



HAL
open science

Towards a metabolic rift analysis: The case of urban agriculture and organic waste management in Rennes (France)

Jean-Baptiste Bahers, Giulia Giacchè

► To cite this version:

Jean-Baptiste Bahers, Giulia Giacchè. Towards a metabolic rift analysis: The case of urban agriculture and organic waste management in Rennes (France). *Geoforum*, In press, 10.1016/j.geoforum.2018.10.017. hal-01961672

HAL Id: hal-01961672

<https://hal.science/hal-01961672>

Submitted on 9 Jan 2019

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.

2
3 **Towards a metabolic rift analysis: the case of urban agriculture and organic waste**
4 **management in Rennes (France)**

5 **Bahers Jean-Baptiste**, CNRS Researcher - Spaces and Societies (ESO) Mixed Research Unit
6 CNRS 6590; Université de Nantes, e-mail: jeanbaptiste.bahers@univ-nantes.fr

7 **Giacchè Giulia**, Associate Researcher, Spaces and Societies (ESO) Mixed Research Unit CNRS
8 6590; e-mail: giacche.giulia13@gmail.com
9

10
11 **Abstract**

12 This work contributes to the urban agriculture field of investigation in one aspect that
13 remains lightly explored: the coupling of material and social dimensions in urban
14 metabolisms studies. This paper offers an urban metabolism path investigation, which
15 aims at confronting the flows of organic waste, the practices of the city-dwellers and the
16 strategies of public bodies. We've applied the "metabolic rift" theoretical framework,
17 established by McClintock (2010), to explore the ecological, social and individual
18 dimensions of organic waste management in Rennes Metropolitan Area (France). In this
19 way, the trajectory of the Rennes Metropolitan waste programs, the material flow analysis
20 of biomass, and the study of inhabitants' composting practices have allowed us
21 apprehending the metabolic rift between its social dimension (the decommodification of
22 land, food, and labor), its ecological dimension (short-loop recycling by distributing
23 compost to participants or other users), and its individual dimension (de-alienation from
24 nature). The strengths and weaknesses relating to these three dimensions are then
25 discussed to bring out some opportunities and threats.
26
27

28 **Key words:** organic waste management, metabolic rift, urban metabolism, community
29 gardens, community waste composting
30

31 **1. Introduction**
32

33 Urban metabolism (UM) is a well-established concept in the field of industrial ecology
34 (Ferrão and Fernández, 2013; Kennedy and Hoornweg, 2012; Rosado et al., 2016). It
35 aims to study the material functioning of cities by examining all flows, e.g. inputs, outputs,

36 and processing activities within the urban system. The challenge of UM studies, according
37 to the Vienna School of Socio-Economic Metabolism (Fischer-Kowalski and Haberl, 2007),
38 is to monitor the material and energy flows, to track their trajectories, and to unveil which
39 flows urban socio-ecological regimes consume and release to the natural environment.
40 The relationship between the functioning of urban societies and the biosphere is therefore
41 central to this concept, the main objective being to reduce the consumption of materials
42 entering and leaving territories (Barles, 2009). Yet it is also necessary to go further by
43 studying the practices of actors involved in the multi-scalar governance of flows, as
44 suggested by several authors (Broto et al., 2012; Pincetl et al., 2012). The purpose of this
45 paper is to combine material and social dimensions of flow analysis to contribute to this
46 growing interest in urban metabolism studies. How to conduct a research that mixes the
47 circulations of flows and their governance by the actors? How can this be used to discuss
48 the concept of urban metabolism? Our article uses the concept of "metabolic rift" to meet
49 this goal.

50

51 Few studies have compared public strategies and actors' practices to UM data and
52 indicators. Quantitative UM approaches and qualitative UM methods are very fragmented.
53 The literature review (Wachsmuth, 2012) clearly brings out that while three scientific fields
54 - Industrial Ecology, the Vienna School of Socio-Economic Metabolism and Urban Political
55 Ecology - draw on the concept of UM, there is no real dialogue between them.
56 Furthermore, a new approach combines the idea of metabolic rift with industrial ecology
57 and social ecology, exploring the links between these fields under the title of "metabolism
58 of the urban ecosystem" (Newell and Cousins, 2015). The objective is to understand the
59 practices of actors involved in governing multi-scalar flows (Cousins, 2017; Guibrunet et
60 al., 2016), and thereby ultimately understand the politics of UM (Cousins, 2017; Cousins
61 and Newell, 2015; Demaria and Schindler, 2016). Such a perspective allows analyzing
62 metabolic links between hinterland and consumption territories, and developing a critical
63 approach under the term "political-industrial ecology" (Breetz, 2017; Cousins and Newell,
64 2015; Pincetl and Newell, 2017). The issues of social, spatial, and organizational proximity
65 are also important to understand these shifts (Bahers et al., 2017).

66

67 Originally developed by Marx, the "metabolic rift" concept has been borrowed by Urban
68 Political Ecology (UPE) researchers to describe the decline of environmental conditions

69 due to industrialization and industrial agriculture (Heynen et al., 2006; Swyngedouw,
70 2006). They study the resultant discontinuity between rural and urban spheres in different
71 sectors such as food, water or land. As underlined by Marx, the industrial capitalist
72 agriculture also disrupted waste cycles: “Excretions of consumption are of the greatest
73 importance for agriculture. So far as their utilization is concerned, there is an enormous
74 waste of them in the capitalist economy. In London, for instance, they find no better use for
75 the excretion of four and a half million human beings than to contaminate the Thames with
76 it at heavy expense.” (Marx 1894, 1993). Foster (1999) reworked the idea of a metabolic
77 rift to develop an analytical framework to understand the separation between social
78 practice and nature, and to develop tools to engage critically with the degradation of
79 ecological sustainability (Demaria and Schindler, 2016; Schneider, 2017).

80

81 In recent years, urban agriculture (UA) has seemed to offer an alternative to industrial
82 agriculture, and one potentially able to mend the metabolic rift. The links between UM and
83 UA seem obvious. As noted by Aubry and Pourias (2012), UA provides cities with many
84 services, which consist in producing positive externalities, such as the recovery of
85 nutrients from urban waste by various means, like composting, while reducing negative
86 ones via the direct treatment of human urine and feces. Some scholars use metabolic rift
87 as a framework to explore these links. McClintock (2010) is notable for looking in greater
88 depth at the social dimension of the metabolic rift, in addition to its ecological aspects. In
89 his discussion of the “metabolic rift”, he puts forward an innovative framework in which the
90 three main dimensions (ecological, social, individual) are co-produced. This brings out the
91 “fault lines and fractures” (McClintock, 2010, p.203) in the agri-food system.

92

93 UA should potentially be promoted as an opportunity to transform the current system into a
94 fairer, healthier, and a more ecological one. McClintock underlines that UA may help
95 overcome the separation between city and countryside through the decommodification of
96 food, labor, and land (social dimensions), as well as through the de-alienation of humans
97 from nature and labor (individual dimensions). Schneider and McMichael (2010) argue that
98 a reunification of the social and ecological dimensions, thanks to historical approaches is
99 the key to repair the metabolic rift, both conceptually and in practical terms. The food
100 sovereignty movement is exemplary in this respect. Finally, Tornaghi (2017) and Dehaene
101 *et al.* (2015) affirm that UA is able to promote “another” type of development, based on the

102 empowerment of communities, which can claim the urban sphere and shape it in their own
103 image. They agree that the agro-ecology model has the potential to mend the rift.

104

105 This paper aims to contribute to this growing interest by focusing on the role of UA in the
106 UM framework. What could be the role of UA in the UM framework? We hypothesize that
107 UA, by altering the waste chain and the geographies of waste, could “mend the metabolic
108 rift” in ecological, social, and individual terms.

109

110 The materials and methods are introduced in the next section, followed by a description of
111 the empirical results (third section). Findings are then discussed (fourth section), before
112 some final remarks concluding the paper.

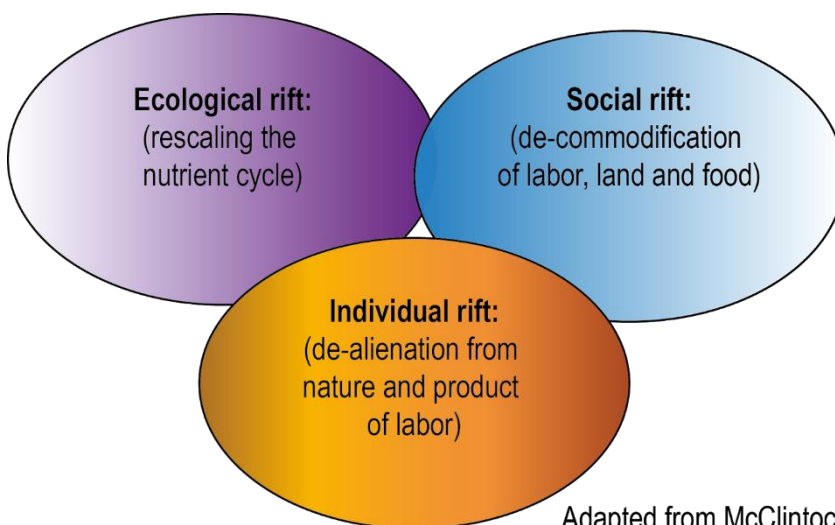
113

114

115 **2. Materials and Methods**

116

117 This paper conducts an UM investigation, examining city-dwellers’ practices in the light of
118 strategies pursued by public bodies. We focus on material exchanges, but also political
119 and socio-economic processes. This research draws on the theoretical framework of
120 “metabolic rift” and explores McClintock’s three dimensions (ecological, social, and
121 individual) (McClintock, 2010) (cf. Figure 1) through the case study of organic waste
122 management (from household, industrial companies and agriculture) in the Rennes
123 Metropolitan Area (France).



124

125 **Figure 1:** The three dimensions (ecological, social, and individual) of metabolic rift

126

127

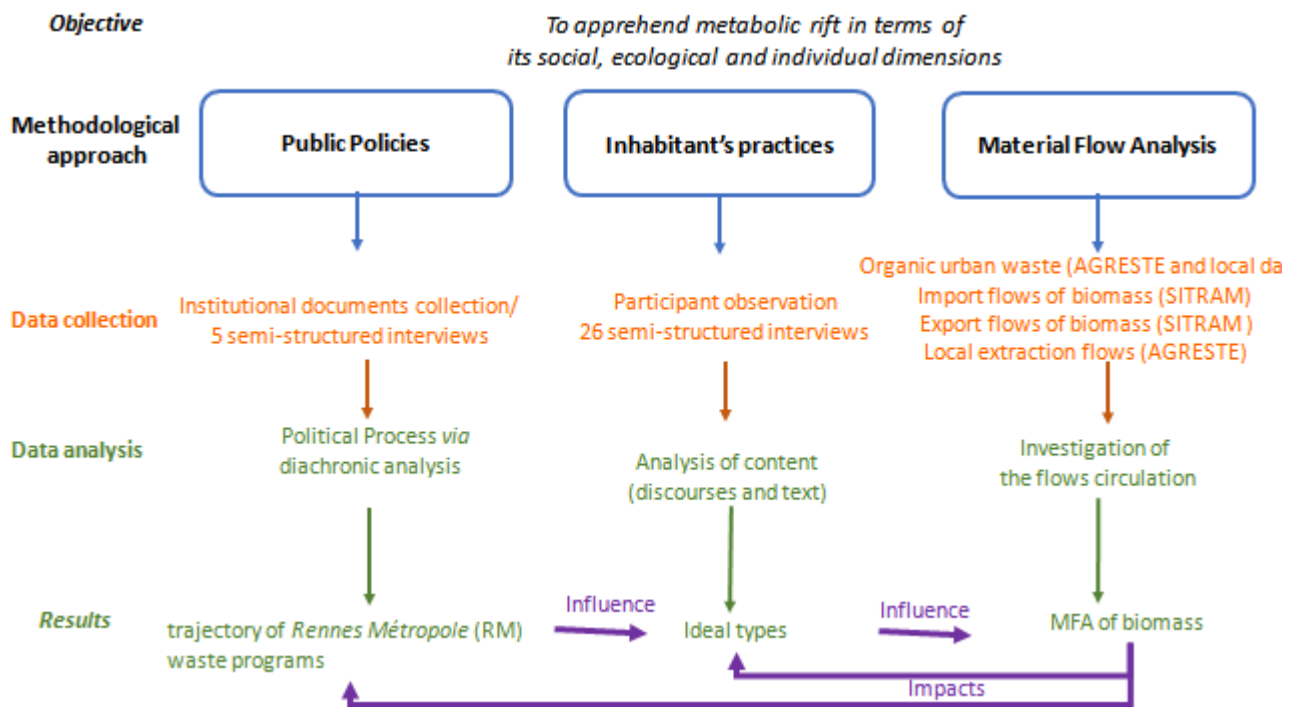
128 **2.1. The chosen case study and the sources of data collection**

129 The chosen case study is the Rennes Metropolitan Area, home to 425,745 inhabitants in
130 2012 distributed in 43 different municipalities (INSEE, 2013). The Rennes Metropolitan
131 Area was created in 2000, from a group of municipalities called "district of Rennes" since
132 1970. Since 2000, mayors from the Democratic Party, called the French Socialist Party,
133 have led an urban waste reduction policy, which makes of this area an interesting case
134 study. In particular, over the last twenty years, the Rennes Metropolitan Area organic
135 waste management policy has evolved, with an increasing proportion of composted
136 residues. Furthermore, the Rennes Metropolitan Area is an interesting case to study
137 inhabitants' contribution to composting in greater details.

138

139 Two different waste streams were analyzed, both occurring at the metropolitan level: first,
140 overall biomass and organic waste flows and, then the household organic waste meant to
141 collective composting, at a lower scale. Three main aspects were studied, namely flows,
142 inhabitants' practices, and public policies on community organic waste composting areas.
143 Data from interviews, institutional documents and observation enabled linking material
144 flows with the practices and policies of composting, and examining how they influence the
145 flows circulation (see Figure 2). Finally, we evaluated the impacts of material flows on the
146 political process and discourse of actors. The social and political impacts of material flows
147 are identified with reference to actors' interviews, and through observations.

148



149

150 Figure.2 Combination of material flow analysis, inhabitant's practices and public policies
151 towards apprehension of metabolic rift

152

153 2.2. The public policies for waste management

154 For public policies, institutional documents and reports, e.g. waste management report of
155 the metropolitan authority (one per year, from 1995 to 2017), have been analyzed to
156 decipher the inherent strategy (see Figure 2). Furthermore, five actors with a good
157 knowledge of the context (one engineer from the metropolitan government, an industrial
158 partner and an associative partner, a consultant of the metropolitan government and a
159 researcher who advises the metropolitan government) were also interviewed with a
160 specific guide, to better understand how waste policies and the communal composting
161 scheme have developed over time. The semi-structured interviews were transcribed and
162 their content analyzed. Diachronic analysis was used, taking into account the goals and
163 challenges of these programs, the actors involved, the bodies driving the scheme, and
164 controversies surrounding policies and their bifurcation over time.

165

166

167 2.3. The inhabitants' practices

168 A fieldwork was conducted, from March 2016 to May 2017, focusing on inhabitants'
169 practices. A qualitative methodology was used to examine composting practices, drawing
170 on semi-structured interviews and participant observation techniques to identify the

171 practices of those involved in organic waste recycling (see Figure.2). A guide was drawn
172 up to interview inhabitants involved in organic waste recycling to understand the impacts of
173 urban agriculture, and its capacity to mend the rift, focusing on its ecological, social, and
174 individual dimensions. Twenty-six semi-structured interviews (twenty-one urban gardeners,
175 five community composting area coordinators) were transcribed and their content
176 analyzed. Furthermore, it was possible to observe the setting up of one composting area
177 and the functioning of four others. This active observation provided us with more elements
178 to better characterize the inhabitants' practices. The analysis of their discourses and the
179 field notebook contents allowed understanding the composting functioning, the evolution of
180 composting practices and the inhabitant's perception. Three ideal-types of inhabitant have
181 been categorized on the basis of their differing perceptions of waste composting.

182

183 **2.4. The Material Flow Analysis**

184 There are numerous methods to characterize UM (Zhang, 2013), which derive mainly from
185 modeling in environmental engineering (Ferrão and Fernández, 2013; Kennedy et al.,
186 2011). Most of these methods are undergoing consolidation. Material flow analysis (MFA)
187 is the most commonly used and the most robust method (Fischer-Kowalski and Haberl,
188 2007; Barles, 2009; Athanassiadis et al., 2016; Rosado et al., 2016). It is a way of
189 identifying the main incoming and outgoing flows in a system, and thus assessing urban
190 pressures on the environment. In France, Barles (2010, 2014) has conducted pioneering
191 work in this field. From a systemic perspective, it aims at measuring the inputs and outputs
192 of materials and energy in each subsystem, and at tracing the trajectory of each category
193 based on its physical qualities (Ayres and Ayres, 2002; Binder, 2007; Bahers and Kim,
194 2018). This flow analysis enabled us to understand the causes and sources of economic
195 externalities, such as pollution or secondary flows.

196

197 The methodology adopted in this article focuses on the MFA. The spatial scale of supply
198 and discarded flows is studied to show the extent of the territories involved for each type of
199 material. It means that the collected data make it possible to identify spatial scales where
200 supply, recycling, recovery, and disposal activities occurred. The data used were collected
201 as part of a research program on urban metabolism (Bahers *et al.*, 2016) and the data
202 refer to 2012, which is the most recent year for some databases. As indicated in figure 2,
203 the investigated flows concern (1) import and export of biomass including food, agricultural

204 and agro-industrial products, (2) the locally produced flows (i.e. agricultural products from
205 urban and peri-urban farms located on the edge of the Rennes Metropolitan Area), and (3)
206 the organic urban waste stream, which consists in household green waste (grass cuttings,
207 branches), household organic food waste also called bio-waste (kitchen waste),
208 agricultural and agro-industrial waste, and sewage sludge.

209

210 The main sources are the database SITRAM (SITRAM, 2013), which is a private database
211 of the Ministry of Environment with freight statistics, and AGRESTE (AGRESTE, 2013),
212 which is a public statistical and evaluation database for agricultural forecasting by the
213 French Ministry of Agriculture. Data of organic waste streams have been collected from
214 the local and regional governments.

215

216

217 **3. Results**

218 The main results of this fieldwork relate to: the trajectory of the Rennes Metropolitan waste
219 programs, the MFA of biomass, and inhabitants' composting practices.

220

221 **3.1 The trajectory of Rennes Metropole waste programs**

222 Three phases of public waste policies have been identified for the Rennes Metropolitan
223 area. The first period (1995-2005) refers to the promotion of individual composting through
224 the installation of composting bins or vermicomposters in private gardens. This policy led
225 to the introduction of collective composting plants (the first was set up in 2006) that are
226 larger in size and usually located in condominiums or public spaces. Despite such
227 initiatives at the local level, national regulatory injunctions for organic waste treatment
228 were weak at the time. Organic waste was just supposed to be managed locally,
229 regardless of the treatment process (French Waste Law of 1992). It was therefore
230 necessary to promote waste prevention, as reflected in the research project conducted in
231 partnership between Rennes Metropolitan waste services and IRSTEA, a research center
232 specializing in organic waste, entitled "Social appropriation of domestic composting".

233

234 The second period (2006-2015) is that of change. Collective household organic waste
235 composting took off thanks to the support from the French Environment and Energy
236 National Agency (ADEME). A politician "who wanted to be a precursor" (interview with a
237 IRSTEA researcher, 2017), was eager to turn the Rennes Metropolitan government into a

238 pioneer in individual and collective composting, resulting in an EU LIFE project, named
239 “Miniwaste”. In 2014-2015 a major shift occurred due to modifications in local policy (in the
240 wake of electoral change), new industrial practices with the repositioning of industrial
241 waste companies, and national regulatory change (with the obligation to sort bio-waste).
242 This led to selection mechanisms, in particular for industrial anaerobic digestion.

243

244 The latest period (2015-2017) is dialectical. This phase results from tensions between
245 various components in the local political process: regulatory tensions, changes in elected
246 representatives, and the fact that strategy oversight was handed back to technical
247 services. This phase thus saw a convergence between technical-economic pragmatism for
248 large flows (industrial waste processing) and urban marketing like the "zero waste" label
249 and the experiment with urban chicken. Finally, it is interesting to study research projects
250 in collaboration with IRSTEA to understand the Rennes Metropolitan strategy on organic
251 waste. Indeed, relations between the metropolitan government and the research center
252 are so strong that city policy is fashioned by the ties between researchers and those staff
253 working in the metropolitan technical service.

254

255 The Rennes Metropolitan Area is an exploratory territory in the “zero waste” national label,
256 whose main goals are to reduce the amount of waste produced, and to recover and
257 recycle it. The metropolitan government funds and coordinates this program, which is
258 implemented by the *Vert le Jardin* association. The Rennes Metropolitan government sets
259 up composting areas at the residents' request, with some differences depending on
260 whether it is located on private or public land. In the first case, a condominium agreement
261 is required. In the second, the RM requires the signature of around twenty inhabitants
262 wishing to compost. The *Vert le Jardin* association is responsible of overseeing the
263 installation of the composting areas, and then helping inhabitants for one year, showing
264 them how to run the composting area. The association usually organizes a neighborhood
265 meeting to explain that the installation of a composting area is under study. This is an
266 important event for deciding how the area will operate, as well as for answering
267 inhabitants' questions. Once installed, the site is managed by two or three inhabitants,
268 who ensure the site runs smoothly (overseeing the supply of dry matter, management of
269 the bins, the transfer of compost, and quality control).

270

271 We have identified three periods that explain the political trajectory of waste management
272 in RM. The objectives of these policies were at first related to the sensitization of the
273 inhabitants to the organic waste sorting and composting. Then the dynamics accelerated
274 towards a technical-economic pragmatism.

275

276 **3.2. Inhabitants' composting practices**

277

278 Analysis of interviews and field notebook reveals that city dwellers have differing practices,
279 attitudes, and representations about waste composting. Considering the qualitative
280 approach of the study we have not been able to produce some quantitative data
281 concerning their numerosity or socio-economic categories, but the five composting areas
282 studied in depth have revealed the presence of three ideal-types (cf. table 1): the skeptic,
283 the convinced, and the activist.

284

285 Identifying their theoretical profiles helps shedding light on how city-dwellers relate to their
286 practices and to urban agriculture. The three ideal-types have been presented according
287 to the social, ecological, and individual variables explored (cf. table 1). These ideal-types
288 refer to three different forms of involvement in composting practices and in the
289 development of composting areas.

290

291 The skeptic

292 This ideal-type was mainly encountered at meetings of condominium residents, where they
293 could voice their opposition to the installation of a composting area. It is harder to identify
294 these people when the proposed installation is on public land, since they do not usually
295 attend the meeting of the introduction to the project. But when there are not enough
296 signatures to install an area, the *Vert le Jardin* association goes door-to-door to explain
297 how it would operate. Skeptics may be male or female, but tend at least middle-aged.
298 They are not interested in taking part in composting for one or more reasons. The most
299 recurrent one relates to the inconvenience that may arise from the presence of rats and
300 bad smells. They express not seeing the utility of composting or advantage since they still
301 have to pay for garbage collection and do not use the compost.

302

303 The convinced

304 This ideal-type takes part in collective composting. Their practices vary, depending on their
 305 level of commitment. The less committed people do not take the necessary precautions to
 306 facilitate the composting process. Indeed, they sometimes throw out their waste as normal
 307 garbage (despite placing it in biodegradable plastic bags). They do not reduce their
 308 amount of waste or cover their waste with dry matter in the composting bins. Finally, they
 309 do not mix composted material to enhance ventilation. A few coordinators of composting
 310 areas stated that younger people tend to be more careful in these respects.

311

312 The convinced tend to take advantage of the site, using the compost for their garden or
 313 balcony. Their perceptions differ, however, with some considering it as one amongst many
 314 different sorting practices, such as for glass or plastic, and others perceiving it as an act to
 315 produce an essential component for soil fertility.

316

317 The activist

318 These people have a strong role for setting up the composting area. They manage the
 319 site, oversee its operation, the compost maturation process, and quality, i.e. checking for
 320 the presence of undesirables, supplying the dry matter, cutting the waste to facilitate the
 321 process and organizing the transfer between bins. They have to follow composting
 322 courses and attend two annual meetings with other coordinators to discuss the issues and
 323 challenges they have encountered.

324

325 These city-dwelling activists are convinced that communal composting practices produce a
 326 precious resource that helps counterbalancing human impact on the environment. They
 327 are environmentally aware and are strongly committed to civic-minded initiatives. For the
 328 activist ideal-type, composting is a way of putting their values and ideas into practice. They
 329 view it within the perspective of societal change, particularly with regard to consumption
 330 patterns and waste. They tend to take part in a community garden scheme (for producing
 331 fruit and vegetables), and try to use the compost produced.

332

333 **Table1** The ideal-types

334

Ideal-type	Social dimension	Ecological dimension	Individual dimension
------------	------------------	----------------------	----------------------

Skeptic	Commodification of labor "I pay taxes so I do not want to compost myself"	Do not trust the quality or do not see the utility of compost	Perceive the compost as an inconvenience: "The compost attracts flies and rats"
Convinced	They take part "I can sort all my waste"	Involved in short-loop recycling: "The compost could be used for private or collective gardens"	Appreciate the utility of the compost "it is the basis of life"
Activist	De-commodification of labor: "I volunteered to be a coordinator for managing the composting process"	Promote proximity: "We can change the model: producing and composting closer to people"	Consider compost as a rare resource: "It is green petrol"

335

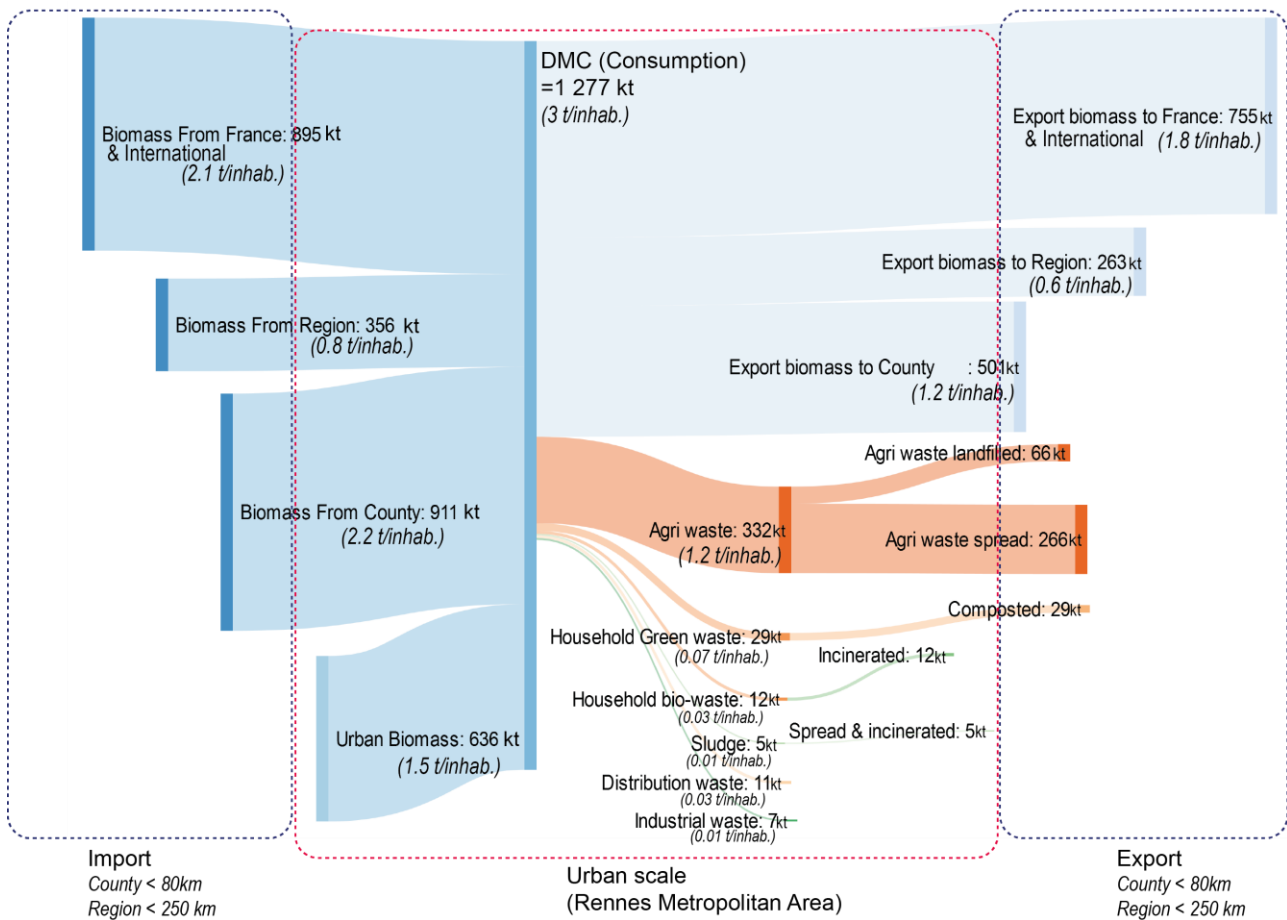
336

337

338

339

3.3. MFA of biomass and organic waste



340

341 **Figure 3.** Organic waste chain in Rennes Metropolitan Area, kt, 2012 (Source: Bahers et
342 al., 2018)

343

344 For biomass inflows into the city (cf Figure 3), we can differentiate the supply areas into
345 four major geographical scales:

346 - The first scale is that of the urban scale of Rennes Metropolitan Area, called "urban
347 extraction" in the MFA method. 22% of the biomass entering the city comes from this
348 supply area.

349 - The second scale concerns the county with a diameter of about 80 km, spreading around
350 the city. In the vocabulary of the MFA method, this production is imported from outside
351 the city to be distributed there. The county is an administrative area at a lower scale
352 than the region. 32% of the food and agricultural supplies in Rennes Metropolitan Area
353 come from this geographical scale.

354 - The third is the region, Brittany, extending up to 250 km from Rennes. Biomass from
355 the regional scale represents 12% of the total input.

356 - The final scale refers to the rest of France and abroad, with 32% of the Rennes'
357 biomass coming from this scale.

358

359 Some of these material inputs are consumed in the city (45%, amounting to 1277 kt per
360 year), while some are exported elsewhere. The city therefore plays a role in the
361 transformation and transit of food and agricultural goods. About half of these exports
362 (49%) go to other French regions or abroad. A sizeable proportion (33%) is exported to the
363 county, traveling less than 80 km, meaning Rennes plays an important role as a local hub.

364

365 Despite the artificialization of 631 ha of soils between 2006 and 2012 according to data
366 from the Corine Land Cover database (Corine Land Cover, 2013), urban production of
367 biomass remains relatively high. It is 1.5 t/inhab per year, meeting half of urban needs (3
368 t/inhab/year, which is called the Domestic Material Consumption DMC in the MFA
369 method). Supplies from the metropolitan area and county (corresponding to a distance of
370 about 80 km around the city) could theoretically meet the city's needs, for 3.7 t/inhab/year
371 are produced in the county, including the city of Rennes.

372

373 For organic waste, we have taken into account several channels governed by different
374 regulatory and normative measures. The agriculture and livestock waste sector (the

375 largest in the MFA, 332 kt in 2012) is overseen by farmers themselves. They have
376 regulatory responsibility for disposing of their waste. According to AGRESTE database
377 (AGRESTE, 2013), the 80% of agricultural waste are spread *in situ* (266 kt/year).
378 Spreading plans since 2002 has regulated this practice by authorizing or banning farmers
379 from spreading waste depending on the soil's environmental conditions (in particular the
380 nitrogen, phosphorus, and nitrate contents). The remainder is sent to landfill (66 kt/year).
381 The second waste stream concerns organic household waste (41 kt in 2012), composed of
382 so-called household "green" waste, and household bio-waste. Green waste, i.e. garden
383 waste (leaves, grass cuttings, branches), is mainly managed by community waste
384 services, which collect, group, and send it to composting (29 kt).

385

386 Since 2012, organic waste from large producers (foodservice, food trade, supermarkets,
387 and industry) has to be source-separated, and then recovered by composting,
388 methanization, or direct spreading. The "energy transition law" [*loi pour la transition*
389 *énergétique 2015*], passed in August 2015 to oversee the energy transition process,
390 stipulates that municipalities should progressively extend this service to all bio-waste
391 producers, including inhabitants. For the time being in Rennes Metropolitan Area, the
392 majority of bio-waste is incinerated (11 kt/year). Industrial waste and waste from
393 distribution account for a large share (18 kt in 2012), which are treated according to the
394 strategies of the industrial companies. The last organic waste stream concerns sludge
395 from sewage treatment plants, where all urban organic residues are grouped (5 kt/year).
396 Most of this waste is spread or incinerated.

397

398 There is one final regulation that plays an important role in structuring waste streams. To
399 qualify as an organic amendment and to be on the market, compost from organic waste
400 must comply with threshold requirements for heavy metals, organic pollutants, and
401 physical impurities set out in French Norm "NFU 44 051". If the thresholds of "NFU 44 051"
402 are exceeded, compost is considered as a waste and treated as such, being sent to a
403 disposal facility (landfill or incinerator). There is currently no standard for compost from
404 individual or collective composting.

405

406

407 **4. Discussion of findings**

408 Triangulating data about waste flow, institutional rules, and individual practices enables us
409 to apprehend metabolic rift in terms of its social dimension (the de-commodification of land,
410 food, and labor, given the participation of city dwellers), its ecological dimension (short-
411 loop recycling by distributing compost to participants or other users), and its individual
412 dimension (de-alienation from nature). The strengths and weaknesses relating to these
413 three dimensions are discussed to bring out opportunities and threats.

414
415

416 **4.1 The ecological dimension of the metabolic rift**

417

418 Strengths: compost production and socio-environmental proximity (cf. Figure 4)

419 According to the 2016 “Zero waste” report from the Rennes Metropolitan government, 45
420 kg/inhab/year have already been recovered, though as yet there is no data on the amount
421 of compost produced. The amount of compost produced may be estimated, based on the
422 size and number of composting areas and their potential production capacity. Each
423 composting area has between 3 and 5 composting bins (Photo 1), composed of 1 bin for
424 dry matter, 1 bin for supply of organic matter, and from 1 to 3 bins for the maturation
425 process. The maturation process takes between 6 and 9 months, and starts once a bin is
426 filled, a process that takes in turn between 2 to 3 months depending on the season and
427 the number of participants. So we may suppose that each site provides 1 full bin of
428 compost during its first year. The 600 liters compost bins are able to produce 120 kilos of
429 compost, for each 600 liters of waste weighs 360 kg (having a density of 0.6). Two-thirds
430 of this mass is evaporated, meaning each bin produces 120 kg/year.



431

432 **Photo1.** Composting area (Rennes, May 2016)

433

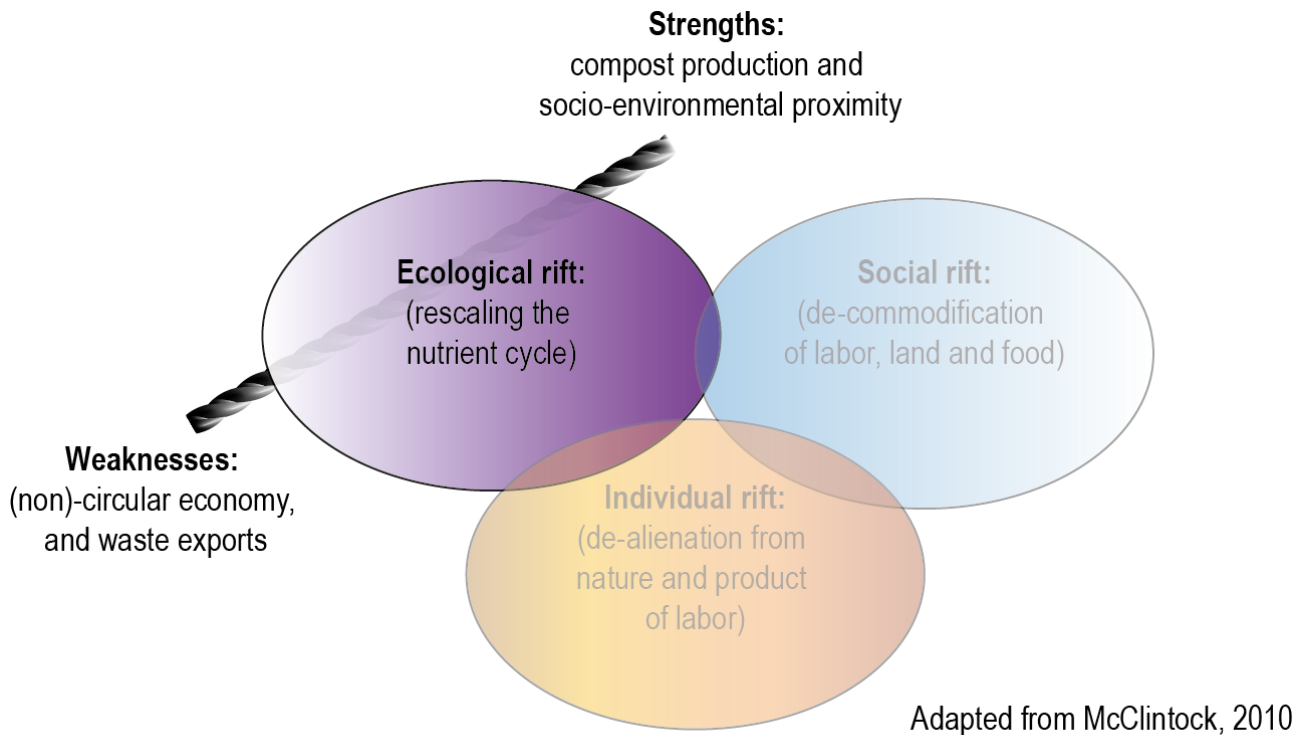
434 In 2016, in the Rennes Metropolitan Area, there were 400 composting areas, and we may
435 assume they produced 48 tons per year. The inhabitants utilized the compost in the
436 community gardens, private gardens, or for their balconies. As one of the composting area
437 coordinators observed: “three-quarters of the compost produced by the collective waste
438 composting area is used in the community garden”. Equally, this interviewee stated that
439 other products are also valued, as fishermen took worms from the compost. Furthermore
440 some coordinators state that the fact of knowing that it will then be used in the gardens is
441 an incentive to control quality, meaning there is social oversight of this chain. The bond
442 established between the collective compost sites and community gardens and the spatial
443 proximity of those spaces ensures good functioning and quality control. As one of the
444 representatives from *Vert le Jardin* pointed out the participation in composting schemes
445 was usually motivated by gardening and viceversa. “There are people who want to garden,
446 and go ahead and set up a communal garden next to their flats with their neighbors, and
447 then say but what am I going to do with all the gardening waste, I pulled up my zucchini
448 plants and now what? We can compost them. How are we going to do that? With our
449 kitchen waste. And so a communal composting scheme is set up. [...] People wanted to
450 compost and it went well and lots of compost was produced, but they wondered what to do
451 with it. Then they had the idea of creating a garden to use this compost, and that way the
452 loop is closed”.

453

454 In 2016 there were 130 community gardens in the Rennes Metropolitan Area. Three-
455 quarters of the community gardens and of the composting sites are located in the city
456 center of Rennes, but they are not distributed evenly across all districts. This results in
457 differentiated access, with some areas where the compost is not immediately used, and
458 others where it is picked up within a few hours due to the presence of gardens or high
459 demand. It may thus be noted that socio-environmental proximity is under construction and
460 consolidation, with collective composting contributing to short-loop nutrient recycling.

461 This system of composting and the potential or existing link with the community garden or
462 other cultivated area is a source of inspiration for gardeners, suggesting that new solutions
463 may be possible. One of the gardeners interviewed said that “we should change the model

464 of our cities from the selfish city to the ecosystem city, by producing and composting closer
465 to people”.



466

467 **Figure 4.** The strengths and weaknesses of metabolic rift ecological dimension

468

469 Weaknesses: (non)-circular economy and waste exports (cf. Figure 4)

470 The MFA tool provides many indicators for discussing the extent to which flows circulate in
471 closed loops. Thus, we obtain total biomass consumption for the city of 1277 kt, with 396
472 kt of agro-food waste produced. This indicates that 30% of the biomass consumed
473 become waste, taking into account the whole chain, including agriculture, agro-industrial
474 and household sectors. There is thus still a long way to go to limit food and agro-industrial
475 wastage. Some of this wasted 30% are recycled. According to our study, only 7% of this
476 stream is composted. Furthermore, without sufficient aeration and high mixing, composting
477 does not work under optimal conditions and thus releases a lot of greenhouse gases
478 (interview with a IRSTEA researcher, 2017). The rebound effect of poor mixing is far from
479 negligible from an environmental point of view. It can also prove to be a serious obstacle
480 to inhabitants' level of commitment.

481

482 Most of the organic waste is incinerated, buried, or spread on soils, with the latter viewed
483 as "dissipative loss" in MFA (Barles, 2009; Krausmann, 2013). This notion is debatable, for

484 while some waste professionals view spreading as a method of waste disposal bringing no
485 added value, others see it as the return of nutrients to the soil. In addition to this, the soil in
486 Brittany region has very high nitrogen levels, meaning it cannot tolerate much spreading.
487 Organic waste flows may be exported outside urban boundaries and sometimes beyond
488 the regional perimeter. Thus 42% of composting is done outside the county around
489 Rennes, and some of the composting (of green waste) is transported about 200 km
490 outside the city. Similarly, landfill takes place outside the urban perimeter, simply because
491 no landfill is located in the Rennes Metropolitan Area.

492

493 In conclusion, organic waste processing sector is far from being a circular economy
494 process (Arnsperger and Bourg, 2016; Ghisellini et al., 2016). Individual and collective
495 composting, potentially a prime example of a short closed-loop, is marginal in terms of
496 volumes (about 0.4% of household bio-waste). Export and disposal are the most common
497 solutions. This is why it is essential to think about opening the "black box" of the city. The
498 study on the "system boundaries" (Guibrunet et al., 2016) leads to "spatial sensitivity and
499 critical political economy" (Newell and Cousins, 2015). In our case, it means that tracking
500 organic waste flows reflects a spatialised political economy, which currently tends to
501 externalise waste treatment and disposal to other peri-urban areas. This results in power
502 relations between cities and territories of disposal, which it would be useful to analyze. A
503 quantitative approach can therefore be relevant for applying a critical analysis of urban
504 waste policies.

505

506

507 **4.2 The social dimension of the metabolic rift**

508

509 Strengths: job creation and citizen commitment (cf. Figure 5)

510 The compost waste chain creates new jobs, with different skills required at different
511 positions along the waste chain while, at the same time, relying greatly on volunteer work.
512 The main actors involved in the household organic waste chain are: an institutional actor
513 (Rennes Metropolitan government) who funds and drives the scheme, intermediary actors
514 (the *Vert le jardin* and *Tribord* associations), and inhabitants. *Vert le jardin* association
515 helps inhabitants setting up a composting area, which means choosing the site and
516 obtaining approval from the metropolitan government. The association also organizes the
517 site (installation of composting bins) and assists the inhabitants over the first year. A

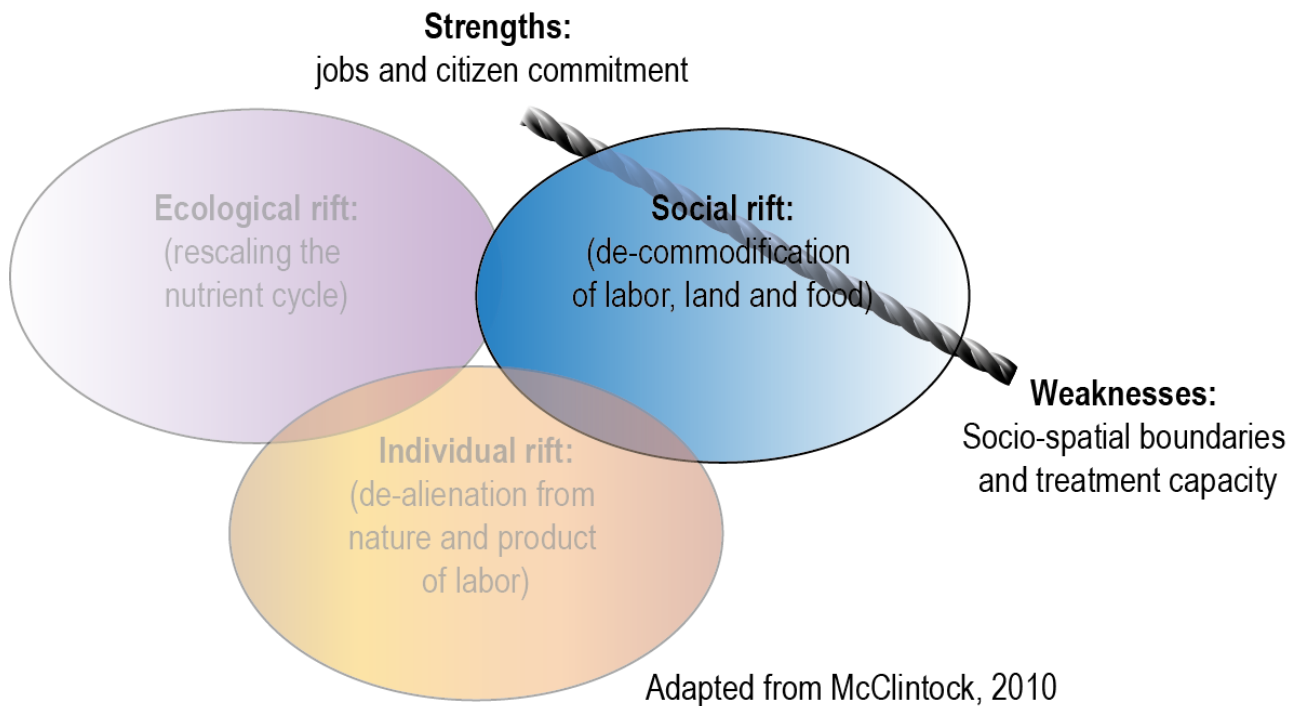
518 composting area is implemented only if the inhabitants apply for it and take part in the
519 management of the composting site. A composting site is set up if at least twenty
520 inhabitants are interested (the number can vary depending on the size of the
521 condominium), ideally with two or three people available to run the site. The *Tribord*
522 association assembles the composting bins. To carry out the Zero Waste (ZW) program,
523 The Rennes Metropolitan government employed almost six full time employees (FTE)
524 (Zero Waste Report, 2016) and the two associations implementing the composting
525 program provided almost six FTEs, attending around twelve FTEs. At the same time we
526 counted almost twenty-six volunteer workers.

527

528 According to the dataset of Vert le Jardin (2016), 400 compost areas are located in
529 Rennes Metropolitan and 6500 households were registered, among which 700 are
530 volunteer site coordinators. Coordinators are in charge of regular maintenance: checking
531 the presence of dry matter, mixing dry and organic matter, measuring organic residues
532 and, if necessary, removing undesirables, and checking the compost temperature. This
533 takes at least two to three hours per month per person. Extraordinary maintenance
534 (transferring material between compost bins) takes three hours every two or three months,
535 requiring the presence of at least two people. Furthermore, it shows the chain is based on
536 a large number of volunteers, suggesting a de commodification of labor. This converges
537 with the issue of the UA described by McClintock (2010, p201): “via the appropriation of
538 land and labour for purposes other than the accumulation of capital”. It represents a
539 rejection of a commodified agricultural and urban waste system.

540

541



542

543 **Figure 5.** The strengths and weaknesses of metabolic rift social dimension

544

545 Weaknesses: Socio-spatial boundaries and treatment capacity (cf. Figure 5)

546 MFA indicates that 30 kg/year of organic waste are produced by each inhabitant of
 547 Rennes, amounting to 12 630 tons of organic waste produced each year in the Rennes
 548 Metropolitan Area as a whole. Moreover, this does not take into account the 29 kton of
 549 garden green waste collected at waste sites. At the moment, only 5% of the population
 550 uses the 400 composting areas. But if all inhabitants wanted to compost, 8,000
 551 composting areas would be required. Maximizing composting areas is correlated to the
 552 issue of spatial boundaries, and could lead to space conflicts. Each site requires between
 553 six and height square meters, which may be on public or private land. It is easier to install
 554 the site on public land, which also helps reclaiming public space. Managing where
 555 composting areas are located is a socio-spatial challenge for the metropolitan government.
 556 The socio-spatial process plays a very important role in shaping “legitimate” expertise and
 557 policy action (Edge and Eyles, 2013). Nevertheless, this does not seem to be a problem
 558 according to Eisenia, a professional organization supporting ecological transition and
 559 composting: “land is a problem in the city center, but there are neighborhoods, there are
 560 always little green spaces and parks in town” (interview with Eisenia representative, 2017).

561

562 If every citizen wanted to compost, the stream to treat would be very large (12 kton, see
563 above). The risk of bad management would also increase, and the need for a
564 professionalized service would soon arise, in a seeming criticism of the associative
565 system. The treatment capacity for collective compost is a big challenge, and as things
566 stand one that is not accepted amongst the population or by the public sector. In addition
567 to this, it would become a potentially lucrative market for the waste management industry.
568 Metropolitan governments leading the field in bio-waste recovery have opted for selective
569 collection of bio-waste rather than collective composting, in response to the 2015 law (for
570 example Lorient, 200km from Rennes). Where there is more waste to be diverted,
571 technical services tend to turn to large-scale industrial solutions: “Collecting bio-waste is
572 still the simplest and most practical solution, and you actually divert the stream” (interview
573 with Esenia representative, 2017). Hence maximizing organic waste collection could lead
574 to the commodification of compost activities.

575

576 In addition, collective composting might appear *prime facie* to be a decommodified activity,
577 but is not necessarily so. For the moment, composted waste costs the metropolitan
578 government 600 euros per ton for collective composting, five times more than incinerated
579 waste, which costs around 120 euros per ton in France. This corresponds to the
580 “implementation cost”, due to the considerable effort expended on public awareness for
581 collective composting. These costs are not on the same scale as investing in an
582 incinerator, and should theoretically decrease as awareness is built up and citizens
583 appropriate composting.

584

585

586 *4.3 The individual dimension of the metabolic rift*

587

588 Strengths: reconnecting people to nature and creating a social bond (cf. Figure 6)

589

590 Taking part in household composting schemes can lead inhabitants to change how they
591 view waste. Their organic waste became a “resource” to use free of charge and to use in
592 their gardens. As stated by a composting site coordinator “we should not incinerate
593 organic waste with household waste. This is absurd! We could value organic waste via
594 composting”. Another site coordinator explains her investment by saying that “It is for the
595 environment when we think that there are 60 kg of lost waste, which could be valued, it's

596 obvious to me". The gardeners belong to convinced or activists categories referring to the
597 process, as waste is transformed into compost, it is "the basis of fertility, of life in the soil"
598 or "green petrol". One interviewee stated that on seeing tomato plants and pumpkins
599 growing in the compost, he finally realized the importance of keeping the seeds of these
600 vegetables rather than throwing them away. So composting practices impact on other agri-
601 food practices not specifically addressing waste, such as harvesting seeds. Reengaging
602 individuals with their own natural environment metabolism involves physically working the
603 soil, treating waste and growing food as McClintock (2010, p.202) suggested.

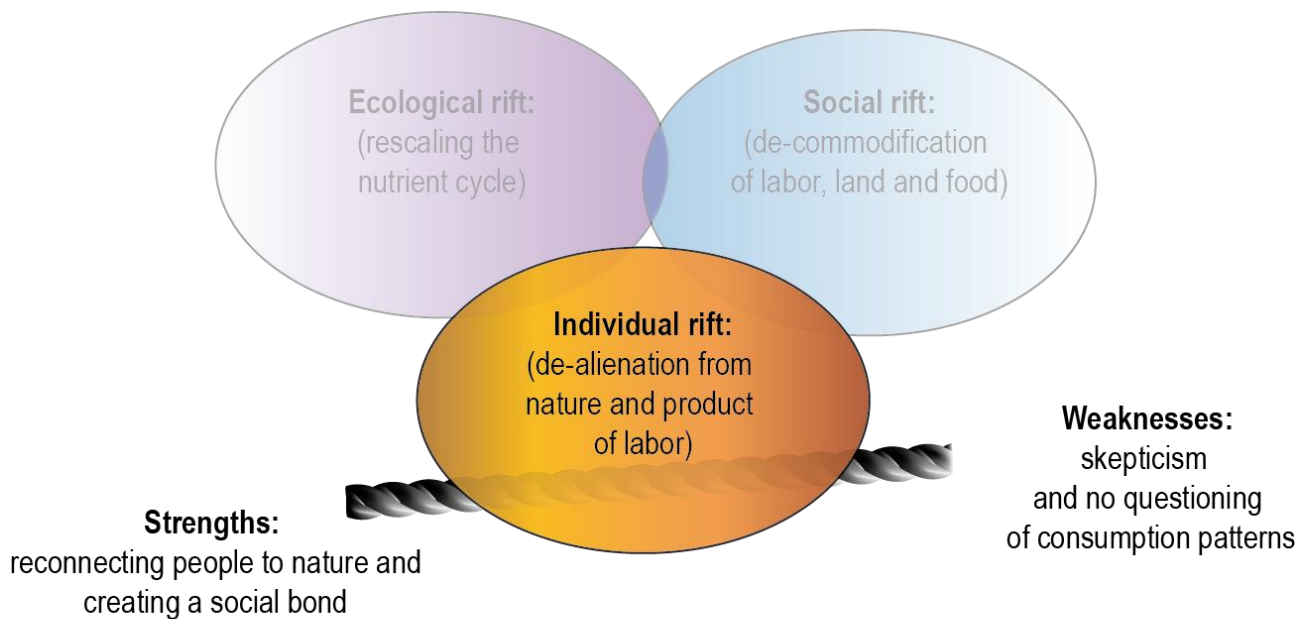
604
605 Some gardeners expressed the sense of purpose they draw from their role in this process,
606 leading to transformations in practices and attitudes. For example, one interviewee said
607 that when invited to dinner by friends who did not compost, he would bring a small bag to
608 collect the organic waste and take it away with him. So composting is incorporated in the
609 daily life of inhabitants, forming part of their routine. The fact of recycling their waste to
610 produce a resource connects the participants with the environment, the soil, the earth and
611 the cycle of nature and the ability to identify and account for the consequences. As
612 expresses by a site compost coordinator that compares the birth of a child to the nine
613 months required to make mature compost. Furthermore, composting is also an opportunity
614 to create social bonds. During a preliminary meeting to present the composting process to
615 inhabitants interested in setting up a site (Photo 2), an old lady said she was interested
616 because "I don't know anyone since I've lived here, for twenty years now, so I want
617 participate to meet my neighbors".

618



619

620 Photo 2. Preliminary meeting to explain the process of setting up the composting site
621



622
623 **Figure 6.** The strengths and weaknesses of metabolic rift individual dimension
624

625 Weaknesses: skepticism and no questioning of consumption patterns (cf. Figure 6)

626 During interviews, some people expressed doubts and skepticism about the sustainability
627 and usefulness of composting. These people were not opposed to the project and took
628 part in communal gardens and collective composting. During discussions there were
629 regular comments along the lines of "it's useless" or "it's cloud-cuckoo land", expressing a
630 form of fatigue or exhaustion at seemingly insurmountable political and social barriers.
631 Other individuals are not ready to take part in a collective scheme based on solidarity: "I
632 prefer to compost in my own bins because my garden is organic and my compost is
633 organic too" (interview with a gardener, 2017). However, the question of "public
634 perception", and particularly doubts about the usefulness of waste sorting (De Feo, 2010;
635 De Gisi, 2017), should not be neglected, both when implementing a project and to win
636 support on the mid-term.

637
638 The perception of the distance to waste often varies from one individual to another. Thus
639 some do not accept being close to collective composters, while also rejecting other
640 disposal solutions. Even gardeners said that "composters attract rats". The record of
641 cleanliness and smell (Corbin, 1982) is still a major factor in waste management. To use

642 the title of an article by Cirelli *et al.* (2017): "The trash is too far, the incinerator too close!".
643 However, some researchers conclude that it is better to concentrate waste infrastructures
644 geographically to avoid conflicts (Ishimura and Takeuchi, 2017). Some interviewees state
645 that "collective composting is good, but not on the condominium. It is better on city land",
646 even if there are only five meters between the two areas. Appropriation of urban waste is
647 at the heart of these issues. Thus, the location of composting areas can lead to social
648 conflicts, even over very short distances.

649

650 The inhabitants go to considerable lengths to better sort their organic waste. These waste-
651 sorting actions receive extensive backing from public policies, suggesting that an
652 instrumentalization of public regarding waste management (Hird, 2017). Collective
653 composting, like the experiments with urban chicken keeping, is taken up by the
654 metropolitan government, tending to legitimize the production of organic waste: "It pleases
655 councilors, because we're all happy to compost" (Interview Esenia, 2017). As the
656 researcher in charge of the project in Rennes explains: "composting is more useful for
657 communication than it is for waste management" (interview with IRSTEA researcher,
658 2017). Installing a waste collection device, if unaccompanied by a questioning of the
659 modes of consumption upstream, can reduce the liability consumers may feel on throwing
660 out waste (Bahers, 2016). Individual perception is therefore very important in urban
661 metabolism policies. Groups of people can struggle very strongly in an urban conflict, even
662 if it is necessary to engage in "unlikely alliances" (Demaria and Schindler, 2016). The data
663 collection of individual aspects is a relevant way to make connection between industrial
664 ecology and political ecology (Pincetl and Newell, 2017). This qualitative approach of UM,
665 relying on individual aspects, reflects the transformation of every-day practices, such as
666 the waste sorting. It also makes it possible to differentiate the contested and militant
667 practices from institutional practices. Integrating individual and social aspects to material
668 aspects is "a first step towards politicizing urban metabolism research" (Guibrunet *et al.*,
669 2016).

670

671 **5. Final Remarks**

672 Our investigation reveals the challenges and limits to city dwellers' commitment to
673 collective composting, and brings out the re-territorialization of the waste chain. It opens
674 up perspectives relating to the theoretical framework of metabolic rift, as well as to the
675 specific case studied here. The theoretical framework could be enhanced by altering its

676 constitutive dimensions. The three dimensions of mending the metabolic rift do not always
677 converge. Most importantly, social practices are embedded in the organizational and
678 ecological dimensions. We therefore propose an analytical framework based on socio-
679 organizational metabolic rift and socio-ecological metabolic rift.

680

681 First, this would make it possible to contrast social practices with the economic structure of
682 waste management. Indeed, convergences between the social and the organizational
683 dimensions may bring into focus past and future conflicts in urban metabolism policies.
684 The political economy of waste is sometimes opposed to, sometimes aligned with
685 inhabitants' perceptions of waste. Analyzing these complex oppositions between economic
686 policy and social representations may help understand trends and tensions. For example,
687 in the case of the Rennes Metropolitan Area, there is no real questioning of the waste
688 management system, but rather a move towards a hybrid system. While promoting
689 communal composting, the metropolitan government is funding a feasibility study for an
690 industrial chain (hygienization-methanization) that could be located outside the region.
691 This hybridization of urban networks (Coutard and Rutherford, 2015) is important for
692 grasping the complexity of metabolic rift policies. It could be revealing to compare it to
693 other case studies on composting practices and policies, for example the "Grand Lyon"
694 area (Dumain and Rocher, 2017).

695

696 Second, quantitative methods for analyzing material exchanges, though useful for critical
697 awareness of the role urban strategies play in flow cycles, are not sufficient. In addition to
698 material exchanges, urban metabolism is affected to an equal extent by political and socio-
699 economic processes. Finally, this program requires funding and resources from public
700 bodies to structure research to make a real transition towards a "zero waste" city. Equally,
701 additional data on others "chains" (e.g. individual composting, collective catering, big
702 producers of bio-waste) and products other than kitchen bio-waste, such as pruning
703 residues, could help improve our understanding of the bio-waste chain.

704

705 **Literature**

706

707

708 AGRESTE, 2013. Annual agricultural statistics in metropolitan France, data on 2012.
709 <https://www.data.gouv.fr/fr/datasets/agreste-statistique-agricole-annuelle-saa/>.
710 Accessed September 18, 2018.

711 Arnsperger, C., Bourg, D., 2016. Vers une économie authentiquement circulaire:
712 Réflexions sur les fondements d'un indicateur de circularité. *Revue de l'OFCE* 145,
713 91–125. <https://doi.org/10.3917/reof.145.0091>

714 Athanassiadis, A., Christis, M., Bouillard, P., Vercauteren, A., Crawford, R.H., Khan, A.Z.,
715 2016. Comparing a territorial-based and a consumption-based approach to assess
716 the local and global environmental performance of cities. *Journal of Cleaner*
717 *Production*. <https://doi.org/10.1016/j.jclepro.2016.10.068>

718 Aubry, C., Pourias, J., 2012. L'agriculture urbaine fait déjà partie du "métabolisme urbain",
719 in: *Déméter 2013*. Club Déméter, p. 432 p.

720 Ayres, P.R.U., Ayres, L.W., 2002. *A Handbook of Industrial Ecology*. Edward Elgar
721 Publishing Ltd, Cheltenham, UK ; Northampton, MA.

722 Bahers, J.-B., 2016. Les dysfonctionnements de « la responsabilité élargie du producteur »
723 et des éco-organismes. *Mouvements* 87, 82.
724 <https://doi.org/10.3917/mouv.087.0082>

725 Bahers, J.-B., Durand, M., Beraud, H., 2017. Quelle territorialité pour l'économie
726 circulaire ? Interprétation des typologies de proximité dans la gestion des déchets.
727 *Flux* 129–141. <https://doi.org/10.3917/flux1.109.0129>

728 Bahers, J.-B., Kim, J., 2018. Regional approach of waste electrical and electronic
729 equipment (WEEE) management in France. *Resources, Conservation and*
730 *Recycling* 129, 45–55. <https://doi.org/10.1016/j.resconrec.2017.10.016>

731 Bahers, J.-B., Barles, S., Durand, M., 2018. Urban Metabolism of Intermediate Cities: The
732 Material Flow Analysis, Hinterlands and the Logistics-Hub Function of Rennes and
733 Le Mans (France). *Journal of Industrial Ecology* 0.
734 <https://doi.org/10.1111/jiec.12778>

735 Barles, S., 2014. L'écologie territoriale et les enjeux de la dématérialisation des sociétés :
736 l'apport de l'analyse des flux de matières. *Développement durable et territoires*.
737 *Économie, géographie, politique, droit, sociologie*.
738 <https://doi.org/10.4000/developpementdurable.10090>

739 Barles, S., 2010. Society, energy and materials: the contribution of urban metabolism
740 studies to sustainable urban development issues. *Journal of Environmental*
741 *Planning and Management* 53, 439–455.

742 Barles, S., 2009. Urban metabolism of Paris and its region. *Journal of Industrial Ecology*
743 13, 898–913.

744 Binder, C.R., 2007. From material flow analysis to material flow management Part I: social
745 sciences modeling approaches coupled to MFA. *Journal of Cleaner Production*,
746 *From Material Flow Analysis to Material Flow Management* 15, 1596–1604.
747 <https://doi.org/10.1016/j.jclepro.2006.08.006>

748 Breetz, H.L., 2017. Political-industrial ecology: Integrative, complementary, and critical
749 approaches. *Geoforum* 85, 392–395.
750 <https://doi.org/10.1016/j.geoforum.2016.11.011>

751 Broto, V.C., Allen, A., Rapoport, E., 2012. Interdisciplinary perspectives on urban
752 metabolism. *Journal of Industrial Ecology* 16, 851–861.

753 Cirelli, C., Maccaglia, F., Melé, P., 2017. « L’incinérateur est trop près, la poubelle trop
754 loin » : gérer les déchets en régime de proximité. *Flux* 61–72.
755 <https://doi.org/10.3917/flux1.109.0061>

756 Corbin, A., 1982. *Le miasme et la jonquille*. Aubier Montaigne.

757 Corine Land Cover, 2013. Land cover data in metropolitan France, data on 2012.
758 <https://www.geoportail.gouv.fr/donnees/corine-land-cover-2012>. Accessed
759 September 18, 2018.

760 Cousins, J.J., 2017. Volume control: Stormwater and the politics of urban metabolism.
761 *Geoforum* 85, 368–380. <https://doi.org/10.1016/j.geoforum.2016.09.020>

762 Cousins, J.J., Newell, J.P., 2015. A political–industrial ecology of water supply
763 infrastructure for Los Angeles. *Geoforum* 58, 38–50.
764 <https://doi.org/10.1016/j.geoforum.2014.10.011>

765 Coutard, O., Rutherford, J., 2015. *Beyond the Networked City: Infrastructure*
766 *reconfigurations and urban change in the North and South*. Routledge.

767 De Feo. G, De Gisi S., 2010, « Public opinion and awareness towards MSW and separate
768 collection programmes: A sociological procedure for selecting areas and citizens
769 with a low level of knowledge », *Waste Management*, 30, 6, p. 958-976.

770 De Gisi S., Casella P., Sabia G., Farina R., Landolfo P., Notarnicola M., De Feo G., 2017,
771 « Assessing the public perception of islanders regarding the implementation of new

772 technologies to optimize the municipal solid waste management system: A
773 Mediterranean case study », *Journal of Cleaner Production*, 164, Supplement C,
774 p. 1586-1601.

775 Dehaene M., Tornaghi C., Sage C., 2015. Mending the Metabolic Rift: Placing the “urban”
776 in Urban agriculture, in Lohrberg F., Licka L., Scazzosi L., Timpe A. (eds), *Urban
777 Agriculture Europe*, Jovis, Berlin, pp. 174-181.

778 Demaria, F., Schindler, S., 2016. Contesting Urban Metabolism: Struggles Over Waste-to-
779 Energy in Delhi, India. *Antipode* 48, 293–313. <https://doi.org/10.1111/anti.12191>

780 Dumain, A., Rocher, L., 2017. Des pratiques citoyennes en régime industriel : les courts-
781 circuits du compost. *Flux* 22–35.

782 Edge, S., Eyles, J., 2013. Message in a bottle: claims disputes and the reconciliation of
783 precaution and weight-of-evidence in the regulation of risks from Bisphenol A in
784 Canada. *Health, Risk & Society* 15, 432–448.
785 <https://doi.org/10.1080/13698575.2013.802293>

786 Ferrão, P., Fernández, J.E., 2013. *Sustainable Urban Metabolism*, 1st ed. MIT Press,
787 Cambridge, Massachusetts.

788 Fischer-Kowalski, M., Haberl, H., 2007. *Socioecological Transitions and Global Change:
789 Trajectories of Social Metabolism and Land Use*. Edward Elgar Publishing.

790 Foster, J.B., 1999. Marx’s Theory of Metabolic Rift: Classical Foundations for
791 Environmental Sociology. *American Journal of Sociology* 105, 366–405.
792 <https://doi.org/10.1086/210315>

793 Ghisellini, P., Cialani, C., Ulgiati, S., 2016. A review on circular economy: the expected
794 transition to a balanced interplay of environmental and economic systems. *Journal
795 of Cleaner Production* 114, 11–32. <https://doi.org/10.1016/j.jclepro.2015.09.007>

796 Guibrunet, L., Sanzana Calvet, M., Castán Broto, V., 2016. Flows, system boundaries and
797 the politics of urban metabolism: Waste management in Mexico City and Santiago
798 de Chile. *Geoforum*. <https://doi.org/10.1016/j.geoforum.2016.10.011>

799 Heynen, N.C., Kaika, M., Swyngedouw, E., 2006. *In the Nature of Cities: Urban Political
800 Ecology and the Politics of Urban Metabolism*. Taylor & Francis.

801 Hird M.J., 2017, « Waste, Environmental Politics and Dis/Engaged Publics », *Theory,
802 Culture & Society*, 34, 2-3, p. 187-209.

803 INSEE (Institut national de la statistique et des études économiques/ National Institute for
804 Statistics and Economic Studies), 2013. Statistics on local population, data for
805 2012. <https://www.insee.fr/fr/statistiques/2119504>. Accessed September 18, 2018.

806 Ishimura, Y., Takeuchi, K., 2017. Does conflict matter? Spatial distribution of disposal sites
807 in Japan. *Environ Econ Policy Stud* 19, 99–120. [https://doi.org/10.1007/s10018-](https://doi.org/10.1007/s10018-015-0137-y)
808 015-0137-y

809 Kennedy, C., Hoornweg, D., 2012. Mainstreaming Urban Metabolism. *Journal of Industrial*
810 *Ecology* 16, 780–782. <https://doi.org/10.1111/j.1530-9290.2012.00548.x>

811 Kennedy, C., Pincetl, S., Bunje, P., 2011. The study of urban metabolism and its
812 applications to urban planning and design. *Environmental Pollution, Selected*
813 *papers from the conference Urban Environmental Pollution: Overcoming Obstacles*
814 *to Sustainability and Quality of Life (UEP2010)*, 20-23 June 2010, Boston, USA
815 159, 1965–1973. <https://doi.org/10.1016/j.envpol.2010.10.022>

816 Krausmann, F., 2013. A City and Its Hinterland: Vienna's Energy Metabolism 1800–2006,
817 in: *Long Term Socio-Ecological Research, Human-Environment Interactions*.
818 Springer, Dordrecht, pp. 247–268. https://doi.org/10.1007/978-94-007-1177-8_11

819 Marx 1894, K., 1993. *Capital: A Critique of Political Economy*, Vol. 3, Reissue edition. ed.
820 Penguin Classics, New York, N.Y., U.S.A.

821 McClintock, N., 2010. Why farm the city? Theorizing urban agriculture through a lens of
822 metabolic rift. *Cambridge J Regions Econ Soc* 3, 191–207.
823 <https://doi.org/10.1093/cjres/rsq005>

824 Newell, J.P., Cousins, J.J., 2015. The boundaries of urban metabolism: Towards a
825 political–industrial ecology. *Progress in Human Geography* 39, 702–728.
826 <https://doi.org/10.1177/0309132514558442>

827 Pincetl, S., Bunje, P., Holmes, T., 2012. An expanded urban metabolism method: Toward
828 a systems approach for assessing urban energy processes and causes. *Landscape*
829 *and Urban Planning* 107, 193–202.
830 <https://doi.org/10.1016/j.landurbplan.2012.06.006>

831 Pincetl, S., Newell, J.P., 2017. Why data for a political-industrial ecology of cities?
832 *Geoforum*. <https://doi.org/10.1016/j.geoforum.2017.03.002>

833 Rosado, L., Kalmykova, Y., Patrício, J., 2016. Urban metabolism profiles. An empirical
834 analysis of the material flow characteristics of three metropolitan areas in Sweden.

835 Journal of Cleaner Production 126, 206–217.
836 <https://doi.org/10.1016/j.jclepro.2016.02.139>

837 Schneider, M., 2017. Wasting the rural: Meat, manure, and the politics of agro-
838 industrialization in contemporary China. *Geoforum* 78, 89–97.
839 <https://doi.org/10.1016/j.geoforum.2015.12.001>

840 Schneider, M., McMichael, P., 2010. Deepening, and repairing, the metabolic rift. *The*
841 *Journal of Peasant Studies* 37, 461–484.
842 <https://doi.org/10.1080/03066150.2010.494371>

843 SITRAM, 2013. Freight database from Ministry of Transport, data on 2012.
844 [https://www.statistiques.developpement-durable.gouv.fr/donnes-ligne/r/flux-](https://www.statistiques.developpement-durable.gouv.fr/donnes-ligne/r/flux-marchandises-sitram-i.html)
845 [marchandises-sitram-i.html](https://www.statistiques.developpement-durable.gouv.fr/donnes-ligne/r/flux-marchandises-sitram-i.html). Accessed September 18, 2018.

846 Swyngedouw, E., 2006. Circulations and metabolisms: (Hybrid) Natures and (Cyborg)
847 cities. *Science as Culture* 15, 105–121.
848 <https://doi.org/10.1080/09505430600707970>

849 Tornaghi, C., 2017. Urban Agriculture in the Food-Disabling City: (Re)defining Urban Food
850 Justice, Reimagining a Politics of Empowerment. *Antipode* 49, 781–801.
851 <https://doi.org/10.1111/anti.12291>

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

855 Zhang, Y., 2013. Urban metabolism: A review of research methodologies. *Environmental*
856 *Pollution* 178, 463–473. <https://doi.org/10.1016/j.envpol.2013.03.052>