Low impact urban design by closing the urban water cycle

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Abstract

Current fast urbanization and increasing quality of life result in increments on resources' demand. Increasing resources demand implies as well increments on waste production. However, limited availability of resources such us: oil, fresh water, phosphorus, metals (Boyle et al., 2010, Gordon et al., 2006; Rockström et al., 2009) and limited earth's productive and carrying capacity (Rees, 1999) are potential restrictions to urban growth and urban sustainability. These pressures, however, are drivers towards more efficient resource use. In a world of cities, urban systems play a key role to find solutions for these global pollution and depletion problems (Xu et al., 2010). To alleviate these pressures, it is needed to minimize demand and to shift from linear to circular metabolism, in which recycling and reusing are key activities (Girardet, 2003).

Knowing that the spatial organization of a city and its infrastructure influence resources management (Alberti et al., 2003), urban planners face the enormous challenge of meeting citizens' needs while protecting and assuring natural resources for future generations. Urban planning for sustainable development needs to go beyond traditional planning and strategy making (Bagheri and Hjorth, 2007). To tackle this challenge, it is imperative to understand how urban metabolic systems function (Decker *et al.*, 2000; Girardet, 2003). Planners faced the challenge to design the urban metabolism of sustainable cities to minimize material throughput (Kennedy et al., 2010), by integrating efficient buildings and urban infrastructure with spatial planning (Rees, 1999). However, great efforts are required to integrate urban metabolism concepts in the practice of urban planning and design (Kennedy et al., 2010).

To achieve overall sustainability, demand and supply should fulfill sustainable requirements. Sustainable consumption cannot exist without sustainable supply and sustainable supply cannot exist without sustainable demand. Furthermore, disposal should be also sustainable. This has become evident for product design, however, not for other context for instance at urban scale. In the current linear system, the potential of cities of producing their own

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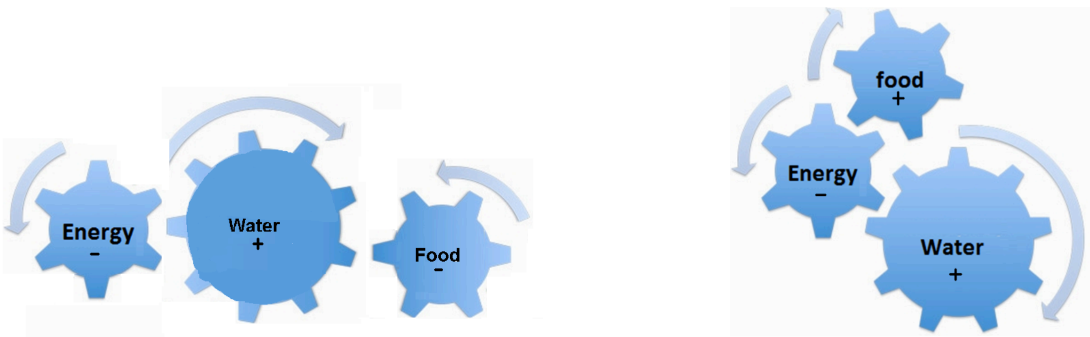
resources has been neglected. However there are multiple potentials in cities to minimize demand, recover resources and harvest primary and secondary resources (Agudelo et al., forthcoming). To solve current urban water/energy/nutrient problems, we have to solve the "metabolic" problems of cities. A paradigm shift from a system which sees wastes as hazard to a system where the same waste is seen as a resource is needed.

Large amounts of resources go in and out of cities continuously having a massive effect at global scale. The most critical urban flow is water, followed by energy and food. Water is considered most critical because it is vital for survival, and in terms of sheer mass it is the largest component of the urban metabolism (Kennedy, 2007). These urban flows are closely interrelated and have competing claims for space within the urban areas. The relationships between wastewater and other flows are summarized in table 1. Figure 1 shows how single flow optimization may cause unplanned tradeoffs, and how by identifying smart linkages positive feedbacks and tradeoffs can be planned. Therefore, to guarantee sustainable urban areas and reliable supply of water, energy, nutrients it is necessary to evaluate them simultaneously.

Table 1. Different flows that can be harvested from urban water flows. (Agudelo et al., 2009)

Urban flows	Water	Heat	Nutrients	Organic matter
Rain water	•			
Urban Wastewater (mixed)	•	•	•	•
Urban Wastewater (separated)				
Grey water	•	•		
Black water			•	•
Urine			•	



a. Single flow optimization b. Smart linkages

Fig. 1 Schematic presentation of infrastructural linkages and their positive or negative feedback. (a. unplanned tradeoffs, b. planned positive loops and tradeoffs).

There is a need to develop methodologies to assess local potentials and provide guidelines for resource management, considering available technology, local context characteristics and tradeoffs among flows. During the last decades, several metabolism studies have contributed to understand and quantify the urban flows; an extensive overview is given by Kennedy et al., (2010). Furthermore, application of urban metabolic studies in the water sector has been highlighted by Pamminger and Kenway (2008) and Novotny and Novotny (2009). An advantage of urban metabolism studies is that they can be performed at different scales. Regarding resources management, different scales will show different limitations and potentials. By doing that, the optimal scale at which each of the flows should be managed can be identified.

Local resources availability is determined by the local context characteristics. This local resource availability is given by the local stock, but also by the natural and man-made flows that can be harvested and reused within the urban environment. The local context characteristics for each neighborhood/city are different due to the complexity of consumption patterns, linkages among different flows and the global nature of resource flow. Therefore, each neighborhood/city must choose a development path that is applicable to and appropriate for its local situation: a ‘one-size-fits-all’ concept will not work. Therefore, a multi-criteria assessment is recommended to evaluate the availability of the different resources. Figure 2 shows how the resource use required per technology should be confronted against local resources availability. Therefore technologies that offer win-win situations such as: source separation of black water to be digested locally to produce gas, will have a positive feedback in the water and energy loop, but a negative in space and materials. Urban potentials are shown in figure 3. Natural local potentials and waste streams of one activity are harvested to feed other activities. Because of these win-win interactions among flows the overall metabolism of the urban area improves.

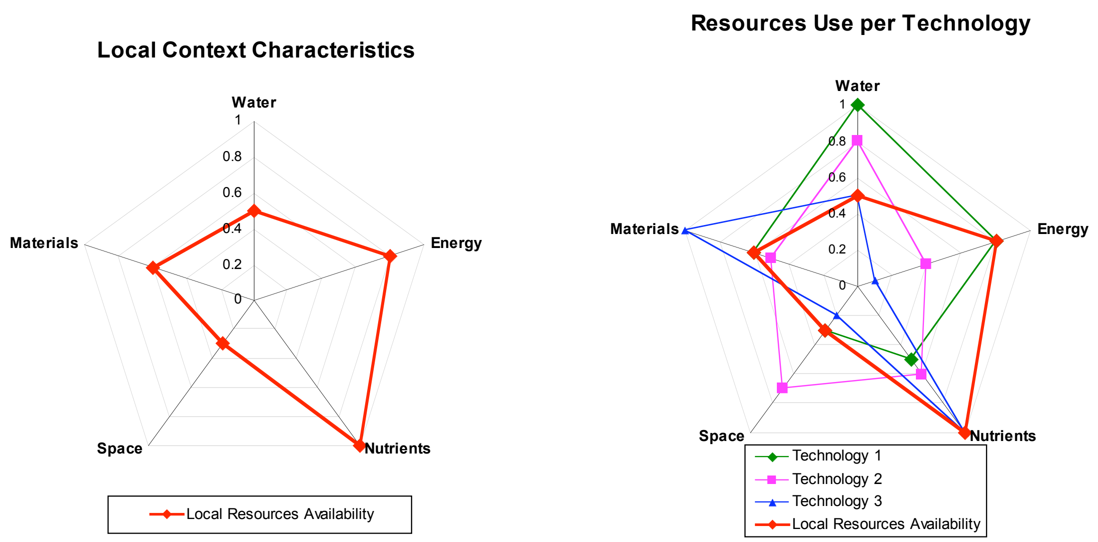


Figure 2 Schematic representation of evaluation of technologies based on local context characteristics

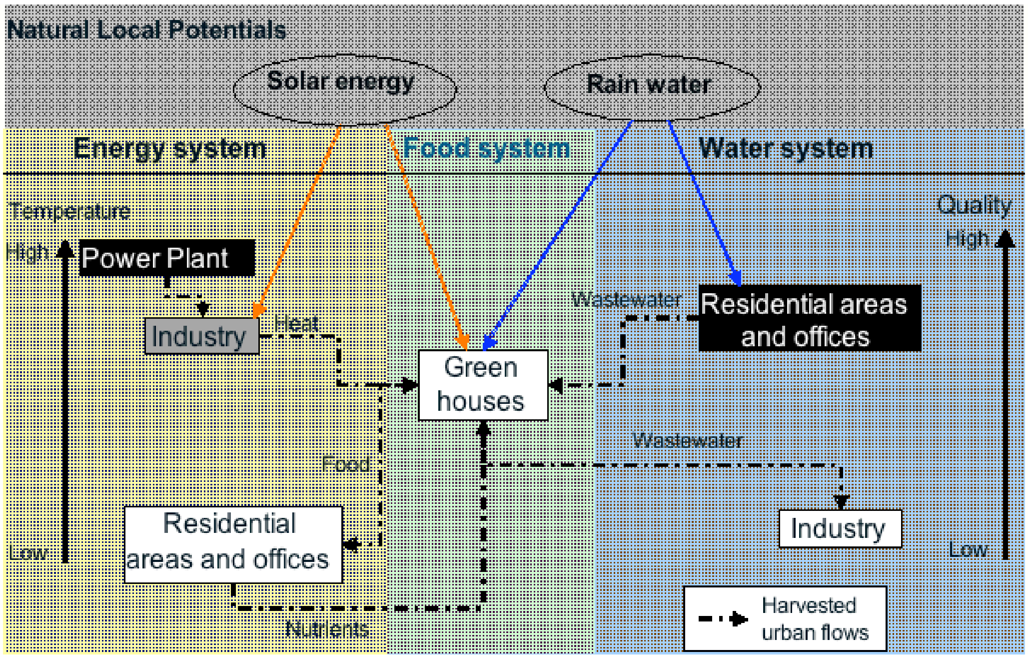


Figure 3 Schematic representation of integration among flows and urban functions

Low impact urban design based on sustainable urban metabolism can only be achieved by integration: integration of disciplines between planning and resources management, integration of flows: water, energy, food, materials and space; integration of scales: on-site, block, neighborhood, city; and integration of functions: residential, industry, green houses, etc.

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