IMPROVING ENERGY EFFICIENCY OF EXISTING SUBURBAN AREAS THROUGH DISTRICT ENERGY PLANNING

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ABSTRACT

Urban sprawl represents a significant contribution to the overall energy consumption of a territory for energy needs in buildings and for transport. It is a huge concern in Belgium where public authorities face the following question: "what to do with existing low-density districts that require a lot of resources?" while households still continue to favour this kind of dwellings. In this context, the paper draws up a typological classification of reference Walloon suburban blocks. Then, energy savings relating to several types of renewal strategy are evaluated. These strategies deal with the measures to reduce heat demand in buildings, to increase the built density and to reduce energy consumption in the transport sector. Results from this analysis show that a strong potential exists to improve energy efficiency in existing suburban districts. Building insulation and travel distances are critically important factors. Solar gains on the roofs are huge even if the built density is increased.

KEYWORDS

Urban sprawl, suburban renewal, energy efficiency, building and transportation.

INTRODUCTION

The process of urban sprawl, which commonly describes physically expanding urban areas, is a major issue for sustainable development (EEA 2006). For the same standard of insulation, detached houses need more energy for heating than terraced houses (Marique and Reiter 2010a). Moreover, suburban developments have created farther spatial separation of activities, which results in an increase in travel distances and transport energy consumption (Silva et al. 2007). But, although the environmental impacts of urban sprawl and uncontrollable urbanization are now well known and may give rise to various issues, such as environmental pollution or large-scale climate change (He et al. 2010, UTF 1999, Young et al. 1996) and despite the growing importance of the energy issues in public debate, low energy-efficient suburban developments are a reality in Belgium. These suburban districts require a lot of resources both in the building sector (the suburban building stock is pretty old and poorly or not insulated) and in the transport sector (car ownership is high and public transport generally less available, which tends to favour the use of private cars). Moreover, although the history of European cities was for a long time marked by continuous and spontaneous demolition / reconstruction process of entire neighbourhoods, heritage considerations and social trends seem now to question the relevance of these strategies to renewal works more respectful of our built environment and the people who live there. In this context, this paper aims at investigating the efficiency and energy savings relating to several suburban renewal strategies. The main objective is to highlight the most efficient ones to help local authorities and owners to manage efficient renewal works in existing suburban districts.

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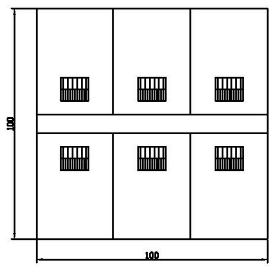
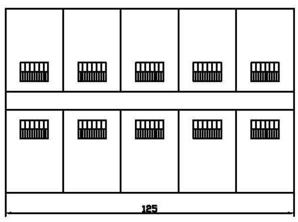
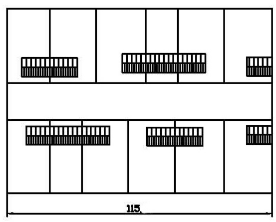
RESEARCH METHODS

A method has been developed to assess energy requirements in Walloon suburban areas. It includes the energy assessment of buildings and transportation and addresses their influences at the neighbourhood scale because, even if the urban context has been mostly neglected in building energy analyses so far, decisions made at the neighbourhood level have important consequences on the performance of individual buildings and on the transport habits of the inhabitants (Popovici and Peuportier 2004). Moreover, the urban fabric shows the spatial configuration for solar access to the building and hence solar gains on the envelope (Cardenas-Jiron 2009). The first part of the method is dedicated to the energy assessment of suburban houses, at the district scale, on the basis of a typological classification of buildings and thermal simulations (Marique and Reiter 2010a). The second part is dedicated to the assessment of the transportation system and takes into account four purposes of travels (work, school, shop and leisure) thanks to empirical and statistical data, type profiles and GIS tools (Marique and Reiter 2010b). The method allows the comparison between the energy requirements in the building sector and in the transport sector, and thus to highlight which strategies would be the most efficient to reduce the overall energy consumption of a district.

On the basis of a cartographic analysis (GIS), we determined that the mean housing density of Walloon suburban areas is contained in a range between 5 and 12 dwellings per hectare. In order to obtain representative results for the Walloon suburban area, three kinds of layout of 1 hectare were identified and studied. All of them are typical suburban shapes in the Walloon region of Belgium and can be combined to form entire neighbourhoods. National censuses conducted at the district scale were used to carry out a survey of cases that allowed us to highlight predominant and representative characteristics in each reference fabric (Table 1).

***Table 1**. Characteristics of the reference districts (1 hectare).*

	Type 1	Type 2	Type 3
North ↑			
Built density	6 dwellings/ha	10 dwellings/ha	12 dwellings/ha
Size of the plots	1,500 m²	900 m²	450 – 700 m²
Size of the house	250 m²	180 m²	120-150 m²
Distance to centre	18 km	15 km	12 km

We assumed that the reference districts were built before the first thermal regulation adopted in the Walloon region of Belgium (1984) and are thus not insulated. The houses have standard single glazing (U = 4.08 W/m²K). We did not consider the heating system in the calculation to focus on heat demand and measures to improve the building envelope. Each house is occupied by a reference household (two adults and two children). The inside temperature considered in the calculation is 20°C. The climate data are those of the Test Reference Year of Brussels (temperate climate). All the districts have the same orientation and were assumed to be located in a representative suburban location where the performance index of transport calculated with our method is equal to the mean performance index of the represented class. Adults work five days per week, 48 weeks per year while children go to school 180 days per year. We finally assumed that each household go shopping twice a week and each member of the family has a leisure activity outside of the house, once a week. Shops and leisure centres are located in the nearest well-equipped core (city centre or secondary shopping centre) because suburban districts are mainly residential and do not provide other kinds of activities.

RESULTS

The measures to reduce the heat demand in buildings

The energy-saving measures were applied to the building envelope. The impact of insulation and better glazing was tested for 5 relevant insulation levels. The first one is the "upgraded standard" (UP) where the most common upgrades used in the Walloon building stock were applied (adding insulation in the roof and replacing single glazing by double glazing (U = 2.76 W/m².K), MRW 2007). The second level (3C) consists in adding 3 cm of insulation in the walls and the slab and 6 cm in the roof (corresponding to the thermal regulation between 1984 and 1996). The third level (6C) corresponds to the thermal regulation adopted in 1996 (6 cm of insulation in the walls and the slab and 10 in the roof), the four one is the current standard (CS) for new buildings in Belgium since 2008 and the adaptation of the European Energy Performance of Buildings. It corresponds to 9 cm of insulation in the walls and the slab and 13 cm in the roof. The last one is the passive standard (heating requirements < 15kWh/m².year, PS) because this level should constitute the standard for new buildings within the year 2020, and gradually also existing buildings will be subject to this request.

***Table 2**. Summary of the results for the three reference districts*

	Reference	UP	3C	6C	CS	PS
			Annual heat demand per dwelling (kWh/year)			
D1	56,000	30,000	19,500	17,750	15,500	3,750
D2	39,780	21,780	14,040	12,600	10,980	2,700
D3	25,675	12,870	8,840	8,125	6,998	1,950
			Energy savings in comparison with the reference situation			
D1	-	26,000	36,500	38,250	40,500	52,250
D2	-	18,000	25,740	27,180	28,800	37,080
D3	-	12,805	16,835	17,550	18,677	23,725

These results highlight the importance of the potential energy-saving through the improvement of the envelope. The main benefits of energy savings are realized in non-insulated dwellings (reference), as the first centimetres of insulation, especially in the roof, are the most effective. The passive standard allows huge energy-savings in comparison with the reference situation. However, unlike the first renewal strategies, it implies huge and expensive improvements works.

The measures to increase density and their impact on solar gains

In addition to the measures applied to the envelope of buildings, the impact of the density was studied. Heat demand, solar gains received through the windows and by the facades and the roofs were evaluated for the reference situation and for variants where the built density of the districts is doubled (Figure 1). The current standard of insulation was used.

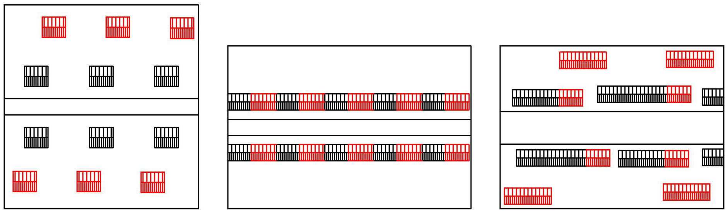


***Figure 1**. Variants where the built density of the districts is doubled*

***Table 3**. Mean heat demand and solar gains*

	Mean heat demand (kWh/m².year)		Mean solar gains through the windows (kWh/house)		Mean solar gains (kWh/m²) in the reference case	
	Reference	Variant	Reference	Variant	Roofs	Facades
D1	62	63	4,562	4,331		
D2	61	58	4,374	2,517	1,000	398
D3	54	57	3,389	2,962		

Increasing the built density reduces solar gains through the windows which lead to an increase in the heat demand per m² in district 1 and 3. In case 2, the heat demand is reduced because terraced houses are more efficient than detached houses. In this case, the rear facade is not shaded by neighbouring buildings. Heat demand increase is the largest in the densest district but heat demand stay the lowest. Solar irradiation on the roof is not affected by the density of the district because all the buildings have the same height. Active solar and photovoltaic systems could thus be used, according to the threshold values proposed by Compagnon (2004) for systems mounted on roofs (min. 600 and 1,000 kWh/m² annual solar irradiation). The orientation of the district and the houses and the slope of the roof are ideal. Photovoltaic systems and solar thermal collectors mounted on facades are not recommended because the minimum threshold values (400 and 800 kWh/m²) are not reached even if the density of the district is not increased.

The measures to reduce the energy consumption of transport

The energy-saving measures relating to 5 strategies were tested: we assumed successively that 50% of the workers of a district work at home one day per week (HW); the performances of the vehicles are improved by 10% (PV); the share of bus reaches 30% for all types of travels (MR); households favour local shops and leisure (SL). The last strategy combined the first and the four ones (HW+SL). Favouring a better bus service and local shops can only be considered if the built density is increased in the considered district and in its neighbourhood.

***Table 4**. Annual energy consumption for transport per household (kWh/year)*

	Reference	HW	PV	MR	SL	HW+SL
D1	23,414	22,042	21,092	22,556	20,887	19,514
D2	21,226	19,930	19,128	20,446	19,229	17,933
D3	19,243	18,024	17,331	18,605	17,746	16,526
	Energy savings in comparison with the reference situation					
D1	-	1,373	2,323	858	2,527	1,373
D2	-	1,296	2,098	780	1,997	1,296
D3	-	1,219	1,912	638	1,498	1,219

The most effective strategies are to favour local shops and home workers, which allows to reduce the travelled distances and thus to significantly reduce energy consumption. Favouring public transport gives more limited results (the considered 30% share of bus is huge in comparison with the actual behaviour of the inhabitants in Belgium) while increasing the performance of the vehicles is also efficient without too many efforts for the households.

The combination of measures

Transport energy consumption represents about 28% of the overall consumption (building + transport) if the buildings are not insulated. If the houses reach the passive standard, the balance between these two sectors is completely changed: transport energy consumption represents about 84% of the overall consumption. To conclude, the following figure shows the expected energy-savings relating to combinations of measures (36 possibilities per district). In the same district, the difference between the best and the worst combination is huge (76.7%).

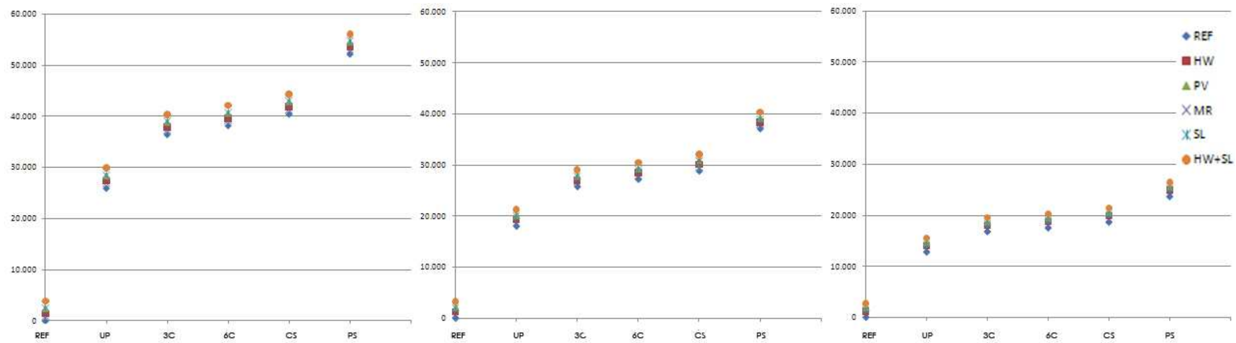


***Figure 2**. Energy-savings in kWh for combinations of measures relating to building and transport (reference district 1 on the left, 2 in the middle and 3 on the right).*

DISCUSSION

Our analysis has shown that suburban areas could favour energy efficiency if the building stock is retrofitted to fit better insulation standards. Verbeek and Hens (2005) namely identified insulation measures as the most cost-effective and durable for energy performance increase of Belgian households (before more energy efficient heating system and renewable energy systems). Solar gains are high in existing districts and stay high if the density is increased which highlight the specificity of suburban areas in comparison with urban centres often studied in the literature. As far as transport is concerned, the reduction in travelled distances (namely through urban planning) is an efficient strategy to promote.

Our method uses dynamic simulation tools, which have been shown to give results significantly different from those observed in reality because of variations in inhabitant behaviours. Real climatic conditions can also differ from the standardized data. The software used in this analysis has been validated by the International Energy Agency Bestest (Peuportier 1989). Nevertheless, it is not possible to compare the results presented in this paper with in situ measurements because of high variation in inhabitant behaviours. The figures presented here must be taken with respect to the hypothesis and assumed conditions. However, they are useful in the identification of important factors related to energy efficiency.

CONCLUSION AND IMPLICATIONS

As suburban developments are not only found in the Walloon region of Belgium but also all over Europe, the USA and even emerging countries (Silva et al. 2007, Yaping et al. 2009), the challenges relating to the renewal of suburban areas are huge. The method, developed and tested in the Walloon context, is parameterized. By adjusting parameters, such as those related to climate, insulation or vehicle characteristics, the method can be transferred to other regions.

Our final goal is to provide an interactive assessment tool dedicated to building performance and transportation in Belgium. The tool will help public authorities and private developers to plan more efficient suburban developments and to improve energy efficiency in existing neighbourhoods. Users of the tool will use it to identify practical strategies to reduce their energy consumption and test the impacts of different locations. Findings might thus be a useful input for suburban planning guidance and a better awareness of the inhabitants.

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