from electrical devices, lighting and from users of the house. For each thermal zone (Table 5), the percentage share was presented for individual comfort classes in relation to the whole year.

Table 5. Percentage division of zone's comfort classes for step 1

	Ventilation and Heating and Cooling							
	Current climate							
	Heating season				Cooling season			
	Class I	Class II	Class III	Discomfort	Class I	Class II	Class III	Discomfort
Thermal zone 1 – ground floor	0.0%	0.2%	99.8%	0.0%	16.4%	41.3%	42.3%	0.0%
Thermal zone 2 – ground floor with entresol	3.0%	7.3%	89.7%	0.0%	45.9%	21.8%	32.1%	0.2%
Thermal zone 3 – attic	0.0%	3.5%	96.5%	0.0%	48.3%	25.8%	25.9%	0.0%

Continued on next page

Table 5 – *Continued from previous page*

	RCP4.5 2035							
	Heating season				Cooling season			
	Class I	Class II	Class III	Discomfort	Class I	Class II	Class III	Discomfort
Thermal zone 1 – ground floor	0.0%	0.6%	99.4%	0.0%	27.4%	39.6%	33.0%	0.0%
Thermal zone 2 – ground floor with entresol	3.5%	8.8%	87.7%	0.0%	48.5%	19.7%	31.3%	0.5%
Thermal zone 3 – attic	0.1%	5.0%	94.9%	0.0%	48.0%	28.3%	23.7%	0.0%
	RCP8.5 2035							
	Heating season				Cooling season			
	Class I	Class II	Class III	Discomfort	Class I	Class II	Class III	Discomfort
Thermal zone 1 – ground floor	0.0%	0.7%	99.3%	0.0%	29.4%	38.1%	32.5%	0.0%
Thermal zone 2 – ground floor with entresol	3.7%	8.8%	87.5%	0.0%	47.7%	20.2%	31.6%	0.5%
Thermal zone 3 – attic	0.0%	5.3%	94.7%	0.0%	47.2%	28.0%	24.8%	0.0%
	RCP4.5 2065							
	Heating season				Cooling season			
	Class I	Class II	Class III	Discomfort	Class I	Class II	Class III	Discomfort
Thermal zone 1 – ground floor	0.0%	1.4%	98.6%	0.0%	33.7%	37.0%	29.3%	0.0%
Thermal zone 2 – ground floor with entresol	5.1%	9.0%	85.9%	0.0%	46.0%	20.0%	32.6%	1.4%
Thermal zone 3 – attic	0.2%	6.5%	93.3%	0.0%	47.4%	26.0%	26.6%	0.0%
	RCP8.5 2065							
	Heating season				Cooling season			
	Class I	Class II	Class III	Discomfort	Class I	Class II	Class III	Discomfort
Thermal zone 1 – ground floor	0.0%	1.9%	98.1%	0.0%	42.7%	31.4%	25.9%	0.0%
Thermal zone 2 – ground floor with entresol	5.2%	9.7%	85.1%	0.0%	45.8%	19.7%	33.5%	1.0%
Thermal zone 3 – attic	0.4%	7.3%	92.3%	0.0%	46.5%	24.7%	28.8%	0.0%

For a building with ventilation, heating and cooling, almost no any discomfort was not noted for each tested climate scenario. During the heating season mainly requirements for class III were met with the assumed heating parameters (set air temperature 20°C). In addition, it was noticed that along with global warming, the percentage of temperatures meeting the criteria for class II increases slightly for the whole year. The technical systems help to meet the thermal comfort criteria specified by PN-EN 15251 [8]. Further analyses were concentrating on determining the impact of the analyzed steps and climate change on the energy need for heating, ventilation and cooling.

5. Calculation results – energy consumption

Based on climate data and building characteristics, the simulation carried out in TRNSYS 17 enabled the determination of the energy need for ventilation, heating and cooling. Different climate changes scenarios and technical systems sets were analyzed. First results were shown for step 2 which includes building with heating and ventilation system without cooling.

Main tasks of the systems are to keeping comfortable conditions during the heating season.

Along with global warming, the energy needs for both ventilation and heating are decreasing (Fig. 2). Energy needs for heating purposes were zero for the summer months, i.e. June, July and August. The energy needs' coefficient for the current climate was 65.7 kWh/($m^2\cdot$ year) and according to the RCP4.5 scenario it will decrease to 57.3 kWh/($m^2\cdot$ year) (by 12.9%) for 2035 and to 54.6 kWh/($m^2\cdot$ year) (by 13.6%) for 2065. A slightly larger decrease was visible for the RCP8.5 scenario and according to the energy needs it will decrease to 56.8 kWh/($m^2\cdot$ year) (by 16.9%) in 2035 and up to 50.3 kWh/($m^2\cdot$ year) (a decrease of 23.4%) in 2065.

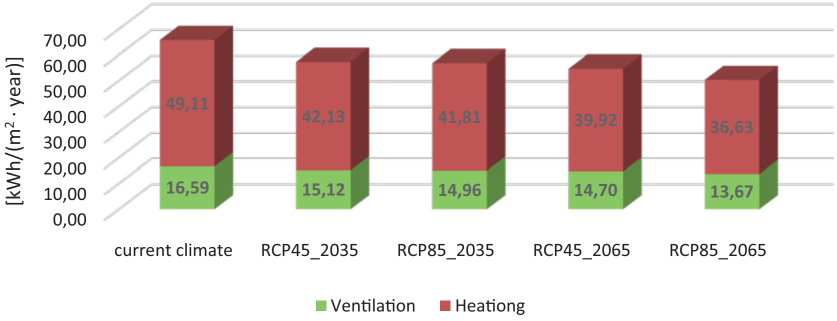

Fig. 2. End-use energy need for ventilation and heating

In the last step, cooling system was added to the previous analysis and the impact of global warming was examined on energy needs. This analysis helped to determine to what extent the elimination of discomfort will affect energy performance.

Along with global warming, the total energy needs for ventilation, heating and cooling decreases (Fig. 3), but at the same time increases for cooling. Energy needs for cooling occur only in the summer months – i.e. in June, July and August. The percentage increase in energy needs for cooling purposes in relation to the current climate was following: for RCP4.5 102% in 2035 and 195% in 2065, for RCP8.5 it is 117% and 232% for 2065 respectively.

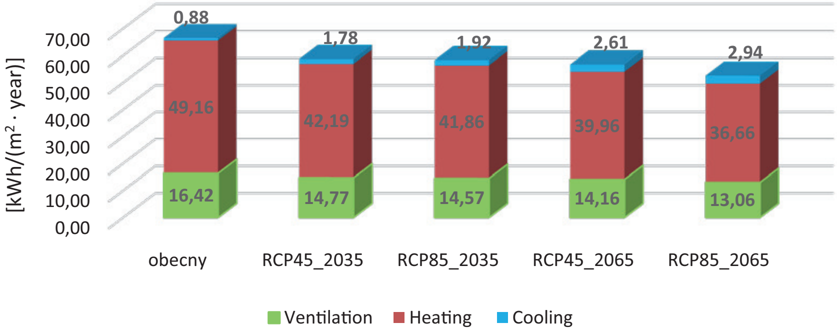

Fig. 3. End-use energy needs for ventilation, heating and cooling in the forecasted scenarios for climate change

All in all the total end-use energy consumption decreased due to climate change as it is presented below in comparison to the current climate.

- decrease by 11.62% for RCP4.5 in the year 2035,
- decrease by 12.20% for RCP8.5 in the year 2035,
- decrease by 14.64% for RCP4.5 in the year 2065,
- decrease by 20.76% for RCP8.5 in the year 2065.

6. Summary and conclusions

The article presents the problem of climate change and its impact on the comfort of using buildings and energy consumption in the future. In the first part of the paper, meteorological conditions for Kielce for 2035, 2065 and 2090 were analyzed and compared with current values. The analyzes were based on 2 scenarios of changes in carbon dioxide concentration (RCP4.5 and RCP8.5). The results confirmed the increase of outdoor temperature in the following years. Relative humidity of outdoor air will be lower and speed of wind will not change significantly.

Thermal comfort and energy performance analyses were made for defined climate scenarios (RCP4.5 and 8.5 for the years 2035 and 2065) and 3 technical systems combinations: ventilation only, ventilation and heating, ventilation, heating and cooling. Considering climate scenarios, there is a noticeable increase in the discomfort in the summer season compared to the current climate. Without cooling system the percentage of discomfort increase from 2.6% to 29% in thermal zone 3 and from 23.7% to 44.2%. Achieving comfortable conditions in summer may be impossible without active cooling systems even in the climate of Kielce.

The forecast climate change will also affect the annual distribution of energy needs for maintain comfortable indoor conditions. The energy needs for heating purposes (during the winter season) decreases by 23.4% compared to the current climate, while the energy need (in summer) for cooling increases dramatically (ten times more) – by 232% compared to the current demand. Nevertheless, the total amount of energy demand decrease for every analyzed scenario in comparison to the current climate. The biggest change will be observed for RCP8.5 in 2065 and it will be 20.76% less energy demanded.

Newly designed and constructed buildings should consider the occurrence (more frequent from year to year) of higher outdoor temperature and increase of heat gains during the summer. Therefore, during designing the building envelope, it is necessary to consider not only heat losses (as a result of transmition, ventilation, and infiltration of air through external barriers [13–15]) in winter, but also losses of cold in summer [7, 16].

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Analiza zmiany klimatu i jego wpływu na charakterystykę energetyczną budynku oraz temperatury wewnętrzne
Część 2: Symulacje energetyczne i środowiska wewnętrznego

Słowa kluczowe: zmiany klimatyczne, efektywność energetyczna, komfort cieplny, budynek niskoenergetyczny, symulacje energetyczne

Streszczenie:

Przedmiotem niniejszego artykułu jest analiza możliwego wpływu zmian klimatycznych na charakterystykę energetyczną budynku i temperatury wewnętrzne. Model budynku oparty jest na domu Maison Air et Lumière, którego koncepcja powstała w ramach projektu Model Homo 2020. Jest to niskoenergetyczny, jednorodzinny, wolnostojący dom. Model został podzielony na trzy strefy i stworzony przy użyciu oprogramowania SketchUp. Analiza zmian klimatycznych została przeprowadzona na przykładzie miasta Kielce i opisana w pierwszej części artykułu. Obliczenia symulacyjne przeprowadzono przy użyciu oprogramowania TRNSYS. Wykonano je dla trzech różnych scenariuszy odnoszących się do systemów technicznych – wentylacja, wentylacja + ogrzewanie, wentylacja +

ogrzewanie + chłodzenie. Dla każdego wariantu określono roczne zapotrzebowanie energii oraz zmianę temperatury operatywnej w pomieszczeniach. Wyniki wykazały większe ryzyko wystąpienia dyskomfortu w okresie letnim oraz zmianę bilansu energetycznego budynku wraz z ocieplaniem się klimatu. W wariancie bez systemu chłodzenia odsetek czasu z temperaturą wewnętrzną powyżej 27°C wzrósł z 2,6% do 29,0% w strefie 3 oraz z 23,7% do 44,2% w strefie 2. Zapotrzebowanie na energię do ogrzewania zmniejszyło się o 23,4% w stosunku do obecnego klimatu, a zużycie energii do chłodzenia (przy opcji z chłodzeniem) znacznie wzrosło o 232% w stosunku do obecnego zapotrzebowania.

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