DE GRUYTER
OPEN

DOI: 10.1515/sspjce-2018-0020

Primary energy and CO_2 emissions for a district city and a suburb

Anton Pitonak, Martin Lopusniak, Miloslav Bagona

Technical University of Košice, Slovakia
Civil Engineering Faculty, Institute of Architectural Engineering
e-mail: anton.pitonak@tuke.sk, martin.lopusniak@tuke.sk, miloslav.bagona@tuke.sk

Abstract

In countries of the European Union, the proportion of buildings in the overall energy consumption represents 40% and their proportion in CO_2 emissions 35%. Taking into account dependence of the European Union on import of energy, this represents large quantity of energy and CO_2 emissions, in spite of the fact that there exist effective solutions for reduction of building energy demand. In Directive 20-20-20, the European Union adopted three main commitments of fulfillment criteria by 2020. On the basis of this directive, the Slovak Republic declares support of renovation of apartment dwelling houses. Taking into account the fact that state subsidy can be obtained only once, and energy requirements of the European Union are increasingly stricter, a comprehensive approach to renovation of buildings is inevitable. At the same time, it is inevitable to propose the renovation of buildings taking into account requirements stated for buildings for year 2020. Two areas were compared within the case study taking into account primary energy and the quantity of CO_2 emissions. Both areas have the same built-up area, but one of them is a district city and the second is a suburb. From results it is obvious that the quantity of primary energy is lower by 88% in the district city than in the suburb. The quantity of CO_2 emissions is lower by 69% in the district city than in the suburb.

Key words: primary energy, CO_2 emissions, district city, suburb

1 Introduction

The new buildings represent an increase by 1% to the existing building stock. In the Slovak Republic (SR), 48% of apartments are situated in apartment dwelling houses. Demographic curve of inhabitants of the SR has been stabilized in last 10 years. The total increase of the number of inhabitants has the decreasing nature [1]. Up to 95% of inhabitants living in the Slovak Republic can be categorized to lower and middle classes [2, 3]. Less than average monthly wage is earned by 58% of inhabitants of the SR [4].

Housing need is a problem of each class of inhabitants. The existing housing stock, mainly in the form of the panel construction in the period of 1970 – 1990 offers a great potential for the solution of housing issue for the dominant group of inhabitants of the SR. In spite of this fact, the construction of apartments is under way at the present for minority groups of inhabitants.

Approximately 970 thousand family houses (94%) and 65 thousand apartment dwelling houses (4%) have been constructed in SR. The number of apartments in family houses is 1.01

million (52%), and the number of apartments in apartment dwelling houses is 932 thousand (48%) [1].
In its strategies for the period of 2020 – 2050, the European Union states the need of renovation of the existing buildings with stress put on saving energy, environment and natural resources [5, 6, 7, 8]. In the SR, the renovation is solved in the form of subsidy for renovation and thermal insulation of apartment dwelling houses. This form is not effective, or it does not solve the renovation issue comprehensively. If the renovation of the existing housing stock should provide full-value housing for next generations, and if it should be solved in accordance with strategies of the European Union (EU), it is necessary to understand such renovation in wider context: Building – Climate – Energy [9].
According to Okamura [10], it should be investigated, solved and paid attention to how to use the existing items better, without necessity of additional useless expansion. It is always necessary to take into account the reserves. It is necessary to look for real economic, social and ecological improvements of functioning using reasonable planning. He states that well-considered urban landscaping is mostly missing [11]. If it comes to any kind of change in urbanism, it is always easier to implement the new ideas in small groups than move huge masses or change a system that people are used to for many years [12]. It is necessary to determine rules for individual subjects implementing their partial investment plans in the area. The existing reality is such that suburbs are intended for residential purposes and downtowns are places for work and entertainment. But this is serious and unfavourable phenomenon. Here, we collide with spatial demands required by cars in the downtown [11].
The Commission of the EU states in its document Green Paper on the Urban Environment 1990: The development of suburbs is perceived as a threat to functioning downtowns and satisfied life [13].

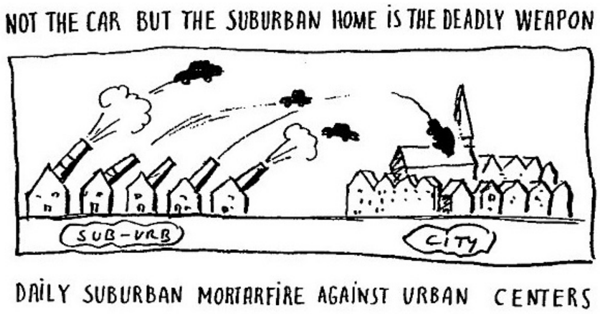


Figure 1: Impacts of suburbs on downtowns [11]

The objective of case study is to verify the statement that the renovation of the existing housing stock is more advantageous from the point of view of energy, economy and ecology than the construction of new housing stock. This case study follows from the current migration of higher and middle classes from down-towns to their suburbs. The objective of this paper is the comparison of designed area from the point of view of the quantity of primary energy to the quantity of CO_2 emissions. This was represented by the area of a district city and the area of a suburb. Both solved areas are equal surface.
Primary energy is a global indicator of energy performance of a building. This is determined from the quantity of energy supplied and conversion factors of primary energy. The quantity

of supplied energy in $kWh \cdot m^{-2} \cdot a^{-1}$ is multiplied by the respective factor of primary energy for the given type of energy (for example the factor for electric energy is 2.20 in the case of wood chips, it is 0.15) [14, 15]. In relation to global warming, stress is increasingly often put on reduction of emissions of harmful substances. This mainly means the quantity of CO_2 emissions. The quantity of CO_2 emissions will be determined from the quantity of supplied energy and conversion factors of CO_2 emissions. The quantity of supplied energy in $kWh \cdot m^{-2} \cdot a^{-1}$ is multiplied by the relevant factor for CO_2 emissions for the specified type of energy (for example the factor for electric energy is 0.167, in the case of lump wood it is 0.020) [14, 15].

2 Formatting requirements

Climate of the SR is determined by its position in the northern temperate zone, where 4 seasons are alternated. The lowest average annual temperature is in the highest altitudes, where it achieves -3.7°C. Lowlands are the warmest areas in the SR with the average temperature of 10.3°C. January is the coolest month in lowlands, and February in highest altitudes. Average temperature of the coolest month ranges from -3°C to -6°C. [16, 17].

2.1 District city

The overall area of the territory solved is 147,550 m^2. The number of 1,724 inhabitants is taken into account on the territory solved. These are inhabitants having their permanent addresses in this territory [18, 19]. The area belonging to apartment dwelling houses is 55,828 m^2. This area is marked out in Figure 2 by bold solid line and with dots.

LB systems (Figure 3) and brick systems of apartment dwelling houses are located in the area solved. The LB construction system was constructed in the period of years 1958 to 1968. External walls consist of expanded-clay concrete with thickness of 250 mm, the roof structure is of the double deck type, filler structures are of wood, doubled [20]. The average heat transfer coefficient is $U = 1.12\ W \cdot m^{-2} \cdot K^{-1}$.

Apartment dwelling houses located in the area solved are connected to the central system of heat supply. Heat and hot water are produced in the city heating plant.

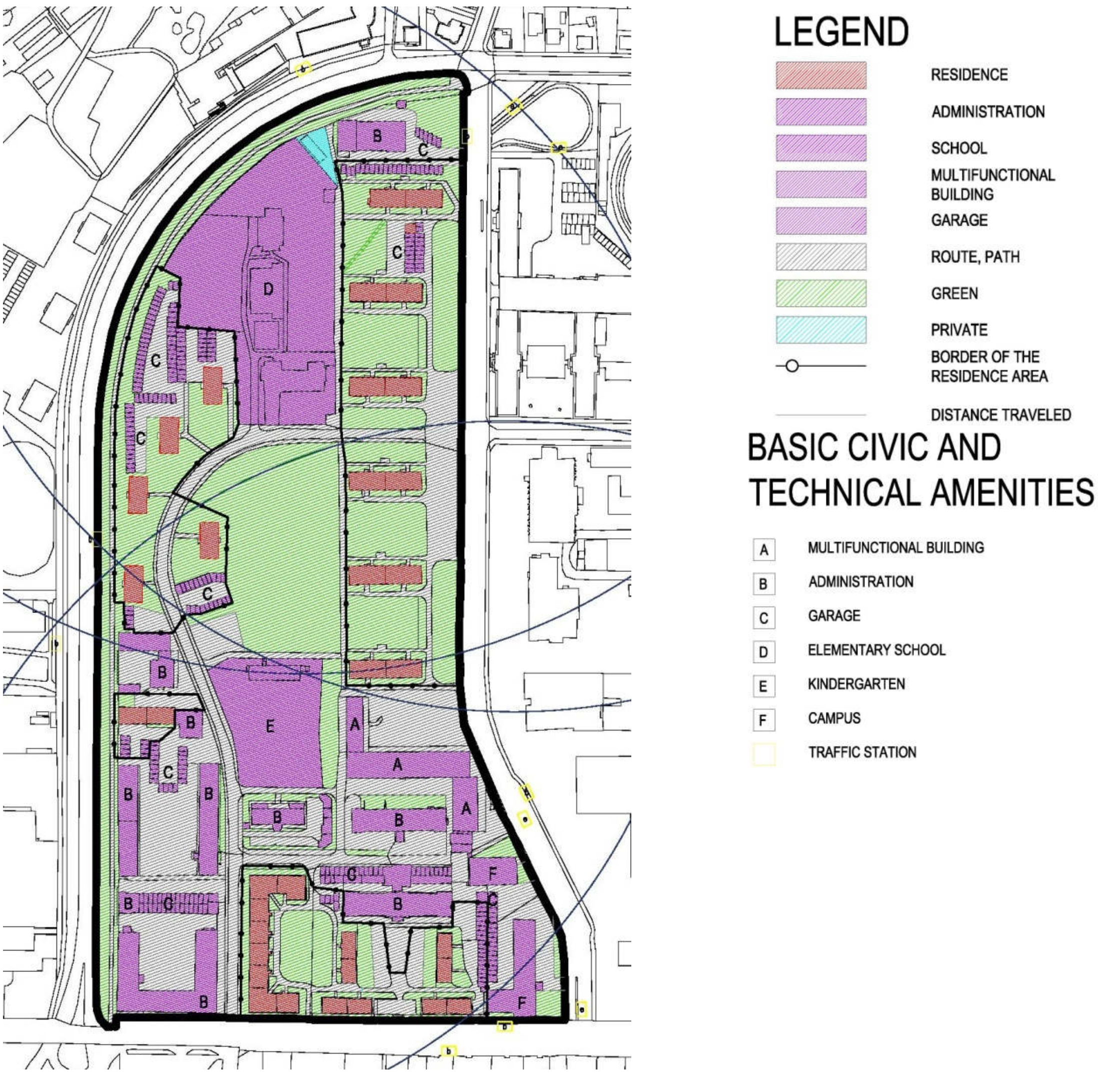
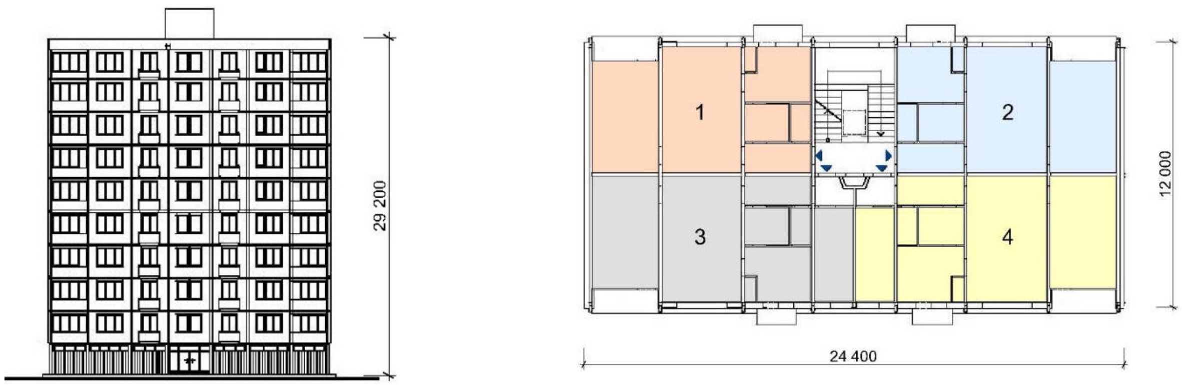


Figure 2: Kosice – North District city



a) b)

Figure 3: A typical representative of apartment dwelling house LB, a) front view and cross-section, b) floor plan [20]

Three energy alternatives were taken into account in the paper. Alternative A1 considered specific demand of energy for heating 141 $kWh \cdot m^{-2} \cdot a^{-1}$ and with specific demand of energy for the preparation of hot water 22 $kWh \cdot m^{-2} \cdot a^{-1}$. These values represent actual measured values of specific demand of energy in the SR [20]. Alternative A2 considered specific demand of energy for heating 52 $kWh \cdot m^{-2} \cdot a^{-1}$ and specific demand of energy for the preparation of hot water 16 $kWh \cdot m^{-2} \cdot a^{-1}$. The aforementioned values represent the existing standard of construction. Alternative A3 considered specific demand of energy for heating 15 $kWh \cdot m^{-2} \cdot a^{-1}$ and specific demand of energy for the preparation of hot water 8 $kWh \cdot m^{-2} \cdot a^{-1}$. These values represent the standard of construction in the future.
The overall floor area of apartment dwelling houses A_b is 70,239 m^2 (this is depicted with red colour – Residence in Figure 2). Primary energy factor for district heating was 0.70, and factor of CO_2 emissions was 0.22 [15].

2.2 Suburb

The area solved is situated 10 km from the downtown. Single storey and two-storey family houses are present in this area. Size of the area solved is 55,800 m^2. This area is marked out in Figure 4 by the bold solid line with dots. Sizes of parcels of land range from 660 m^2 to 810 m^2, their number is 70. The average size of the parcel of land situated in the area solved is 720 m^2. Floor areas of family houses range from 130 m^2 to 155 m^2. The average floor area of family houses is 140 m^2. The number of persons living in a family house is 3. The total number of persons is 210. The overall area of family houses A_b is 9,800 m^2 [21, 22].

Figure 4: The area solved – Krasna suburb – land register [22]

The paper solves two energy alternatives for family houses. Alternative B1 considered specific energy demand for heating 42 $kWh \cdot m^{-2} \cdot a^{-1}$ and specific energy demand for the preparation of hot water 12 $kWh \cdot m^{-2} \cdot a^{-1}$. The aforementioned values represent the existing standard of construction. Alternative B2 considered specific energy demand for heating 15 $kWh \cdot m^{-2} \cdot a^{-1}$and specific energy demand for the preparation of hot water 8 $kWh \cdot m^{-2} \cdot a^{-1}$. These values represent the standard of construction in the future.
Mainly natural gas, electric energy and solid fuel are used in family houses in the SR. These three media were considered in the calculation. The distribution in percentage was considered equal, namely 33.3% for each medium. Primary energy factor/CO_2 emission factor is 1.10/0.22 for natural gas, 2.20/0.167 for electric energy and 0.15/0.02 for solid fuel [15].

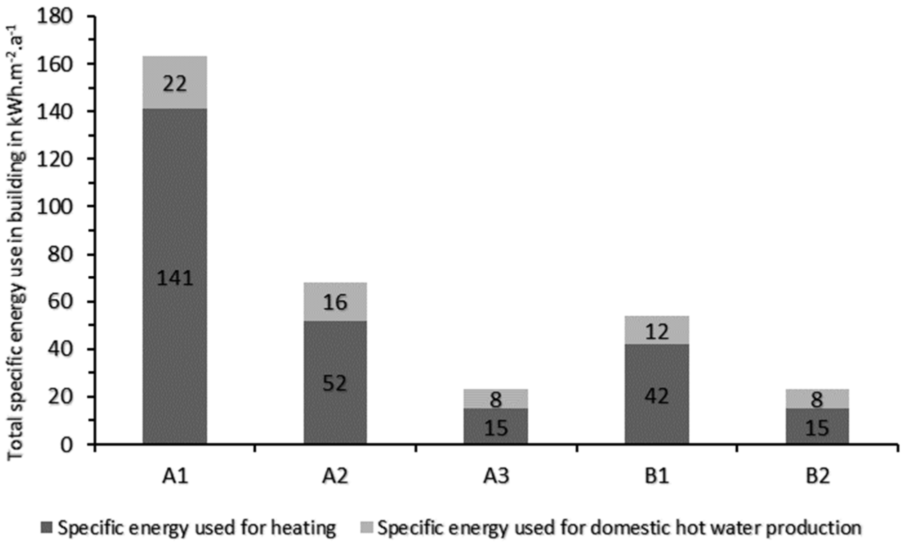


Figure 5: Variants of overall energy demand

3 Methodology

Overall supplied energy was calculated in the first step. This was calculated from demand of energy for heating, demand of energy for the preparation of hot water, effectiveness of resources, distribution and regulation. Subsequently, values of primary energy and CO_2 emissions quantity were determined on the basis of overall energy supplied. They were calculated on the basis of conversion factors of primary energy and CO_2 emissions. The calculation was carried out according to national laws, regulations and standards [14, 15, 23]. The quantity of primary energy and the quantity of CO_2 emissions shall be calculated as the overall quantity, or the quantity conversed to the specific unit. The specific unit is 1 m^2 of the floor area. This specific unit does not take into account density of residential settlement. Therefore, a new specific unit was introduced, namely coefficient of the number of inhabitants (KPO). KPO was considered as the ratio of the number of residents living in the area solved to its size.

$$KPO = \frac{the\ number\ of\ persons\ living\ in\ solved\ area}{size\ of\ the\ solved\ area} \quad [\text{inhab}\cdot\text{m}^{-2}] \qquad (1)$$

4 Results

Calculated values of primary energy Q_{prim} for the area solved and their individual variants are stated and compared in Figure 6. The difference between resulting values of alternatives A1 and A3 is 79%, which represents 6,884 MWh. The difference between resulting values of alternatives B1 and B2 is 57%, which represents 350 MWh. These differences are caused by input values, or by the level of thermal protection of buildings. The difference between resulting values of alternatives A3 and B2 is 86%, which represents 1,609 MWh. These alternatives were compared because of their equal input values. However, primary energy conversed to the number of inhabitants on the basis of the coefficient of the inhabitant number is by 88% lower for district city than for suburb.

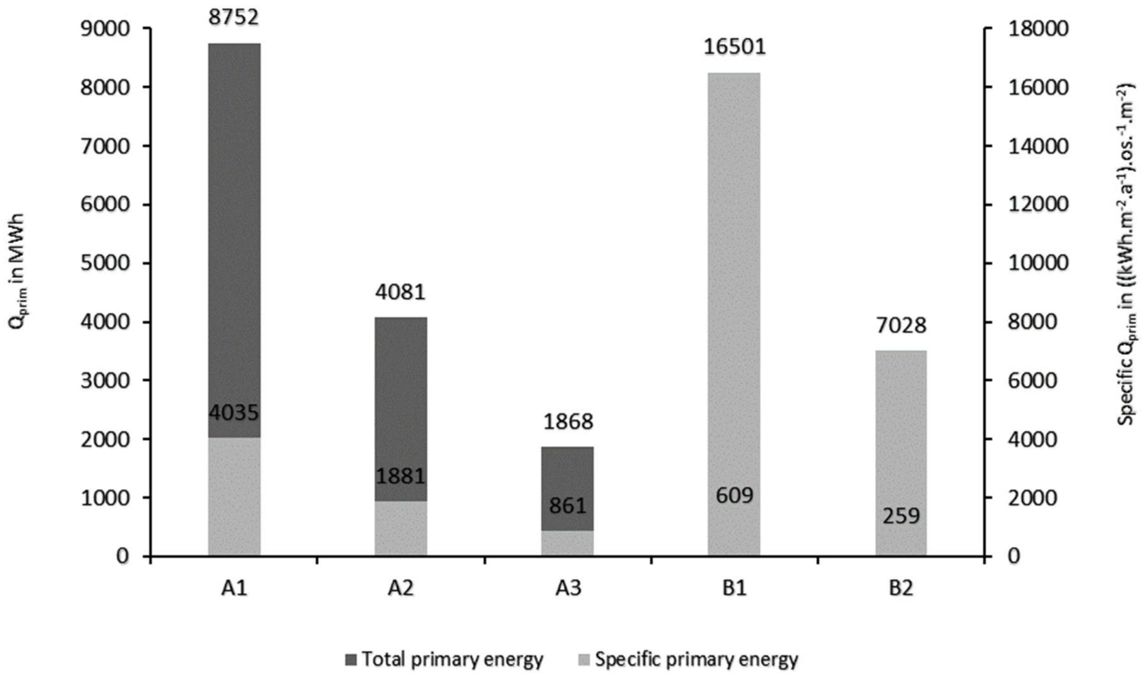


Figure 6: Comparison of primary energy in relation to areas solved

The calculated quantity of CO_2 emissions for areas solved and their individual variants are stated and compared in Figure 7. The difference between resulting values of alternatives A1 and A3 is 79%, which represents 2,164 t. The difference between resulting values of alternatives B1 and B2 is 57%, which represents 41 t. These differences are caused by input values or by thermal protection of buildings. The difference between resulting values of alternatives A3 and B2 is 95%, which represents 556 MWh. These alternatives were compared because of their equal input value. However, the quantity of CO_2 emissions conversed to the number of inhabitants on the basis of the coefficient of the inhabitant number is by 67% lower for district city than for suburb.

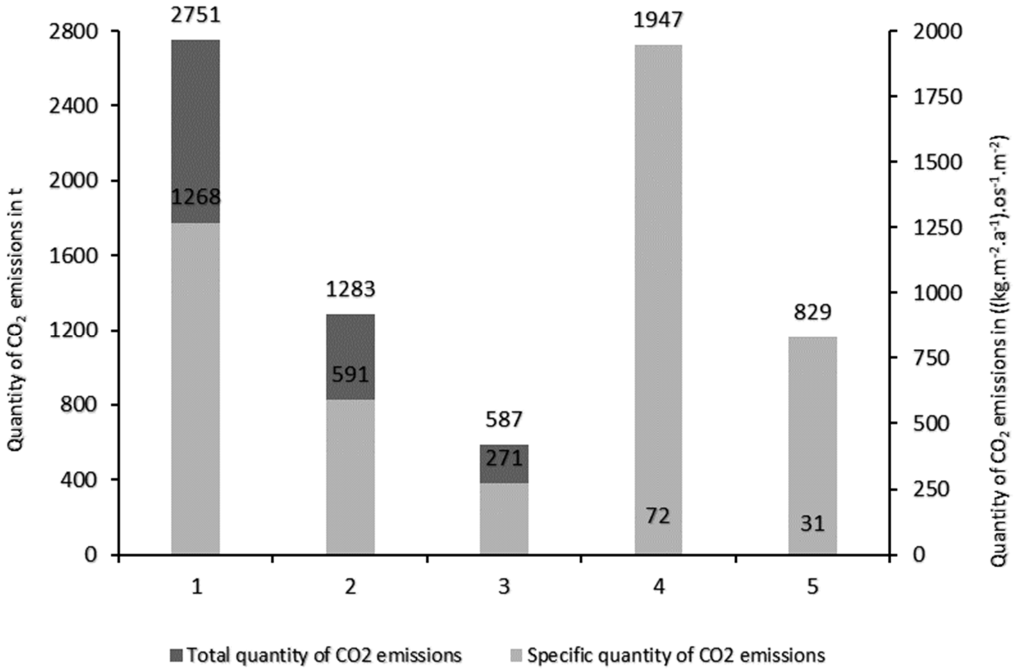
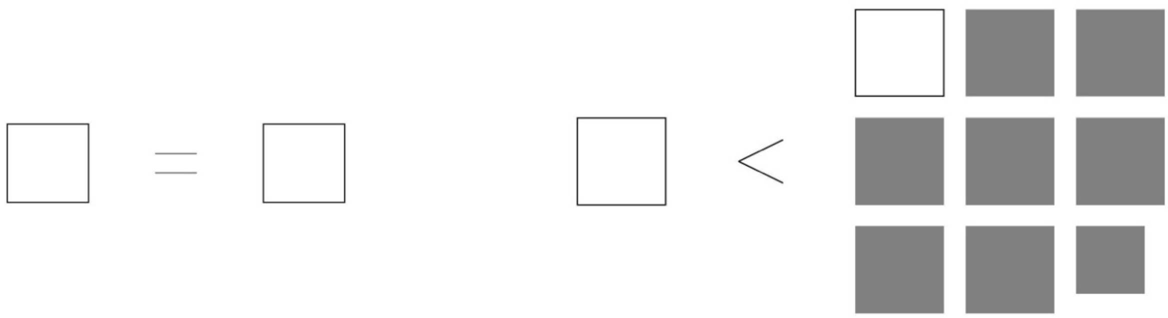


Figure 7: Comparison of the quantity of CO_2 emissions in relation to areas solved

5 Discussion

Overall primary energy is in the district city by 86% higher than in suburb. The same number of inhabitants is considered in both areas preserving input values. The area of the suburb would be 8.6 times larger than the area of the district city. Additional costs for the construction of new buildings, infrastructure and civic amenities are associated with occupation of new territories. Last but not least it is necessary to mention work trips to downtown, increased costs of transport, fuel, transport means and increased production of CO_2. Therefore, in the next part of case study, we will focus on environmental and economic comparison of areas solved.



a) b)

Figure 8: Comparison of areas solved, where a) equal size of areas solved, b) suburb area 8.8 times larger than the district city

6 Conclusion

The existing housing stock in the panel construction provides a potential, from the point of view of the development of housing and requirements for housing that is not used in full extent. From the long-term point of view, we are trying to verify the statement that renewal of the existing housing stock is more advantageous from the energetic, economic and ecological point of view than the construction of new housing stock. The objective of this paper is the comparison of areas solved taking into account the quantity of primary energy and CO_2 emissions. Areas of the district city and the suburb were compared. In order to take into account density of settlement, a new specific unit was introduced, namely coefficient of the number of inhabitants (KPO). KPO was considered as the ratio of the number of residents living in the area solved to its size, or to the area belonging to apartment dwelling houses. From results it is obvious that the quantity of primary energy conversed on the basis of KPO is by 88% lower in the district city than in the suburb. The quantity of CO_2 emissions conversed on the basis of KPO is by 69% lower in the district city than in the suburb.

Acknowledgements

This paper was created based on the solution of transparent constructions in interaction of the contemporary architecture and the human health VEGA 1/0389/17.
This paper was created based on the solution of Solar energy influences and integrated envelopes on the quality of the environment in buildings and cities VEGA 2/0042/17.
This paper was created thanks to the financial support from the EU Structural Funds, through the R&D Operational Program and project OPVaV-2008/2.2/01-SORO "Architectural, engineering, technological and economic aspects of the design of energy efficient buildings, codenamed ITMS: 26220220050; which is financed by EC funds.

References

[1] Information on https://slovak.statistics.sk

[2] Information on http://www.median.eu/cs/

[3] Information on http://www.median.eu/cs/

[4] Information on https://www.platy.sk/

[5] European Commission. Information on https://ec.europa.eu/clima/policies/strategies/2020_en

[6] Agenda 21. Information on https://sustainabledevelopment.un.org/outcomedocuments/agenda21

[7] Environment information portal. Information on http://www.enviroportal.sk/Sk_SK/eia

[8] Directive on environmental Assessment. Information on http://www.europskaunia.sk/sea

[9] Bielek, B. 2014. Nízkoenergetická, zelená, udržateľná – budova, klíma, energia. Bratislava STU. ISBN 978-80-227-4185-9.

[10] Information on https://korzar.sme.sk/c/6433262/osamu-okamura-sidliska-prichadzaju-do-mody.html.

[11] Hnilicka, P. 2005. *Sidelni kase, Otazky k suburbanni vystavbe kolonii rodinnych domu*. Era. ISBN: 80 – 7366 – 028 – 8, 2005.

[12] Tkac, S. Vranayova Z. 2013. The “Efficiency electric power grid circles” an ideal micro-urban development approach. *Applied Mechanics and Materials. Vols. 361 – 363.* Switzerland: Trans Tech Publications.

[13] Green Paper on the Urban Environment, Office of Official Publications of the European Communities Luxembourg. ISBN: 92-77-61187-1, 1990.

[14] Regulation No. 364 Coll. of 12 November 2012. Implementing Act No. 555/2005 Coll. on energy performance of buildings and on change and amendment of certain other acts as amended.

[15] Regulation No. 324 Coll. of 30 November 2016, Implementing Act No. 555/2005 Coll. on energy performance of buildings and on change and amendment of certain other acts as amended.

[16] Farkaš, C. et al., 1997. *Geografia.* Enigma Nitra. ISBN 80-85471-45-0.

[17] STN 73 0540, 2012. Thermal protection of buildings, Thermal performance of buildings and components, Slovak office of standards metrology and testing. Bratislava.

[18] Information on https://sk.wikipedia.org/wiki/Ko%C5%A1ice_%E2%80%93_mestsk%C3%A1_%C4%8Das%C5%A5_Sever

[19] Information on http://www.kosicesever.sk/miestny-urad

[20] Sternova Z. 2001. *Renovation of apartment dwelling houses, Mass housing construction to 1970*, JAGA group, Bratislava, ISBN: 80-88905-53-2, ISSN: 9788088905530.

[21] Information on https://www.google.sk/maps/place/040+18+Kr%C3%A1sna/@48.6772431,21.2896932,13z/data=!3m1!4b1!4m5!3m4!1s0x473edf62f907f097:0x500f7d1c6979260!8m2!3d48.6726061!4d21.3188165

[22] Land register. Information on https://www.katasterportal.sk/kapor/

[23] STN EN ISO 13790/NA, 2010. Energy performance of buildings, Calculation of energy use for space heating and cooling.