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Comments on 'A multi-level framework for metabolism in urban energy systems from an ecological perspective' by Pulido Barrera et al. (2018)

We would like to comment on the article by Pulido Barrera et al. (2018) who while reviewing the Urban Metabolism and Allometric literature argue for a 'Multi-level framework for metabolism in urban energy systems from an ecological perspective'. In this letter, while sympathetic towards the overall call for a multi-level conceptualization of urban and regional metabolism by Puildo Barrera et al., we would like to point out that

A.) The authors' disregard of a crucial subset of the literature reviewed which has resulted in raising gaps and discontinuities that have been and are currently under investigation in active research communities, and

B.) A number of cases where we suspect fundamental concepts have been misinterpreted and/or misrepresented by the authors.

Pulido Barrera et al. (2018) begin by offering a review of prominent and seminal works undertaken under the banner of urban metabolism (Wolman, 1965; Kennedy et al., 2011) and the biological allometry literature (West et al., 1997) setting up a dichotomy of ecological and urban metabolism. They do so by highlighting the hierarchical nature of urban energy systems as compared with those of ecological systems. They posit that inefficient and unregulated urban energy consumption, at the highest levels of systems hierarchy, is attributable to a lack of energetic constraints at the lowest hierarchical levels in direct contrast with those observed in biological systems. As such, they argue for implementation of regulatory resource mechanisms at the lowest hierarchies of urban energy systems in order to enable energy use efficiency as cities grow.

A)

To address the limited scope of the authors' review, we first invite attention to a number of the statements made with regards to the current state of urban metabolism and systems consideration of urban metabolic flows by the authors:

> '…the applicability of urban metabolism is limited to urban and industrial ecology with the main purpose of describing flows of materials and energy as an accounting method with no practical implications in the way resources should be used or distributed across the city.'
>
> '…there is no evidence that cities organise themselves to cope with inefficiencies in energy transfer as ecological systems do so by organising into trophic chains.'

These, however, are gaps so long as one's review of the field is limited to the papers cited by Pulido Barrera et al. A cursory bibliometric analysis (White and Griffith, 1981; Persson, 2010) of the literature pertaining to 'urban metabolism', Fig. 1, could have more easily demonstrated the disciplinary boundaries of the literature. Similar approached have been used previously (Meerow and Newell, 2015; Newell and Cousins, 2015). Pulido Barrera et al., in their review, rightfully identify the contributions of three communities. These are

1 those works such as Batty (2012, 2009), Bettencourt et al. (2007), West et al. (1999, 1997), etc., among many in a community that we have labeled 'complexity, allometry, and others',
2 works similar to Wolman (1965), Kennedy et al. (2014, 2011), and Broto et al. (2012) under 'urban metabolism and material flow analysis', and finally
3 works following Odum's concept of 'emergy' (1996) so labeled as 'emergy analysis'.

Missing from their review is an entire community of works dedicated to the application of 'Ecological Network Analysis' to quantify and characterize urban metabolic flows, both material and energetic. The use of the network analysis enables an extended exploration of the direct and indirect effects of different subsystems and their synergetic relations beyond the simple accounting exercises of the MFA studies (Fan et al., 2017; Fath and Borrett, 2006; Li et al., 2012; Ulanowicz, 2004; Zhang et al., 2014). Furthermore, this family of approaches can establish trophic hierarchies based on the flow contributions of each node to the rest of the network or vice versa. As such, they provide a basis for drawing comparisons between sector hierarchies within urban metabolic structures and those of more balanced and self-sustaining 'natural' ecosystems (Li et al., 2012; Liu et al., 2013; Yang et al., 2014) gauging self-sustenance in urban systems. More recently, similar network based analyses have been applied in spatially explicit contexts studying the transformation of land-use types through time. These examine changes in the trophic consumption, production, and accumulation in and over different land-use patches, e.g. urbanized land, forests, grasslands, etc., in lieu of the traditional flows of the conceptualized sectors, e.g. primary and secondary energy producers, consumers, etc. They also investigate the overall emission savings or losses associated with change from one land-use to others (Zhang et al., 2016). Although a majority of these have been focused on sectoral flows within the boundaries of the same urban area, more recent studies (Zhang et al., 2015; Zheng et al., 2018) have included the application of the method in a 'multi-level' manner concurrently analyzing flows within cities and those between them.

As a result of this community having been left out, Pulido Barrera et al. appear to perceive the gap as one of missing framework and methodology while in reality the primary obstacle is that of data availability (Clift et al., 2015; Horta and Keirstead, 2017; Krausmann et al., 2017) and normalization of quantification of flows of various resources in unified units. Finally, in particular to the two statements we have quoted previously, we leave the preceding passage as a counterpoint to the first. As for the second, Bristow and Kennedy (2013) investigate the ability of different system topologies in 'maximizing the

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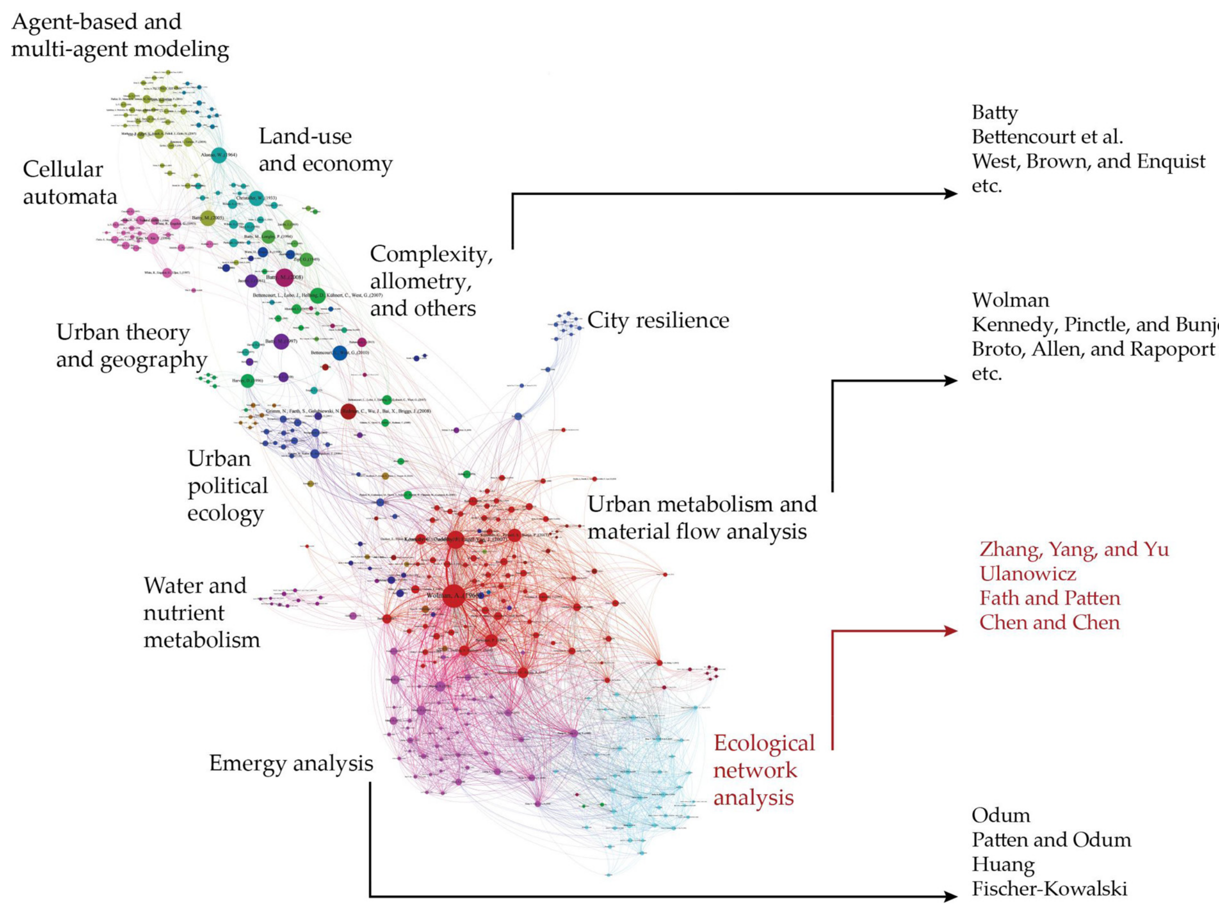

Fig. 1. Co-citation map of scholarly works pertaining to 'industrial ecology', 'urban ecology', 'urban metabolism', and 'urban energy'. Clustering denotes disciplinary communities with prominent authors indicated. Highlighted in red are the works absent from Pulido Barrera et al. (2018) – bibliometric performed autumn 2015.

use of energy in cities' noting in particular that Toronto's energy system topology balances the trade-offs between overall system efficiency and the variance of individual component performance.

B)

Regarding our contention that Pulido Barrera et al. appear to have misinterpreted and/or inadvertently misrepresented a number of concepts, we tally the following discrepancies.

Firstly, the 'spatial scales' the authors argue for and demonstrate in illustrations are not strictly spatial as they are communicated in terms of aggregate of micro units which are not in reference to geographic and/or spatial boundaries. Having drawn from a biological context, notions such as organism, specie, community, or an entire ecosystem while usually, but not always, limited to certain physical territorial boundaries do not themselves have spatial definitions the way cities, network of cities, and countries do. The authors also state that:

> 'While a city is conditioned by energy resources, it can still expand because there is the possibility of importing energy from outside the system. This pattern will occur as long as there is available imported energy. This is different to what occurs in natural ecosystems where the use of energy is regulated since there is limited energy availability'.

Although energy and/or materials can be and are routinely imported across urban boundaries, the vast majority of these resources are still finite at country and planetary boundaries. The authors organic parallel is hence drawn at incomparable boundaries causing what they seem to take as structural differences. Additionally, the exclusion by the authors of flows besides energy gives the illusion of flows with no constraints when importing energy across system boundary. In reality, these imports are only possible as part of a trade involving other physical or monetary resources which are also finite and limited.

Secondly, Pulido Barrera et al. seem to conflate different power-law distributions governing populations of species locally (in their local environment, these are the exponential prey-predator models) and those describing patterns across the properties of different species generalizing characteristics using them interchangeably. Metabolic power-law scaling is based on all resources consumed by an organism dictated by the geometry and volume of their body, and as such their 'infrastructural' network and hierarchy, across different species (as measured by the average of each species). Meanwhile, individual human development indicators do not and are not expected to scale other than linearly with city size as the average human would remain the same and unchanged (Schläpfer et al., 2014).

More importantly, the authors argue for an overall sub-linear scaling of urban energy consumption without a consideration on whether or not existence of such scaling would be theoretically justifiable given the type of consumption and its relation to the physical characteristics of the city as expected from such metabolic scaling. For example, the energy consumed for heating or transport in cities can be related to the geometry of its transport network and to the massing of its buildings justifying an expectation for economies of scale (Arbabi and Mayfield, 2016). This is not so much the case with electricity consumption of gadgets and devices, however. Finally, the authors state that

> '…variables at the micro level relate to variables at the aggregated level evidencing emergent patterns characterized by linear relationships as well…'

This appears to be categorically incorrect as a constant return to scales by definition signifies a lack of emergent behavior whereby a larger entity is exactly equal to the sum of its constituting members and nothing more.

We would like to reiterate that we are sympathetic to the premise proposed by the authors regarding a need for a multi-level framework and assessment of the urban systems and their components. However, the arguments presented by Pulido Barrera et al. in support of their conclusions, as previously enumerated, appear incorrect and/or inconsistent.

Author contributions

H.A. undertook the bibliometric review; H.A., L.M.T., and M.M. contributed to the discussion and the manuscript; H.A. assembled the manuscript. All usual disclaimers apply.

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