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# **Urban infrastructures, metabolic resource flows and the contradictions of circular economy ‘solutions’ in Nantes and Gothenburg**

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## **Abstract**

Urban infrastructures, as socio-technical systems that transform metabolic flows, are a key focus for efforts at initiating a more circular economy of resource use and waste recovery. Beyond exemplar discourses and claims, an infrastructure-mediated understanding of and focus on actually existing circularity projects attends to the diverse array of components, sites and exchanges through which transformative socio-technical change is envisaged, enacted and challenged. The paper uses in-depth studies of circularity infrastructure initiatives in Nantes (France) and Gothenburg (Sweden) that involve a range of public and private stakeholders. We focus on the contradictions and tensions in these initiatives to draw attention to circularity as a material and political process of relocalising resource use while spatially expanding resource networks. We show how this process involves reworking large-scale infrastructure while nurturing community-level initiatives of the foundational economy, and thereby shaping urban futures through reuse and recycled flows but with a view to sustaining economic growth strategies. We argue that the materialist and productivist logic underpinning the urban infrastructures of the circular economy largely serves to aggravate the underlying fundamental systemic concerns that circularity was supposed to address in the first place.

## **Keywords**

Urban metabolism, Circular economy + Foundational economy; Metabolic flows; Urban infrastructure

## **1. Introduction**

The emergence of circular economy concepts and initiatives – broadly concerned with closing the loop in resource provision and waste removal to promote reuse of finite resources (Bolger and Doyon, 2019; Williams, 2019) – is in some ways a response to the limits of the large technical system of globalization. Indeed, these vast, interconnected infrastructures are calibrated to circulate people, goods, services and resources ever faster, in greater quantities and over longer distances. The outcome of this system has been an increasingly linear and externalized ‘socio-ecological regime’ (Barles, 2017) based on an ‘extract - consume - eliminate’ logic that is totally at odds with any notion of sustainability or planetary limits. Cities have been able to use and constantly extend their hinterlands of resource provision and waste discharge to support their development (Arboleda, 2016; Krausmann, 2013). Efforts to relocalise resource use and recycle urban metabolic flows, the material and energy inputs and outputs that are processed in the functioning of cities, disrupt to some extent this logic, notably by building on the capacity of some local authorities to develop more sustainable resource management (Bolger and Doyon, 2019; Williams, 2019). Nevertheless, it remains an open question as to whether a turn to circularity, i.e. the principles of the circular economy, can constitute a meaningful, systemic urban infrastructure solution producing potentially transformative change.

Recent policy documents from organisations at different scales (e.g. (European Commission et al., 2022; Ministère de l’Ecologie (France), 2019) and normative studies in industrial ecology especially have lauded the tremendous potential of circularity for more efficient management of resources and waste across all levels of society and the economy (Ghisellini et al., 2016). More generally, circularity has become a frame of reference among many actors, whether public or private, profit-making or associative, in favour of environmental protection or the development of the green economy (Kirchherr et al., 2017).

This leads to a question of how such diverse groups and interests can be brought together by ‘circularity’, and whether, why, and for whom in fact ‘circularity’ works, or can be made to work, in distinct ways. The emergence of circularity on the agenda of urban policies is currently driven by a largely technocentric and management focus, without much reflection on these socio-political issues (Bassens et al., 2020; Corvellec et al., 2022). It is a question of orienting the debates on industrial changes to create new material loops and new technological innovations, without calling into question the expanding use of resources. The more critical literature focuses in particular on the depoliticization of the circular economy and how its technoscientific representations thus reinforce an eco-modernist agenda (Corvellec et al., 2022; Gregson et al., 2015). Circularity becomes a mode of justification of the neoliberal economy by allowing the latter to value the negative hazards of economic growth without political appropriation (Bolger and Doyon, 2019; Flynn and Hacking, 2019; Hobson, 2016).

Less attention has been paid, however, to the wider role and environmental contribution of urban infrastructures in the circular economy of cities, ignoring the substantial quantities of materials that are stored in infrastructures, and their central role in the circulation of resources. Some of the normative literature implicitly views the technological optimisation of these systems as capable of solving urban sustainability problems (see e.g. Ghisellini et al., 2016; Kirchherr et al., 2017), while more nuanced approaches tend to focus on the socio-political prospects and values of circular economy visions and practices. In both cases though, there is little consideration in literature, as mentioned in Korhonen et al. (2018) of the actual material (re)configurations through which any circularity efforts must inherently come about. Whatever version of circularity is proposed, it is invariably and necessarily initiated, at least partially, through the socio-technical systems of a city for water and energy provision, waste removal, etc. It is therefore crucially important to understand

how the infrastructures of urban metabolism are questioned, renewed or consolidated by emerging urban circularity agendas and initiatives.

This paper contributes then to our understanding of emerging urban circularity policies and initiatives by focusing on their infrastructural rationales, modalities and implications. We do this in order to study in particular the variety of actors and interests that ‘circularity’ draws together, and the transformative potential of urban circularity ‘solutions’. The paper is structured in five further sections. We continue in section 2 by discussing existing work on urban circularity and tracing how a closer focus on the infrastructures of circularity can help to unpack the materiality and politics of initiatives and projects. Circularity objectives come up against existing infrastructure configurations that can prove difficult to change. In refocusing attention on fundamental issues of access to resources and services, other work invokes a different notion of change as emerging in more situated, local infrastructure initiatives. The methodology underpinning the paper and its results is discussed in section 3. In section 4, we explore the development and contested mainstreaming of urban circularity policies in Nantes and Gothenburg and highlight the varied forms and roles of circularity infrastructures in effecting urban transformation. Section 5 analyses the case studies in relation to wider questions of the socio-political significance, material enactment and transformative potential of urban circularity. Finally, the conclusion sums up the argument and suggests some avenues for further research.

## **2. Engaging the reworking of infrastructures for urban circularity**

At the urban scale, the application of the circular economy has been criticized as being inadequate and posing many difficulties (Hobson, 2016; Williams, 2019). It is often reduced to a question of implementing circular economic models technically at the scale of the city,

constituting a “spatial fix” for sustaining economic growth even in the face of growing environmental challenges (Bassens et al., 2020). By developing initiatives that re-use material and energy flows already present in cities, urban actors claim to be reducing their territories’ dependence on external supply chains and infrastructure production systems and creating local autonomy to manage or govern urban flows. Yet, work in urban studies, from planetary urbanisation to urban metabolism studies, constantly draws attention to the continuous exchange of materials and energy between cities and their environments that sustains urban operations and urban life (see e.g. contributions to Angelo and Wachsmuth, 2020). Urban resources circulate at different scales, especially in the global economic system, which is ignored in the common conceptualisation of circular cities (Williams, 2019). Closer attention needs to be paid to the systems and networks through which this circulation takes place and is intended to be made more ‘efficient’, relocalised, etc.

As argued more generally in this special issue, it is here that a focus on urban infrastructures can prove pertinent. Urban infrastructures are central to the construction of imaginaries and enactments of sustainable futures of resource-efficient, circular or resilient cities (Gandy, 2014; Kaika and Swyngedouw, 2000; Moss, 2020; Rutherford, 2020; Tzaninis et al., 2021), and the modernisation of metabolic infrastructures, where flows are transformed from one state or function to another, is no exception. Meilinger and Monstadt (2022) have, for example, demonstrated that circular economy narratives in Los Angeles have made their way into supporting promising technical solutions in engineering debates and practices. At the same time, they constitute interrelated sociotechnical systems providing essential services to enable, maintain or improve living conditions in cities. In keeping with the approach of this special issue, we therefore explore and study infrastructure change through the lens of the emergence of circularity discourses, logics and practices in cities. Williams (2019: 2759) has argued that “A circular city is about a great

deal more than creating a circular economy and circular business models within the urban context”, and we argue in this paper that at least some of this “great deal more” can be revealed through attention to infrastructure reconfigurations.

As physical and/or digital networks that enable flows and exchanges of goods, people and resources, these systems are intrinsic to urban circularity and not somehow external to, or even just the vector of, circular economy implementation. Indeed, the organisation and functioning of these systems have, in many cases, long sought the kinds of exchanges and efficiencies that ‘circularity’ discourses currently promote: symbioses between systems, infrastructure nexuses such as waste-to-energy, etc. (see for example Monstadt and Coutard, 2019).

But optimising, shifting and transforming existing urban infrastructures requires overcoming their path dependency and embeddedness in urban contexts both in a material/physical and institutional sense (Melosi, 2000; Moss, 2020).<sup>1</sup> They have been historically constituted over time leading to complex infrastructure configurations and ways of doing that emerging new policy thinking such as circularity has difficulty in moving. Longstanding research in urban political ecology, for example, has shown that urban infrastructure plays a major role in the externalisation of urban metabolism (Heynen et al., 2006), i.e. the process of cities ‘outsourcing’ resource provision and discharging waste into ever more distant spaces. This has long been part of the modern urban process of rendering invisible urban metabolic circulation and its infrastructures (Kaika and Swyngedouw, 2000; Tarr, 1996). This dominant, increasingly extensive urban metabolic configuration or ‘operational landscape’ ostensibly weakens the capacity of cities for local

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<sup>1</sup> Infrastructural path dependency broadly captures the notion that specific choices and courses of action taken in the past – about systems and networks and/or their organisations – prove difficult to shift or reverse because of their accumulated ‘weight’ and dominance in society and in the provision of core services and resources.

autonomy (Arboleda, 2016). A key research question is to understand whether and how urban actors increasingly use infrastructure reconfiguration to create room for manoeuvre in management of otherwise heavily embedded and obdurate material and resource flows. Urban circularity may thus be a means to either rework or reaffirm the temporality of urban infrastructure in terms of the constraints of past decisions and pathways.

An infrastructure focus also foregrounds the role of public policy actors and essential often public providers in fostering urban circularity – but also in ensuring access to basic services and infrastructures. Recent work on infrastructure as part of a foundational economy reset is relevant here, notably in reframing away from ambitious systemic overarching goals to addressing socially meaningful and transformative objectives in the everyday lives of local people and groups. Foundational economy writing draws explicit attention to the diverse set of basic infrastructures, resources and services of society that everybody uses/consumes – water, energy, food, transport, health, welfare etc – and that are fundamental to individual and societal well-being (Collective, 2018). A focus on this ‘grounded’ part of the economy, rather than glossy hi-tech innovation and economic competitiveness, so the argument goes, could lead to long-term sustainable benefits for the majority of people – economic development should, in short, be repurposed towards improving material quality of life (Engelen et al., 2017; Morgan, 2022).

This “truly novel” (Hansen, 2022: 1034) approach implies a rethinking of the service or value provided by infrastructure (the transformation and distribution of metabolic resource flows) more in terms of local community benefits and futures than as necessarily part of a big urban transition to a reuse economy based on new technical solutions and innovations. Urban circularity in this sense may be measured through tracing the reuse of resources at quite small scales within the above constraints of the complex shifting of large



urban/regional infrastructure systems onto more virtuous paths of recycling and reuse. As Lekan et al (2021) began to explore, this may open up a space of community-oriented interventions and services for reuse and redistributing resource flows that have the potential to produce tangible social and environmental benefits. A more foundational approach to urban circularity thus draws attention to how the reuse and redistribution of resources is tied to questions of wellbeing and livelihood, which may lead to a foregrounding of different forms or scales of infrastructure.

Beyond all the 'exemplar' discourses and claims around circularity, an infrastructure-mediated understanding of and focus on actually existing circularity policies/projects attends to the diverse array of components, sites, relations and exchanges through which socio-technical change is envisaged, enacted and challenged. The constraints associated with existing system arrangements and the possibilities of alternative infrastructural engagements attuned to the needs of local communities and environments highlight that there is a social and political salience to the development of urban circularity infrastructures. Tracking tensions and struggles over this development can reveal the active role of otherwise often shrouded material networks and resource flows in constituting particular urban configurations.

A final framing element is that circularity must inevitably be seen as part of ongoing reflections on the evolving materiality of cities and urban processes, both in terms of the overall 'weight' and pressure of urban functions and operations on global resources and the spatial distribution of material and resource flows between or across territories. In other words, analysis of changes in the infrastructures of urban metabolism is crucial to thinking further about wider resource and sustainability challenges (Savini, 2023). Indeed, Sabine Barles calls for infrastructures to be used primarily as a tool to reduce material footprints

by fully integrating the problematic of dematerialisation (Barles, 2017; Barles and Bahers, 2019). Circularity practices contribute in theory to optimizing resource efficiency and reuse but they do not seek to reduce the amount of material resources necessary for urban processes. As well as closely tracing how urban circularity strategies draw on, mediate and produce more or less extended networks of resource provision and waste extraction, exploration of whether and how such strategies can go further towards addressing degrowth and dematerialization can be pertinent (see Kaika et al., 2023).

### **3. Methodology**

To develop an infrastructure-mediated understanding of recent urban circularity initiatives and practices, we draw on two in-depth case studies centered on Nantes in France and Gothenburg in Sweden, two medium-sized cities of about 1 million inhabitants, made up of an urban area and an industrial-port area. Many studies of urban metabolism focus on large cities, yet urbanization trends also point to the importance of intermediate or medium-sized cities (Rodríguez-Pose and Griffiths, 2021) that likewise have strong metabolic relationships with their surrounding environments in terms of resource supply and waste disposal (see e.g. Bahers et al., 2019).

Furthermore, these two cities have implemented what are held to be pioneer urban policies on a European level over the last ten years in the sustainability and circular economy domains. Nantes was labelled an 'eco-city' in 2009 by the French government as an exemplary city in terms of sustainable development, and then named 'Green Capital of Europe' in 2013, before organising the 'Climate Chance' in 2016. Gothenburg is also cited as an exemplary city in terms of sustainability, in particular by the GDSI (Global Destination Sustainability Index) which awarded it the prize for the most sustainable city in

the world for 5 years (2016-2021). Both cities are among the ‘100 smart cities towards climate neutrality 2030’ of the European Union (European Commission et al., 2022).

Moreover, recent studies have shown that these two cities are located quite favourably on sustainability and circular economy indicators (Bahers and Rosado, 2023; Kalmykova et al., 2015). These labels and results capture the positive prevailing context of the two cities for urban sustainability policies. Circular economy efforts have involved a range of public and private stakeholders, and a particular focus in both cities on the reconfiguration of urban infrastructures of energy and waste, and the development of community-oriented circularity initiatives in local neighbourhoods.

Our analysis is based on 40 semi-structured interviews carried out between 2018 and 2022 with relevant stakeholders in the two cities, as well as in-depth study of pertinent policy documents, reports and media articles over the period in question. Semi-structured interviews were chosen and then conceived as an optimal means of interrogating the politics of the circular economy in the cities at multiple scales. Interviewees were selected for their roles in the implementation of the circular economy: engineers and managers of urban waste agencies and infrastructures at local, urban and regional scales, representatives of private companies and environmental organisations, and local researchers working on these cities (see Appendix 1). We identified relevant actors first through public reports, then through a snowball effect by asking interviewees to recommend other contacts. This was done with a view to building up a varied panel of interviewees with distinctive expertise on the subject and to obtain as many different points of view as possible. An interview guide was devised with main topics, a series of broad questions, and a range of specific questions that could be adapted to the focus of each interview. The interviews were fully transcribed and their content analyzed, enabling a diachronic analysis of the emergence of circularity policies and infrastructures in the two cities, the actors and

organisations involved, the objectives and challenges of implementing programmes, and the controversies surrounding particular developments and policy orientations.

The interviews were supplemented by analysis of strategic institutional documents and reports to understand the shifting public policy context. These included annual reports by relevant authorities on sustainable development progress, as well as on waste management, circular economy and energy transition objectives and practices. In addition, local researchers with good knowledge of the urban context were interviewed to better understand how circular economy policies have evolved over time.

We now go on to explore the material emergence of urban circularity agendas and practices in the two cities, and to analyse their wider significance, implications and limits as infrastructure ‘solutions’. We discuss each case in turn in the next section, focusing on the emergence of circularity policies and contrasting sets and scales of infrastructure initiatives that cropped up in stakeholder interviews in both cities. In particular, we studied two scales of circular infrastructure: large-scale infrastructure of energy recovery from waste and community and civic initiatives that involve recycling, repair and reuse, which have emerged in both cities, but with different actors, through strategies. We then tease out analytical similarities and dissonances in section 5 that may be more widely relevant in other contexts.

## **4. The emergence of circularity infrastructure solutions in Nantes and Gothenburg**

### **4.1. Circularity and infrastructures in Nantes**

#### *Circularity in action*

The implementation of circularity policies in Nantes originated out of the development of an Agenda 21 in 2004 and its adoption in 2006, following the main principles of sustainable development erected in the 1990s. This Agenda 21 was driven by the deputy-mayor Jean-Marc Ayrault (who later became Prime Minister of France) who wished to “achieve the objective of sustainable, inclusive and controlled development” (editorial for Nantes’s first sustainable development report) (Nantes métropole, 2006). Five years later, a new Agenda 21 was adopted, with a particular priority concerning sustainable economic development and the challenges of “waste as new resources to be mastered” (Nantes métropole, 2006), the beginnings of the circular economy. This strategy led to the rehabilitation of waste collection centres, the collection of bulky items and the development of neighbourhood composters.

Following the implementation of these urban policies, Nantes became the first French city to be Green Capital of Europe in 2013 and has produced “Sustainable Development” reports each year. By continuing to work on the reduction and recovery of waste, policies have notably led to actions aimed at eliminating all waste and illegal dumping in public spaces, the organisation of events intended to promote local initiatives on food waste, and a partnership with the Chamber of Commerce to develop companies specialising in repair. The city also undertook a major urban extension of its heating network between 2013 and 2017 with new boilers supplied by a waste incinerator and wood combustion.

But it was especially national government funding for a ‘Zero waste territory’ project in 2017 which allowed the city to develop a ‘Circular Economy Action Plan’, and which in turn led to the development of a CE roadmap adopted in October 2018 (Nantes métropole, 2020) by the vice-president of the Nantes region in charge of waste and the circular economy. This roadmap outlined objectives for increasing the composting of

organic matter, repair of small electrical equipment of the inhabitants and recycling of local construction waste (Nantes métropole, 2018a). A 4-hectare former industrial wasteland area owned by the port of Nantes-Saint-Nazaire was transformed into a new industrial platform for recycling and recovery in 2020. According to the industrial group Suez that owns the recycling platform, this project “is fully in line with Nantes Métropole's circular economy roadmap with a very large capacity to receive construction waste that can be transformed into new resources through recycling or energy production” (Interview 11). This urban solution requires substantial private investment (6.6 million euros) by the group, to create economies of scale by industrially treating massive quantities of waste. For all these actions, the Nantes city-region received the circular economy label from the French Ecological Transition Agency (ADEME) in 2021.

The circular economy agenda in Nantes is therefore perceived by some players as a lever for the economic development of new infrastructural solutions. This is confirmed as a justification for the creation of new infrastructures: “before we were in the mono-solution, now the multi-solution” (Interview 10). However, this interest in new infrastructures can create a problem concerning the competition for waste: “but we must be careful that there are not too many projects, too many solutions for not enough waste!” (Interview 11).

These new urban infrastructures of the circular economy must create local economic development above all and therefore fall within a techno-optimistic paradigm: “There is shared interest between the community which wishes to treat its waste and green its energy, and the energy company that wants to green its image and we [the industrialists] who offer a waste gasification solution that is suitable for everyone” (Interview 25). This process involves heating and breaking down organic waste into a synthetic gas that can either be burned for energy or reused as methane or hydrogen. Thus, the circular economy approach

in Nantes is strongly oriented around large infrastructures, and in particular those that transform waste into energy.

### ***Spatial divisions of waste-to-energy infrastructures***

Nantes's circularity policy strongly supports waste-to-energy infrastructure development, in particular through commitment No. 19 of Nantes's wider energy transition strategy, which clearly sets out the objective of “making waste a source of renewable energy” (Nantes métropole, 2018b). As a result, household waste incineration plants, organic waste methanisation plants and boilers using fuel from a mixture of solid waste are all favoured in this context of energy recovery from waste in association with the desired development of district heating networks. In Nantes, these systems were extended by 68 kilometres between 2013 and 2020 to reach a total length of 85 kilometres across more than ten districts of the city. This network is supplied by the incineration plant and by a wood-fired biomass boiler. A new project is being developed to extend it further.

The implementation of these circular infrastructural solutions is carried out through spatial divisions. The resources drawn to supply these waste-energy infrastructures come from sometimes distant territories. For example, the wood-fired biomass boiler that supplies the city's heating network is dependent on wood obtained from up to 150 kilometres away. This translates into tensions between actors, particularly rural ones, in the face of urban infrastructure: “As regards the urban biomass thermal power plant, people are tired of providing the urban middle class with their ecological thermal power plant of which they are so proud. If there were no (rural) territories like us, there would be no biomass.

Besides, this is starting to be very worrying because all the wood resources are running out!” (Interview 18).

The city is also home to Cordemais, one of the last coal-fired power plants in France, which represents a major local energy transition challenge. Indeed, since 2016, the Cordemais plant has begun to be transformed so that it can operate with waste and biomass instead of coal, following the decision of the French government to abandon coal. This major infrastructure (employing approximately 400 direct jobs) is at the centre of the region's economic challenges according to a majority of the actors interviewed and the local press. The coal is supposed to be replaced by a mixture of solid waste, green waste and wood. For this reason, the CEO of the plant had the idea of calling this mix “the new green coal” to respond to the requirements of sustainability. Yet the question of the availability of these resources remains unresolved, as massive volumes would be required for the facility: “Cordemais could siphon off deposits and tilt the market. These are deposits [waste] which tomorrow could become rare!” (Interview 23). Some actors in the renewable energy and waste sectors see the threat of an opposition between a large infrastructure based on an old model, and the relocalised energy circuits which are gradually emerging but which may no longer have enough resources to operate. These new relocalised models include, for example, peri-urban or rural communities that are investing in wood boilers to replace their gas boilers. One industrial actor who collects wood and wood waste explained the incompatibility of having these two types of infrastructure in the area which would put pressure on the resource market: “Cordemais: we try not to interfere, we are neither for nor against... but big projects of this type and local energy circuits do not go in the same direction” (Interview 7).



The Cordemais project seeks to maintain the role of a dominant centralised metabolic infrastructure, which could become a major producer of renewable energy on a wider regional scale, but which would increase the competition for waste. So, while the city-region of Nantes's policy objectives seek "to enable the development of demonstrators of this [circularity] transition" (Nantes métropole, 2018a), these large-scale demonstrators do not profoundly change the materialist and productivist logic of energy production in the city, since they accelerate the pressure on waste resources.

### ***Appropriation of civic circularity infrastructures***

Nantes's urban circularity policy also attempts to promote community and civic initiatives, in particular via "the recycling and repair of small electrical equipment" and "the organic loop from field to plate to field" in the roadmap on the circular economy (Nantes métropole, 2018a). There is a constellation of more civic infrastructure initiatives: around 360 are listed in a map by the "zero waste gallery", a local site that tries to raise awareness of waste and recycling issues ([Galerie du Zéro Déchet, 2024](#)). Such initiatives include repair workshops, second-hand stores, bulk grocery stores, or recycling centres such as 'Environnements-Solidaires', which recuperates old or unwanted furniture in order to furnish apartments for disadvantaged newcomers to Nantes. Actors involved work towards "neighbourhood-level re-use between low-income people" because "here we are doing the circular economy of the inhabitants!" (Interview 14). They have also extended their activities to local composting "to fight against the social injustice of access to the composter at 30 Euros" (Interview 14), by setting up a site for collective composters and a shared garden in the neighbourhood. This association has notably received financial assistance from the Nantes city-region as part of its waste reduction policy.

These associations can also find themselves in a situation of contradiction with regard to the prevention of waste production. Indeed, through their reuse activities, they are constantly faced with paradoxes: “we are in fact in a double discourse: we have to produce less waste, but we need it to make the resource centre live. It is a rebound effect because in a sense we are promoting the production of waste” (Interview 13). It is effectively the same type of pressure on resources as for large waste-energy infrastructures, albeit with very different volumes. However, the significance of this constellation of initiatives is equally derived from their creativity in the type of activities they support and enable. They contribute in particular to increasing the visibility of the challenge of waste and the reappropriation of infrastructures of modest sizes: “we only recover what is reusable, we are not a large disposal infrastructure” (Interview 13).

## **4.2. Circularity and infrastructures in Gothenburg**

### ***Circularity in action***

In Gothenburg the movement towards the circular economy came first from the implementation of the “Strategic Climate Program” in 2006 (Gothenburg, 2006), of which the objective was to reduce the city’s carbon and waste footprint. In 2016, this strategy was renewed and the objective was clearly stated to reduce the quantity of waste produced in the city by 30% by 2030 (Gothenburg, 2017). This program strived to intervene on aspects of household waste (Hult and Larsson, 2016) and repair of household objects (Ordonez and Hagy, 2019; Rask, 2022). This strategy is now part of the framework program “Environment and Climate Program for the City of Gothenburg 2021–2030”, which aims to develop “new climate-smart business models and resource-efficient and non-toxic

products for the circular economy in cooperation with trade, industry and academia” (Gothenburg, 2017).

The Swedish national level has influenced and supported these initiatives for more than 25 years, notably through the early eco-cycle report “Strategy for adapting materials and goods to eco-cycles”, which established the principles of reuse, recycling and recovery for resources extracted from nature. More recently, the “Circular Economy report” of 2017 held that waste was not to be generated and that the value of products, materials and resources should be retained in the economy for as long as possible (Johansson and Henriksson, 2020). Yet, the Swedish Environment Agency (EPA), which establishes national objectives, must rely on Swedish regions and cities to achieve its overall recycling and waste reduction goals (-30% for household waste and -40% for small company waste) (Göteborgsregionen, 2020).

Municipalities are very powerful and have autonomy in the Swedish political system. Like other municipalities, the city council of Gothenburg has voted environmental plans, which they must respect and with quantified targets to be reached, in particular -30% of household waste and -50% of the carbon footprint of the construction and demolition sectors (Gothenburg, 2021). The objectives of the “Circular Gothenburg” project of 2016 were to “drive, coordinate, support and co-create the transition towards a circular economy” in the areas of competence of the city of Gothenburg (Gothenburg, 2021). These areas include both the internal processes of the municipality and the wider activities in the city that help citizens to live in a circular way.

The City of Gothenburg also has responsibility for the management of major infrastructures, in particular those of the waste incinerator connected to a large heat network which supplies 80% of the city. 80% of the heat is produced from the waste

incinerator, which was commissioned in 1972 (Holmquist and Göteborg Energi, 2021). Sweden was a pioneer in promoting energy recovery from incineration. These infrastructures of waste incineration are also structured on the model of municipally-owned waste management companies which have a monopoly on urban waste (Corvellec et al., 2013). Swedish municipalities are therefore very powerful in the area of urban waste infrastructure, because they control the entire waste-energy-heat 'chain'. The context is therefore less dependent on the complexity of actor relations than on the positioning of dominant actors in the sector. The circular economy is seen as a lever for local production with the mission of valuing resources to the maximum. It is thus written in the circularity strategy that "The city of Gothenburg, in collaboration with economic actors, will offer attractive solutions that encourage sustainable consumption. But also encourage economic actors to design and produce more circular products and services" (Gothenburg, 2021). This approach is confirmed in interviews with public actors: "The circular economy is about reusing, recycling, recovering but not reducing. It takes as many resources as possible to circularize! The more the better" (Interview 33). It is therefore less about economy in the sense of saving resources, than about configuring circular production to optimize the use of waste from a metabolic perspective.

### ***Competition over waste resources for energy production***

Large infrastructures are key in Gothenburg for the development of the city's urban circularity policy. The GoBiGas project, for example, is a demonstration of the production of biomethane from organic waste by gasification, which circular economy actors in Gothenburg actively promote. According to the project sponsors, this is the first project in the world to use biogas to fuel vehicles through a collaboration between industry and local

authorities. The project is funded by the municipally-owned energy company Göteborg Energi AB and the Swedish Energy Agency, with the aim of reducing dependence on fossil fuels for automobile mobility in the Gothenburg region. It is in line with the target of the regional planning department for 70% of food waste to be used for organic recycling and biogas production (Göteborgsregionen, 2020).

The development of biogas in Gothenburg also demonstrates the contradictions of enacting circular futures in Sweden. The manager of the regional public agency in charge of the development of biogas argued that the problem is not to replace fossil fuels or to reduce energy consumption, but to find new market shares: “Thanks to SUVs, biogas from waste is on the rise” (Interview 36). According to him, the main determinant of the development of these infrastructures of biogas production is not political or ecological will, but mechanisms linked to the costs of waste and energy: “It all depends on the price of oil. If the price of oil is very high, there are a lot of projects. But now it is low and the projects are blocked!” (Interview 36). In addition, the distance from which organic waste is collected to feed the infrastructure is not really a problem, as it is collected throughout the Västra Götaland region and beyond: “We collect waste up to 100 kilometres away... This circular economy is a green argument, being a pioneer allows you to sell to people concerned with environmental issues” (Interview 36). Rather than the distance of waste collection, the constraint is the access and availability of the waste resource. For the moment, development is slow because waste belongs to the municipalities. Corvellec et al (2013) showed how communities in Sweden are tied in to incinerators by political and institutional lock-ins, such as Swedish regulations that favour the incineration of waste and the municipality's long-term contracts with the industrial operator. These lock-ins imply in particular that local authorities do not want to lose their monopoly status on waste to the benefit of alternatives such as industrial biogas projects. There is therefore competition for

waste resources, between incineration and biogas, for which infrastructure will take over the waste.

In addition, incineration is itself subject to transition. As a result of European waste reduction policies, incinerators lack the waste to supply the furnaces and produce heat for inhabitants. This logic also led the energy recovery project manager in Gothenburg to admit that they are obliged to import waste from across Europe (especially from the UK and Italy) through port logistics and facilities in particular, according to their calorific qualities to supply incinerators: “we import waste for good quality” (Interview 37). Thus, the manager of the municipally-owned waste management company chooses the waste to be imported by controlling its calorific value, and buys it accordingly by forming partnerships with other European cities. Furthermore, the availability of resources to be incinerated is increasingly under tension with the challenges of reducing single-use plastic objects according to European Directive 2019/904: “if Sweden bans plastics, we would have to look for other waste and from further afield to replace it” (Interview 37). Thus, the primary objective is to maintain the productivity of incinerators, as heat networks depend on them. It is important to note too that the construction of heat networks represents a larger investment than the incineration plant (Corvellec et al., 2013).

### ***The challenges of sustaining local circularity initiatives***

Alongside major infrastructures, many citizen-led initiatives have emerged as part of a social and solidarity economy in Gothenburg supported by the “Circular Gothenburg” programme of 2016. There are many open and shared spaces for DIY repair of objects, exchanges and loans, such as the ‘Fixotek’, the ‘bike kitchen’, or ‘freeshop’ in Gothenburg.

The city's goal is that "Gothenburg residents and visitors can easily recycle, share and cook" (Gothenburg, 2021). These initiatives are examples of the participation of residents of all social statuses in neighbourhood repair workshops (Bradley and Persson, 2022; Ordonez and Hagy, 2019). The aim is also to "work on social and economic relations between inhabitants through these experiences" (Interview 29). The city services have also created a "sharing economy" map of these initiatives which promote a low-impact future (Smarta Kartan, 2024). There are also larger facilities outside the city that organise spaces for reuse, donations and recycling and are also the "only place [in the region] to sell second-hand building materials" (Interview 34).

We observe, however, that these promising local circular futures are based on experiments that are not completely sustained over the long term (Zapata Campos and Zapata, 2017; Zapata and Zapata Campos, 2019). The existence of these initiatives makes it possible to build a discourse around new local and circularity infrastructures such as Fixotek, but which are sometimes abandoned over time: "There were five great Fixotek experiences for two years, but only two will remain" (Interview 30). As a researcher who worked on waste prevention in Gothenburg until 2018 put it: "The majority of these [circularity] initiatives have been cancelled. The City has produced its "how to do it" manuals, but they have not found the rationale for extending them more widely" (Interview 40). Indeed, the City has taken back part of its subsidies to these initiatives for other purposes. The lack of support from the City prevents the initiatives from becoming anything more than a temporary solution: "Another example is the 'solidarity fridge' house, which has been a food recovery project for 20 years. This association just needed a space and not a rotten hangar as they were offered. But the City said "we can't help them without helping others too, that's European legislation". But we know that if the City wants to do it, it can do it!" (Interview 35).

In other cases, the divergence of interest between the national and local scales has led to the abandonment of new, more civic-minded infrastructures, such as those of the repair workshops in the districts: “At the beginning it was an NGO which financed the ‘Fixotek’, but it lost its national subsidies. The city said, ‘ok, but you have to zoom out and think bigger’” (Interview 40). Similarly, for the pioneering recycling center of ‘Återbruket’, financial balance is also difficult to find: “We want to give the right price [for second-hand materials], but sometimes we end up lowering prices. Except that we have to ensure our income. And sometimes we give away for free to unburden ourselves (Interview 34). Finally, as this interview confirmed, this can lead to discrepancies between the political support of these initiatives and the concrete contingencies of the financial balances to be found: “the politicians do not realise what they have signed up to with the objectives for a regional Circular Economy” (Interview 29). In conclusion, while these social initiatives are supported in public discourse, they lack material and financial support. It is therefore more a question of drawing attention to bottom-up social infrastructures than of any real attempt at constituting mass waste management tools.

## **5. The limits and contradictions of circularity infrastructures**

The two case studies of Nantes and Gothenburg illustrate some of the tensions and contradictions in the implementation of the circular city. In this section, we discuss the two cases in the light of the questions we posed at the outset around whether and how circularity reworks or is also enrolled into path-dependent infrastructure configurations, the significance of alternate foundational circularity initiatives, and the role of circularity infrastructures in evolving urban metabolism and resource use and distribution. We draw



out three sets of socio-spatial implications of these emerging circular infrastructural capacities and configurations.

In the first instance, strategies of public and private actors in Nantes and Gothenburg in terms of circularity infrastructures are based on an environmental argument aimed at promoting waste as a resource. This logic leads them to develop waste-to-energy infrastructures, particularly those connected to district heating networks. In this process, a mixture of waste is incinerated in boilers to extract heat that then flows through pipes to homes, offices and other buildings, replacing the need for heating through other production methods. It is thus indeed pertinent both economically and materially to recover and re-use waste as part of an urban/regional energy transition (Florentin, 2019; Fontaine and Rocher, 2021). However, through the study of these infrastructures, a double paradox emerges: mutation or creation of infrastructures for the local waste-to-energy sector is accompanied by an increasingly *distant* external supply of this waste, while the whole system relies on *increasing* quantities of resource inputs rather than any decreasing or dematerialisation of metabolic flows. Indeed, urban waste from the immediate territory alone is not nearly enough to supply circularity infrastructures. In Gothenburg, the incineration company collects waste from all over Europe. Likewise, the new infrastructure for the production of biogas from organic waste is supplied from throughout the Västra Götaland region and beyond. In Nantes, the biomass boiler and the incinerator recover waste from well beyond the immediate urban area, but rather on the wider regional scale, even though there are other infrastructures of this type in the wider region.

These are therefore projects that require an organisation of waste collection over long distances, a shift that increases rather than decreases outsourcing of the urban metabolism.

The spatiality of these infrastructures is paradoxical: they are both close to places of

consumption – heating networks benefit the inhabitants of the cities of Nantes and Gothenburg – and far from places of supply. The metabolic processes of externalisation are reversed here: it is not so much a question of exporting waste-as-externality to ever more distant spaces (Barles, 2010; Pincetl et al., 2012), but of importing waste-as-resource from ever more distant spaces to meet the objectives of the urban circular economy. This circularity of waste by urban infrastructures appears incompatible with an ambition to organise urban metabolism within city limits, thereby reinforcing the idea that local autonomy in resource management is largely fictional. Indeed, these infrastructures draw on waste exported from other territories which, in turn, may make it more difficult for these territories to develop their own local resource capacity and autonomy.

Secondly, another important dimension to urban circularity strategies in Nantes and Gothenburg is to promote community-led or bottom-up infrastructures. There are a myriad of activities and approaches across the two cities – re-use and repair workshops, second-hand stores, bulk grocery stores, resource centres, and open and shared spaces for exchanges and sharing – which are identified by institutional or associative maps, and that constitute the opposite of simple urban circular business (Williams, 2019). The urban public actors of Nantes and Gothenburg encourage and promote these initiatives through their grants, communications and space hiring tools. They also help in actively promoting a beneficial discourse on the prevention of waste and material decline.

We can see limits to these forms of local circularity initiative. If the socio-technical change envisaged through these initiatives is significant, the level of actual metabolic transformation is low because these initiatives represent a limited volume of waste flows compared to the large infrastructures discussed above. Public reports and local actors confirm that these are currently only marginal solutions for the treatment of metabolic

flows, with very small budgets. Thus, the urban metabolism of Nantes and Gothenburg is currently only slightly transformed, even if the potential degree of transformation could be greater if initiatives were given more durable support. For the actors involved, these are not so much resource and waste management operations as visible social operations to raise awareness of the material nature of consumption.

These ‘softer’ infrastructural configurations are therefore not necessarily intended to materially transform the urban metabolism, but to make visible possible alternatives, and to refocus attention on the small-scale local foundational infrastructure that communities require most. As in other European cities where they are support mechanisms for the underprivileged (see Lekan et al., 2021)), they are the promise of alternative spaces of circularity, in which circularity is a form of solidarity, reducing inequality of access to repaired and reusable objects. This raises an important issue of whether there can be a productive disconnect in urban circularity strategies between the level or degree of transformation of urban metabolism and the social significance of socio-technical change. Within the constraints of difficulties in shifting obdurate path-dependent systems, perhaps transformative change is more likely to emerge through community-oriented circularity infrastructure that does not necessarily foster large-scale modification in resource flows and urban metabolism but that does meet local needs and desires for more access to a circular economy of re-use and recycled materials.

Third, we might have expected emerging circularity infrastructures in Nantes and Gothenburg to show signs of constituting tools for a reduction of material footprints and addressing the challenges of dematerialisation and degrowth (Barles, 2017). These infrastructures are based, at least in public reports and actor discourses, on the principles of the circular economy by limiting the extraction of resources and the production of waste.

Nantes and Gothenburg circularity infrastructures aim to optimise the recovery of waste, and thus reduce the import and consumption of materials. But despite these efforts of urban policies on material consumption, research shows that the material footprint of these cities continues to increase significantly (see Bahers & Rosado, 2023). This is explained by the fact that the material footprint also takes into account the environmental impacts associated notably with the production of goods and commodities that are then imported into the city. As the material footprint is about twice the size of the material consumption, this means that the majority of the environmental impacts of these cities is located externally. However, urban policies and actors of the circular economy in Nantes and Gothenburg have not so far integrated these finer-grained, complex issues, necessary for attending to dematerialisation, into their strategic reflections.

In sum, these new circularity infrastructures are configured according to an increasing, rather than decreasing, materialist and productivist logic. They aim to produce more and more flows (especially of waste for energy production for heating networks), more readily and in a very centralized manner. They are not designed to reduce consumption levels and address dematerialisation. In both cities, for example, we see an extension of the heating networks and an increase in the level of energy production. While circularity practitioners have to work to a large degree within the constraints of prior infrastructure choices, the objective remains, as has long been the case in urban infrastructure management, to optimise existing technical tools and to create economies of scale. The emerging more foundational circularity of community initiatives can be viewed as part of the same process, whereby reinforcing mainstream infrastructure configurations leads to alternatives forming in other or marginal spaces on smaller scales. There is little policy support for these alternatives and therefore an absence of joined-up circularity thinking and action across levels/scales.

From this viewpoint then, circular urban policies are dominated by prevailing technocentric imaginaries aimed at making circularity infrastructures elements of ecological modernisation rather than any radical shift towards degrowth and dematerialisation. More infrastructures, more flows, and more environmental ‘impact’ – it is therefore likely that these systems are, at the end of the day, largely serving to aggravate the underlying fundamental systemic concerns that circularity was supposed to address in the first place.

## **6. Conclusion**

This paper has focused on the infrastructural rationales, modalities and implications of emerging urban circularity policies and initiatives. Using case studies in Nantes and Gothenburg that highlighted the possibilities but also the tensions and limits of ‘infrastructured’ circularity in practice, we were able to draw attention to circularity as a contradictory process of relocalised resource use and spatially expanded resource networks, of reworking existing large-scale infrastructure and nurturing community-level initiatives, of shaping urban futures through reuse and recycled flows but with a view to sustaining economic growth.

Prime amongst these ongoing tensions is the increasing reliance in ‘nexus’-based infrastructure systems such as waste-to-energy on the transformation of metabolic outputs into new inputs and resource streams. In short, rather than continuing to reproduce a linear metabolism of production – consumption – disposal that sends waste to distant, external sites, or a relocalised circular metabolism in which everything is re-used on a local scale, urban circularity requires the configuration of an infrastructure system for the import of increasingly vast quantities of waste that can serve as a resource for the increased production of energy. This is a very particular form of recycling that does not necessarily

take place on a local level but often on a transnational scale through logistical and port infrastructures for new circulations of waste resources. The circular economy is thus far removed from the issues of overall waste reduction and the dematerialisation of production and consumption systems. We argue that this renewed materialist, productivist and expansionist logic to circularity infrastructures (seeking increased waste inputs from further away) not only goes against their supposed relocalisation of metabolic flows but actually contributes more broadly to increasing ostensibly 'unsustainable' systemic processes and practices that make more difficult the prospect of any switch to a pathway of degrowth.

Our research thereby identifies a key challenge that will require the attention of urban studies scholars, namely how cities and urban actors go about proclaiming and enacting circularity, relocalisation and decreasing or even de-materialisation in, of and through infrastructure systems while endeavouring to capture new resource streams and reconfigure existing large infrastructures for an intensely materialised organisation of urban metabolism and metabolic functioning. We suggest that urban research could therefore usefully focus on at least four areas in order to track these evolving, contradictory dynamics and practices.

First, we will continue to require more quantitative analysis of flows in, through and out of urban areas to provide a firmer knowledge baseline for the articulation of more situated and adapted circularity policies and initiatives. Second, attention will be needed on the shifting economy of circularity, and namely how authorities, providers and companies can work with, benefit from, and distribute the benefits of and creation of value from reduced, or indeed increased, flows and inputs. Third, more research could focus on the forms and implications of foundational circularity infrastructures in local neighbourhoods. In redirecting concern to issues of access to reuse and recycling initiatives for community livelihoods, there is potential for supporting more inclusive, bottom-up circularity practices.

Challenges remain in sustaining and extending support more widely and over time, but these kinds of locally anchored initiatives may prove particularly auspicious in laying the foundations for a degrowth economy. Finally, there is the related question of uneven access to future waste flows and resource streams. Research could usefully continue to track the extent to which global circulations of resources (including waste) are dominated by major urban centres, and perhaps particular areas or districts within these cities that seek eco-exemplarity, which have the capacity to import and pay for these streams. The wider spatial and social implications of a prospective re-centralisation of these resources, i.e. shaped by and for major urban centres, is a crucial question for further exploration.

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