HEAT ENERGY CONSUMPTION IN UNRENOVATED BUILDINGS AND IN BUILDINGS AFTER PARTIAL RENOVATION

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ABSTRACT

The aim of the present study was to analyse the heat energy consumption in public buildings. Our data contained information about more than 400 public buildings, including the data of the heat energy consumption depending on the use of the building, electric energy consumption and the data about the quantity and quality of windows in these buildings in 2008. The data were analysed dividing all public buildings into twelve groups: schools, special status education schools, day-care centres, hospitals, libraries, cult buildings, recreation centres, local government buildings, museums, sport centres, academy of music, and shelters. The largest groups are schools and day-care centres /kindergartens/. These two groups we analysed particularly.Our analysis focused on the heat energy consumption in buildings with new double-pane windows and frames from polyvinylchloride (PVC) with heat transmittance $U \leq 1{,}8$ W/(m²·K) and in buildings with simple windows divided into two-panes with two separate wooden frames (heat transmittance $U \geq 2{,}5$W/(m²·K). We analysed the data of the indoor air quality (IAQ) in three day-care centre buildings from March 11 to 16, 2011.The data analysis showed that partial renovation – change of the windows, doors etc. with and without heat insulation of the buildings - does not provide the heat energy consumption economy required by the Ministry of Economics by the year 2020, and in the majority of cases made consumption even bigger.

Keywords: heat, consumption, day-care centres, renovation, public buildings

INTRODUCTION

Energy consumption economy and optimisation lead to less carbon dioxide emission. Significant decisions of the European Parliament and of the Council are:

- Directive 2002/91/EC of the European Parliament and the Council of 16 December 2002 – on the energy performance of buildings,
- Directive 2004/8/EC of the European Parliament and the Council of 11 February 2004 – on the promotion of cogeneration based on a useful heat demand in the internal energy market and amending Directive 92/42/EEC,
- Directive 2006/32/EC of the European Parliament and the Council of 5 April 2006 on energy end-use efficiency and energy services and repealing Council Directive 93/76/EEC (Text with EEA relevance).

On the basis of these documents the Latvian Cabinet of Ministers made laws for local use: Latvian Construction Standard LBN 002-01 "Building Envelope Calorific",

- Latvian Law on The Energy Performance of Buildings,
- Latvian Construction Standard LBN 208-08 "Public Buildings and Structures".

The main ministry for energy issues is the Ministry of Economics. The Latvian Energy Development Guidelines for the years 2007- 2016 define that the heat energy consumption should decrease by approximately 28%. In the time period up to the year 2020 the heat energy consumption should decrease by 40%. Is it possible to achieve this with the previous renovation methods? We researched it and give an answer in this study.

Buildings that have very high heat energy demands are part of Latvia's heritage from the Soviet times. The great majority of public buildings do not have mechanical ventilation systems.

Heat energy consumption in public buildings has been explored in very few Latvian scientific researches. We did not find a similar study in Latvian scientific publications. Building renovation was made under conditions of inadequate information. The IAQ started to worsen after the end of the time period. This unpleasantness is omitted. Outdoor air infiltration had stopped and people need to open windows to make the IAQ better. Our study shows that we need to change something in the building process in Latvia. This time we presented day-care centres and school buildings heat consumption on average in the year 2008 and a part of the data processing results from IAQ parameters in the six day-care centre buildings which were obtained in February and March 2011.

MATERIALS AND METHODS

Total obtained data

Aggregate information contained data about 420 public buildings which were divided into 12 groups: special status education schools – 43 060m² ; shelters – 9 993m²; local government buildings – 44 077m²; recreation centres – 59 994m²; museums - 369m²; hospitals – 15 232m²; sport centres – 18 435m²; libraries – 8 324m²; academy of music – 5 368m²; day-care centres – 248 923m²; schools – 841 395m²; cult buildings – 6 067m².

Our analysis focused on heat energy consumption in unrenovated day-care centres and school buildings and in day-care centres and school buildings after a partial renovation (data contained and analysis included also some new ones that were built as a control group). The data of these two groups had to be analysed particularly. At last before the analysis was finished we compared heat consumption in unrenovated buildings and in buildings after a partial renovation. The methods of analysis were based on (E.Krumins et al., 2010) software. Our analysis showed that there was a big difference after renovation in heat consumption in buildings with similar total floor areas.

IAQ measurements

In the winter season (from 11 March to 16 March) 2011 we continued the research in the six day-care centre buildings with the aim to attain data from the IAQ parameters. In this research, we used: in unrenovated day-care centre building – MINILOG GSOFT 40K V7.80 (air temperature logger), EASYLOG 40RF GSOFT 40K V7.80 (air relative humidity logger) from 11 February to 17 March. Two Wöhler CDL 210 version 1.1.6. (air temperature, relative humidity and carbon dioxide quantity) loggers in partially renovated and new day-care centre buildings with different time of building. After attaining the measurement data, we analysed and compared these data.

RESULTS AND DISCUSSION

Heat consumption

Now we present the heat consumption per annum in correlation with the building floor areas in school buildings Fig.1, Fig.2 and day-care centre buildings Fig.3 and Fig.4 in 2008.

In Fig.2 we clearly see that in partially renovated school buildings something was done incorrectly. The school buildings with similar total floor areas have different heat consumption per annum. For example, comparing the building total floor areas (m^2) and heat consumption (MWh) per annum in:

- school building no.1: 3607m^2 – 412,97MWh;
- school building no.2: 3675m^2 – 459,00MWh;
- school building no.3: 3570m^2 – 517,61MWh;
- school building no.4: 3484m^2 – 645,82MWh;
- school building no.5: 3224m^2 – 723,15MWh.

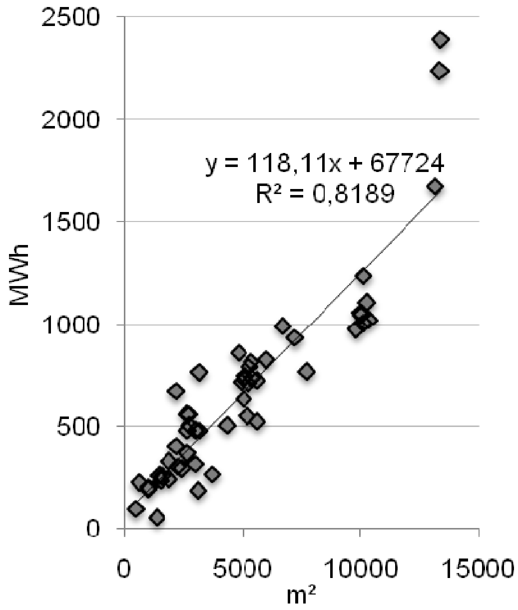

Figure 1. Unrenovated school buildings. Total heat energy consumption (MWh) per annum correlation with building floor areas (m^2).

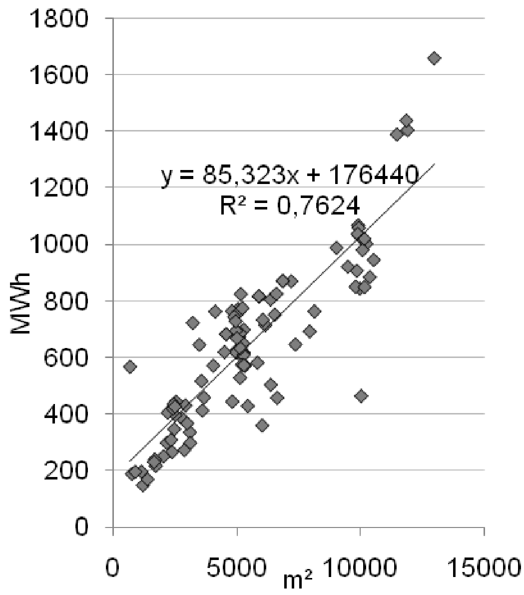

Figure 2. Partially renovated school buildings. Total heat energy consumption (MWh) per annum correlation with building floor areas (m^2).

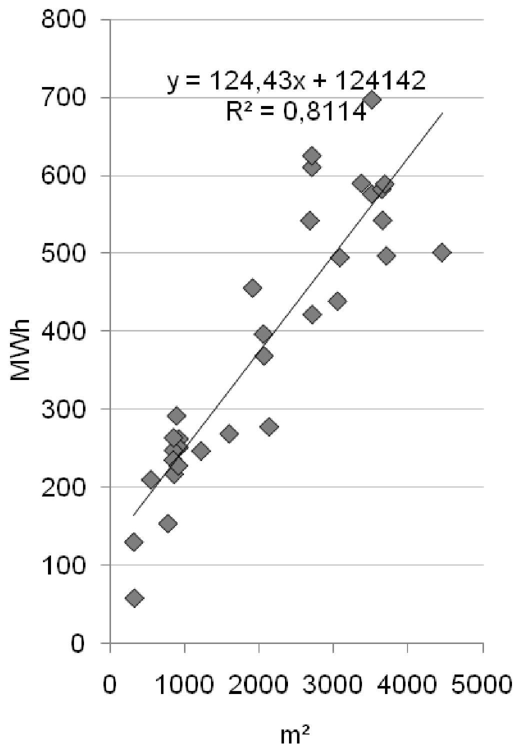

Figure 3. Unrenovated day-care centre buildings. Total heat energy consumption (MWh) per annum correlation with building floor areas (m^2).

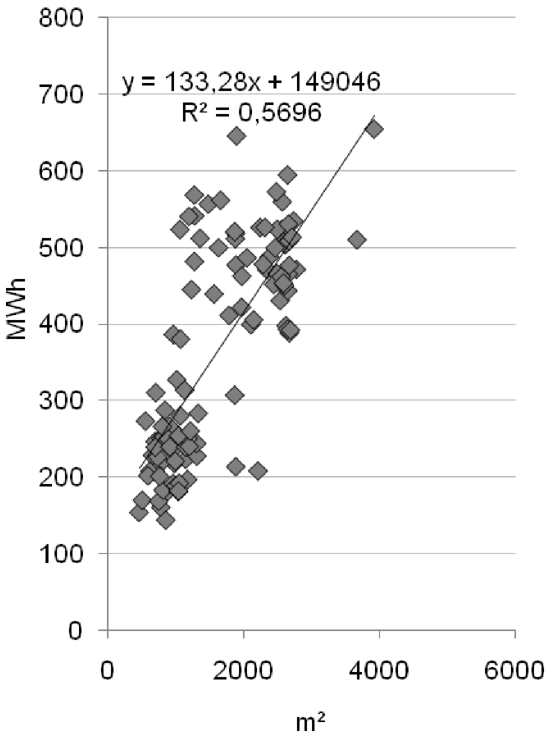

Figure 4. Partially renovated day-care centre buildings. Total heat energy consumption (MWh) per annum correlation with building floor areas (m^2).

In Fig.4 we clearly see that in the partially renovated day-care centre buildings also something was done incorrectly. As in the school buildings in the day-care centre buildings with similar total floor areas also there is different heat consumption per annum. For example, comparing the building total floor areas (m^2) and heat consumption (MWh) per annum in:

- day-care centre building no.1: 2217m^2 – 208,00MWh;
- day-care centre building no.2: 1890m^2 – 213,53MWh;
- day-care centre building no.3: 2142m^2 – 278,02MWh;
- day-care centre building no.4: 1875m^2 – 306,82MWh;
- day-care centre building no.5: 1976m^2 – 421,39MWh;
- day-care centre building no.6: 1893m^2 – 476,61MWh;
- day-care centre building no.7: 2054m^2 – 486,00MWh;
- day-care centre building no.8: 1886m^2 – 517,69MWh;
- day-care centre building no.9: 1901m^2 – 645,00MWh.

Fig.5 demonstrates four trendlines: 1. abstract – trendline made under the Latvian Energy Development Guidelines for the years 2007- 2016 and by the year 2020 the heat energy consumption must be decreased by 40% (from 250kWh/m^2 per annum to 150kWh/m^2 per annum on average in Latvia); 2. unrenovated buildings trendline; 3. Partially renovated buildings trendline; 4. Normative – trendline that demonstrates right renovation under the Latvian Energy Development Guidelines for the years 2007- 2016 and till the year 2020 from school buildings. It is evident that only three unrenovated school buildings and three school buildings after a partial renovation are located under the normative trendline. We analyzed 101 partially renovated school buildings and 55 unrenovated school buildings. That spells out a necessity as four buildings were not renovated and in only five (!!!) school buildings (5% from all partially renovated school buildings) partial renovation was done properly this time.

Fig.6 also demonstrates four trendlines: 1. abstract – trendline made under the Latvian Energy Development Guidelines for the years 2007- 2016 and by the year 2020 the heat energy consumption must be decreased by 40% (from 250kWh/m^2 per annum to 150kWh/m^2 per annum on average in Latvia); 2. unrenovated buildings trendline; 3. partially renovated buildings trendline; 4. normative – trendline that shows proper renovation under the Latvian Energy Development Guidelines for the years 2007- 2016 and to the year 2020 for day-care centre buildings.

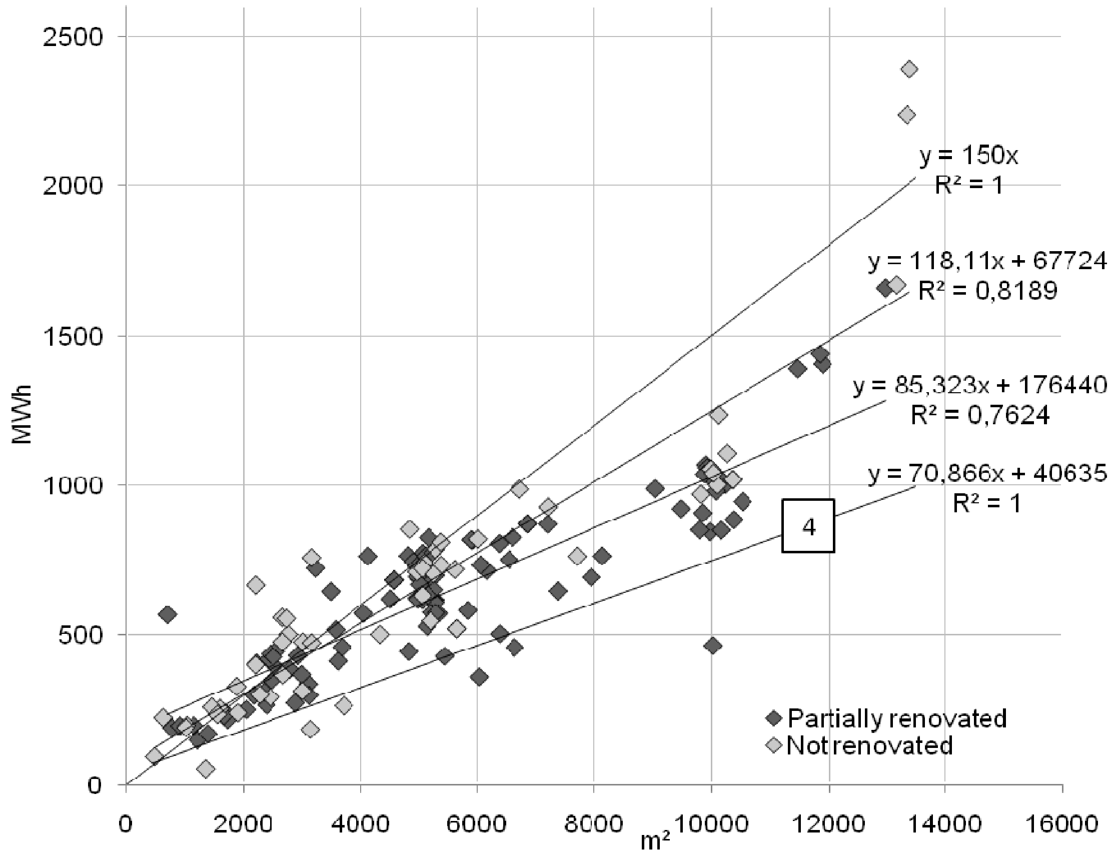

Figure 5. Unrenovated and partially renovated school buildings.
Total heat energy consumption (MWh) per annum correlation with building floor areas (m^2) with trendlines: 1. abstract; 2. unrenovated buildings; 3. partially renovated buildings;4. normative.

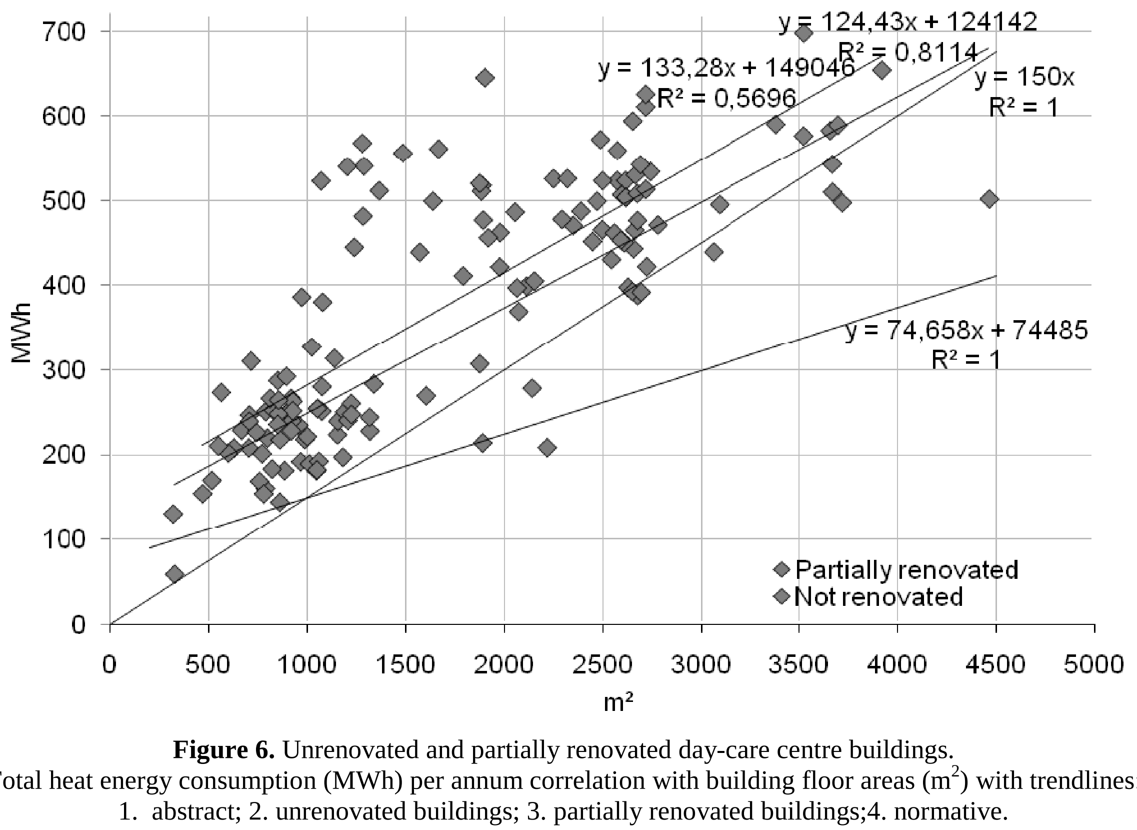

Figure 6. Unrenovated and partially renovated day-care centre buildings.
Total heat energy consumption (MWh) per annum correlation with building floor areas (m^2) with trendlines: 1. abstract; 2. unrenovated buildings; 3. partially renovated buildings;4. normative.

It is evident that only one unrenovated day-care centre building and three day-care centre buildings after a partial renovation are located under (on) the normative trend line.

We had to analyse 111 partially renovated day-care centre buildings and 32 unrenovated day-care centre buildings. That spells out a necessity as one day-care centre building was not renovated and in only three (!!!) day-care centre buildings (2,7% from all partially renovated day-care centre buildings) partial renovation was done correctly this time.

IAQ measurements

This time we present the data from the IAQ measurements in three day-care centre buildings from 11 March to 16 March 2011in:

1. unrenovated day-care centre building (total floor area – 2142m^2, heat consumption per annum – 278 020kWh;
2. partially renovated (in the year 2007) day-care centre building (total floor area – 1901m^2, heat consumption per annum – 645 000kWh;
3. new (was built in 2005) day-care centre building (total floor area – 2217m^2, heat consumption per annum – 208 000kWh).

The average outdoor air relative humidity and temperature are presented in Fig.7 and Fig.8. This was made from information data bases from the state limited liability company "Latvian Environment, Geology and Meteorology Centre" homepage.

They did not have information about the outdoor carbon dioxide (CO_2) quantity. Our measurements show the CO_2 quantity from 400ppm (parts per million, 10^{-6}) to 450ppm in Riga city.

Fig.9 presents the outdoor air and indoor air relative humidity in per cents in day-care centre buildings. The horizontal axis presents the data of times and date. Minor gridlines disclose time:

- first 2:00;
- second 5:00;
- third 8:00;
- fourth 11:00 etc..

Major gridlines, for example from:

- zero to eight are the first data, achieved on 11March;
- nine to sixteen are the second data achieved on 12March
- seventeen to twenty four are the third data achieved on 13 March, etc..

(12 March - Saturday and 13 March - Sunday)

The following figure clearly shows that the indoor air relative humidity is very low. The recommended IAQ minimum is 30% (maximum is 70%) as was written in the Labour Protection Requirements in Workplaces as prescribed in the Regulation no. 359 from 28 April, 2009 of the Cabinet of Ministers of the Republic of Latvia.

Renovation and new building of day-care centre buildings did not guarantee this requirement. In the partially renovated day-care centre building, the indoor air humidity was insignificantly lower than in the unrenovated building and in the new one.

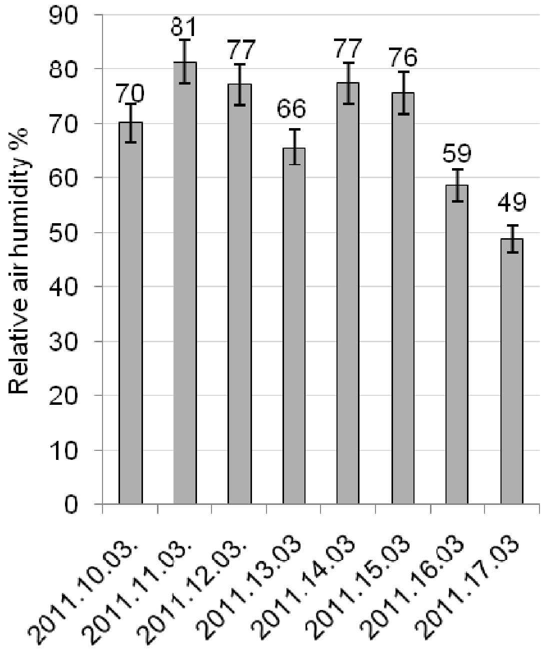

Figure 7. Average outdoor air relative humidity from 10 March till 17march 2011 with error bars.

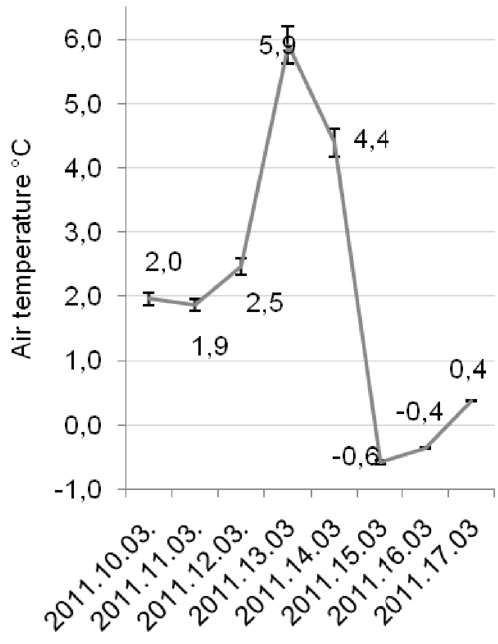

Figure 8. Average outdoor air temperature from 10 March to 17march 2011 with error bars with 5% value.

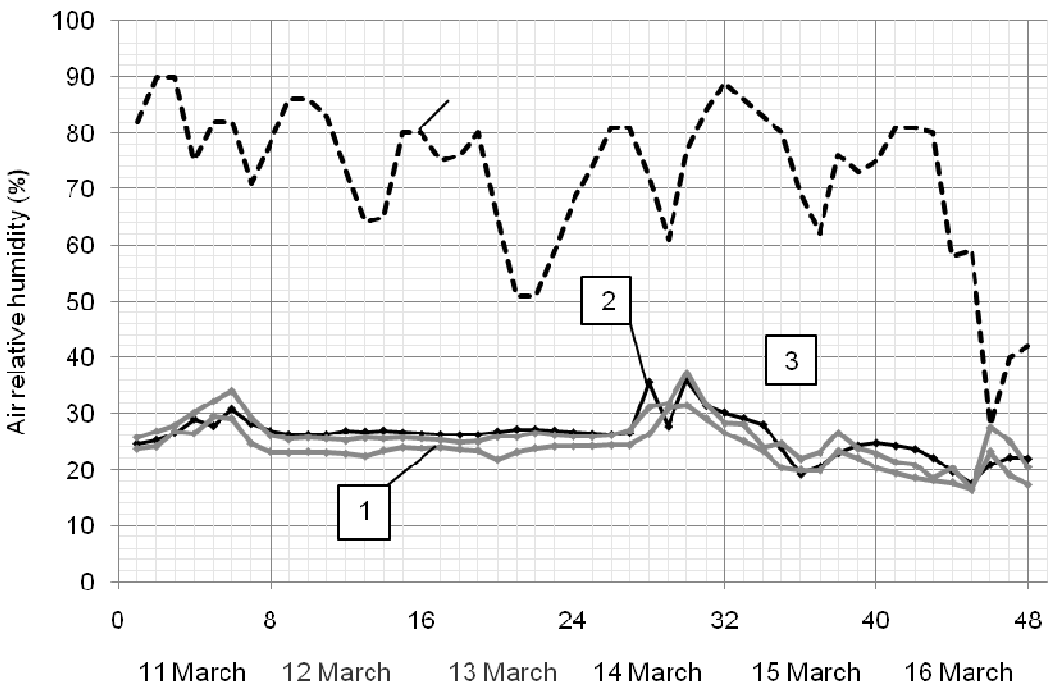

Figure 9. Air relative humidity in:
1 – partially renovated building (2007, average heat consumption 339kWh/m^2 per annum);
2 – newly erected building (built in 2005, average heat consumption 94kWh/m^2 per annum);
3 – unrenovated (average heat consumption 130kWh/m^2 per annum); 4 – outdoor.

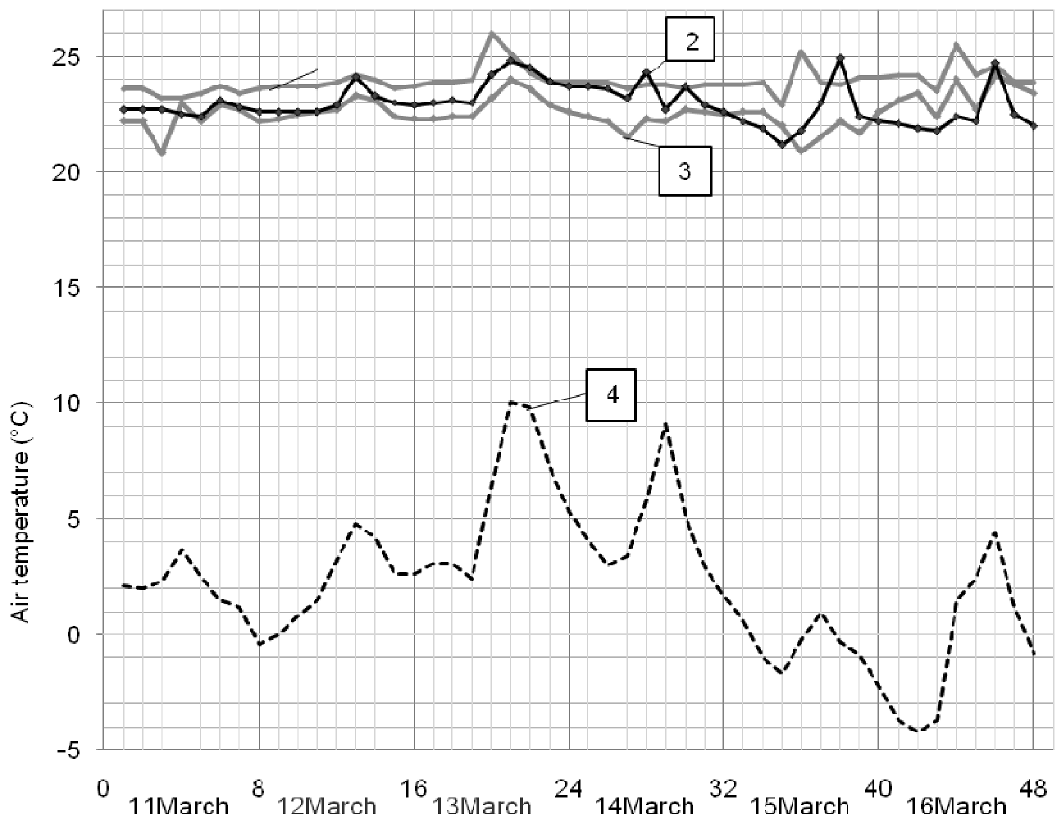

Figure 10. Air temperature in:
1 – partially renovated building (2007, average heat consumption 339kWh/m^2 per annum)
2 – newly erected building (built in 2005, average heat consumption 94kWh/m^2 per annum)
3 – unrenovated (average heat consumption 130kWh/m^2 per annum); 4 – outdoor.

Fig.10 presents the indoor and outdoor air temperature in Riga city in the time period from 11 March to 16 March 2011 (12 March - Saturday and 13 March - Sunday). The horizontal axis presents the data of times and date. Minor gridlines disclose time:

- first 2:00;
- second 5:00;
- third 8:00;
- fourth 11:00 etc..

Major gridlines from:

- zero to eight are the first data achieved on 11March;
- nine to sixteen are the second data achieved on 12March;
- seventeen to twenty four are the third data achieved on 13 March, etc..

The highest indoor air temperature was in the partially renovated day-care centre building, medium indoorair temperature was in the newly erected building and the lowest was in the unrenovated building. In the partially renovated and in the newly erected buildings it was higher and just 1-2 degres lower than +25°C. This temperature is the maximum from the recomended optimum in the Labour Protection Requirements in Workplaces as prescribed in the Regulation no. 359 from 28 April 2009 of the Cabinet of Ministers of the Republic of Latvia. The recommended air temperature is from +19 to +25°C if the outdoor average air temperature is +10°C or lower. In our case, better and more economical indoor air temperature from +21 to +24°C was in the unrenovated day-care centre building.

As we see in Fig.10, the outdoor air temperature was from minus four degrees to pluss ten degrees Celsium. The indoor air temperature in all types of the buildings changed in accordance with the outdoor air temperature changes. This indicates that in thermal energy consumption it is possible to realize optimization. The first step is to change the established heat demand for each day-care centre building. It is necessary to make the day-night conditions and workday and holyday conditions with a temperature difference. Our study justified this. Fig. 11 presents the change in the carbon dioxide level in the indoor environment in our study period in two day-care centre buildings. They are a partially renovated day-care centre building and a new one.

Fig.11 presents the carbon dioxide (CO_2) level in ppm in the indoor environment. In Latvia we did not find an institution or structure which had a fixed CO_2 level outdoors. The state limited liability company "Latvian Environment, Geology and Meteorology Centre" has information about the outdoor air quality, but not included information about CO_2 in the outdoor environment.

We find a similar study in the Minnesota Department of the Health Fact Sheet from April 2010: "Carbon dioxide is a colourless, odourless gas. It is produced both naturally and through human activities, such as burning gasoline, coal, oil, and wood. In the indoor environment, people exhale CO_2, which contributes to CO_2 levels in the air.

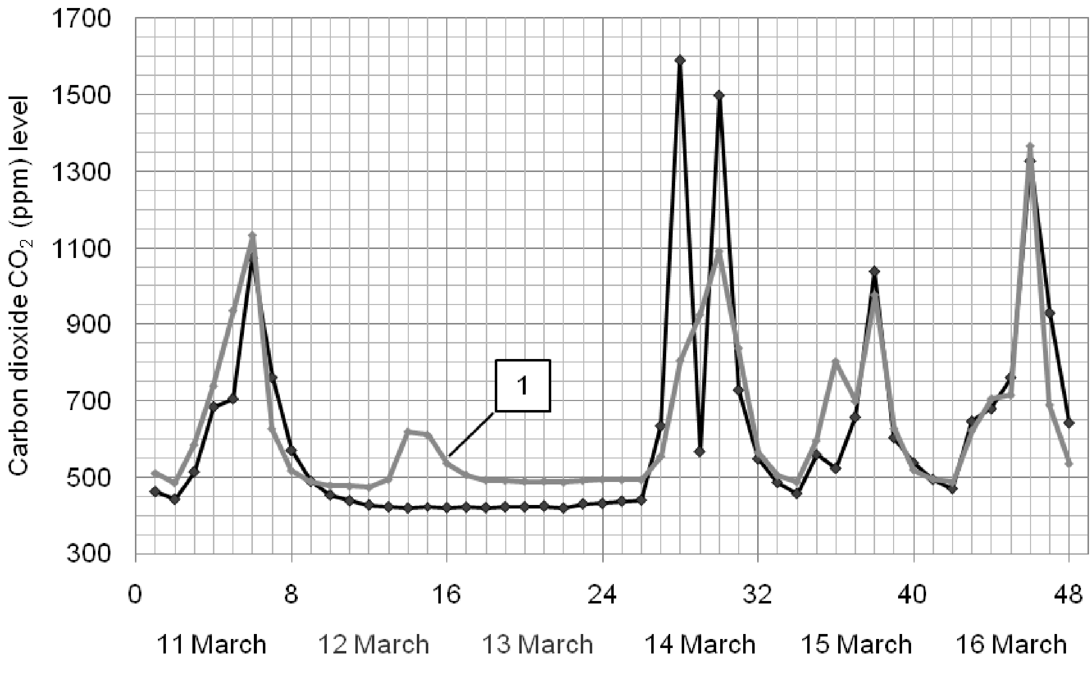

Figure 11. Carbon dioxide in the indoor environment in:
1 – partially renovated building (2007, average heat consumption 339kWh/m^2 per annum)
2 – newly erected building (built in 2005, average heat consumption 94kWh/m^2 per annum)

The outdoor concentration of carbon dioxide can vary from 350-400 ppm or higher in areas with high traffic or industrial activity." Our fixed CO_2 level varied from 410 till 440 ppm in February and March 2011. The Minnesota Department of Health had written: "the level of CO_2 indoors depends upon:

1. the number of people present;
2. how long an area has been occupied;
3. the amount of outdoor fresh air entering the area;
4. the size of the room or area;
5. whether combustion by-products are contaminating the indoor air (e.g., idling vehicles near air intakes, leaky furnaces, tobacco smoke), the outdoor concentration.

Carbon dioxide concentrations indoors can vary from several hundred ppm to over 1000 ppm in areas with many occupants present for an extended period of time and where outdoor air ventilation is limited." In Fig.11 the horizontal axis presents the data of times and date. Minor gridlines disclose time:

- first 2:00;
- second 5:00;
- third 8:00;
- fourth 11:00 etc..

Major gridlines from:

- zero to eight are the first data achieved on 11March;
- nine to sixteen are the second data achieved on 12March;
- seventeen till twenty four are the third data achieved on 13 March, etc..

Our fixed occupancies (floor area and existence of the ventilation system) are:

1. in a partially renovated day-care centre building (3 – 4 years old children/adults), floor area $64m^2$, there is no mechanical ventilation system:
    - 11 March – 17/2
    - 12 March – 0/0
    - 13 March – 0/0
    - 14 March – 17/2
    - 15 March – 17/2
    - 16 March – 16/2
2. in the new one (4-5 years old children/ adults), floor area $45m^2$, there is a mechanical ventilation system:
    - 11 March – 14/2
    - 12 March – 0/0
    - 13 March – 0/0
    - 14 March – 18/2
    - 16 March – 15/2
    - 15 March – 16/2

Fig.11 displays that in the newly erected day-care centre building with a mechanical ventilation system, the CO_2 concentrations in the indoor air in many cases are larger than in a partially renovated day-care building without a mechanical ventilation system. This indicates a necessity to analyse and optimise the ventilation system operation .

CONCLUSIONS

Our presented study of the heat consumption and IAQ measurements in different types (unrenovated, partially renovated and newly erected buildings) of existent day-care centre buildings has affirmed:

1. Partial renovation does not decrease heat energy in most cases. Buildings with similar total floor areas after a partial renovation had big heat consumption differences.
2. Partial renovation was done incorrectly in the majority of cases in school buildings and in day-care centre buildings. This was confirmed by the IAQ measurements in the day-care centre buildings and heat consumption analysis on building per one square metre per annum.
3. After a partial renovation in day-care centre buildings it is necessary to set correct heat demands on the control panel in each heat exchanger.

In each day-care centre building and renovation project it is necessary to include a mechanical ventilation system which can attain the building requirements for correct IAQ as defined in the Latvian Building Laws.

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