THE PULSE OF THE CITY: EXPLORING URBAN METABOLISM IN AMSTERDAM

05-11-2014

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Considering ongoing, rapid urbanisation and the vast resource consumption of metropolitan areas around the world, it is important to integrate urban resource management with the design of our future cities. But how can resource management become an integral part of planning and designing urban landscapes?

Amsterdam Institute for Advanced Metropolitan Solutions (AMS)
The City of Amsterdam recognized the need to address the challenges cities are facing and so launched a call for the creation of a new research institute on metropolitan solutions in April 2013. The proposal by the consortium consisting of Massachusetts Institute of Technology (MIT), TU Delft, Wageningen UR and several industry and knowledge partners was selected and in June 2014 the official opening of the so-called Amsterdam Institute for Advanced Metropolitan Solutions (AMS) took place. The institute has three pillars: research, education and data platform. Research focusses on how the provision and management of resources and services can contribute to urban sustainability while improving the quality of life. Key themes are water, energy, waste, food, data, and mobility as well as the integration of these themes. The universities have appointed Principle Investigators for each theme and the co-author of this article is responsible for energy. From an interdisciplinary perspective, AMS aims to develop a thorough understanding of the city (i.e. sense the city), to design metropolitan solutions and to integrate these in the city.

Understanding urban systems by means of Urban Metabolism
Urban Metabolism is a concept that is increasingly used to gain understanding of cities [4]. Using the metaphor of the city as ecosystem or organism, urban metabolism has proven valuable for a range of disciplines -from economics to political science– to study

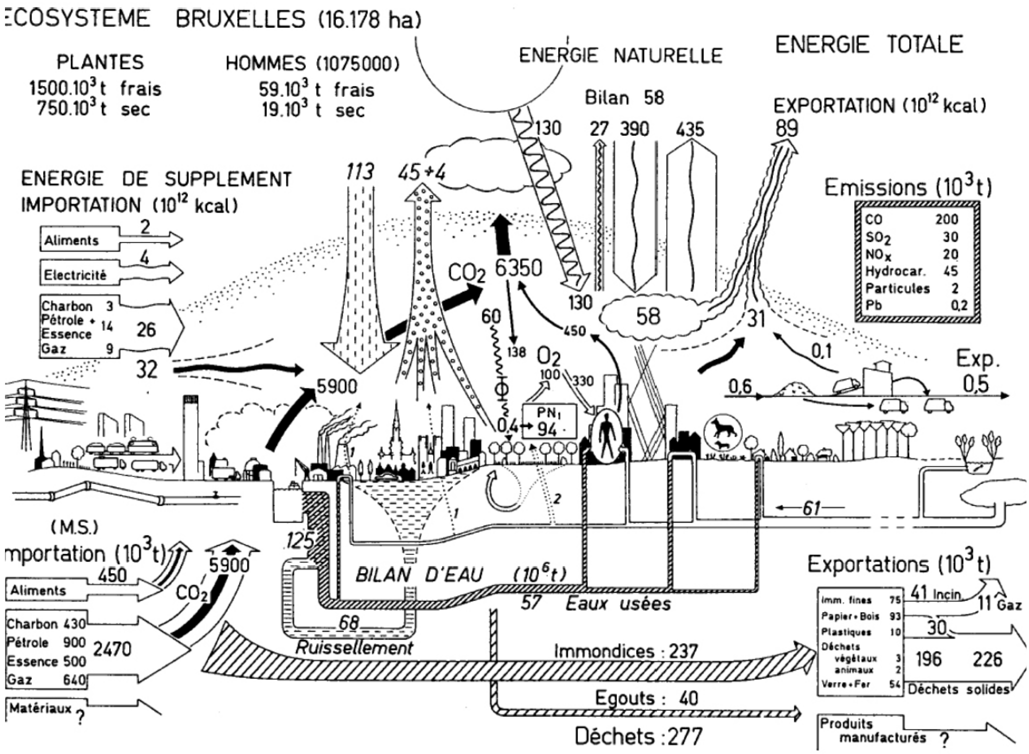


Figure 1: Study of the urban metabolism of Brussels by Duvigneaud and Denaeyer-De Smet, 1977 [9].

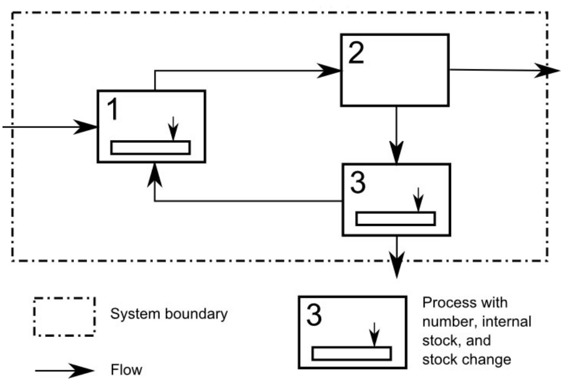
the resource flows in cities [1]. The majority of urban metabolism research has been performed by industrial ecologists to study the conversion of raw materials, energy, and water into built structures, human biomass, and waste [2]. In this context, urban metabolism is defined as "the sum total of the technical and socio-economic processes that occur in cities, resulting in growth, production of energy, and elimination of waste" [3]. Related urban metabolism studies are primarily focussed on quantifying urban resource flows -like water, energy, material– or fluxes of particular substances within these flows –like phosphorous, nitrogen, metals [4]. The results of one of the earliest studies on urban metabolism are shown in figure 1.

Urban metabolism studies generally used to be limited to quantifying the total inputs and outputs of an urban system [3]. Yet, currently the majority of studies goes beyond this "city as black box" approach and also includes resource flows within cities, from source to sink. The most prominent method used for this is Material Flow Analysis (MFA). Such analyses can provide qualitative and quantitative insight in where resources originate from, how they are converted and when they are disposed. MFAs allow to systematically assess the inputs and outputs of selected resources of a predetermined system as well as the flows and stocks within the boundaries of that system [1].

One of the ways to visualize the outcomes of a MFA is a flow chart that specifies the resource flows and how they are converted by different processes (figure 2). Another way of visualising MFA outcomes is a Sankey diagram. Sankey diagrams provide information on the sizes of (sub)flows within a system as the widths of the arrows correspond to the quantities of the various flows (figure 3).

Urban metabolism has inspired new ways of thinking about urban sustainability. It fuelled, for example, the idea that urban areas should become more self-sufficient and resource demands of cities should not exceed the carrying capacity of their hinterlands. This advocates a shift from the current linear metabolism of cities -using inputs only once- to a circular metabolism that incorporates recycling of resources [1]. Moreover, urban metabolism studies have shown to be useful to define sustainability indicators, for example on energy efficiency [4], and to identify processes that are critical for the (un) sustainability of an urban area [3]. It is also increasingly argued that urban metabolism can contribute to sustainable urban planning and design [4]. Scholarly practitioners and design practice increasingly embrace urban metabolism too. This is illustrated, for example, by the substantial attention the 2014 International Architecture Biennale Rotterdam "Urban by Nature" paid to urban metabolism.

Figure 2: Example of a simple MFA flow chart [10].



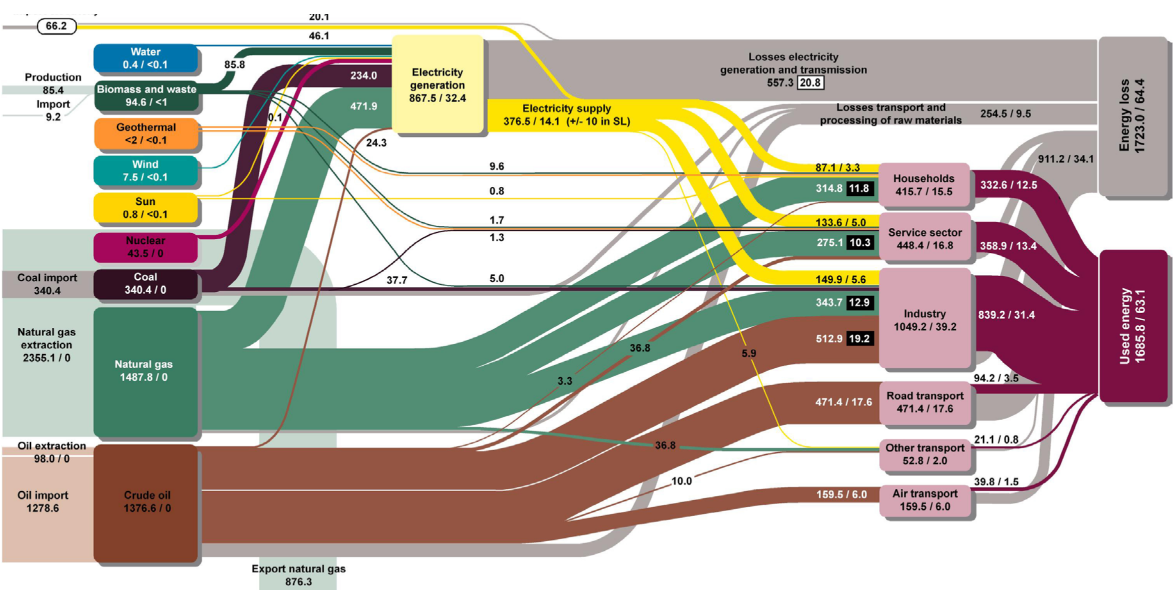
Urban Metabolism for planning and designing sustainable cities

The envisaged value of urban metabolism for planning and design disciplines has different aspects. The metaphor of the city as ecosystem and urban metabolism in particular can be useful for landscape architects, urban planners and designers to think about a city as system with associated resource flows. When urban planners and designers incorporate metabolic thinking while designing urban form and processes, resource management is integrated in urban designs. Here another useful application of urban metabolism surfaces: when aiming to increase the sustainability of a particular city by reducing resource inputs and/or outputs within a (part of the) system, an understanding of the different flows within that city, districts and neighbourhoods is required. For this, an MFA can be a valuable means. Firstly, an understanding of the status quo of resource flows of a city can provide insight where the design challenges lay to adjust a city's metabolism. So, when starting a planning or design process on the scale level of the city, a MFA can provide insight in what are key locations to zoom in and propose interventions for. Think for example of locations where large amounts of resources are consumed and/or large quantities of waste are generated. Secondly, urban metabolism analysis can be useful when the location for physical interventions is already known (i.e. working on district and neighbourhood scale). Then the MFA can reveal how resource flows on that particular location connect the site to its surroundings. This is essential knowledge to account for the cross-scale implications of design interventions.

In spite of the great potentials, to this moment urban metabolism is hardly used in urban planning and design. One possible reason for this lack of application is that urban metabolism fails to acknowledge the importance of socio-economic indicators (e.g. lifestyle) for achieving sustainability [4]. Yet, designing is a means to identify integrated solutions to ecological, spatial and social challenges. The concept of urban metabolism is (with few exceptions) used in a technological paradigm that fails to acknowledge that the interplay between society and biophysical processes is part of and influences the metabolism of cities [8]. Another reason could be that up till now the link between resource flows and spatial characteristics is not well established. This is clearly exemplified by the majority of MFA representations, which lack a spatial dimension. MFAs do not provide information on the spatial organisation of the flows and processes they describe [5]. Moreover, there seems to be a mismatch between the scale level at which urban metabolism studies are performed (city or regional scale) and the scale level of urban planning and design practice (district, neighbourhood, building block) [7]. Finally, the concept of time is not properly dealt with in current metabolic studies [6]. To fully understand the metabolism of a city, it is essential to acknowledge the variability of resource provision and consumption through time. Understanding these temporal dynamics is essential when planning and designing sustainable cities.

Studying Urban Metabolism in Amsterdam
The chair group of Landscape Architecture and the Environmental Technology sub-department (ETE) have, over the past six months, prepared a comprehensive research proposal to study the urban metabolism in Amsterdam (see figure 4). In October 2014, the so-called Urban Pulse project was awarded as one of the first three AMS research projects. Urban Pulse aims to address the spatial and temporal challenges of urban metabolism studies stated heretofore. The objective of this initial project is to understand and map resource

Figure 3: Sankey diagram of the energy flows in the Netherlands and South Limburg [6].



Notes: All numbers in Peta Joule (PJ). First numbers account for the entire Netherlands (e.g. Sun 0.8/<0.1), second number for the region of South Limburg.

20.8 Energy loss due to electricity production and transmission for South Limburg amounts to 20.8 PJ. Residual heat of power plants remains to be utilized.

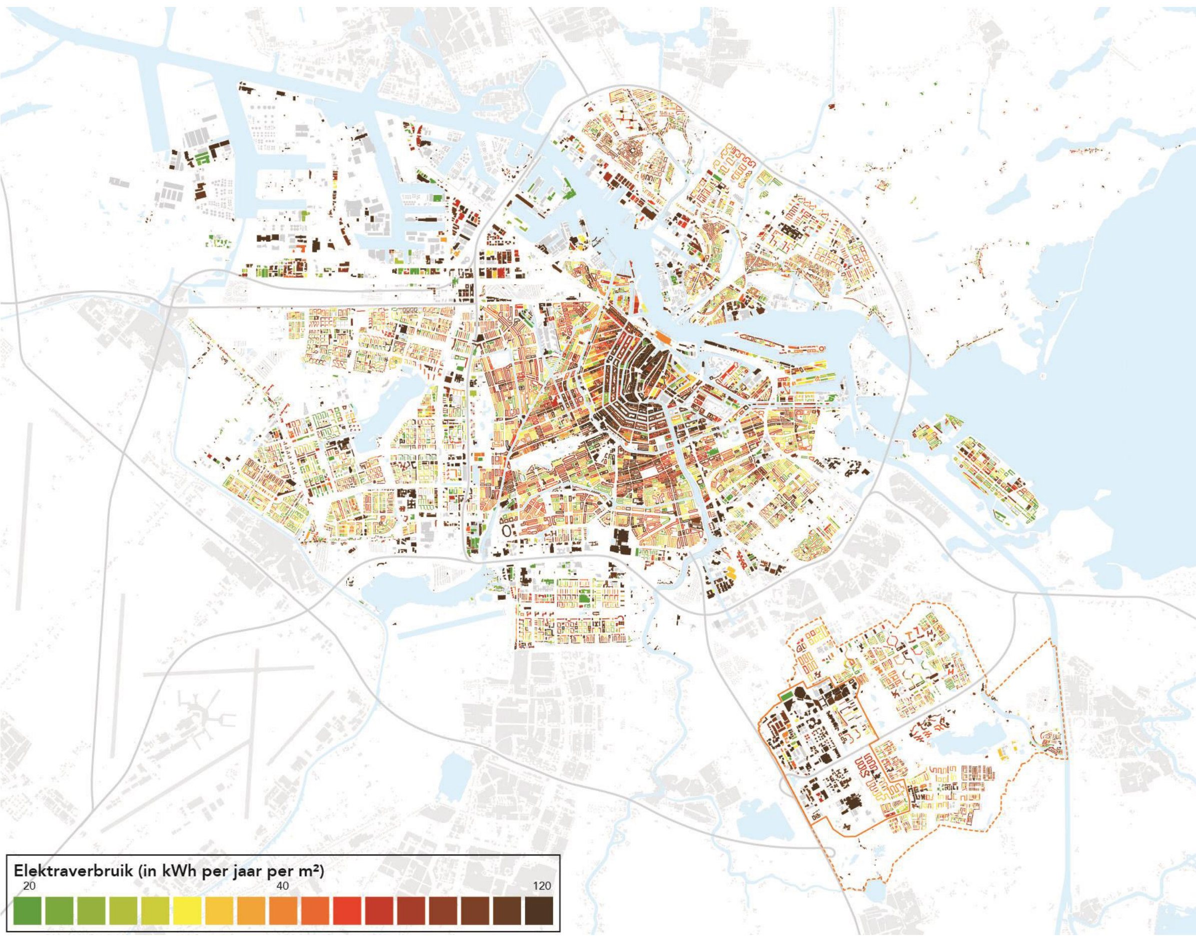
54.2 South Limburg's share of natural gas and crude oil consumption, primarely for heat production, amounts to 54.2 PJ or approximately 50% of total energy consumption.

flows in the city of Amsterdam. The flows of water, energy, food and selected materials will be identified in terms of "quantity" (volume/weight) and quality. Their temporal dynamics and location in space will be analysed too.

The project aims to provide planners, designers and decision makers with a precise understanding of the dynamic flow patterns in Amsterdam. In addition the researchers will, by closely collaborating with the SENSEable city lab at MIT, explore how to communicate temporal and spatial variations of urban resource flows by new means of representation. Research will be carried out in collaboration with the city of Amsterdam and a number of knowledge and industry partners.

Currently two LAR-students conduct research on the energy metabolism of Amsterdam by means of a minor thesis. Other students that are interested in this topic for their thesis can contact the authors.

Figure 4: Electricity consumption in Amsterdam as part of the energy metabolism [11].



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