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► **To cite this version:**

Olivier Coutard, Daniel Florentin. Resource Ecologies, Urban Metabolisms, and the Provision of Essential Services. *Journal of Urban Technology*, 2022, pp.1 - 10. 10.1080/10630732.2021.2001718 . hal-03522547

HAL Id: hal-03522547

<https://hal.science/hal-03522547>

Submitted on 12 Jan 2022

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Resource ecologies, urban metabolisms and the provision of essential services

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To cite this article: Olivier Coutard & Daniel Florentin (2022): Resource Ecologies, Urban Metabolisms, and the Provision of Essential Services, Journal of Urban Technology, DOI: 10.1080/10630732.2021.2001718

To link to this article: <https://doi.org/10.1080/10630732.2021.2001718>

Abstract

This short commentary starts from the observation that, until recently, most research addressing infrastructures within urban studies has largely downplayed crucial environmental resource issues. While urban and broader inequalities in and through the distribution of resource *flows* have been examined, especially within an urban political ecology perspective, other issues, fundamentally associated with resource qualitative and quantitative *limitations*, largely haven't. We therefore argue in this paper that resource issues, broadly construed, can and indeed should be explicitly addressed within an extended conceptualization of (urban) metabolisms. This leads us to re-envisage the frameworks through which urban infrastructures and the provision of essential services should be analysed. We thus advocate for an update of the urban political ecology agenda that brings resource issues, in their material, political and spatial dimensions, to the centre of scientific attention.*

Keywords

Infrastructure, essential services, resources, metabolism, splintering urbanism

In this short piece, we argue that taking into account the environmental resources issues associated with the provision of essential services ultimately invites us to revisit the legacy of the “modern infrastructural ideal” and reassess alternative sociotechnical configurations of provision of those services.

Resource issues have so far largely been neglected in infrastructure studies. Admittedly, research referring to the metaphor of urban metabolism (within or without a Marxist perspective) (Castan-Broto et al., 2012) has explored power issues around the circulation, and uneven distribution, of (natural) resources through infrastructure and other technological systems, mainly from an urban political economy perspective. But little work has addressed the issues associated with resource extraction and depletion, transformation and degradation, as well as waste disposal and dissemination and the deterioration of the environment (climate, atmosphere, soils, water...) associated with these processes – in other words acknowledging and

* We wish to thank JUT's two anonymous referees for their constructive comments, which helped us clarify the core argument of this short 'commentary'.

exploring the consequences of the fact that resources (broadly construed) are limited. This disembods services from resources and disregards what can be either called planetary boundaries (see Rockström or Steffen) or a resource-sensitive metabolic approach. As argued by some scholars in territorial ecology, this neglect of the *materiality* (both in terms of quality and quantity) of resources – or ‘technomass’ (Inostroza and Zepp, 2020) – involved in urban metabolism has resulted in major shortfalls. So-called nexus approaches fostering an integrated approach of water-food-energy systems, for example, omit the second largest urban material flow, i.e. construction materials, with major implications from an ecosystem perspective (Barles, 2017).

In this article, we first argue for a more resource-sensitive ‘metabolic turn’ in infrastructure studies (1) and discuss some implications of one such shift towards the integration of resource issues into the analysis of essential urban services. This translates into a discussion of the decoupling of resource use and service provision (2). The paper concludes with some suggestions for a tentative research agenda in infrastructure studies centred around resources and the commons (3).

1. Infrastructures and the environment: the call for a resource-sensitive metabolic turn in infrastructure studies

Some historians of technology and historians of the (urban) environment were the first to emphasize and explore the connections between the development of infrastructure systems and the production, reproduction or transformation of local environments, in terms of resource availability and use, waste generation, local and remote pollution, and impact on landscapes (see, e.g., Cronon 1991, Tarr 1996, Melosi 2008).

Research on material concerns and urban metabolism have upsurged ever since (Dijst *et al.*, 2018), remaining however fairly siloed between two lines of analysis of the material nature of the urban: politically critical work on resource flows from an urban political ecology perspective (Swyngedouw 1996, Heynen *et al.* 2006, Heynen 2014), and ecosystemic approaches inspired by the Vienna School documenting flows and stocks of materials and seeking to ‘optimize’ metabolisms, but remaining largely acritical (see, e.g., Erkman 2004).

Some authors have dissected the political dimensions of natural resources management (Swyngedouw, 2015, March, 2015) or the “co-evolutionary dynamics between social and technological systems extending from the private spaces of the modern home to the largely hidden physical infrastructures which have enabled the modern city to function” (Gandy, 2004, p. 365). Yet little research has really embraced at the same level the sociopolitical and the material dimensions of infrastructures, thus downplaying the qualitative and quantitative resource issues associated with the provision of infrastructure services — even, we dare say, in urban political ecology.

In the context of growing concerns around resources coming increasingly under pressure, it seems highly desirable to relate more closely service provision to resource management. For example, in a paper exploring water supply and sanitation in Rio de Janeiro, Barraqué and Formiga (2014) show that a disconnected apprehension of water services and resource management had resulted in contradictory management decisions and major issues of pollution and floods which eventually deteriorated both the water supply service and the water resource.

In accord with this perspective, we consider that the articulation of resources and services will allow to better understand and address the metabolic crises that our predominantly urban societies are experiencing. This is valid not only for the analysis of water supply and wastewater management, but also for energy supply, for waste management (Florentin, 2019), for pollution management, and for the use of energy and materials in all infrastructure sectors (consider energy consumption and greenhouse gas emissions in transportation or digital infrastructures and services). This approach is also needed to further investigate the more indirect processes by which the development of infrastructure has historically supported an unsustainable use of non-renewable resources.

As key tools for the catchment and transformation of resources, infrastructure systems are central in the study of the metabolism of cities and, more generally, of societies. Though metabolic studies have already experienced a seemingly important development, they remained insufficiently cross-disciplinary (in broad terms between the quantification of fluxes and analyses of unequal access to infrastructure services), hence failing to fully articulate measures of resource flows (and stocks) and concerns about their governance. A more resource-sensitive *metabolic turn* in (urban) infrastructure studies is thus needed, in which service provision and resource transformation are analysed jointly; and in particular in which pressures on resources and their implications on the organization of service provision, are explicitly addressed. This would help surpass the dichotomy emphasized by Loftus “between the site-focused analysis of material cultural ecology on the one hand and acknowledgement of the site’s connections to increasingly global scales of economic and political organisation on the other” (Loftus, 2020, p.140).

2. Decoupling service provision from resource use: a persistent bias

Resource efficiency is increasingly acknowledged as a key challenge by ecological modernisers and other promoters of green growth, who put forward two main responses (and sometimes combine them): smart infrastructures and “infrastructural symbioses”. But available evidence suggests that neither of these approaches really challenges the dominant, resource-intensive model.

The deceits of smart infrastructure

“Smartification” is often presented as a way to provide similar or enhanced services while using a similar or reduced amount of resources. The argument spans from the smart tap which only provides water when it detects the presence of hands to wash, to smart grids allowing to “optimally” combine all sorts of (obviously renewable and low-carbon) sources of energy in the same energy supply system. Hence smart infrastructures are expected (and promoted) to both avoid resource waste and “optimize” resource sharing.

Both parts of this statement require critical scrutiny however. On the one hand, the development of so-called smart technologies comes at a substantial and often underestimated (or altogether ignored) material cost (in terms of energy resources as well as rare earths and other non- or little-renewable energy, as well as in terms of unrecyclable waste and pervasive pollution generated by electronic waste). In addition, expected energy savings are often rapidly cancelled out by additional use in an unsurprising manifestation of the Jevons paradox. Recent works such

as the survey developed by the Shift Project (2018) around the energy and environmental impact of ICT use worldwide have shown in particular that energy use linked to ICT is verging on the worst-case scenarios outlined by researchers such as Andrae and Edler (2015), with a 10% annual increase of primary energy use due to ICT, which is thus expected to use two to three times more energy in 2025 than in 2015.

The algorithmic mutualisation of various types of resources, on the other hand, contributes to the invisibilization of resource issues, in accordance with a long tradition in the governance of infrastructure (as thoroughly documented by Lopez, 2019), when on the contrary they should be actively visibilized and explicitly debated as they become a major political and social welfare issue and should therefore be handled as such.

The limitations of ‘infrastructural symbioses’

The recent proliferation of narratives, discourses and research on the circular economy underlines the immense and still largely unsolved challenges of decoupling (urban) activities from resource uses (Haberl *et al.*, 2017). Indeed, large infrastructural systems have historically contributed to the production and reproduction of a certain socioecological order, resting primarily on an “unequal environmental exchange” (Bonneuil and Fressoz, 2013) which is at the core of the dominant regime of accumulation and which remains largely growth-oriented and unsustainable from a resource perspective. This has led some authors to qualify these systems as “infrastructures of Capitalocene” (Haraway, 2015, Lopez, 2019).

The principles of circular economy are undeniably ‘virtuous’ from a resource perspective. Yet most of the initiatives claiming to promote a more circular urban economy do not fully comply with these principles, nor do they produce significant effects (see the recent extensive literature review by Wiedenhofer *et al.*, 2020 and Haberl *et al.*, 2020). A focus on resources, then, helps develop a critical framework on the real magnitude of these transformations and their socioecological effects. Flipo (2017), for example, shows the substantial challenge of combining digital and ecological transition. This echoes the proposal made by Arnsperger and Bourg (2017) and aimed at ensuring the long-term preservation of the human habitability of the planet at different scales. The two authors argue that this requires to depart from a locally-circumscribed circular economy approach typically based on, e.g., the so-called “5 R” approach (reduce, repair, reuse, remake, recycle) in manufacturing processes, which often neglects effects on resources at different (larger) scales. This approach, they argue, should be replaced by the development of a global (macroeconomic and macro-societal) “permacircular society” promoting a restrained and frugal use of resources, compatible with global environmental and resource constraints, and additionally involving the regeneration of resources and milieus. Even in symbioses seeking to take advantage of complementarities between infrastructure sectors (as typically in waste-to-energy schemes), large infrastructure systems have clearly not (yet?) reached the stage of permacircularity.

A resource-sensitive metabolic approach will help characterise the difficulties encountered by both smart systems and symbiotic experiments to tackle the local *and global* boundaries of our resource systems. It may also help question on new terms the scales and institutional assemblages of infrastructure management, thus contributing to shape a research agenda within infrastructure studies that better articulates resource and service issues.

3. Rescaling infrastructure? From a state-centric to a commons perspective

The hidden costs of the “modern infrastructural ideal”

Research on urban infrastructures has often emphasized, or focused on, the advantages of large, centralized, homogenous technological systems. In *Splintering Urbanism*, for example, Graham and Marvin refer to “a set of practices (...) developed [into the 1960s in industrialized countries] to ensure the rapid roll-out of standardised infrastructure at equal price across national economic space” (p. 80). They analyse the destabilization of this “modern infrastructural ideal” as a sign of urban fragmentation and hence as a socio-spatially regressive process.

The hypothesized socio-spatial processes and dynamics underlying “splintering urbanism” have generated considerable discussions (Coutard 2008). A more resource-sensitive approach of the urban suggests a complementary line of discussion. In particular, it leads to questioning the central assumption that, insofar as the provision of essential services for the needs of everyday life is concerned, any increase in social differentiation between groups of users or in spatial differentiation on a local scale is necessarily socially regressive. From a metabolic point of view, there are in fact “hidden costs” associated with the modern infrastructural ideal: prevalence of end-of-pipe solutions to issues of resource availability or quality; lesser ability to value local “endogenous” resources (Hourcade and Colombier, 1989); promotion of modes of industrial and urban/territorial development indifferent to (local) resources; invisibilization of the resource (inter)dependencies between more or less remote spaces. Within this resource-sensitive approach, a more locally-differentiated infrastructure is not necessarily socially regressive per se.

Relocalizing infrastructure? From metabolic to political local autonomy, and back

On a political level, closer attention to local resources reinforces calls for local (political) autonomy, i.e. notions of self-organization and self-administration on local institutional and sometimes even civic or ‘community’ levels. This political-metabolic perspective on resources points to the need to articulate three (fundamentally interdependent and intertwined) dimensions when examining the organization of essential service provision either from an analytical or from a normative perspective (Lopez et al. 2019):

1. (relevant) spaces and scales of metabolic interdependencies, joint reliance on common resources and self-sufficiency;
2. (relevant) forms, spaces and scales of social solidarity;
3. (relevant) spaces and scales of self-organization, self-administration and political autonomy.

Calls for increased local self-sufficiency proliferate, sometimes as injunctions by higher-tier institutions but more often as an aspiration of local communities seeking to rely more on local resources or resisting the catchment or appropriation of local resources by distant groups, interests or activities. From an analytical perspective, the articulation of these three dimensions is therefore essential to fully account for contemporary urban changes and critically analyse

their degree of compatibility with the environmental challenges of our time. This should help identify the types of territorialization at play in service provision and assess to what extent "resource frugality" is embedded in the service provision scheme. One such assemblage will delineate the features of a new (socio-) ecological modernity, probably quite distant from the modern infrastructural ideal depicted and invoked by Graham and Marvin but not necessarily less progressive.

We do not wish, however, to "eco-romanticize the local" and frame it as a panacea to the impasses of Capitalocenic infrastructure. Indeed, a focus on territorial metabolism also helps reveal the interdependencies linking that given territory with others from a resource perspective, and the potential tensions between spaces or scales associated with these interdependencies. Rather, we would like to emphasise how the converging effects of rising ecological concerns and the relative weakening of national welfare state institutions may contribute to a redefinition of territorial solidarities: all this calls for a renewed attention on the assemblages, technical solidarities and regulations that are emerging from this. From a more normative perspective, it could be argued that the "relocalization" of metabolism may prove very effective in visibilizing resource use hence fostering wider "resource awareness" among decision-makers and the population.

Territorial biocapacities

A metabolic approach documenting the resource flows necessary for a territory to function (Fischer-Kowalski, 1998) – and hence reflecting the complex relationship between biophysical and social processes (Gandy, 2004) – reveals that urban territories remain largely 'heterotrophic', i.e. dependent upon external territories, and often deteriorate, or even destroy, unsustainably large amounts of limited resources (Odum, 1989; Barles, 2010). This dependency makes urban spaces highly vulnerable socio-politically and in terms of resource availability.

Recent research has shown that the supply of a city like Paris in food, energy and materials was almost entirely externalised with only marginal local provision and loops of recycling (Barles, 2015); and that a dysfunction of less than a week in the food supply system would result in a complete disruption in food provision for the entire city (Bognon, 2015). These still predominantly linear, and intensifying, metabolic flows are a powerful potential factor of contemporary and future urban crises. The governance of these flows from the perspective of the resources they rely upon or tap into thus stands out as a crucial issue in a contemporary urban political ecology research agenda. This requires both to measure these metabolisms and to shift from a focus on the technical materiality of infrastructures to a focus on the fluxes (Bognon et al., 2020) and stocks (Haberl et al., 2017) of resources these infrastructures transform and carry.

Commons

The resources used by infrastructure systems providing essential services can be viewed as common pool resources (Ostrom 1990): each user taps into a limited overall amount of resource or contributes to deteriorating the environment through the degradation of the resource, the production of waste or the direct or indirect emission of pollutants (notion of subtractibility of

use); and, because they are essential services, excluding potential users is generally undesirable (non-excludability).

Apprehending essential services in terms of common pool resources renews how we define their social value and suggest exploring the possibility of providing for such services based on local arrangements rather than direct and exclusive control from the state. It allows to account for, and make sense of, emerging civic or community-based organizations and configurations of (non-state) collective action aiming at the provision of essential services. And it helps scholars focus on actually existing configurations of supply, access and use; and address questions of efficiency, sustainability, legitimacy in the extraction, production, transformation, distribution and deterioration or preservation of common pool resources associated with these configurations.

The design of just and lasting configurations of collective provision of essential services ultimately raises the issue of the (re)constitution of a common world – or common worlds on various scales – i.e., a world simultaneously and inseparably understood as a political arena and as a living environment whose protagonists agree to share a common destiny (Coutard et al, 2020). Obviously, it also renews issues of sociospatial and metabolic solidarity on larger scales (regional, national, world regional, global).

Epilogue

A resource-sensitive metabolic approach of the urban thus raises a large number of research issues that need to be explored in order to embody this *aggiornamento* of urban political ecology and to embrace the different facets of the socioecological challenges of our times. One such research agenda would for instance pay more attention to the social and material appropriation, circulation and transformation of urban resources, opening critical questions on the regulation and governance of matters in the city and urban region.

The resource-service conundrum which is at the core of the metabolic crises we have briefly evoked can also be interpreted as a call for a renewed attention to practices, policies and discourses on care for infrastructures and on management of existing infrastructures instead of focusing primarily or solely on new developments. Practices and strategies of care applied to urban infrastructures are not necessarily preservationist resource-wise, but are essentially resource-focused. As such, they are interesting loci of tensions and (re-)articulations between the preservation and upkeep of old Capitalocenic infrastructures, the limitations of the material footprint of these systems and possible development of less intensive energy and material systems. This largely echoes the development of maintenance studies (Denis and Pontille, 2017; Denis and Florentin, 2019; Ureta, 2014), which lie at the articulation between service and resource management.

All this implies connecting traditional urban political ecology more strongly to territorial ecology, and therefore rematerializing the question of urban governance not only in relation with the technological (inert) materiality of infrastructures and the built environment, but also with the stocks and flows of partly non-renewable resources sustaining the urban — and more generally the human — condition.

Olivier Coutard & Daniel Florentin (2022): Resource Ecologies, Urban Metabolisms, and the Provision of Essential Services, *Journal of Urban Technology*, DOI: 10.1080/10630732.2021.2001718

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References

- Arnsperger C. and Bourg D., (2017) *Ecologie intégrale. Pour une société permacirculaire*, Paris, PUF.
- Barles S. (2017) « Écologie territoriale et métabolisme urbain : quelques enjeux de la transition socioécologique », *Revue d'Économie Régionale & Urbaine*, 5, p. 819-836.
- Barles S. (2015) “The main characteristics of urban socioecological trajectories: Paris (France) from the 18th to the 20th century”, *Ecological Economics*, 118: 177-185.
- Barles S. (2010) “Society, energy and materials: the contribution of urban metabolism studies to sustainable urban development issues”, *Journal of Environmental Planning and Management*, 53(4): 439-455.
- Barraqué B. and Formiga-Johnsson R.M. (2014) “Water governance in megacities: innovation facing the techno-political hurdle”, *A Planet for life*. p. 293-298.
- Bognon S. (2015), “Nourrir Paris: trajectoire de l’approvisionnement alimentaire de la métropole capitale, de la fin de l’Ancien Régime à nos jours”, *Géocarrefour*, 90(2):163-171.
- Bognon S., L'Her G. and Lejoux P. (2020), “De la ville des réseaux à la ville des flux. Enjeux techniques, sociaux et politiques d’une appréhension de l’urbain par les flux”, in Adisson et al. (eds.) *Pour la recherche urbaine*, Paris, CNRS Editions.
- Bonneuil C. and Fressoz J.B. (2015) *The Shock of the Anthropocene: The Earth, History and Us*, Verso, London
- Castan-Broto V., Allen A. and Rapoport E. (2012) “Interdisciplinary Perspectives on Urban Metabolism”, *Journal of Industrial Ecology*, 16(6), p. 851-861. Coutard O. (2008) “Placing Splintering Urbanism”, *Geoforum* 39(6), p. 1815–1820.

Olivier Coutard & Daniel Florentin (2022): Resource Ecologies, Urban Metabolisms, and the Provision of Essential Services, *Journal of Urban Technology*, DOI: 10.1080/10630732.2021.2001718

Coutard O. (2008) 'Placing Splintering Urbanism', special issue of *Geoforum* 39(6): 1815-1950.

Coutard O. and Lévy J.P., eds. (2010) *Écologies urbaines*, Paris, Anthropos.

Coutard O., Audren G., Nafaa N. (2020) "Services essentiels de la vie quotidienne : questions prospectives sur une fabrique étatique de la condition urbaine", in Adisson et al., *Pour la recherche urbaine*, CNRS Editions. p. 205-225.

Cronon W. (1991) *Nature's Metropolis: Chicago and the Great West*, New York: W. W. Norton.

Denis J. and Florentin D. (2019) "Overlooked pasts and fragile futures: the age of infrastructure maintenance", paper presented at the conference *Infrastructural futures across cities of the global north*, Sep 2019, Manchester

Denis J. and Pontille D. (2015). "Material Ordering and the Care of Things", *Science, Technology, & Human Values*, 40(3): 338–367.

Dijst M, Worrel E, Böcker L and Brunner P. (2018) "Exploring urban metabolism—Towards an interdisciplinary perspective", *Resources, Conservation and Recycling*, 132: 190-203.

Fischer-Kowalski M. (1998) "Society's Metabolism. The intellectual history of material flow analysis", *Journal of Industrial Ecology*: 61-136

Fliipo F. (2017) "Peut-on croire aux TIC vertes ?", *Annales des Mines - Responsabilité et environnement*, 87(3), 105-107.

Florentin D. (2019) "From multi-utility to cross-utilities: the challenges of cross-sectoral entrepreneurial strategies in a German city", *Urban Studies*, 56 (11): 2242-2260.

Gandy M. (2004), "Rethinking urban metabolism: Water, space and the modern city", *City* 8 (3): 363-379.

Haberl H., Wiedenhofer, D, Virág, D et al. (2020) "A systematic review of the evidence on decoupling of GDP, resource use and GHG emissions, part II: synthesizing the insights", *Environmental Research Letters*, <https://doi.org/10.1088/1748-9326/ab842a>

Haberl H., Wiedenhofer D., Erb K.H., Görg C., Krausmann F. (2017) "The Material Stock-Flow-Service Nexus: A New Approach for Tackling the Decoupling Conundrum", *Sustainability*, 9 (7): 1049-1067.

Haraway D. (2015) "Anthropocene, Capitalocene, Plantationocene, Chthulucene: Making Kin", *Environmental Humanities* vol. 6: 159-165.

Heynen N., Kaika M. and Swyngedouw E., eds (2006) *In the Nature of Cities: Urban Political Ecology and the Politics of Urban Metabolism*, Routledge, London. 271 p.

Heynen, N. (2014) "Urban political ecology I: the urban century," *Progress in Human Geography* 38(4), 598-604.

Inostroza L. and Zepp H. (2020) "The metabolic urban network: Urbanisation as hierarchically ordered space of flows", *Cities*, DOI: 10.1016/j.cities.2020.103029

Loftus A. (2020) "Political ecology II: Wither the State?", *Progress in Human Geography* 44(1) 139-149.

Olivier Coutard & Daniel Florentin (2022): Resource Ecologies, Urban Metabolisms, and the Provision of Essential Services, *Journal of Urban Technology*, DOI: 10.1080/10630732.2021.2001718

March H. (2015) “Taming, controlling and metabolizing flows: Water and the urbanization process of Barcelona and Madrid (1850–2012)”, *European Urban and Regional Studies* 22(4): 350–367.

Lopez F. (2019) *L'ordre électrique*, Genève, Métis Presses.

Melosi, M. V. (2008) *The Sanitary City. Environmental Services in Urban America from Colonial Times to the Present*, University of Pittsburgh Press.

Odum E.P. (1989), *Ecology and our endangered life-support systems*, Sinauer Associates Inc.

Swyngedouw E (1996) The city as a hybrid: On nature, society and cyborg urbanization. *Capitalism Nature Socialism* 7(2): 65–80.

Swyngedouw E. (2015) *Liquid Power: Contested Hydro-Modernities in Twentieth-Century Spain*. Cambridge, MA: MIT Press.

Tarr, Joel A. (1996) *The Search for the Ultimate Sink: Urban Pollution in Historical Perspective*. Ohio: University of Akron Press.

Ureta S. (2014) “Normalizing Transantiago: On the Challenges (and Limits) of Repairing Infrastructures”, *Social Studies of Science* 44(3): 368–392.

Wiedenhofer D, Virág D, Kalt G et al. (2020) “A systematic review of the evidence on decoupling of GDP, resource use and GHG emissions, part I: bibliometric and conceptual mapping”, *Environmental Research Letters*, <https://doi.org/10.1088/1748-9326/ab8429>