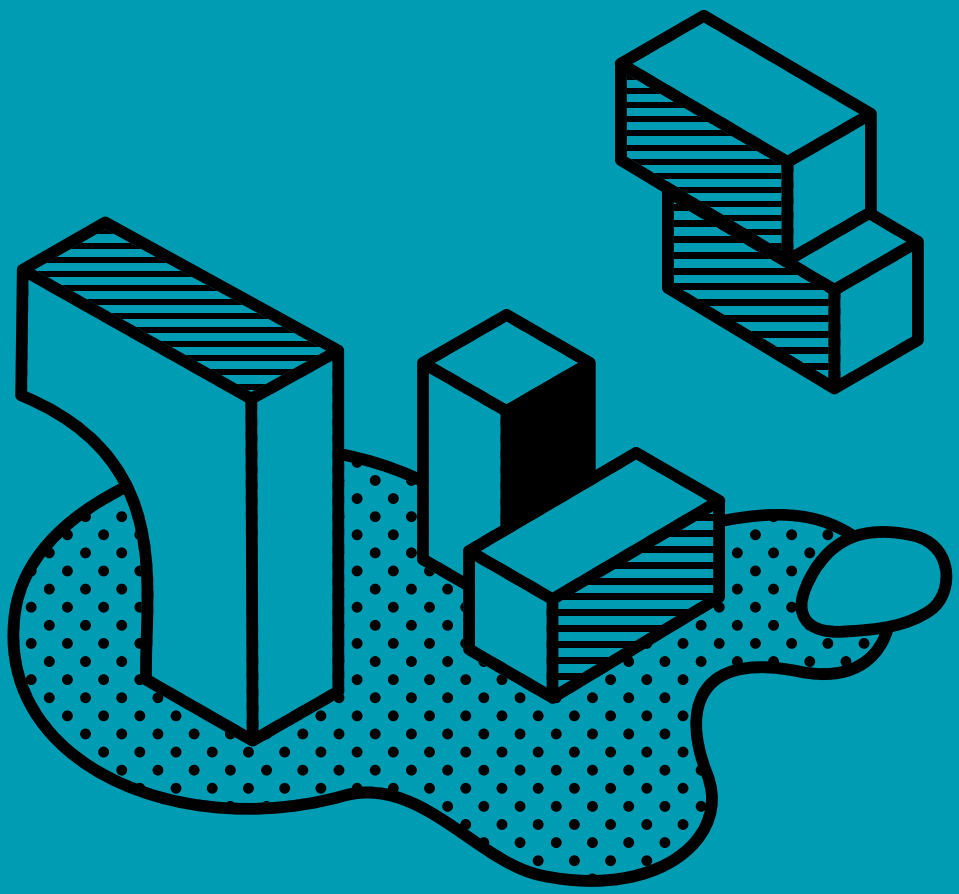
# Designing Brussels Ecosystems

## Metrolab Brussels MasterClass II



Bernard Declève
Geoffrey Grulois
Roselyne de Lestrange
Andrea Bortolotti
Corentin Sanchez Trenado
(eds)

Metrolab series

# Designing Brussels Ecosystems

## Metrolab Brussels MasterClass II

Bernard Declève
Geoffrey Grulois
Roselyne de Lestrange
Andrea Bortolotti
Corentin Sanchez Trenado
(eds)

# Circularity

# On scales and agency – territorialising circularity

**Andrea Bortolotti, Geoffrey Grulois, Stephan Kampelmann**

**Steering the transition towards a circular economy (CE) is one of the pillars of the EU's regional development strategy. The concept is appealing for its promises of boosting new economic cycles in times of crisis while tackling major environmental issues (such as resource depletion, pollution, etc.). Drawn from the European strategy, the concept of circular economy — together with that of sustainable urban metabolism, intended as a model of material economy with reduced negative externalities — has gained traction in Brussels among business and policy-makers, being translated into objectives in regional plans and programmes. Addressing the issue of 'circularity' within the framework of the Metrolab MasterClass and in collaboration with the ULB Chair on Circular Economy is thus a way to reflect on the urgent question about how to territorialise discourses and strategies on circular economy and sustainable urban metabolism in the context of Brussels' regional development and policy.[1]**

## Three challenges for a circular economy

Today, city administrations in Beijing, Amsterdam, Paris and Brussels have in common that they claim to use the principles of 'circular economy' as their compass for navigating economic and environmental challenges. The policy roadmaps they produce in this context often describe the circularisation of urban systems in terms of their 'metabolism'. The two central concepts underpinning these policies — the urban 'metabolism' and its 'circularisation' — remain, however, often very poorly characterised. Regarding the notion of 'metabolism', the metabolic overviews that have been commissioned by cities are largely confined to discussing material flows to, from and within a given urban agglomeration (see, for instance, EcoRes, ICEDD and BATir, 2015). In most cases, this is achieved through quantitative accounts in form of

1. This paper is an elaboration based on our contribution to the publication *Designing Territorial Metabolism* published in 2018 (Grulois et al.).

Material and Energy Flow Analysis (MEFA) or Sankey diagrams.[1] As shown by the seminal experience of Paul Duvigneaud in Brussels, the intensity of flows is, however, not the only dimension of a city's metabolism. The first objective of this contribution is to discuss the implications of the spatial scale and structure at which these flows and circularities are organised and the socio-technical agencies that govern them.

Current uses of the notion of 'circularisation' are often simplistic. Arnsperger and Bourg (2016) recently pointed out that many of the CE policies and promises churned out by governments, consultancies and corporations are, in fact, not 'authentically' circular. Being soaked in the language and ideology of economic growth, these circular economy initiatives might eventually fall short of expectations. A better understanding of the various dimensions of urban metabolism and their circularisation is not only of theoretical interest; the issues of **intensity, scale and socio-technical agencies** are also relevant in the practical context of developing plans and strategies aimed at improving metabolic flows in the urban environment. To be sure, previous research on planning for circular economy — and, in particular, contributions based on research by design (Grulois, Casabella, Crosas and Perea, 2015; Grulois, Tosi and Crosas, 2018) — has already touched upon all of the three dimensions of urban metabolism we highlight in this paper. However, a critical approach that frontally and explicitly addresses the multidimensional character of circularity is still missing in the literature.

### Intensity

The intensity of stocks and flows of water, construction materials, nitrogen, food, fuel, final products, municipal waste, etc. is arguably the most explored aspect of urban metabolism in Industrial Ecology and neighbouring fields (Weisz and Steinberger, 2010). The analysis of metabolic intensity relies on quantitative indicators such as the primary and final consumption of a given territory. The literature has also developed tools that pull several quantitative indicators of metabolic intensity together, such as Material and Energy Flow Analysis (MEFA), Life Cycle Analysis (LFA) or Sankey diagrams. These approaches have the merit of allowing more systemic analyses of the relationships between different material flows (Haberl, Fischer-Kowalski, Krausmann, Weisz, and Winiwarter, 2004). Following quantitative indicators over time has led to the observation that the flows of many substances have intensified in most cities over the 19th and 20th centuries (Barles, 2015; McNeill, 2001).

How would circularisation affect the intensity of stock and flows of the urban metabolism? The answer to this question marks a clear divide between, on the one hand, those that see circular economy as a 'Third Industrial Revolution' harbouring the prospect of renewed economic growth and those, on the other hand, who argue that the circularisation of material flows necessarily entails a drastic reduction of their intensity. The drum of the former fraction has been banged most loudly by the Ellen MacArthur Foundation, a lobbying group that never misses an opportunity to tell the world's largest corporations that they can grow bigger and faster by embracing the principles of circular economy. Among the spearheads of the critical stance are Christian Arnsperger and Dominique Bourg, whose recent work sums up convincing arguments leading to their conclusion that an 'authentically circular economy' is incompatible with strong economic growth (Arnsperger and Bourg, 2016).

To the extent that economic growth and material throughput continue — at least at larger scales — to be highly correlated, the critical stance developed by Arnsperger, Bourg and others offers a sobering message: the circularisation of the urban metabolism not only implies purging toxic materials, but also a general reduction of throughput intensity of all other substances whose reproduction cannot keep up with the pace of economic growth. This calls for reducing the throughput of virtually all resources whose global use exceeds a growth rate of 1%, and therefore also materials with an already very high recycling rate, such as metal or paper.

Circular economy might stand at a crossroads: either it will become entirely

2 A Sankey diagram depicts flows of any kind, where the width of each flow pictured is based on its quantity.



subsumed under the promise — and illusion — that economic expansion and resource circularity are compatible; or it embarks on a more critical programme that asks for ways towards circularisation that do not depend on economic growth. We believe that the critical programme cannot succeed if it is only confined to issues of material and energy intensity. A pro-growth interpretation of circular economy is hardly concerned with issues of political economy: the champions of the business-as-usual approach are also supposed to be those who underpin circular resource flows (see the list of corporations endorsed by the Ellen MacArthur Foundation for their circular business practices: Total, Renault, H&M, Unilever, etc.). By contrast, a post-growth interpretation of circular economy is a heterodox undertaking that needs to explain how economic systems such as urban economies can operate within certain limits. These limits are biophysical in nature, but need to be negotiated socially. This negotiation could give rise to a new social(-ecological) contract defining viable throughput intensities, but also the spatial structure and socio-technical agencies of circular flows. This negotiation could be greatly helped if social scientists, planners and designers provide concepts and representations for territorial metabolism in which economic actors (including for-profit and non-profit organisations) consider the physical and social boundaries of the ecosystems that sustain them. So far, for instance, the physical, spatial and social implications of a post-growth economy have hardly been explored at all. The goal of the circularity transdisciplinary group working in the framework of the Metrolab MasterClass is therefore to shake the industrial ecology and urban metabolism paradigm in order to tackle the questions of scale, place and agency that are implicit in the notions of territorial metabolism and political ecology.

### Scales

The intensification of throughput that characterises the historical evolution of most cities has been accompanied by spatial externalisation (Barles, 2007, 2015; McNeill, 2001). This means that urban regions such as Brussels source materials and energy from outside of the urban core from ever larger and more distant ecosystems and territories. Not only the provision of materials and energy has been externalised to a globalised hinterland: since the second half of the xixth century, cities also depend on external ecosystems to absorb growing quantities of waste. Geographers and ecologists have documented the spatial externalisation of urban metabolism through a series of indicators such as Ecological Footprints, (Wackernagel and Rees, 1996), Food Miles (Weber and Matthews, 2008) or Food-Prints (Billen, Barles, Garnier, Rouillard and Benoit, 2009). Applying the latter to the case of the Île-de-France region, Billen et al. show that the territory of the food metabolism includes various provisioning areas at different scales, ranging from the traditional and relatively close agricultural hinterland surrounding Paris to vast stretches of South America. This fact leads critical urban theory inspired by Henri Lefevbre to consider that beyond the city, urbanisation is a planetary phenomenon as the territory of resource extraction and waste disposal is global (Brenner, 2014).

What does the objective of circularisation imply for the territory of a city's provisioning and disposal areas? First of all, it should be clear that the circularisation of flows cannot be considered at a single scale. The multi-scalarity of resource extraction and waste disposal make it impossible to return to the dichotomy of a city versus a clearly defined agricultural hinterland. To go back to the biological origins of the metaphor, the metabolism of, say, a tree cell is not circular if we look at it at the scale of the cell. Even the entire organism, i.e. the whole tree, is not circular, as it is mostly engaged in biochemical interactions with its environment. Only if we zoom out and take into view the entire forest ecosystem can we perceive natural cycles of nitrogen or carbon that have been described by scientific ecology. Metabolic exchanges are also mostly linear if we confine the analysis to cities. In fact, with the exception of acute crises, it seems to be a historical constant of a city to behave as a 'parasite' (Odum, 1989), in the sense that it depends on hinterland for their survival (Barthel and Isendahl, 2013). This implies that restricting circular economy policies to the single scale of a city such as the Brussels-Capital Region can only provide relatively anecdotal leverage. Even urban agriculture, which is arguably one of the most emblematic efforts of organising circular flows within city boundaries, will hardly reduce the need for access to arable land outside of the

city. Indeed, early contributions on urban metabolism by Wolman (1965) and others were not confined to the limits of the city, but rather used the concept to 'characterise the city as an ecosystem embedded in a larger system' (Broto, Allen and Rapoport, 2012, p. 852) Today, this larger ecosystem is the biosphere and it involves various interdependencies on many different scales. As a consequence, rather than eradicating resource input and waste output to a city, circularity implies activating exchanges across areas with different urbanisation patterns (urban core, agricultural hinterland, extraction and waste territories, etc.). Such intricate territorial metabolism can only be circular if we recognise that the provisioning and disposal spaces overlap at different scales.

A circular territorial metabolism is, however, as much a social as an ecological problem. In addition to ecological parameters, the contours of a circular territorial metabolism will also depend on social and technical factors. It forces us to set aside the traditional division between nature (material resources) and society (human and technical agency) (Wachsmuth, 2012). For example, returning nutrients to cultivated ecosystems implies designing, financing and operating socio-technical infrastructures that are fit for this purpose. It means that actors from both urban hubs and agricultural areas will have to cooperate in order to coordinate the flows of organic resources — which, in turn, necessitates a system of governance that goes beyond the boundaries of the region and that is able to attenuate the inevitable conflicts of interests between the urban hub and the agricultural hinterland.[2] Another issue relevant for the design of circular metabolism appears if we consider the urbanised territories as a multifunctional whole. In this perspective, sustaining the urban hub not only requires a certain space or territory from which resources are sourced, but also raises questions about how the spatial diversity and the different functions of urbanisation can be grasped in order to be circular beyond the traditional division of the city vs country and society vs nature.

One way to frame the complexity of a circular territorial metabolism beyond the question of territorial scale and the nature-society division is by looking at it as a social-ecological system, an ensemble in which biophysical and anthropogenic elements interact in complex ways (Olsson et al., 2006). Since the vast number of social and ecological factors cannot be expressed in a commensurate metric, the design of a circular social-ecological system is a transdisciplinary qualitative exercise that needs to define new social, economic or political institutions that underpin these flows. An example of designing new and circular social-ecological systems is the idea of 'bioregionalism' as proposed by David Brunckhorst (2000). This approach combines the definition of ecosystems at regional scales with the problem of social institutions capable of sustaining them through durable forms of extraction and resource renewal. A 'bioregion' is therefore not only an ecological system with a regional scope, but also a political entity. While certainly attractive for the circularisation of flows that can be organised at the regional scale (like food or certain building materials), bioregionalism should not obliterate material and social interdependencies at other scales.

In summary, the implications of circularity and territorial metabolism are both extremely simple and almost infinitely complex. Simple because their physical organisation can be expressed in a concise formula: provisioning spaces need to overlap with disposal spaces so as to allow for closed loops of resource production, use, disposal and renewal. Complex, because the scale at which these loops can occur will vary greatly depending on the material flow, geomorphological context and urbanisation rate at hand and require designing not only technical infrastructures, but also institutions that are capable of organising the social, political and economic ramifications of circular flows. The following section uses the lens of socio-technical agencies to look in more detail into these non-physical aspects of circular territorial metabolism.

### Socio-technical agency

The literature on circular economy, and, more specifically, on the circularisation of urban metabolism, still offers an extremely rudimentary understanding of agency.

2 In the case of Brussels, the Brussels-Capital Region versus Flanders and Wallonia.



Wachsmuth (2012) noticed the absence of 'the social and the historical' in early theories on circular and linear urban metabolism in the Industrial Ecology tradition. But issues of agency are even less topical in the more recent discourse on circular economy by the Ellen MacArthur Foundation, arguably because the great transition towards circularity that this discourse advocates leaves the distribution of economic and political power of the linear economy almost untouched: citizens continue to be passive consumers of goods and services, the only difference being that these products are redefined to allow for more efficient resource circulation; public administrations are supposed to play a role in the transition towards circular economy, but only within the neoliberal tradition of supporting and facilitating agencies that leave most of the initiative to the market; and corporations like Total and H&M can simply switch from linear to circular business models without giving up their habitus of profit maximisation, capital accumulation, shareholder satisfaction and economic expansion.

How could a critical interpretation of circular economy principles reintroduce questions of agency? We argue that a pivotal aspect of agency should revolve around the relationships between different social groups and technology. To be sure, the technological configuration plays a central, if not overriding, role in how materials and energy flow through territorial social-ecological systems. In most cities these flows are organised in centralised networks such as underground sewage systems. Historiographical accounts on the emergence of these centralised networks suggest that they have been conditioned and marked by a specific social group: engineers and technicians (Barles, 2015; Deligne, 2016; McNeill, 2001). From an Industrial Ecology perspective, we can add that this group also plays a dominant role for the possibility of reforming current technological configurations. Engineers are, to use the terminology of the *Multi-Level Perspective on social-ecological transitions* (Fischer-Kowalski and Rotmans, 2009), part and parcel of the 'hardness' — in a literal and metaphorical sense — of socio-technical landscapes, which 'include the material aspect of society, e.g. the material and spatial arrangements of cities, factories, highways, and electricity infrastructures' (Geels, 2004, p. 913). The flipside of the central position of engineers and other technical experts in territorial metabolisms is the relative powerlessness and passivity of the large group of individuals that use the technical infrastructures on a daily basis, but also a relative dependence and captivity of decision makers.

Similar to the opposition between pro-growth and post-growth stances regarding circular urban metabolism, different types of socio-technical agencies can also give rise to contrasting paths towards circularisation. On the one hand, circularisation initiatives can be as technocratic as the linear arrangements they aim to replace. Indeed, if the circularisation of metabolic flows will be driven top-down by large corporations and market-oriented public administrations, it is not unlikely that the infrastructures that will underpin the circular flows will resemble current infrastructures in their capital-intensity and centralised nature, thereby maintaining both the centrality of experts, passivity of users and dependence of political decision makers. On the other hand, there are circularisation initiatives that challenge the current technocratic set-up and propose to organise circular flows in which users become agents and have a much more proactive role. This type of initiative tends to rely on less capital-intensive and more decentralised technical infrastructures (Coutard and Rutherford, 2009). To the extent that the latter can often be understood, modified or even replaced by the users themselves, they allow for a degree of socio-technical emancipation.

### Framing circularity in Brussels: the Metrolab experience

How did Metrolab reflect on these challenges of territorial metabolism and circularity? In October 2018, we invited David Wachsmuth and Matthew Gandy to question the notion of urban metabolism and the society-nature division at the Brussels Ecosystems conference. In the same conference, we discussed the issue of 'circularity' during a round table gathering stakeholders, professionals and academics concerned with two projects funded by the ERDF programme (2014-2020) for Brussels directly linked with the topic of the circular economy: IRISPHÈRE and BBSM (Bâti Bruxellois comme source de nouveaux matériaux de construction — Brussels buildings as a source for new

construction materials). IRISPHÈRE is a project coordinated by citydev.brussels — a public body and major property developer in the Brussels-Capital Region — that seeks to foster industrial symbiosis in Brussels by identifying and seizing economic opportunities for material reuse and sharing of facilities, resources and services among enterprises. In particular, the programme aims to invest in the creation of a container park in an industrial area along the canal for the collection and reclamation of organic waste through a collaboration with a local farm. IRISPHÈRE faces some of the challenges described above, such as the question of determining the right scale for governing circular economy projects.

BBSM is a research project coordinated by UCLouvain that aims to show that construction materials are resources whose recirculation can improve the sustainability of the region. The project tackles some major socio-economic challenges for Brussels, such as the steadily increasing amount of construction and demolition (C&D) waste, the reinforcement and implementation of local value chains, and the creation of new jobs. It explores potential waste material flows in the construction sector in order to steer waste planning and management and examines the opportunities of the construction sector's value chains, the technical and legal aspects related with material recovery (reuse and recycling) and the role of design. The final objective is to develop a tool for an efficient management and exploitation of local C&D waste in Brussels. While BBSM has developed a clear model of material reuse, it seeks a governance model to steer the circular transitions in the construction sector.

Discussions of the workshop unfold some common issues in recycling and the circular economy such as the absence of appropriate regulatory frameworks to incentivise reuse over disposal, the uncertainty of business models and lack of space to store materials in dense urban contexts. At the time of the conference, the recircularization of organic matter projected by IRISPHÈRE faced difficulties due to the lack of environmental authorisations required for waste transport and treatment by the project stakeholders and technologies chosen for this purpose. Experts from BBSM, instead, raised the question of the lack of skilled workers, appropriate planning and storage space for materials in C&D sites in Brussels, three necessary conditions to enable materials sorting and sending to recycling. These questions shed light on the complex and intricate system of actors, knowledge and practices that underlie and challenge the project of circularity.

In January 2019, the MasterClass on 'Designing Brussels Ecosystems' brought together again academics and researchers, regional stakeholders and professionals from different fields for a two-week intensive workshop in order to address some of the questions previously identified during the conference. We chose to propose the topic of circularity within the construction sector in Brussels as one of the four themes to be discussed. In addition, and in concertation with the ULB Chair on Circular Economy, we suggested addressing the issue by focusing on a particular neighbourhood of Brussels — the Northern Quarter, a mono-functional business district neighbouring the city centre — and leveraging the concept of hotspot of the circular economy.

Construction materials and minerals make up 20% of total material import in the Brussels-Capital Region (BCR), or 2.239 kt (in 2012). Unlike other imported material flows, which are for the most consumed or accumulated within the region (e.g. food products, fuel, etc.), construction materials and minerals are exported outside Brussels in even larger quantities (2.422 kt in 2012). The construction sector is the main economic activity in the Brussels region. As a consequence, construction and demolition (C&D) waste is the most important waste flow for the region, accounting for more than one third of its total solid waste (EcoRes, ICEDD and BATir, 2015)[3]. In addition to the demolition of existing buildings, C&D waste is generated as a result of design errors in new construction, improper procurement and planning, inefficient material handling and changes in building design and regulation. Composed of building debris, rubble, earth, concrete, steel, timber and mixed site clearance materials, at present, these materials are largely hauled, landfilled or

3 see map of main urban transformation projects and plans p. 68-69



downcycled (e.g. used as inert material for the foundation of roads and buildings) outside Brussels.

Is decoupling the use of material and natural resources from economic development a fundamental challenge for the Brussels construction sector? As new constructions and renovations (e.g. of mobility infrastructure) are growing in Brussels, current circular economy policies are pushing for some of these materials to be reused and exploited within regional boundaries. It thus remains to understand how to manage this material in Brussels, as it is bulky, hard to compress and requires large storage space that might not always be available on site. The challenge is also to rethink the collaboration of stakeholders (building construction and demolishing contractors, construction site managers, architects, construction material providers, construction waste companies, etc.) at different scales (construction site, neighbourhood, region, etc.). On the one hand, waste characterisations showcase increasingly refined accounting methods that integrate factors affecting waste generation such as building design and structure codes, material quantity take-off, material wastage levels and mass balance principle (Jin, Yuan and Chen, 2019; Yeheyis, Hewage, Alam, Eskicioglu and Sadiq, 2013). Building Information Modelling (BIM), for instance, virtually reproduces a project in a way that all facets can be properly planned before site construction begins, including spatial coordination of all materials, labour and sequencing for the construction of the project (Goedert and Meadati, 2008). BIM can be used in the building design stage to estimate the amount of construction and (eventual) demolition waste produced in the construction stage. Emilie Gobbo has developed a similar tool within the BBSM project to predict the amount (and type) of waste generated from the renovation of a typical early xxth century Brussels' house. But very little has been said concerning the actual process of demolition and construction and agency of its stakeholders.

On the other hand, planning strategies to minimise waste and improve reuse and recycling are still rare. These include sustainable procurement of materials, design, construction scheduling and site layout, where proper management of materials plays a major role in site waste reduction (Ekanayake and Ofori, 2004). Demolition methods used to remove materials from a structure are also an important factor that affects the amount and quality of waste generated in a form appropriate for reuse and recycling. For instance, recycling aggregate requires demolished concrete to be screened on-site to sort out impurities and stored beside the construction site to be readily used as aggregate for new concrete. Other aspects include the workforce, the lack of which is a major impediment to on-site sorting requiring extra labour; the existence of a market for recycled materials, without which contractors might not be interested in performing on-site sorting; the ease of disassembly of construction components, which affects the quality of recovered materials.

From these few lines, we can clearly see sustainable territorial metabolism and the project of circularity require active coordination (also in terms of temporality) between C&D sites, standards, agents, materials producers and waste collectors, in order to enhance the effective exchange of materials for reuse and recycling.

### The design task: scaling circular economy hotspots

The MasterClass questioned how to steer circularity into the construction sector building on the notion of hotspot — intended as a spatial catalyst and key urban sector for rethinking urban flows. The Brussels Regional Programme for the Circular Economy (PREC) supports the circular economy in order to enhance the competitiveness of regional companies and create new job opportunities. One of the biggest challenges of the Brussels-Capital Region is now to understand how to territorialise generic programmes and strategies at the regional level. The Chair on Circular Metabolism suggests reorienting this territorial axis of the PREC by deploying the concept of 'circular economy hotspots'.[4] The concept focuses on the idea that the territorialisation of circular economy policies requires catalyst places (urban districts, neighbourhoods, etc.) that play a strategic role in the spatial and quantitative organisation

4 https://www.circularmetabolism.com/output/7

of important flows of the region's material economy. Those are also places where proximity allows to trigger synergies between multiple projects, actors, and programmes. The notion of hotspot remains open to various scales, and is not delimited to a specific area. It allows to investigate the multi-scalar complexity of material exchanges and stakeholders' agencies while addressing a concrete case.

In the MasterClass, we proposed exploring and developing the notion of circular economy hotspot in Brussels by focusing on the case of the Northern Quarter. As a place of concentration of business activities located next to large-scale infrastructures (canal and railway) and a former industrial area (Masui), the district is currently invested by a process of significant transformation of its physical structure and outdated built environment, supported by the pressure of the residential sector. Given its strategic role and importance for the future of Brussels, this place and its development could benefit from the experience gained by the many actors and projects of circular economy in Brussels. The goal of the design exploration is to address the complex network of stakeholders and material flows that the important physical transformation of this environment will entail. To do so, we asked the participants to seek out and build synergies with the (eco)system of material reuse and recovery projects (among which ERDF projects BBSM and Usquare) and inspiring practices such as Rotor and BC Architects, which have gained relevant experience in the field in Brussels (Ghyoot, Devlieger, Billiet and Warnier, 2018; Lefebvre and BC Architects & Studies, 2018).

During these two intensive weeks, we have pushed to radically rethink agency within the current material economy (in the conception, production and application in the construction sector). We questioned current compartmentalised visions and practices in the C&D sector, trying to imagine, in the time available, the mix of policies and integrated actions needed to support greater circularity of construction materials. We questioned regulatory issues, as well as issues of material lifecycle, of collaboration among material producers, designers, university and schools and labour, in order to promote the use of materials that better meet criteria of repairability, durability and upgradability. We question whether Brussels is able to metabolise its material construction flows within new productive cycles with positive relapses for the whole citizenry as to escape its destiny of being 'modernity in a state of ruin' and rise from the vestiges of its industrial past to build, collectively, a more circular territorial metabolism.



**References**


Arnsperger, C., & Bourg, D. (2016). Vers une économie authentiquement circulaire. *Revue de l'OFCE*, *N° 145*(1), 91–125.

Barles, S. (2007). Feeding the city: Food consumption and flow of nitrogen, Paris, 1801–1914. *Science of the Total Environment*, *375*(1–3), 48–58.

Barles, S. (2015). The main characteristics of urban socio-ecological trajectories: Paris (France) from the 18th to the 20th century. *Ecological Economics*, *118*, 177–185.

Barthel, S., & Isendahl, C. (2013). Urban gardens, agriculture, and water management: Sources of resilience for long-term food security in cities. *Ecological Economics*, *86*, 224–234.

Billen, G., Barles, S., Garnier, J., Rouillard, J., & Benoit, P. (2009). The food-print of Paris: long-term reconstruction of the nitrogen flows imported into the city from its rural hinterland. *Regional Environmental Change*, *9*(1), 13–24.

Brenner, N. (ed.) (2014). *Implosions / Explosions: Towards a Study of Planetary Urbanization.* Berlin: Jovis.

Broto, V. C., Allen, A., & Rapoport, E. (2012). Interdisciplinary Perspectives on Urban Metabolism. *Journal of Industrial Ecology*, *16*(6), 851–861.

Brunckhorst, D. (2000). *Bioregional Planning*. London: Routledge.

Coutard, O., & Rutherford, J. (2009). Les réseaux transformés par leurs marges : développement et ambivalence des techniques 'décentralisées'. *Flux*, (2), 6–13.

Deligne, C. (2016). Industrialisation, manure and water quality in the 19th century. The Senne River in Brussels as a case study. *Water History*, *8*(3), 235–255.

EcoRes, ICEDD, & BATir. (2015). *Métabolisme de la Région de Bruxelles-Capitale*. Brussels: IBGE.

Ekanayake, L. L., & Ofori, G. (2004). Building waste assessment score: design-based tool. *Building and Environment*, *39*(7), 851–861.

Fischer-Kowalski, M., & Rotmans, J. (2009). Conceptualizing, observing, and influencing social–ecological transitions. *Ecology and Society*, *14*(2).

Geels, F. W. (2004). From sectoral systems of innovation to socio-technical systems. *Research Policy*, *33*(6–7), 897–920.

Ghyoot, M., Devlieger, L., Billiet, L., & Warnier, A. (2018). *Déconstruction et réemploi: comment faire circuler les éléments de construction*. Lausanne: Presses polytechniques et universitaires romandes.

Goedert, J. D., & Meadati, P. (2008). Integrating Construction Process Documentation into Building Information Modeling. *Journal of Construction Engineering & Management*, *134*(7), 509–516.

Grulois, G., Casabella, N., Crosas, C., & Perea, J. (Eds). (2015). *UpCycle Barcelona: Cogenerative Design Strategies for a Sustainable Urban Metabolism*. Retrieved from http://hdl.handle.net/2013/

Grulois, G., Tosi, M. C., & Crosas, C. (Eds). (2018). *Designing Territorial Metabolism: Barcelona, Brussels and Venice*. Berlin: Jovis Verlag.

Haberl, H., Fischer-Kowalski, M., Krausmann, F., Weisz, H., & Winiwarter, V. (2004). Progress towards sustainability? What the conceptual framework of material and energy flow accounting (MEFA) can offer. *Land Use Policy*, *21*(3), 199–213.

Jin, R., Yuan, H., & Chen, Q. (2019). Science mapping approach to assisting the review of construction and demolition waste management research published between 2009 and 2018. *Resources, Conservation and Recycling*, *140*, 175–188.

Lefebvre, P., & BC architects & studies. (2018). *BC architects & studies: the act of building*. Antwerp: Flanders Architecture Institute.

McNeill, J. R. (2001). *Something New Under the Sun: An Environmental History of the Twentieth-Century World (The Global Century Series)*. New York, NY: W. W. Norton & Company.

Odum, E. P. (1989). *Ecology and Our Endangered Life-Support Systems*. Sunderland, MA: Sinauer Associates.

Olsson, P. A., Gunderson, L. H., Carpenter, S. R., Ryan, P., Lebel, L., Folke, C. S., & Holling, C. S. (2006). *Shooting the Rapids: Navigating Transitions to Adaptive Governance of Social-Ecological Systems*.

Wachsmuth, D. (2012). Three Ecologies: Urban Metabolism and the Society-Nature Opposition. *The Sociological Quarterly*, *53*(4), 506–523. https://doi.org/10.1111/j.1533-8525.2012.01247.x

Wackernagel, M., & Rees, W. (1996). *Our Ecological Footprint: Reducing Human Impact on the Earth*. Philadelphia: New Society Publishers.

Weber, C. L. & Matthews, H. S. (2008). Food-Miles and the Relative Climate Impacts of Food Choices in the United States. *Environmental Science & Technology*, *42*(10), 3508–3513. https://doi.org/10.1021/es702969f

Weisz, H. & Steinberger, J. K. (2010). Reducing energy and material flows in cities. *Current Opinion in Environmental Sustainability*, *2*(3), 185–192. https://doi.org/10.1016/j.cosust.2010.05.010

Wolman, A. (1965). The metabolism of cities. *Scientific American*, 213, 179–190.

Yeheyis, M., Hewage, K., Alam, M. S., Eskicioglu, C., & Sadiq, R. (2013). An overview of construction and demolition waste management in Canada: a lifecycle analysis approach to sustainability. *Clean Technologies and Environmental Policy*, *15*(1), 81–91. https://doi.org/10.1007/s10098-012-0481-6