A contextual and spatial approach towards resource cycles

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Abstract

Multiple system-based concepts exist to analyse and manage urban throughput of resource flows, examples are Urban Metabolism, Industrial Ecology and Energy Potential Mapping. Common threads in these propositions are fundamental principles valid in nature, notably homeostasis and thermodynamics. Those and likeminded concepts are valuable links in the shift from a reductionist towards a holistic notion of the built environment. However, practical implementations of system-based interventions appear to lag behind. This 'system failure' can be allocated to the inherent complex nature of associated challenges and threats. This paper focuses on attributes of sustainable urban development that are as yet insufficiently understood, revolving around contextuality and spatiality. A case study in the metropolitan region of Amsterdam Airport Schiphol is introduced to explore regional synergies, in particular with regard to two hotspot zones. It is urged that for sustainable resource management, regional systems-integration is a critical factor. Unravelling supply & demand patterns in the designated area unveiled multiple potentials for circular resource flows and mutual benefits for networked actors.

Key words: sustainable development, systems integration, resource efficiency, circularity, urban mining, energy potential mapping

Introduction

Within the current European governmental and scientific agendas, the aim for sustainable urban development is increasingly approached in an integrated manner [1]. This means that critical interrelated components comprising urban systems should all be taken into account when diagnosing the performance of that system on the one hand, and developing improved pathways on the other. Furthermore, special attention is addressed at essential resources that drive urban processes, and – more specifically – the way to shift from a predominantly linear approach to a circular one in order to increase resource efficiency.

For the analysis and management regarding urban throughput of resource flows such as energy, materials, water and food, multiple system-based concepts exist. Examples are Urban Metabolism, Industrial Ecology and Energy Potential Mapping. Common threads in these and likeminded propositions are fundamental principles valid in nature, notably homeostasis and thermodynamic laws. These principles are aimed at the creation of synergies between components in a system and – ultimately – sustainable societies. Abovementioned concepts are valuable links in the shift from a reductionist towards a holistic notion of the built environment. However, it can be observed that practical implementation of interventions that derive from such system-based concepts lags behind. This system failure can be allocated to the inherent complex nature of associated challenges and threats, with regard to e.g. technical limitations, sectoral concerns, regulatory framework and knowledge gaps [e.g. 2, 3]. Vernay [2013] argues that the largely technocratic nature of developed ideas within the existing concepts leads to an implementation gap, because there is "a poor understanding of *how* these ideas can actually come into being".

The rationale behind this paper relates to a better alignment of technical interventions on the one hand and regional characteristics on the other in achieving integrated sustainable urban development. The paper stems from studies of resource flows and their infrastructures in urban areas, accentuating two attributes of sustainability that are as yet insufficiently understood: context *and* space*. The former refers to the notion that understanding – and intervening in – aspects of a system (e.g. energy use in buildings, neighbourhoods or regions), aimed at potential synergies between functions, can only occur in conjunction with the regional characteristics, such as geography, morphology, production/consumption patterns, and planning strategies. The latter refers to the notion that spatial arrangements associated with shifts in resource management have a huge impact on the lay-out and quality of our living environments.*

This paper is structured around the following main research question:

- *Taking into account contextual and spatial characteristics, which potentials can be identified that facilitate the shift to sustainable urban systems based on circular resource flows and regional integration?*

In the following section, first a methodology is presented in which empirical and theoretical data of selected resource flows are inventoried, interpreted and synthesized into flow maps and potential maps. This methodology is part of the Better Airport Regions project [4], with the metropolitan region of Amsterdam Airport Schiphol as its case study area. Next, the results of the flow analyses in the case study area are briefly addressed, and the results of the potential maps in more detail. Finally, the findings are discussed against the backdrop of sustainable transitions in urban (airport) regions from the perspective of integrated systems.

Better Airport Regions (BAR), case study Amsterdam Airport Schiphol

The methodology introduced in this paper is part of an integrated endeavour, addressing sustainable development of metropolitan airport regions. BAR comprises multiple interwoven modules that focus on technical, spatial characteristics of resource flows in the airport region on the one hand and the related organisational and institutional context on the other [5].

Figure 1 visualises the methodical steps for analysing and mapping resource flows relevant to the performed case study of Amsterdam Airport Schiphol (from here on: Schiphol).[1] We

[1] As performed in Module 1 (Essential Flows) of the BAR project

applied an iterative method, in line with the dynamics around acquiring knowledge necessary for advancing in the research. After a literature study, the context of the study was laid out, area boundaries were set, and resource flows and indicators determined. The inventory stage comprised: i) system analysis, ii) initial flow charts, and iii) data collection. The quality of the findings was assessed and monitored to see whether they were in line with the goal and scope or adjustments were required. Next, the generated data were synthesized into flow maps. Through interviews and workshops with researchers as well as private and public stakeholders the flow maps were validated and interpreted. Subsequently, several geographic and thematic areas emerged with specific potential. These so called *hotspot zones* dictated a tailor-made analysis, of which the results are precursors for generic lessons, potentially applicable in other regions as well. Moreover, the generated data and – flow and potential – maps contributed to an indication of ways in which the various flows are or could be interconnected.

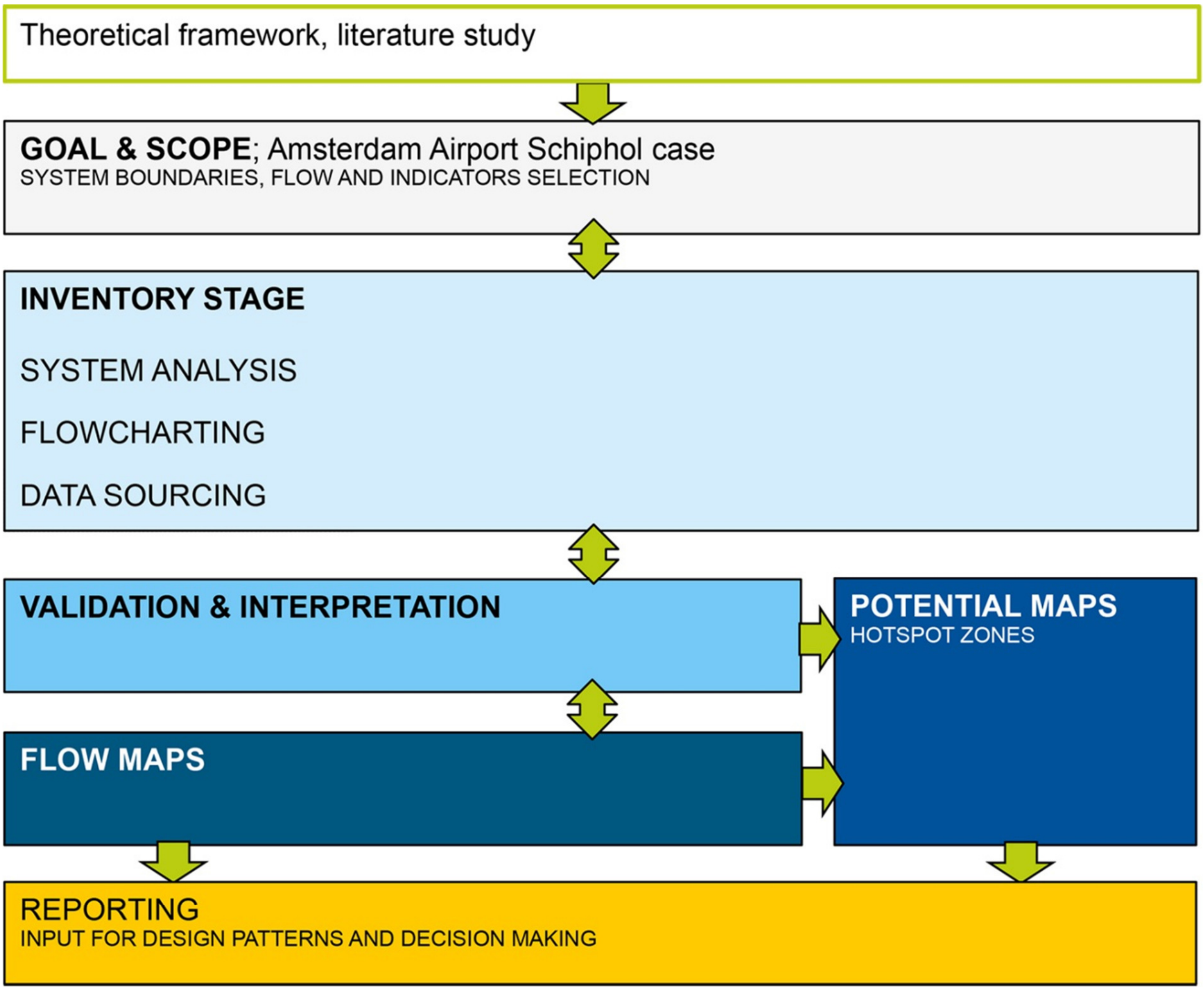


Figure 1: Better Airport Regions project research methodology (module 1: Essential flows)

Schiphol with its surrounding municipalities formed the geographical system boundaries central to this study, see Figure 2. Schiphol was defined as the 1st level system, subject to a detailed flow analysis. The 2nd level area follows the borders of the municipalities that directly surround Schiphol. Flows in the latter area were explored in broad outline.

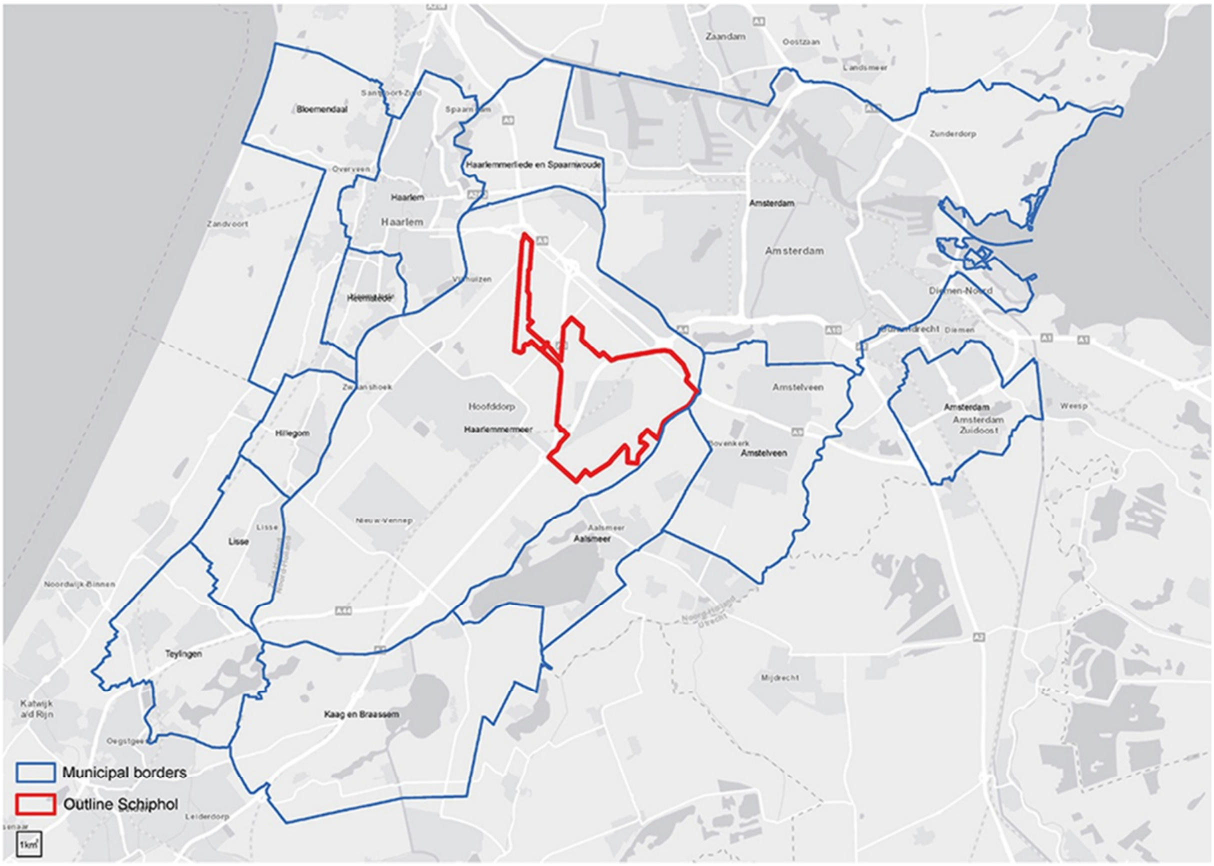


Figure 2: System boundaries of the Schiphol airport region as applied in the BAR project

Selected flows & throughput of Amsterdam Airport Schiphol

The people ‘inhabiting’ Schiphol can be divided in three categories: passengers, workforce and visitors. Approximately 50 million passengers passed through Schiphol in 2011 [6]. The workforce at Schiphol contains around 60,000 employees, working for 500 companies. The category of visitors adds up to 13 million visitors in total. Furthermore, about 1.5 million ton of freight passed through the airport in 2011 [7]. All these people and processes make use of resources. The resource flow selection stage led to a focus on: energy (electricity, gas and transport fuels), materials (plastic packaging materials), food (divided in six food groups: carbohydrates, vegetables, fruits & nuts, meat products, fish products, and dairy products), water (drinking water and wastewater) and waste. Table 1 is an overview of the volumes through Schiphol concerning these flows.

Table 1: Schiphol throughput of selected flows in 2011

PEOPLE	Passengers	Workforce	Visitors			
	50.000.000	**60.000**	**13.000.000**			
ENERGY	Electricity *TJ*	Gas *TJ*	Fuels *TJ*			
	1.180	**975**	**11.900**			
WATER	Drinking Water *m^3*	Wastewater *pollution units*				
	1.220.000	**45.000**				
MATERIALS	Plastics: PET *tonne*	Plastics: Uspecified *tonne*				
	388	**434**				
FOOD	Carbohydrates *tonne*	Vegetables *tonne*	Fruits/nuts *tonne*	Meat products *tonne*	Fish products *tonne*	Dairy products *tonne*
	11.500	**5.930**	**3.290**	**5.270**	**1.650**	**5.270**
WASTE	Total waste *tonne*					
	13.900					

Flow Potentials: Hotspot zone studies

Characteristics and associations that emerged from the initial flow analysis were listed in order to identify zones with particular interest to explore in greater detail. During internal workshops, researchers with various backgrounds – notably engineering, industrial ecology and urban planning & design – further discussed these characteristics and developed a shortlist of six *hotspot zones*, visualised in Figure 3. Through interviews and workshop sessions with public and private stakeholders these hotspot zones further evolved. Determination of the shortlist was done by five primary criteria:

- Presence of specific flow potentials; for example large volumes of excess heat
- Spatial relevance; the area's morphology and its spatial potential for interventions in resource management (production, storage, infrastructure)
- Strategic relevance; the area's identity regarding the organisational and regulatory status
- Current or planned developments
- Spatial and thematic dispersion

Each hotspot zone revolves around one or more coinciding main theme rooted in, but not exclusive to, that specific context; generic lessons can be drawn through the specific examples. In the next section two of six hotspot zones are further discussed, namely: nr 1. BESt Energy Exchange, and nr 3. Urban Mining of Airports (UMA) – plastics[2].

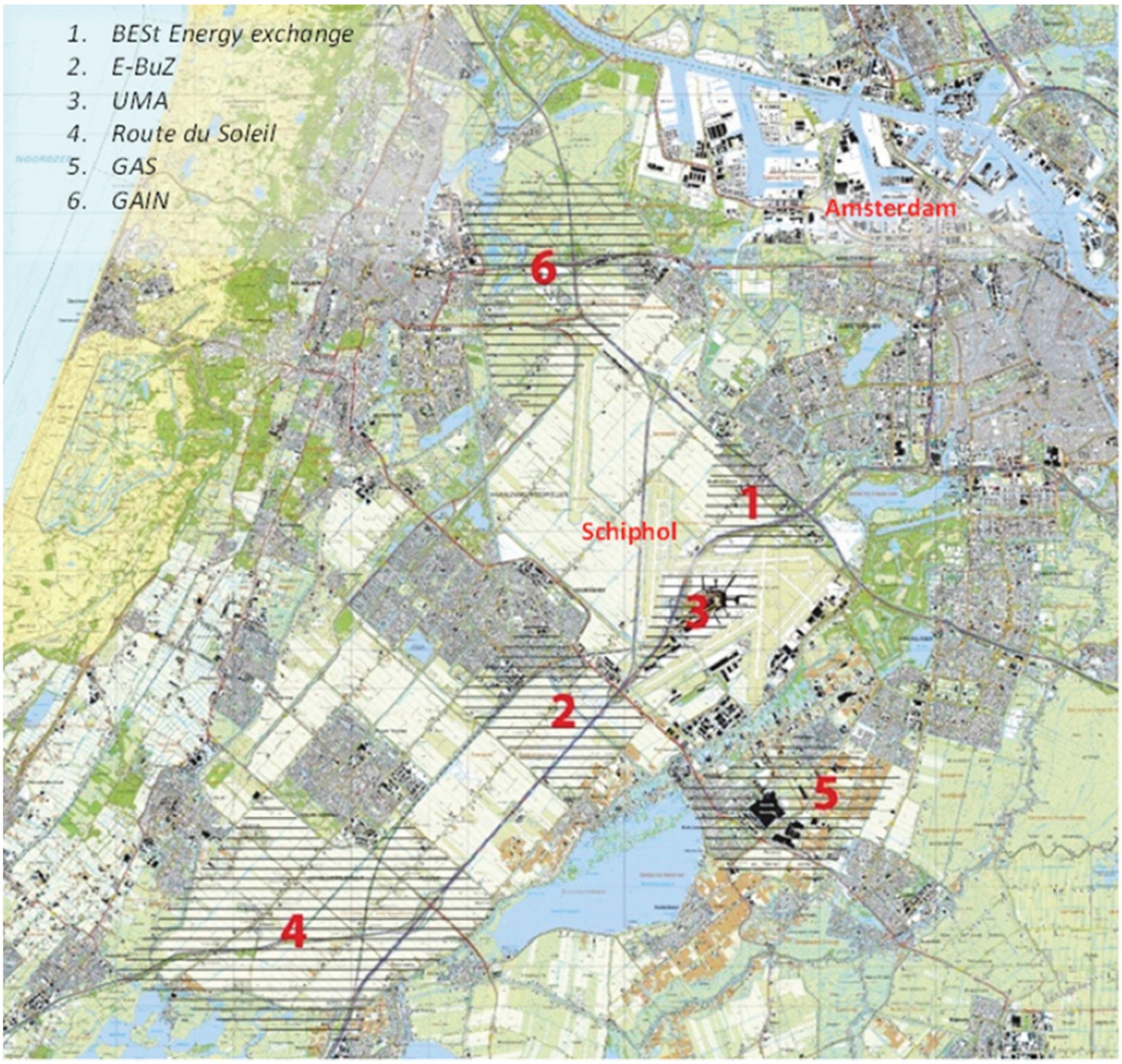


Figure 3: Six hotspot zones in the Schiphol airport region

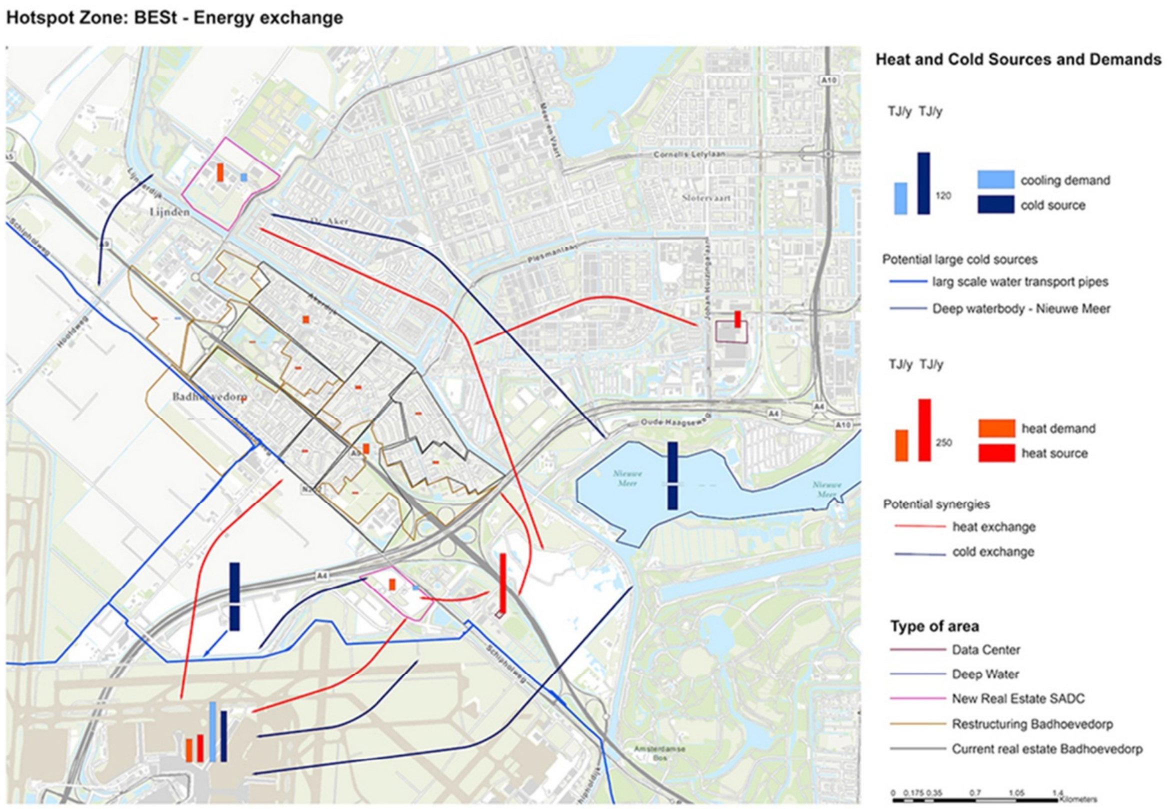
Hotspot zone BESt – A smart grid for heat and cold exchange

In Badhoevedorp, just North of Schiphol, a variety of real estate and restructuring plans is under development or foreseen for the near future. Each plan comes with a particular energy demand, which could in theory be covered by collective thermal energy systems centred on a low temperature heating/high temperature cooling net. Excess heat from Schiphol could be part of such a thermal energy net. On the other hand Schiphol has a large and energy intensive

[2] A second research in this hotspot zone was allocated to the recovery of nutrients in wastewater

cooling demand, for example relating the heat production associated with daily fluxes of passengers in terminals. Water transport pipes that run under the north of Schiphol could provide a significant and constant source of cooling, albeit with temperatures that vary over a year.[3] Furthermore, business zone Elzenhof, neighbouring Schiphol and Badhoevedorp, accommodates a large datacentre. This datacentre produces a constant flow of waste heat and explores options to render this waste heat useful. Lastly, in Amsterdam, a city-cooling grid is currently under development, using deep lakes – that came into existence through sand extraction – as point sources. One of these lakes, namely the Nieuwe Meer, borders the Badhoevedorp/Elzenhof/Schiphol triangle (BESt) in the northeast.

Built on the abovementioned facts, a distribution and storage net for heat and cold in the BES triangle presents an opportunity to serve mutual interests of suppliers and customers. The associated technology and infrastructure is relatively straightforward, and both supply and demand capacities are promising. Moreover, the thermal quality of the transport medium can be sustained over reasonably long distances, in that respect bridging the distances in the BES triangle is not an obstacle. The map of figure 4 displays heat and cold sources and sinks, with an indication of the capacities (in TJ/year), and potential synergies in the BES triangle. New real estate of Schiphol Area Development Company (SADC) outside of the airport boundaries is also indicated with its estimated heat and cold demands. Furthermore, the underground water supply transport pipes are visualised on the map.



[3] The 'Rivier- Duinwaterleiding' (River-Dune water supply)

Figure 4: Energy exchange potential in the Badhoevedorp/Elzenhof/Schiphol triangle

The BESt energy-exchange concept brings energy supply and demand patterns of local components together. Some characteristics are predominantly generic, such as the presence of water-bodies and occurrence of heat losses (excess heat) from industrial processes. Other characteristics are more specific, in particular with regard to the subterranean water supply pipes. There is a variety of temperatures associated with the supply and the demand side; roughly from 5°C (e.g. lake water in winter) to 40°C (e.g. datacentres). A smart distribution grid is envisioned, in which the required thermal qualities are available at the right place at the right time, following a *cascade* of functional applications, including storage capacity for load balancing. Supplementing such a grid with functions that utilize leftover energy at the end of the cascade would enhance its effectiveness. An opportunity in this respect is making a link with algae cultivation at Schiphol. This relates to an earlier experiment at the airport concerning the purification of glycol-containing de-icing water with algae. One of the main reasons for the failure of this experiment was that glycol containing feedstock is primarily available in winter, when temperatures are far from optimal for algae growth; this discrepancy could be compensated by utilizing low temperature waste heat as part of the proposed heat/cold exchange and storage network. Algae could subsequently play a role in multiple applications, providing feedstock for food, feed, pharmaceuticals, fine and/or bulk chemicals.

Hotspot zone UMA – Urban Mining in Airport regions; plastics

On-going efforts at Schiphol to valorise valuable waste fractions lead to increasing recycling rates associated with solid waste. Plastics, mainly from packaging, are to some extent separately collected and transported to recycling facilities. With 100 tonnes per year, PET is currently the primary polymer in this context, but there is good recycling potential for other polymers as well. With regard to waste from aircraft, recycling is virtually absent; in accordance with safety regulations, much of the total aircraft waste is incinerated within 24 hours. The plastic fraction of this waste flow – 720 tonnes annually of which 40% PET (288 ton) and 60% unspecified (432 ton) – could easily be fed into common practice recycle routes. Recycling generally leads to a better environmental score and conserves more energy than is generated by incineration [e.g. 8, 9].[4] Given the specific conditions of the waste collection in aircraft, i.e. hardly accommodating for waste separation at the source, post separation seems the most appropriate step towards recycling – and the next best option after *reducing* that waste flow. With regard to plastics in municipal solid waste (MSW), on average 25 kg is produced per capita per year, the majority of which disappears in incinerators: 15-20 kg. In the municipalities surrounding Schiphol this implies a production of 20-27 kton plastics in domestic waste streams for incineration annually. However, the lion's share, consisting of the polymers PET, PP, PE (HDPE and LDPE), PVC, and PS can be recycled following common recycling routes (see also Table 2).

[4] Incineration with energy recovery – electricity and heat – leads to approx. 500 GJ of electricity and 1,900 GJ of heat + losses. Caloric value of this waste is approximately 10 GJ/tonne and the efficiency is 21%.

Figure 5 displays the division in percentages per polymer type in the solid waste flows of Schiphol and its surrounding municipalities.

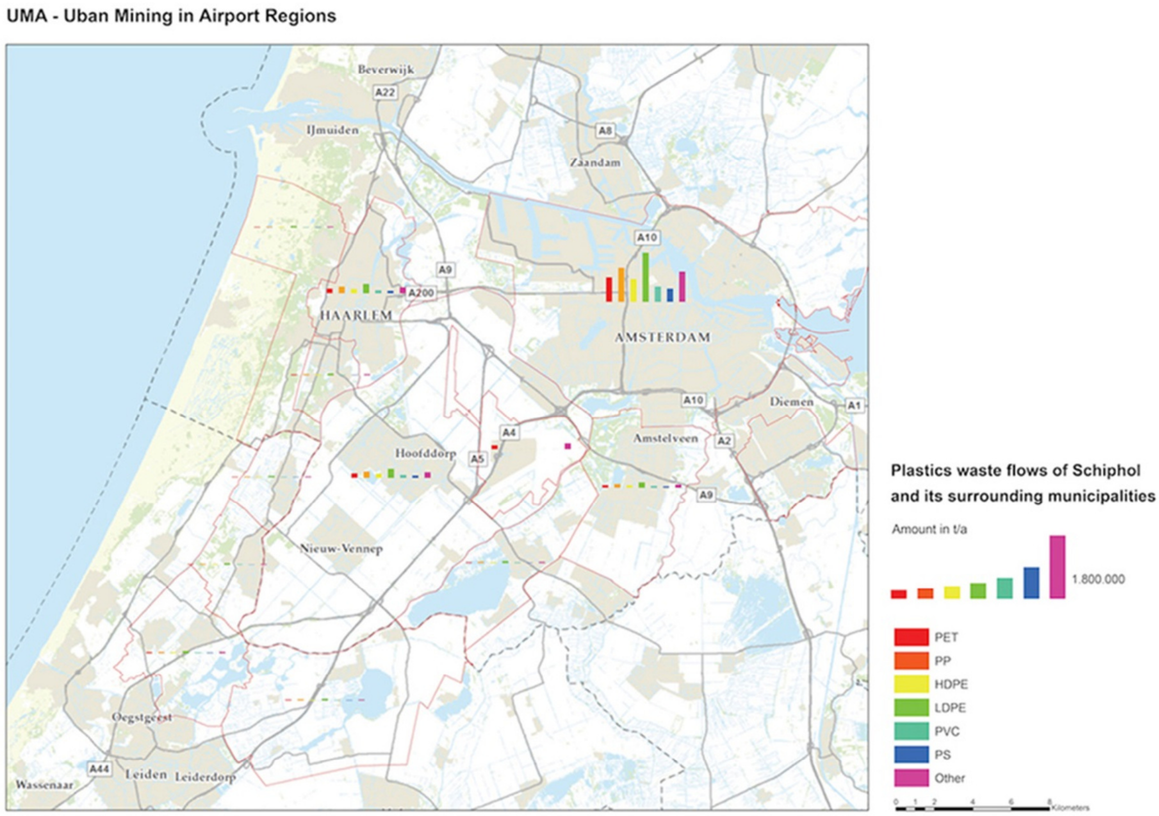


Figure 5: Plastic packaging throughput of Schiphol and its surrounding municipalities in 2011

Expanding the plastic recycling efforts in the airport region centres on potential economies of scale and the shift from waste related costs to added value through recycling. Table 2 lists the main polymers used for packaging, whilst also being indicative for the main products or product categories that enter the airport. Furthermore, the table lists the packaging applications, identification code for recycling purposes, and recycling routes. Because of the close relation with food – another resource flow included in the BAR research – other plastic products associated with airports, such as disposable containers, cutlery and trays, are also included in the table.

The polymers could either be recycled into the same type of product; closed loop recycling, or into another; open loop recycling. Given the fact that many of the currently applied recycling steps imply a diminished material quality, compared to that of the polymer materials used in the primary stage, *downcycling* is usually more appropriate as a term.[5]

[5] In their book 'Remaking the way we make things' [2002] Braungart and McDonough introduce their Cradle to Cradle approach, which distinguishes different kinds of recycling. In their reading, down-cycling implies the loss of intrinsic quality, whereas up-cycling implies added quality to the recycled material or product.

Regional collaboration relating collection, separation and storage may offer the economies of scale required for viable business cases based on circular resource flows. A remanufacturing – or polymer recovery – facility could well be implemented in one of the industrial/business zones in the region.

Table 2: Polymers for packaging + recycling routes

Polymer	Identification code	Examples of (packaging) application	Examples of recycled content applications
Polyethylene terephthalate (PET, PETE)	01 PET	Plastic bottles for soft drinks, water, juice, sports drinks, beer, mouthwash, catsup and salad dressing; food jars; food trays	Fiber for carpet; fleece jackets; comforter fill; carrier bags; containers for food, beverages (bottles), and non-food items; film and sheet; strapping.
High-density polyethylene (HDPE)	02 PE-HD	Bottles for milk, water, juice, cosmetics, shampoo, dish and laundry detergents, and household cleaners; grocery bags, cereal box liners; reusable shipping containers.	Bottles for non-food items; plastic lumber for outdoor decking, fencing and picnic tables; piping; floor tiles; buckets; crates; flower pots; garden edging; film and sheet; recycling bins.
Polyvinyl chloride (PVC)	03 PVC	Rigid packaging applications, such as blister packaging for non-food items; flexible packaging, such as bags for bedding; cling films for non-food use.	Piping; decking; fencing; paneling; gutters; carpet backing; floor tiles and mats; resilient flooring, mud flaps; trays; electrical boxes; cables; traffic cones; garden hose; packaging; film and sheet; binders
Low-density polyethylene (LDPE)	04 PE-LD	Bags; squeezable bottles; cling films; flexible container lids; coatings for paper milk cartons; hot and cold beverage cups.	Shipping envelopes; garbage can liners; floor tile; paneling; furniture; film and sheet; compost bins; trashcans; landscape timber; outdoor lumber.
Polypropylene (PP)	05 PP	Reusable microwaveable ware; kitchenware; yogurt containers; margarine tubs; microwaveable disposable take-away containers; disposable cups; plates.	Automobile applications, such as battery cases; signal lights; battery cables; brooms and brushes; ice scrapers; oil funnels; bicycle racks; garden rakes; storage bins; shipping pallets; sheeting; trays.
Polystyrene (PS)	06 PS	Egg cartons; protective and insulating packiging; disposable cups, plates, trays and cutlery; disposable take-away containers;	Thermal insulation; thermometers; light switch plates; vents; trays; rulers; license plate frames; cameras or video cassette casings; foamed foodservice applications; plastic mouldings; expandable polystyrene (EPS) foam protective packaging.
Other (often polycarbonate: PC or Acrylonitril-butadieen-styreen: ABS)	07 O	Beverage bottles; baby milk bottles; custom packaging; housing for electronics and compact discs	Bottles and plastic lumber applications.

main source: American Chemistry Council

Discussion and Conclusions

The described approach to analyse essential resource flows in airport regions has led to a better comprehension of current flow management at the airport. In the presented methodology qualitative and quantitative flow analyses on the one hand and local characteristics on the other are coupled, whilst revealing synergetic potential between resource flow considerations and spatial planning directions. These synergies derive from the case study region, containing specific potential for local projects as well as generic lessons applicable to other airport regions. Contextualization of the detected flow potential is facilitated by zooming into designated hotspot zones The five main criteria to determine these zones will arguably lead to a more integrated, region-specific selection procedure. Studying the hotspot zones reveals patterns in which challenges, context, potential solutions and spatial implications are coupled. The methodology thus helps to better understand the fabric that complex challenges, such as sustainable development, are made of. Two – interrelated –

aspects in particular have come to the surface as critical factors that determine the value of the proposed methodology and its results: complex system dynamics and data quality. Below, those aspects are further discussed.

Complex system dynamics

Airports, being complex systems in their own right, interact with their direct surroundings in complex and multifaceted ways. Reciprocal relationships with those surroundings imply surplus value rather than nuisance in the form of noise, pollution and traffic congestion; associations that currently seem to prevail. This reciprocal relationship relates to new paradigms in dealing with essential resources. Reciprocity not only implies a symbiotic relationship but also a degree of mutual obligation that comes with it. These are properties of systems thinking and underline the non-linearity in complex systems. The proposed methodology results in identified potentials that are largely of a technical nature. But technology is often not the limiting factor with regard to breakthroughs of sustainable innovations [Vernay 2013]. In that respect, the methodology contains a paradox: a *reductionist* approach to ultimately understand a *holistic* system. However, this methodology is part of an integrated effort to understand complex systems, whilst yielding *sub*-results as input for design patterns. Those patterns are subsequently coupled with spatial design, planning and governance modules. In this way the opportunities detected in the case study area of the Schiphol airport region obtain systems based value.

Data quality

During the research, we have strived for the highest data quality possible within the restrictions dealt with. However, due to the complexity and size of the study area, as well as the amount of data owners and stakeholders, a certain asymmetry in data has to be taken into account. In those cases the emphasis is more on qualitative than on quantitative results. Despite the cooperation of several key players, data –if existent at all– are in many cases not readily available. Lack of transparency is an issue here in two ways: firstly, actors may not want to – or be allowed to – share certain information. Secondly, actors may not share the piece of information that is valuable for us, and/or they may not be aware what the significance of specific information is. In the first case it is clear that confidentiality renders data out of reach. The latter case, however, is more ambiguous and seems closely connected with individual sectorial concerns, as referred to in the introduction. During the research we have explicitly operated from a systems approach towards sustainability; data are assembled to anticipate non-sectorial solutions. It is not self-evident that this approach coincides with the interests of individual actors. However, outlines of specific projects become discernible in the hotspot zones, which may appeal to individual actors as much as the society. This appeal is thought to create the required incentives for individual actors to take next steps in generating and sharing data.

References

[1] Piskorz, W., Garcia-Patron Rivas, S. (Eds.) [2011]; Cities of tomorrow – Challenges, visions, ways forward, European Commission, Directorate General for Regional Policy

[2] Rotmans, J. [2006]; Tools for Integrated Sustainability Assessment: a two-track approach, Integrated Assessment Journal Vol. 6, no. 4, 35-57

[3] Vernay, A-L.B.H. [2013]; Circular urban systems, moving towards systems integration, Delft University of Technology, Faculty of Technology, Policy and Management, Delft

[4] Dobbelsteen, A. van den, Verkade, G.J. (Eds.) [2014]; Better Airport Regions – Final Report, NWO Programme Urban Regions in the Delta, Delft

[5] Geldermans, R.J., Wandl A., Dobbelsteen, A. van den [forthcoming]; Essential resource flows in airport regions – a case study of Amsterdam Airport Schiphol

[6] Schiphol Group [2012]; Annual report 2011, Schiphol Group, Schiphol

[7] Schiphol Media [2012]; Facts & Figures 2012, Schiphol Group, Schiphol

[8] Morris, J. [1996]; Recycling versus incineration: an energy conservation analysis, Journal of Hazardous Materials 47, 277-293, Elsevier

[9] Jetten, L., Merkx, B., Krebbekx, J., Duivenvoorde, G. [2011]; Onderzoek kunststof afdankstromen in Nederland, Berenschot Groep B.V., Utrecht, 2011