Energy and Buildings xxx (2013) xxx–xxx

Contents lists available at SciVerse ScienceDirect

Energy and Buildings

journal homepage: www.elsevier.com/locate/enbuild

Spatial planning as a driver of change in mobility and residential energy consumption

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ARTICLE INFO

Keywords:
Spatial planning
Energy consumption
Building stock
Mobility

ABSTRACT

This paper analyses the impact of territorial structures upon energy consumption in the Walloon Region (Belgium). The rationale for this research is to consider the long-term influence of spatial planning decisions upon energy consumption in both residential building stock and home-to-work commuting. The analysis has been conducted on a regional scale (16,844 km^2) and includes urban, peri-urban and rural settlements. Those settlements that perform well in mobility also appear to perform well in terms of building energy consumption. Even though this is not generally the case, it further reveals that some rural settlements characterized by low density show good performance in terms of energy efficiency. This permits a much more progressive approach in terms of spatial planning, whereby compact cities may be viewed as part of the solution, albeit not the whole solution.

1. Introduction

The influence of the spatial pattern of human activities on energy consumption in the transportation and/or the building sectors has been the subject of a great deal of empirical, theoretical and policy research.

Based on the observation that existing computer models adopt the perspective of the individual building as an autonomous entity and neglect phenomena linked to larger scales [1], a growing body of literature since the late 1990s has explored the effects of urban structures on building energy consumption. It highlights that decisions made at the neighbourhood and city levels regarding built volume and surface, orientation of façades and obstructions have important consequences for the performance of individual buildings in heating, ventilation and cooling [1–3]. Conversely, for the same level of insulation, lower density and detached types of houses tend to require more energy to heat than multi-unit developments or terraced housing [4,5]. In the same vein, the Energy and Environment Prediction (EEP) model [6] is based on a regional database that provides energy consumption figures for 100 building types. The variables considered in the typology are heated floor area, facade area, window percentage and age. Integrating these values into a Geographic Information System (GIS) allows comparison of energy policies at the city level. It highlights the magnitude of potential energy savings at the urban level through a renewal of existing building stock.

The relationship between urban form and transport energy consumption is also discussed. Based on data from 32 large international cities, Newman and Kenworthy [7,8] highlighted a strong inverse relationship between urban density and transport energy consumption. Nonetheless, their work is only valid under certain conditions and is often criticized by other scholars [9,10] mainly for methodological reasons. Bannister [11] applied a similar approach to British cities, but based on statistical data obtained from a national survey. He demonstrated that transportation energy consumption is slightly higher in London than in smaller cities, which refutes Newman and Kenworthy's observations. Boarnet and Crane [12] are also sceptical about the relationship between urban design and transportation behaviour. By analysing case studies, they suggested that the use of land and the urban form impact transportation behaviour because of the price of travel (public transport prices are reduced in dense areas). Gordon and Richardson [13] demonstrated that urban density only plays a limited role in energy consumption in transport if fuel prices are included in the analysis. In the sample of cities used by Newman and Kenworthy, Breheny and Gordon [14] demonstrated that the density coefficient and its statistical significance decrease when petrol price and income are included as explanatory variables. Breheny [15] emphasized minor reductions in transportation energy consumption because of the compact city model. His experiments showed that energy used in transport could only be reduced by 10–15%, even under very strict conditions that are difficult to reproduce. By studying 10 cities around the world, Souche [16] showed that the most

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http://dx.doi.org/10.1016/j.enbuild.2012.10.059

statistically significant variables for transport energy consumption are transport cost and urban density. Finally, Ewing and Cervero [17] highlighted that per capita vehicle travel tends to decline and the use of alternative modes to increase with a rise in density. For these authors, compact developments, which reflect the cumulative effects of increased density, functional mix and transit accessibility, typically reduce the per capita vehicle travel by 25–30%. Similarly, Stead [18] found that if 43% of the variation in distances travelled is explained by socio-economic variables, 27% of this variation is directly related to land-use variables, which is considerable.

Various studies argue that more compact urban forms would significantly reduce energy consumption, in both the building and transportation sectors [2,19–21] by combining such factors as high density, mixing land uses and a better share of active commuting, whereas other authors [22] indicate that lower energy consumption may be achieved by decentralized concentration.

Considering this background, the present paper specifically analyses the impact of territorial structures on energy consumption in the Walloon Region (Belgium), examining both residential building stock and home-to-work commuting. Territorial structures are discussed here in terms of three main components: the location of households, the location of employment and mobility infrastructure (roads, buses, trains). It is considered that the interaction between these three components is a structural property of a territory that may affect energy use via mobility and housing consumption patterns. Increasing household densities generally entail more compact buildings (terraced houses and apartments), which tends to lessen energy losses. Mixing places of employment and households allows people to find jobs at closer locations, which may reduce the distances they travel to work, or to destinations for purposes such as shopping or leisure. Adequate access to transportation facilities may impact travel modes, and indirectly, housing densities and energy consumption. Obviously it should be acknowledged that there is an important behavioural dimension in these relations [23]. The proximity of jobs does not constitute a guarantee that householders will effectively select a job near home. Developing the analysis on a statistical basis reveals empirical trends in the relation between these variables and observed behaviour.

The combination of these three variables is assumed to be an element that can somehow be handled by urban planning policies. The effective influence of urban planning upon employment and household locations is obviously limited [15]. Still it should be acknowledged that planning policies at a European level lead to striking differences in this respect, as is evident in the relative extent of sprawl in different regions [24].

Accordingly, Section 2 describes the general methodology adopted in this research, which is based on a combination of Geographic Information Systems with survey and cadastre data at the regional level. Sections 3 and 4 introduce and discuss maps of energy consumption, respectively, for home-to-work commuting and for residential building heating in the Walloon Region. Section 5 combines observed results and indicators of density and mixed use to highlight the impact of territorial structures on energy consumption. The concluding section is a general discussion of the results and possible policy recommendations regarding spatial planning policies.

2. Methodology

The overall methodology of this research is based on spatial correlations between energy performance indicators, namely mean home-to-work commute energy consumption and mean residential building energy consumption, with two territorial indicators, namely mean density and mixed use. Each of these four indicators has been calculated on the scale of statistical units. The territory of the Walloon Region is covered by 9876 statistical units. The area of these statistical units varies between 1.3 ha and 5834 ha with a median value of 47.7 ha, which corresponds to a circle of slightly less than 400 m in radius. Statistical units correspond to neighbourhoods in urban areas and encompass large depopulated zones in rural areas. It is important to note that the analysis has been conducted for all statistical units in the entire region (16,844 km^2) and includes urban, peri-urban and rural settlements. This is an important difference from the approach developed by Newman and Kenworthy [7], who deliberately focused on large scale agglomerations.

For home-to-work commute, the model is based on the general survey undertaken in Belgium every 10 years amongst all citizens over 16 years of age. The survey provides figures about home-to-work distances travelled by workers and their choice of mode of travel. Altogether, data from 8,572,000 respondents were extracted from the census survey. This represents approximately 73.1% of Wallonia's working population in 2001. These data were used to build a mobility energy performance index, following Boussauw and Witlox [25]. It was calculated for 1991 and 2001, corresponding to the two most recent general surveys in Belgium. The following conversion table was used to estimate kWh and CO_2 emissions per kilometre travelled and passenger on the various modes of travel. Table 1 also provides regional energy consumption and CO_2 emissions for home-to-work commuting, considering annual distance travelled and mode choice of all respondents to the survey.

Figures for energy consumption and CO_2 emissions per kilometre travelled and passenger were obtained by dividing the total amount of energy consumed for a given travel mode, calculated on the basis of the annual kilometres travelled and fuel type, by the occupancy rate of that mode. Conversion factors for electricity to CO_2 emissions were provided by the Walloon Air and Climate Agency (AWAC). Details of the calculation were published in [26]. A mean number of passengers for each travel mode is considered here; the calculation does not consider known variations of energy consumption within public transport according to occupancy rate.

Table 1
Specific energy consumption and CO_2 emissions by travel mode in the Walloon Region.

Mode	Modal share 2001 (%)	Energy consumption by km travelled and passenger (kWh per km)	CO_2 emissions by km travelled and passenger (gCDE per km [gram of CO_2 equivalent per passenger and km])	Regional energy consumptions for home-to-work commute (GWh)	Regional CO_2 emissions for home-to-work commute (TCDE [metric tonne of CO_2 equivalent])
Car	80.2	0.45	118.3	18,722.0	4894.7
Moto, scooter	1.9	0.41	105.0	251.4	64.6
Bus, tram, metro	4.1	0.35	79.5	417.6	93.7
Train	7.2	0.15	35.7	451.1	104.4
Bike	1.2	–	–	–	–
Walking	5.4	–	–	–	–
Total	100	–	–	19,842.1	5157.5

Please cite this article in press as: S. Dujardin, et al., Spatial planning as a driver of change in mobility and residential energy consumption, Energy Buildings (2013), http://dx.doi.org/10.1016/j.enbuild.2012.10.059