Sustainable Cities and Society 13 (2014) 192–206

Contents lists available at ScienceDirect

Sustainable Cities and Society

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

Modelling socio-economic and energy aspects of urban systems

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ARTICLE INFO

Keywords:
London
Energy poverty
Climate change

ABSTRACT

There is an urgent need to limit greenhouse gas emissions from cities if ambitious mitigation targets are to be met. On the other hand the economic crisis and the ambiguous relationship of inequality with economic growth have raised the issue of energy poverty. The need to connect economic activity with employment, energy poverty, climate change is becoming increasingly recognised. This paper describes the socioeconomic–energy–environmental component of an urban integrated assessment facility developed by the Tyndall Centre for Climate Change Research, which simulates socio-economic change, energy demand, climate impacts and greenhouse gas emissions over the course of the twenty first century at the city scale. The research is focussed upon London, UK, a city that has taken a lead role in the UK and globally with respect to energy poverty and climate protection. The paper demonstrates, through the implementation of several scenarios, quantifiable synergies and conflicts between economic development, employment and energy poverty in order to improve decision making in achieving sustainable and equality outcomes for cities.

1. Introduction

Urbanisation is not merely a modern phenomenon, but a rapid and historic transformation of human social roots on a global scale. However, over the last century it has been considerably increased in the developed countries and is expected to be further increased in developing countries by 2050 (UN, 2012). As urbanisation is closely linked to modernisation and to industrialisation, the rapid technological developments are expected to accelerate the concentration into cities. Urban areas occupy less than 2% of the Earth's land surface (Balk, Pozzi, Yetman, Deichmann, & Nelson, 2005), but house just over 50% of the world's population, a figure that was only 14% in 1900 (Douglas, 1994) and one which is expected to increase to 60% by 2030 (UN, 2012). Urban activities acquire significant amounts of energy and release greenhouse gases (GHGs) that drive global climate change directly (e.g. fossil fuel-based transport) and indirectly (e.g. electricity use and consumption of industrial and agricultural products).

Considering that over the last decade, two challenges – namely economic crisis and climate change – have been prioritised in the political and scientific agenda, the role of cities in tackling those challenges is becoming crucial. The economic crisis and the inequalities among different economic quintiles have raised the issue of energy poverty, namely the lack of access to modern energy services. Modern energy services are crucial to human well-being and to a country's economic development (IEA, 2010) and yet globally over 1.3 billion people are without access to electricity and 2.6 billion people are without clean cooking facilities (IEA, 2010). The lack of access to modern energy services is a serious hindrance to economic and social development, and must be overcome if the UN Millennium Development Goals are to be achieved.

Moreover cities are potential hot spots of vulnerability to climate change impacts by virtue of their high concentration of people and assets. Responding to climate change by mitigating greenhouse gas emissions and adapting to the impacts of climate change is placing new and complex demands upon urban decision makers. The climate drivers that adaptation is responding to will amplify over a period of decades but manifest themselves most vividly in the form of intermittent extreme climate shocks of windstorms, floods, droughts or heat waves. There is increasing understanding of the synergies and conflicts in the objectives of mitigation and adaptation (McEvoy et al., 2006). These interactions are no more vivid than in urban areas, where they play out through land use, infrastructure systems and the built environment. Without sensible planning, climate change can induce energy intensive adaptations such as air conditioning or desalination, driving higher emissions. Urban decision makers need to understand the implications of these interactions and the potential influences of future global changes. The processes of influence and interaction within urban areas are so

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2210-6707/$ – see front matter
http://dx.doi.org/10.1016/j.scs.2013.11.003

complex (Hall et al., 2010), that aspiration for integrated responses to the challenges facing urban areas is widely articulated (Walsh et al., 2011). There is therefore a need for methods and tools that can help to facilitate and inform integrated assessment. Considering that the first step in integrated assessment modelling is the derivation of assumptions about population and economic activity (GDP growth), which will feed then the different more technical models, it is crucial to provide a robust analysis of the socio-economic aspects of urban development. Therefore, a detailed quantitative representation of the socio-economic and energy aspects of urban systems is of high importance, as providing credible input to the different sub-models that consequently face more technical aspects of the urban systems, enables the exploration of feasible solutions of the climate-change and energy poverty problems.

The economics for avoiding dangerous climate change requires analysis from many disciplines. The multi-disciplinary risk analysis carried out by the Stern Review team (Stern, 2006) and the IPCC 4th Assessment Report (IPCC AR4, 2007) has revealed critical weaknesses of the traditional, neoclassical approach, especially as regards the treatment of uncertainty and risks such that equilibrium-based models by themselves are not considered appropriate for providing an adequate understanding of the climate change problem (Beinhocker, 2006; DeCanio, 2003). For these reasons, an approach has been adopted that emphasises the dynamics of the energy–environment–economy system in its historical setting, using a UK model that incorporates many aspects of the "new economics" described in Barker (2008). This paper aims to describe in more detail the socioeconomic–energy–environmental branch of an integrated assessment model (Hall et al., 2010; Walsh et al., 2011) of the Greater London Area (GLA), together with a scenario analysis of different socio-economic futures of the GLA, including London, South-East and East England, over the period 2000–2100. A useful and important contribution of the paper, is that due to high uncertainty of the economic structure in the future, especially when examining 2100, the analysis is made by classifying the 41 economic sectors of the UK economy on 8 aggregate sectors, based on their technological characteristics and on the likely effects of three pervasive technologies (information technology, biotechnology and nanotechnology). This analysis is proving to be of value in stimulating more integrated thinking about cities and informing complex decision making problems. Therefore, a decision maker can take signals from this analysis, on which economic sectors can provide higher economic output, how employment issues can be tackled at macro level and how energy policies can tackle energy poverty issues.

2. Modelling framework

For the needs of this paper, the MDM-E3 model (Barker & Peterson, 1987) of the UK economy has been used and developed. MDM-E3 is a very detailed, integrated energy–environment–economy (E3) model (Hall et al., 2009) of the UK economy. The model has been developed by the University of Cambridge (4CMR) and Cambridge Econometrics (CamEcon), a leading economic consultancy. It is one of a suite of E3 models:MDM-E3: Multisectoral Dynamic Model of the UK Economy, including energy–environment–economy (E3) interactions, E3ME: E3 Model of Europe and E3MG: E3 Model at a Global level. All three follow the same overall principles in their economics, construction and operation and are appropriate in exploring long-term policies of the UK economic–energy–environment system (Dagoumas & Barker, 2010). The model is a demand-driven model and as it is based on Post Keynesian macro-economics, it assumes that equilibrium is not a useful concept for market analysis, unlike the General Equilibrium approach. It is a dynamic simulation model, putting an emphasis on 'history', as it is based on time series and cross-section data, using input–output data from Office of National Statistics (ONS). It uses cointegration techniques to identify long-run trends in 22 sets of equations. It is a structural and hybrid model, where the disaggregation of the variables is further extended in the submodels, focusing for a more detailed representation of the UK economy and especially for the energy system as there exist several relevant submodels for (1) Energy demand and fuel-shares, (2) the electricity sector, including an Energy Technology Model (ETM), (3) CHP, (4) Household energy use and (5) Transport energy use and emissions.

The model contains 41 production sectors, which enables a more accurate representation of the effects of policies than is common in most macroeconomic modelling approaches. The model addresses the issues of energy security and climate stabilisation both in the medium and long terms, with particular emphasis on dynamics, uncertainty and the design and use of economic instruments, such as emission allowance trading schemes. MDM-E3 is a non-equilibrium model with an open structure such that labour, foreign exchange and public financial markets are not necessarily closed. It is disaggregated, with 12 energy carriers, 19 energy users, 28 energy technologies, 14 atmospheric emissions and 41 production sectors, with comparable detail for the rest of the economy. The model represents a novel long-term economic modelling approach in the treatment of technological change, since it is based on cross-section and time-series data analysis using formal econometric techniques, and thus provides a different perspective on stabilisation costs.

The author, within the Cambridge Centre for Climate Change Mitigation Research (4CMR), has extended the MDM-E3 model up to 2100 (Hall et al., 2009, 2010) with an overall objective to provide output tables of economic activity with regional and industrial disaggregation (measured in terms of economic value added at constant prices), of employment with regional and industrial disaggregation (measured in terms of full-time-equivalent – FTE – employees) and of energy demand (in terms of thousands tonnes of oil equivalent (toe) consumed by different fuel type) at national level with industrial disaggregation as input to the land use and population distribution model, the transport emissions accounting model and the energy use emissions accounting model.

2.1. Description of the treatment of aggregate energy demand in MDM-E3

For the energy demand, a 2-level hierarchy is being adopted. A set of aggregate demand equations on annual data covering 19 fuel users/sectors and 12 UK regions (where GLA is one of them) is estimated and is then shared out among main fuel types (coal, heavy fuel oil, natural gas and electricity) assuming a hierarchy in fuel choice by users: electricity first for "premium" use (e.g. lighting, motive power), non-electric energy demand shared out between coal, oil products and gas. The energy demand for the rest of the 12 energy carriers is estimated based on historical relations with the main 4 energy carriers. An autoregressive distributed lag (ARDL) model is developed for modelling energy consumption, considering also that some users' aggregate demands are affected by upward movements in relative prices only (ratchet or asymmetrical price effects). Historical data for the last 40 years are used, while an error correction model (ECM) distinguishes between long-term and adjustment parameters. A long-term behavioural relationship is identified from the data and embedded into a dynamic relationship allowing for short-term responses and gradual adjustment (with estimated lags) to the long-term outcome. The equations and identities are solved iteratively for each year, assuming adaptive expectations, until a consistent solution is obtained.