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Comparison of household consumption and regional production approaches to assess urban energy use and implications for policy

Timothy Baynes [a,*], Manfred Lenzen [b,1], Julia K. Steinberger [c,d,2], Xuemei Bai [e,3]

[a] Ecosystems Science Division, CSIRO, P.O. Box 310, North Ryde, NSW 1670, Australia
[b] ISA, School of Physics A28, The University of Sydney, NSW 2006, Australia
[c] Institute of Social Ecology Alpen-Adria University, Schottenfeldg. 29, Vienna A-1070, Austria
[d] Sustainability Research Institute, School of Earth and Environment, University of Leeds, LS29JT, UK
[e] Fenner School of Environment and Society, Australian National University, Canberra, ACT 0200, Australia

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ABSTRACT

Assessment of urban energy use may proceed by a number of methods. Here we derive an energy account from local statistics, and compare them with an input output (IO) analysis as applied to Melbourne, Australia. These approaches highlight different aspects of urban energy use and comparable outputs are presented together to assess consistency, to identify complementarities and discuss the insight each approach brings to understanding urban energy. The IO method captures the direct and embodied primary energy requirements of local household expenditure (235.8 GJ/capita/year) while the regional assessment more directly accounts for local production activity (258.1 GJ/capita/year). The parity of these results is unexpected for a developed city with a strong tertiary sector. Sectoral detail reveals differences between the primary energy required by Melbourne's economic structure and that ultimately required through the full supply chain relating to household expenditure. This is accompanied by an IO analysis of the geography of Melbourne's 'energy catchment'. It is suggested that the IO consumption and regional production approaches have particular relevance to policies aimed at consumption behaviour and economic (re)structuring, respectively. Their complementarity further suggests that a combined analysis would be valuable in understanding urban energy futures and economic transitions elsewhere.

1. Introduction

With globally growing urban populations and the concentration of economic activities in cities, urban energy supply and demand has become increasingly significant. The intimate part that energy plays in the urban economy means that energy statistics are reasonable indicators of economic activity and concurrently a potential measure of the impact of that activity depending on how energy is sourced and used. Energy use is the single largest source of greenhouse gas emission (GHG) from cities and thus it is a key metric when assessing their global impacts (Bai, 2007; Ramaswami et al., 2008).

Having an accurate urban energy account can provide information on overall sustainability performance and input for policy and planning e.g., regarding energy conservation or GHG emissions (Lin et al., 2010) or the relationship between urban energy demand, urban forms and density (Banister et al., 1997; Shammin et al., 2010). However, energy accounting at city level is not always an easy task and different approaches render different results.

Although we acknowledge the potential environmental impacts and the links to sustainability in general, in this study we are primarily concerned with energy itself, and we compare and contrast two methods for analysing urban energy consumption in application to the metropolitan area of Melbourne, Australia.

It is important to clarify immediately some energy accounting terms used in this paper. 'Final' energy is that which is ultimately consumed (e.g. petrol used in cars), primary energy is the energy source as extracted from nature (e.g. crude oil) and secondary energy is that transformed or exchanged within the energy sector in any process between the primary and final forms (e.g. natural gas used in district heating).

"Direct energy" in the regional production analysis refers to primary, secondary or final energy consumed directly by any sector

* Corresponding author. Tel.: +61 294 908 824.
E-mail addresses: Tim.Baynes@csiro.au (T. Baynes), m.lenzen@physics.usyd.edu.au (M. Lenzen), j.k.steinberger@leeds.ac.uk (J.K. Steinberger), Xuemei.Bai@anu.edu.au (X. Bai).
[1] Tel.: +61 293 515 985.
[2] Tel.: +44 113 343 1631.
[3] Tel.: +61 261 257 825.

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Glossary of terms and acronyms

ABS Australian Bureau of Statistics.
ABARE Australian Bureau of Agricultural and Regional Economics.
BITRE Bureau of Infrastructure, Transport and Regional Economics (Australian).
Consumption approach measures final energy consumption and estimates all associated direct and embodied energy by various expenditure categories based on proxy energy per $ value indicators derived from LCAs or national IO tables.
Direct energy use (regional assessment) primary, secondary or final energy consumed directly by a sector in the study area (including the residential sector).
Direct energy use (IO consumption) primary energy purchased and used directly by households.
Embodied energy defined here as in an IO consumption analysis: refers to energy used in the production and transport of goods and services consumed by households.
Energy catchment the (location of) direct and embodied energy consumed by all industries that supply Melbourne households with goods and services.
Final energy use energy ultimately consumed (e.g. petrol used in cars).
GDP gross domestic product.
GRP gross regional product.
Indirect energy use is defined here as in regional production analysis. It refers to any primary, secondary or final energy imported from outside the boundary of a region.
IO input output analysis.
LCA life cycle analysis.
LPG liquefied petroleum gas.
MRIO multi-region input output analysis.
PKT passenger-kilometres travelled.
Primary energy the energy source as extracted from nature (e.g. crude oil).
Regional energy assessment an account of direct energy production and consumption across all sectors for a defined territory. This may also be referred to as a 'production' approach elsewhere in the paper.
Secondary energy that used in any process between the primary and final forms of energies
TPES total primary energy supply
Upstream energy use primary or secondary energy required to produce the final energy consumed.
VKT vehicle-kilometres travelled
UITP The International Association of Public Transport

of the economy in the metropolitan area. In an Input–Output (IO) consumption analysis, "direct energy" refers only to the primary equivalent of energy purchased and used directly by households (e.g. transport fuels, electricity, fuels for cooking and heating).

"Indirect energy" can also be defined in two ways depending on the context. In a regional analysis, it refers to any primary, secondary or final energy consumed outside the boundary of the metropolitan area in order to produce energy, goods or services consumed by any entity, public or private, inside the metropolitan area. In an IO consumption analysis, indirect energy refers to energy embodied in the production, storage and transport of goods and services consumed by households in the metropolitan area. To allay confusion we will usually refer to the latter as "embodied energy". Elsewhere there may be other definitions for embodied energy.

The regional energy assessment draws on a top-down energy account, which records direct energy use across all production sectors and the residential sector. Such an assessment has much in common with "production approaches" similar to those used to generate national energy accounts. Here we refer to 'regional energy assessment' as synonymous with the production approach. Separately, an IO approach is used which involves a bottom-up derivation of direct and embodied energies using data on household expenditure for the same metropolitan area. This is classed as a "consumption approach" as in Refsgaard et al. (1998).

The main purpose of this study is to assess the consistency across the results of these two approaches and the source and meaning of any differences. Results appear in tabulated totals of residential energy use and also in the per-capita measures that total energy use across all sectors. We also present an analysis of the 'energy catchment' relating to Melbourne's household expenditure. The energy catchment is essentially the geography of where primary energy is used initially in the full chain of supply to final household demand. This is compared with the primary energy needs of the local economy within the metropolitan area. The use of energy in the urban area by households and industry categories illuminates the relationship between energy consumption due to household expenditure and that due to the local economic structure.

There are some data common to both methods but very different techniques are used for arriving at measures of urban energy consumption. The extent to which they agree or disagree is of practical and academic interest in urban energy accounting and reporting. We demonstrate that these approaches reveal different aspects of the energy characteristics of Melbourne with different implications for policy and decision making about urban energy. These two approaches are complementary and consideration of both is recommended to better understand the energy impacts of changes in economic production and consumption.

2. Accounting for urban or regional energy

Energy accounts at state or national levels usually attribute direct energy production or use to sectors of the economy, including "residential" and "transportation" categories (ABARE, 2008a; USEIA, 2010). Within a state or country, regional energy accounting often uses the same categories and definitions and is internally consistent to allow comparisons and benchmarking. These forms of energy accounting predominantly deal with direct energy and usually do not provide separate statistics of primary, secondary and final energy use, (although the International Energy Agency separates these in national energy balances (OECD/IEA, 2010; OECD/IEA and Eurostat, 2004). Detail on those energy measures may have to be derived through some form of additional analysis, for example, using reported losses in conversion processes as in Baynes and Bai (2009).[4] Furthermore, energy data are not always collected at a regional resolution. In these instances, regional energy data have to be modelled or inferred

[4] See Appendix for details.