

# Are Polycentric Cities More Energy-Efficient?

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## Introduction

Cities are the largest consumers of energy and emitters of greenhouse gas emissions through heating, air conditioning, manufacturing and transport, and by their high density are particularly vulnerable to negative impacts of climate change, such as floods, draughts and heat waves. With a population of more than five million, the Ruhr region is one of the major urban agglomerations in Europe. Through its industrial past and its polycentric settlement structure, it has a particular potential for the reuse of former industrial brownfields and the development of transport-reducing settlement structures.

The history of cities is a history of energy transitions. In the medieval city heating and cooking occurred with wood and peat. The growth of the industrial city in the 19th century was built on coal and electricity. The sprawling metropolis of the 20th century was made possible by oil and gas. How will the city of the 21st century look after the next energy transition from fossil to renewable energy? The challenges of the energy transition affect all fields of urban development: settlement structure, landscape/water, socioeconomic structure, person travel and goods transport, environment. Until now measures to achieve the energy transition have been mostly dealt with in isolation from each other. But it is necessary to consider the interactions and positive and negative synergies between them.

This is why the Mercator Foundation launched a major programme to enhance knowledge and awareness of the need for and challenges of the energy transition in the municipalities of the Ruhr region. The four-year programme consists of a combination of empirical surveys, research projects, citizen participation and implementation studies.

The project presented in this paper is part of this programme. In it a computer simulation model of urban land use, transport and environment developed at the Institute of Spatial Planning of the University of Dortmund (Wegener, 2011) is being further developed and applied to assess the impacts of land use, transport and other policies to reduce energy consumption and promote the transition to renewable energy on economy, mobility, quality of life and environment in the Ruhr region (Huber et al., 2011, 2013). For this the model is being extended by submodels of renewable energy and energy efficiency of buildings (Fuerst and Wegener, 2012). The model will be used to simulate scenarios of future energy price increases and possible combinations of measures to reduce fossil energy consumption and to increase energy efficiency and renewable energy use to achieve the energy policy targets of the German Federal Government. The project is a co-operation between the Wuppertal Institute for Climate, Environment and Energy and the Faculty of Architecture and Civil Engineering of the University of Wuppertal and Spiekermann & Wegener Urban and Regional Research, Dortmund (S&W).

In this paper first results of the transport submodel of the integrated model are presented. It is asked whether the general held hypothesis is correct that polycentric cities are more energy-efficient with respect to mobility than monocentric or dispersed urban regions. There are empirical studies comparing cities or urban regions by indicators of polycentricity and sustainability, but these suffer from the effects of region size and different transport systems. Therefore here the impacts of different fictitious distributions of population and workplaces on mobility behaviour and energy consumption of transport are explored, everything else being equal. The result is that the hypothesis about the energy efficiency of polycentric cities cannot be confirmed by the method applied, so that policies making car driving more expensive or slower and policies making public transport, cycling and walking more attractive are required to promote sustainable mobility.

## Research Question

There is a broad debate among urban planners about what is the ideal urban structure to comply with stated sustainability goals. There are two contrasting positions: The first position argues that urban density is the most important factor resulting in shorter trips and more trips by environment-friendly modes. The second position argues that polycentric cities are more energy-efficient than both monocentric and dispersed cities. Which of the two positions is correct?

## Method

There is mixed empirical evidence for both positions: Starting with the seminal publication by Newman and Kenworthy (1989) there are numerous reports on the impacts of density on trip length and mode choice. There is also a significant number of studies comparing cities by their polycentricity and energy use. However, these studies suffer from the lack of comparability of cities in terms of size and transport infrastructure. In the study presented here therefore different fictitious distributions of population and workplaces in one and the same region were compared by transport energy use, everything else being equal.

For this the transport submodel of the integrated model of the Ruhr region under development was applied. The integrated model forecasts for each year until 2050 intraregional location decisions of firms, developers and households, the construction activity and migration and travel flows resulting from them and the impacts of public policies in the areas of land use, housing, infrastructure and transport. The transport submodel forecasts the commuter and other travel flows resulting from the distribution of households and firms in the region.

In a first group of scenarios, the distribution of population and workplaces was varied as in the table below. Each scenario was run with two assumptions about energy prices: moderate energy price increases (the A scenarios) and strong energy price increases (the B scenarios).

		Workplaces		
		Centralisation	Baseline	Decentralisation
Population	Centralisation	A07/B07	A01/B01	A06/B06
	Baseline	A03/B03	A00/B00	A04/B04
	Decentralisation	A05/B05	A02/B02	A08/B08

Table 1. Centralisation and decentralisation scenarios

In a second group of scenarios the distribution of population and workplaces was varied according to four different paradigms of polycentricity:

- *Local centres*: Development in 228 local centres is increased (A11/B11).
- *TOD* (Transit-Oriented Development): Development at 114 rail stations is increased (A12/B12).
- *Higher centres*: Development in and near five major cities is increased (A13/B13).
- *Monocentric*: All development is concentrated in and near the city of Essen (A14/B14).

The three-dimensional surfaces of population and workplace density on the following two pages visualise the fictitious scenarios examined. It can be seen that in the Ruhr region population is indeed polycentric, whereas workplaces are concentrated in the cities, Essen and Dortmund.

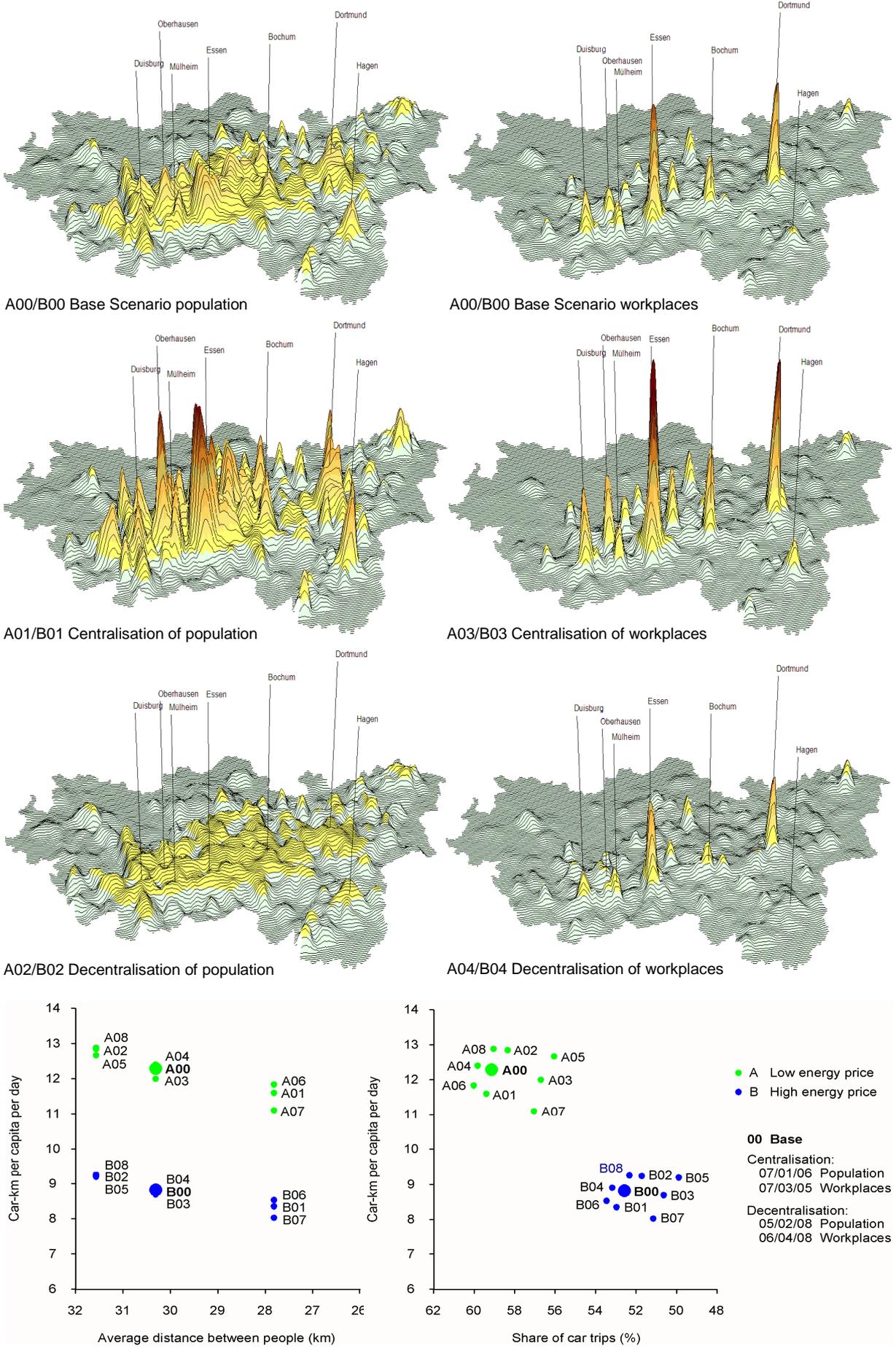


Figure 1. Centralisation/decentralisation scenarios

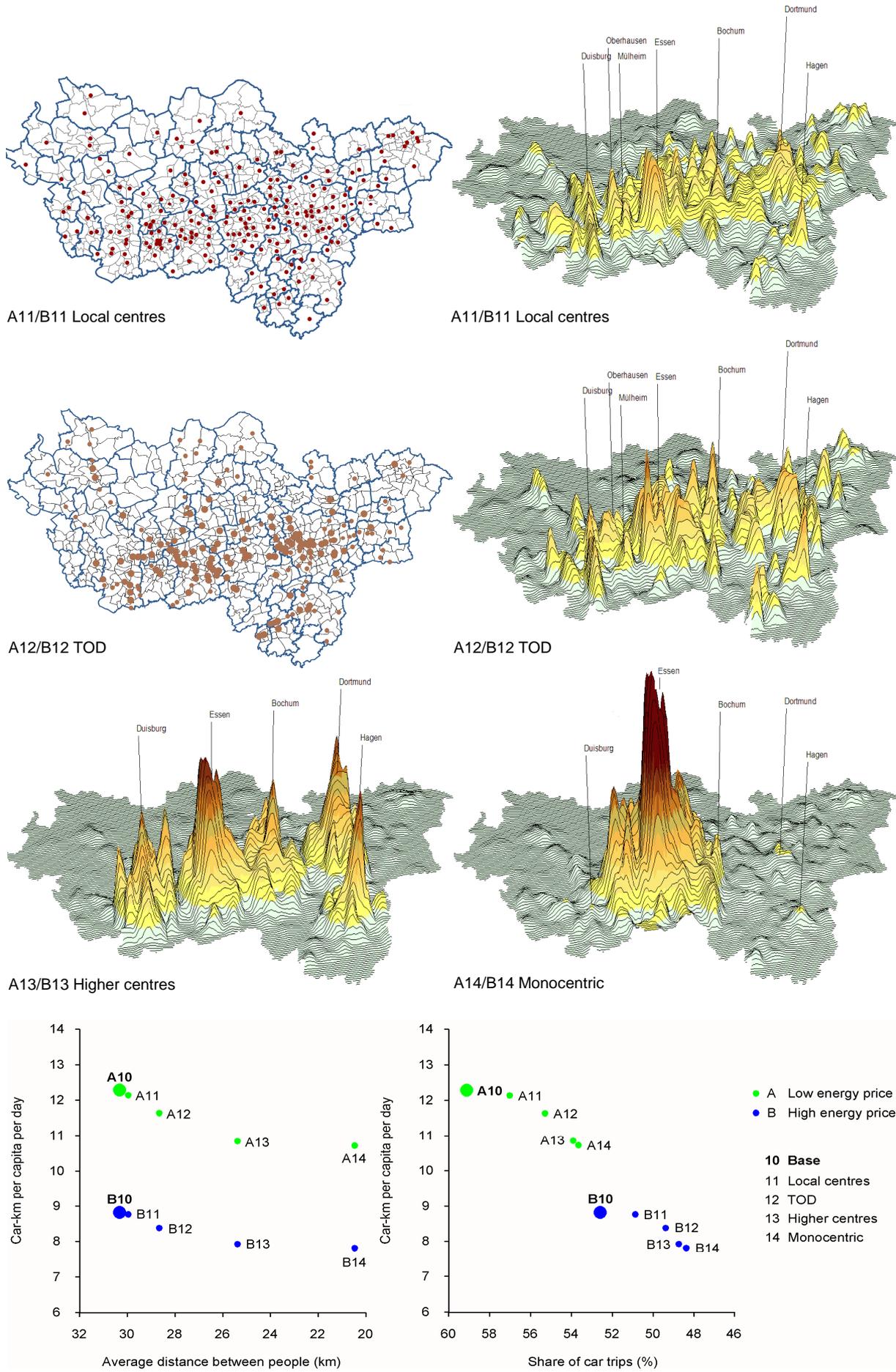


Figure 2. Polycentricity scenarios

## Results

The diagrams at the bottom of the two previous pages show the results of the experiments. In each group of scenarios the target variable, car-km per capita per day as a proxy for energy consumption and CO<sub>2</sub> emissions, is shown in relation to average distance between people as an indicator of polycentricity and share of car trips as an indicator of changed travel behaviour – the dimensions of the diagrams differ because of the different magnitude of the fictitious scenario interventions.

The hypothesis that polycentric cities are more energy-efficient could not be confirmed by the method applied: In both scenario groups the scenario with the highest degree of centralisation (densification) was the most energy-efficient and the scenario with the highest degree of decentralisation (sprawl) was the least energy-efficient. Throughout, the energy price increases assumed in the B scenarios were more effective in reducing energy use than the changes of urban form in the A scenarios.

This implies that policies making car driving more expensive or slower and policies making public transport, cycling and walking more attractive are required to promote sustainable mobility.

Future research in the ongoing project will re-establish the interaction between transport and land use in the integrated model, implement the model extensions addressing electro mobility, building energy consumption and distributed energy generation, integrate the environmental submodels with the land use model to implement environmental feedback and test land use, transport and other policies and policy combinations to implement the energy transition in the Ruhr region.

## References

Huber, F., Spiekermann, K., Wegener, M. (2011): Cities and Climate change: a simulation model for the Ruhr Area 2050. In: Schrenk, M., Popovich, V., Zeile, P. (Hg.): Proceedings of the Conference REAL CORP 2011, Essen. [http://www.corp.at/archive/CORP2011\\_94.pdf](http://www.corp.at/archive/CORP2011_94.pdf).

Huber, F., Schwarze, B., Spiekermann, K., Wegener, M. (2013): Modelling the energy transition in cities. Paper presented at the 13th International Conference on Computers in Urban Planning and Urban Management (CUPUM), Utrecht, 2-5 July 2013.

Newman, P., Kenworthy, J.R. (1989): *Cities and Automobile Dependence: An International Source Book*. Aldershot: Gower.

Wegener, M. (2011): The IRPUD Model. Dortmund: Spiekermann & Wegener Urban and Regional Research. [http://www.spiekermann-wegener.de/mod/pdf/AP\\_1101\\_IRPUD\\_Model.pdf](http://www.spiekermann-wegener.de/mod/pdf/AP_1101_IRPUD_Model.pdf).

Fuerst, F., Wegener, M. (2012): Energy efficiency of buildings: a new challenge for urban models. Paper presented at the Applied Urban Modelling Symposium, University of Cambridge, 24-26 May 2012.