ENV 501 / GR A3 30

Material Flow Analysis and resource management

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Laboratory on Human-Environment Relations in Urban Systems

Fall 2024

Last week

- MFA and EW-MFA: definitions
- Main material categories in EW-MFA
- EW-MFA indicators
- Data Sources
- How to perform an EW-MFA
- Cross-country comparisons

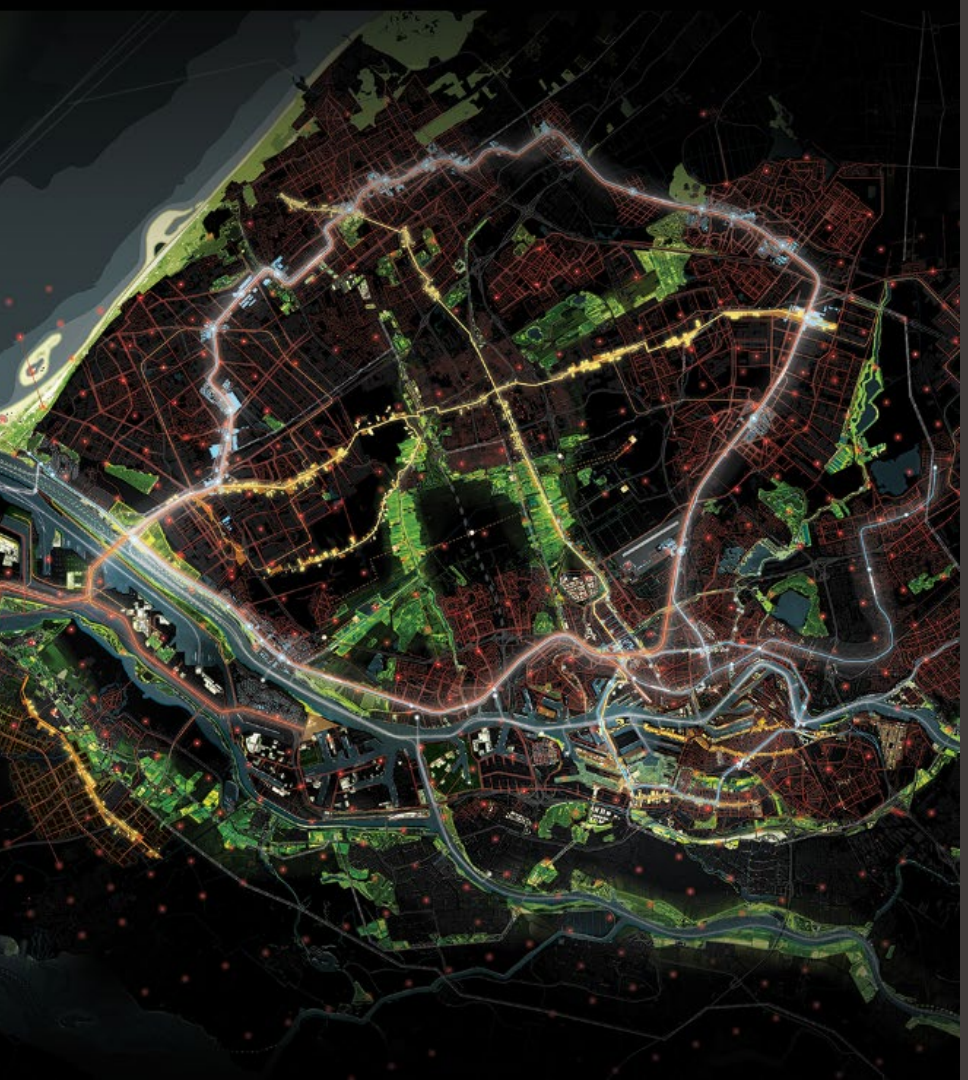
Course outline

		8:15 - 9:00 and 9:15 - 10:00		13:15 - 14:00	14:15 - 15:00
Block I: EW-MFA global / national	W1 - Sep 12	Introduction to the course and general concepts	All	Exercise	Project
	W2 - Sep 19	EW – MFA and EW – MFA in different countries	FMC	Exercise	Project
	W3 – Sep 26	EW – MFA in the Swiss context, Urban Metabolism	External Guest – Florian Kohler	Exercise	Project
	W4 - Oct 03	EW – MFA in the Swiss context: Cantons and Circular Economy	FMC	Exercise	Project
Block II: MFA regional / urban	W5 - Oct 10	The Service-Stock-Flows Nexus	CRB	Exercise	Project
	W6 - Oct 17	Dynamic MFA	External Guest – Stefan Pauliuk	Exercise	Project
	Oct 24	Autumn break			
	W7 - Oct 31	Spatial MFA	FMC	Exercise	Project
	W8 - Nov 07	Input-Output Analysis and Material Flow Cost Accounting	External Guest – Vincent Moreau	Exercise	Project
	W9 - Nov 14	MFA and Uncertainty	External guest – Stefan Pauliuk	Exercise	Project
	W10 - Nov 21	Case studies: Waste management in Indonesia / Critical Raw Materials in the Swiss context	GF & FMC	Exercise	Project
Block III: Social sciences and public policy	W11 - Nov 28	Social Metabolism	CRB	Exercise	Project
	W12 - Dec 05	Agent-based model	CRB, FMC, MAH, SLC	Past exam	Project
	W13 - Dec 12	Group Project Presentation	CRB, FMC, MAH	Project	Project
	W14 - Dec 19	Group Project Presentation	CRB, FMC, MAH	Project	Project

Content of lecture

- Urban Metabolism vs. Urban MFA
- System boundaries of cities
- Accounting approaches
- Where to find data
- Insights from Urban MFA’s and policies

Binder, Félix Martín del Campo, Hecher, Campfens



Urban Metabolism vs Urban MFA

Definitions, relevance

Source : Behance

Urban Metabolism ≠ Urban MFA

What is Urban Metabolism?

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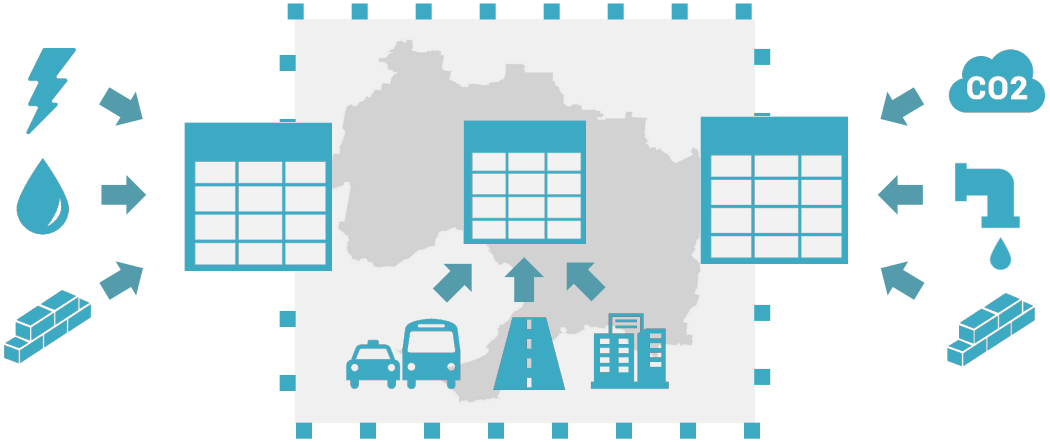
What is Urban Metabolism?



An (unconsolidated) field studying urban flow/stocks and actors from a systemic perspective

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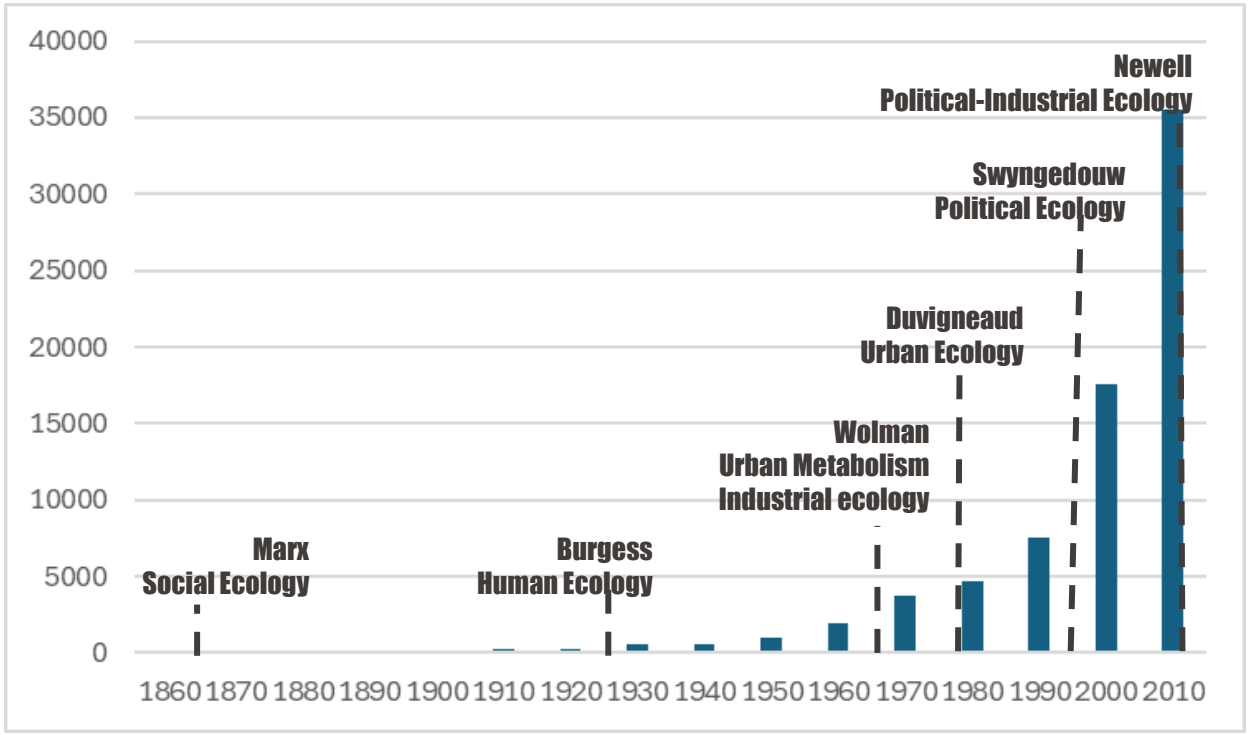
What is Urban Metabolism?



Use of « urban metabolism » over time

Source : Constellate

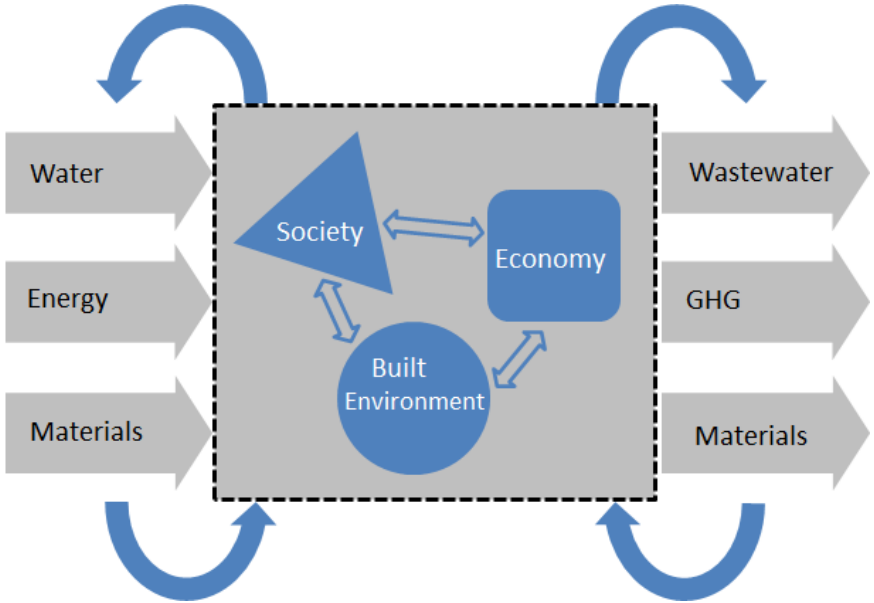
Definitions: Urban Metabolism

- … a model to facilitate the description and analysis of the flows of the materials and energy within cities (material flow analysis of a city).
- **Industrial ecology:** UM as the total technical and socio-economic processes within a city. Mass-balance accounting (MFA) of the related flows of water, materials and energy, input-output; city-hinterland.
- **Marxist ecology / Urban political ecology (Human geography):** UM to characterize alienation of nature from society under capitalist regimes and urbanization, social power and the shaping of urban space. Qualitative analyses of the socioeconomic relations shaping the infrastructure, space and metabolism; dialectic nature-society.
- **Urban ecology:** UM as a complex system, the urban system as an ecosystem, structure and function, transformative processes emerging from system properties. Complex system models; nature-society hybridity.

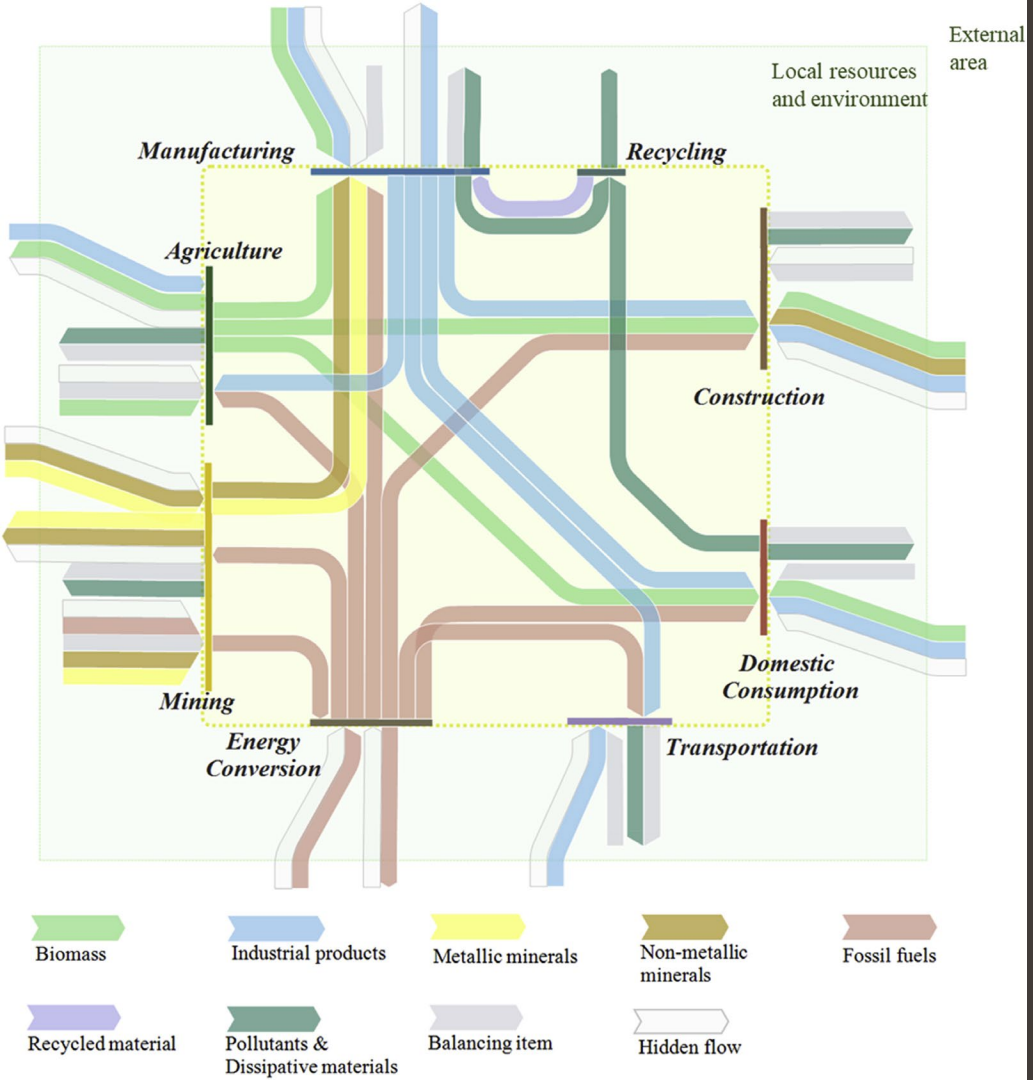
Source : Newell & Cousins 2016; Broto et al. 2012

Why is Urban Metabolism relevant?

Interrelationship between urban activities and flows

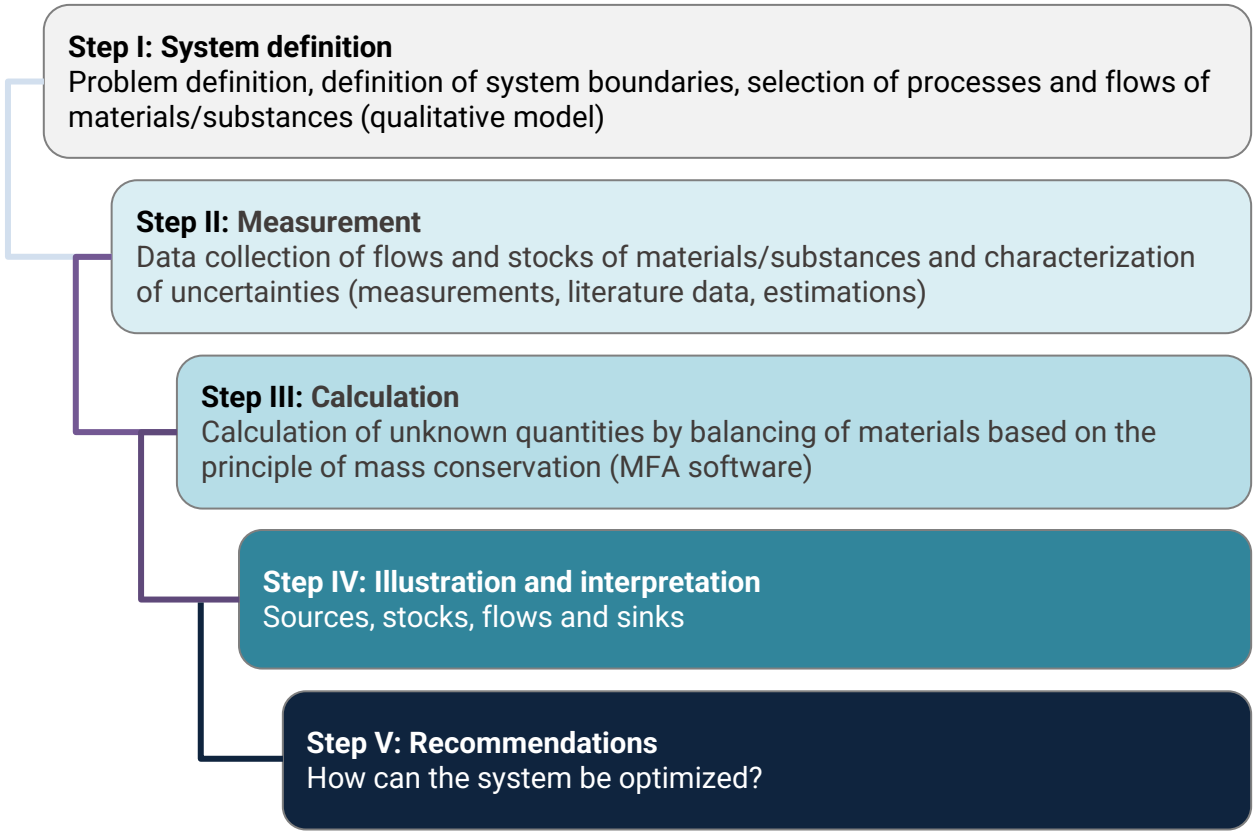


System boundaries of cities



Source : Wang et. Al, 2020

Reminder: Steps of MFA



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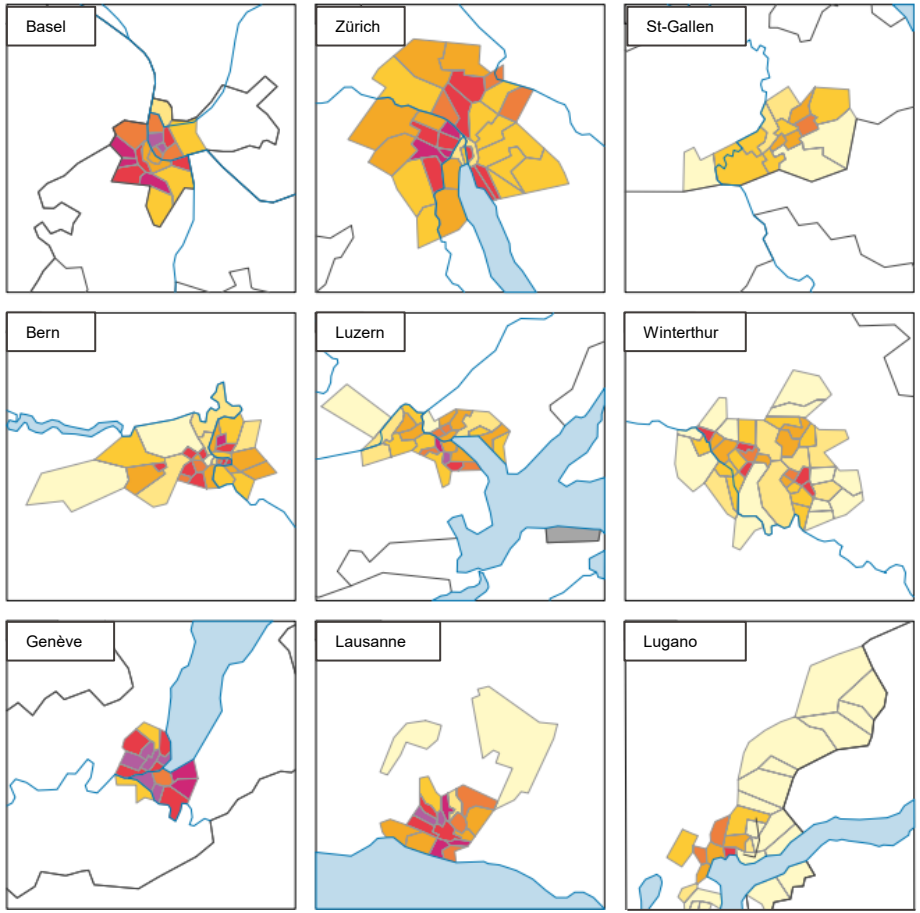
What is a city?



Habitants* par km²

	≥ 16 000,0
12 000,0	– 15 999,9
8 000,0	– 11 999,9
6 000,0	– 7 999,9
4 000,0	– 5 999,9
2 000,0	– 3 999,9
1 000,0	– 1 999,9
	< 1 000,0

sans indication (–)

* Population résidante permanente au 01.01.2022 (= 31.12.2021)

Source : OFS, 2022

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What is a city?

Spatial units

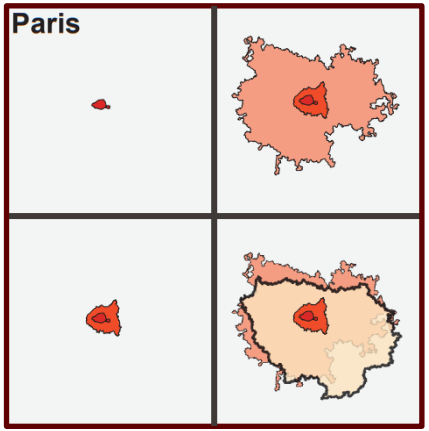
Data are collected for several levels:

- A **City** is a local administrative unit (LAU) where the majority of the population lives in an urban centre of at least 50 000 inhabitants.
  The city of Paris has approximately 2 200 000 inhabitants

- The **Greater city** is an approximation of the urban centre when this stretches far beyond the administrative city boundaries.
  The greater city of Paris has approximately 6 700 000 inhabitants.

- The **Functional Urban Area** consists of a city and its commuting zone.
  The functional urban area of Paris has approximately 11 800 000 inhabitants.

- **Metropolitan regions** are NUTS 3 regions or a combination of NUTS 3 regions which represent all agglomerations of at least 250 000 inhabitants. These agglomerations were identified using the Functional Urban Area (FUA). Each agglomeration is represented by at least one NUTS 3 region. If in an adjacent NUTS 3 region more than 50% of the population also lives within this agglomeration, it is included in the metropolitan region.
  The metropolitan region of Paris has approximately 12 000 000 inhabitants.



Source : Eurostat, 2016

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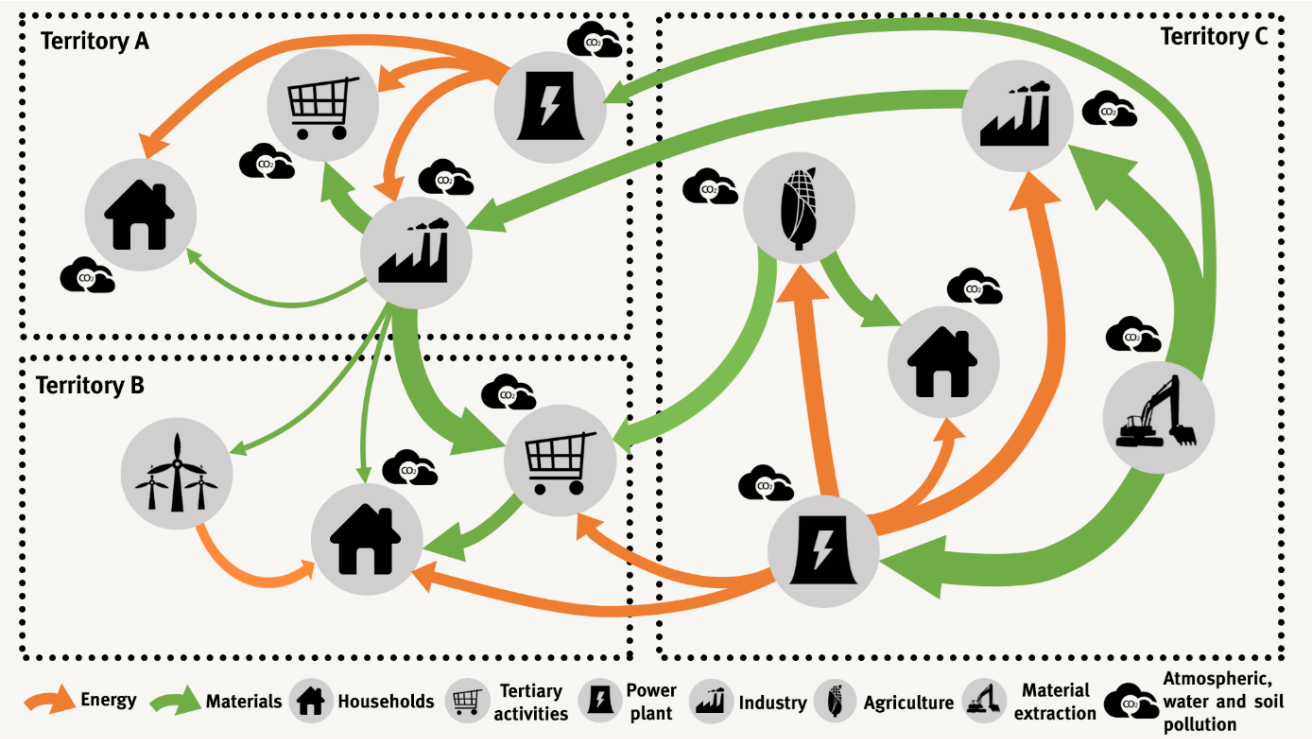
What boundaries to choose?



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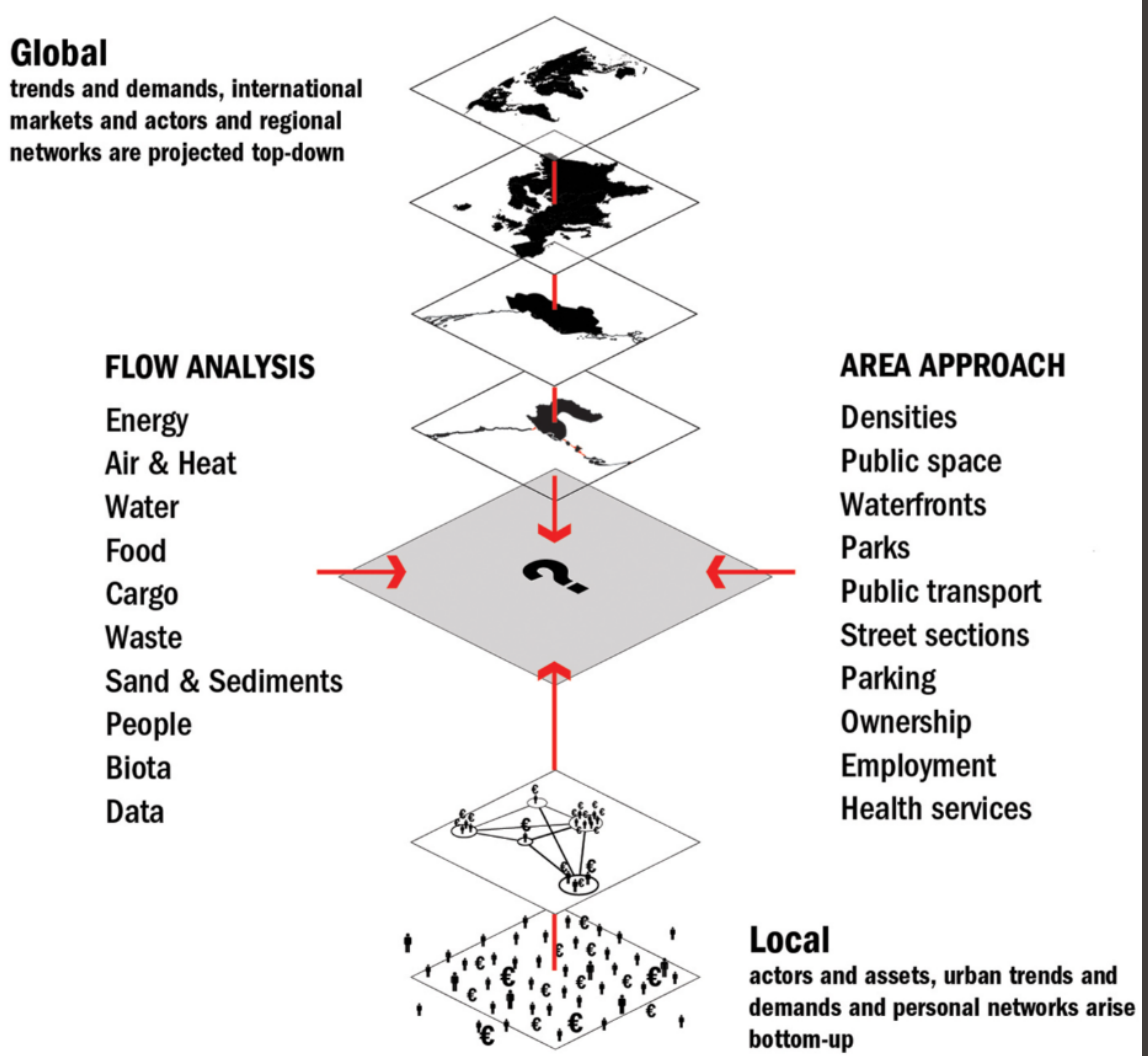
Accounting approaches and methods



Source : Behance

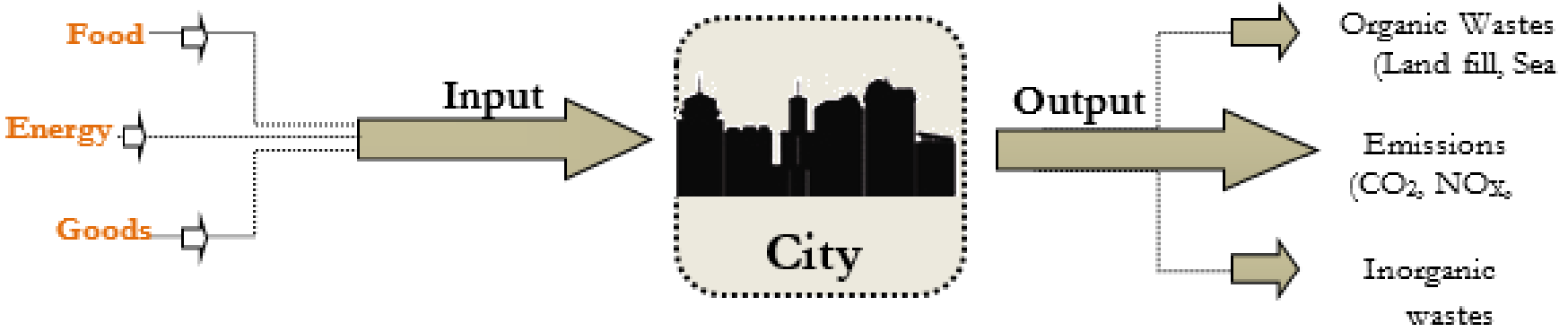
Accounting approaches and methods

- Top-down
- Bottom-up

- Territorial-based
- Consumption-based

Top-down vs Bottom-up

Top-down accounting



Source: Marwa Adel & Nourhan Magdy, 2016

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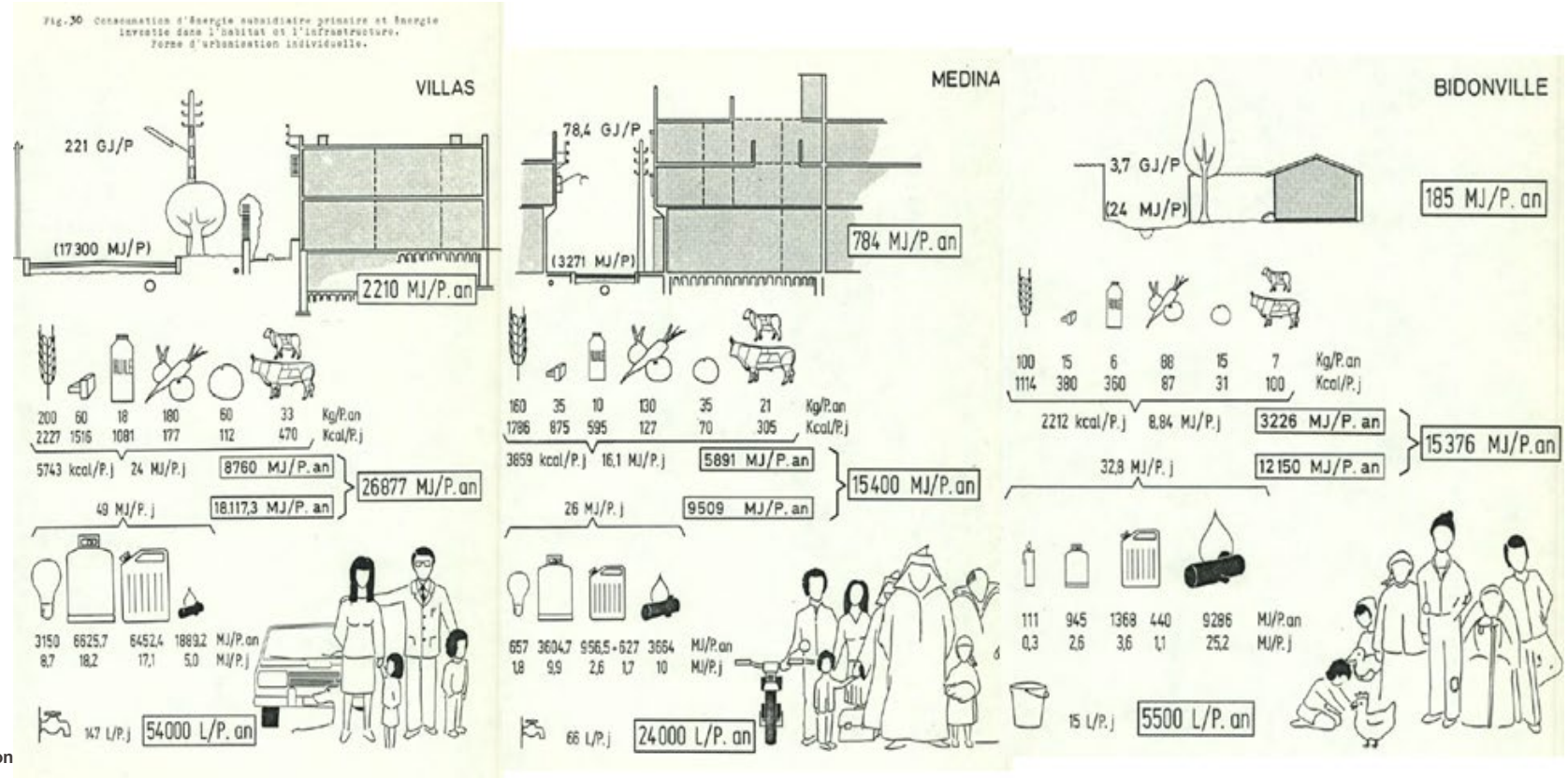
Bottom-up accounting

Kenitra, Morocco, 1982



Source : Kempeneers, 1982

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Bottom-up accounting

Kenitra, Morocco, 1982

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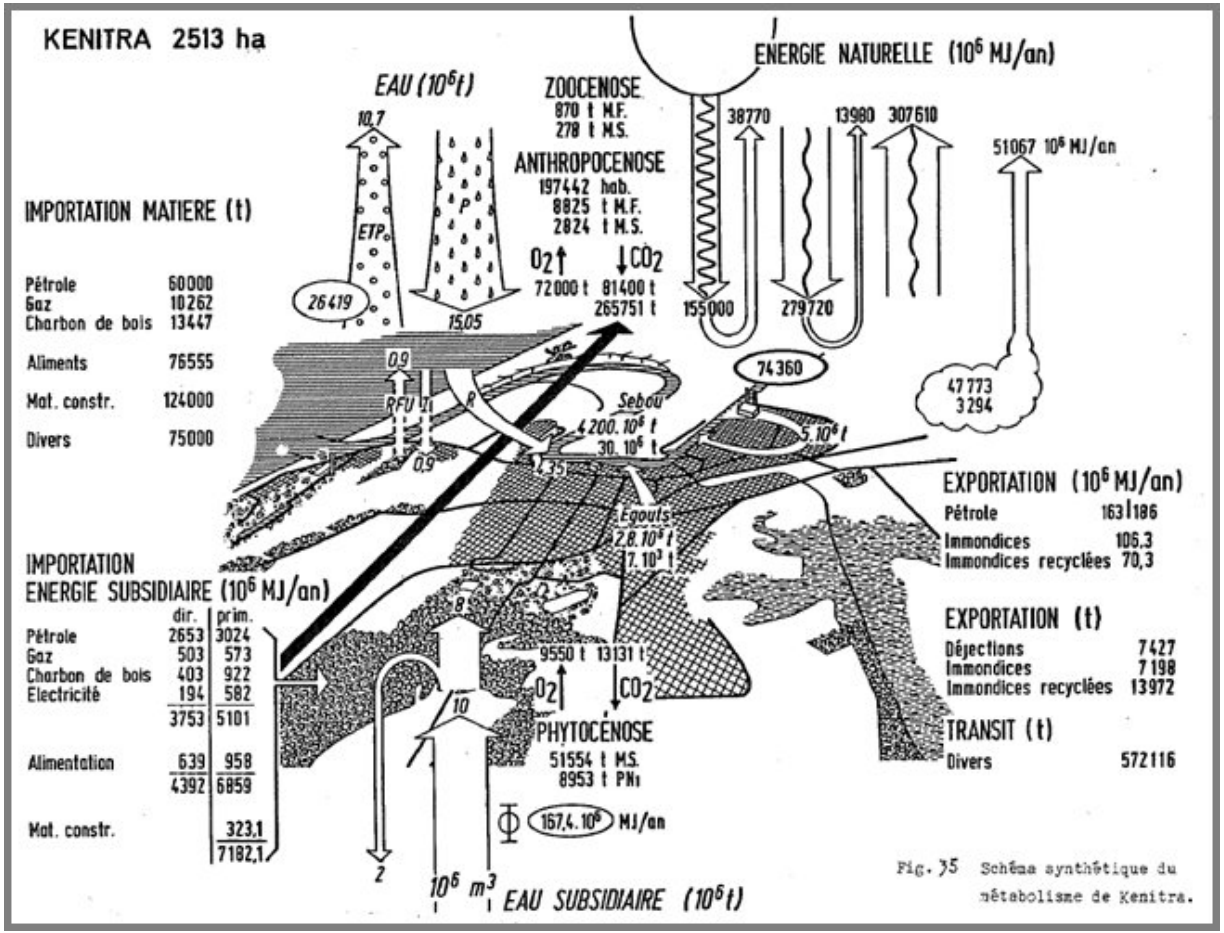
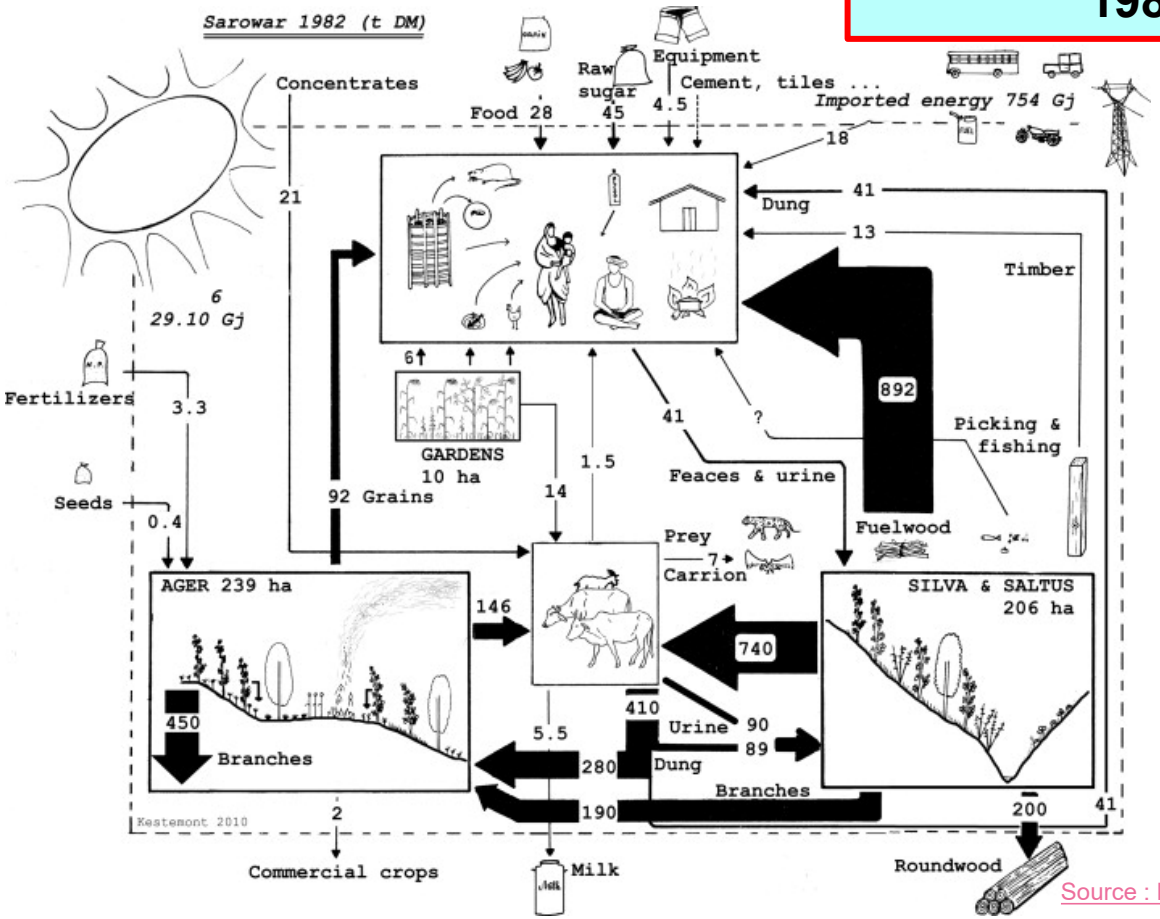


Fig. 35 Schéma synthétique du métabolisme de Kenitra.

Source : Kempeneers, 1982

Bottom-up accounting

Sarowar village, India, 1982



Source : Kestemont & Kerkhove, 2010

Top-down vs Bottom-up.

Pro's of top-down

- Comparable to other years/cities
- Frequently published data
- Comparable to economic & urban data

Pro's of bottom-up

- Reliable data
- Relatively easy to develop
- Provides behavioural aspects

Con's of top-down

- Not available in data scarce environments
- Treats city homogeneously
- Requires institutional infrastructure
- Not always enough knowledge on what's measured

Con's of bottom-up

- Difficult to reproduce
- Time consuming

Territorial/production vs Consumption-based accounting

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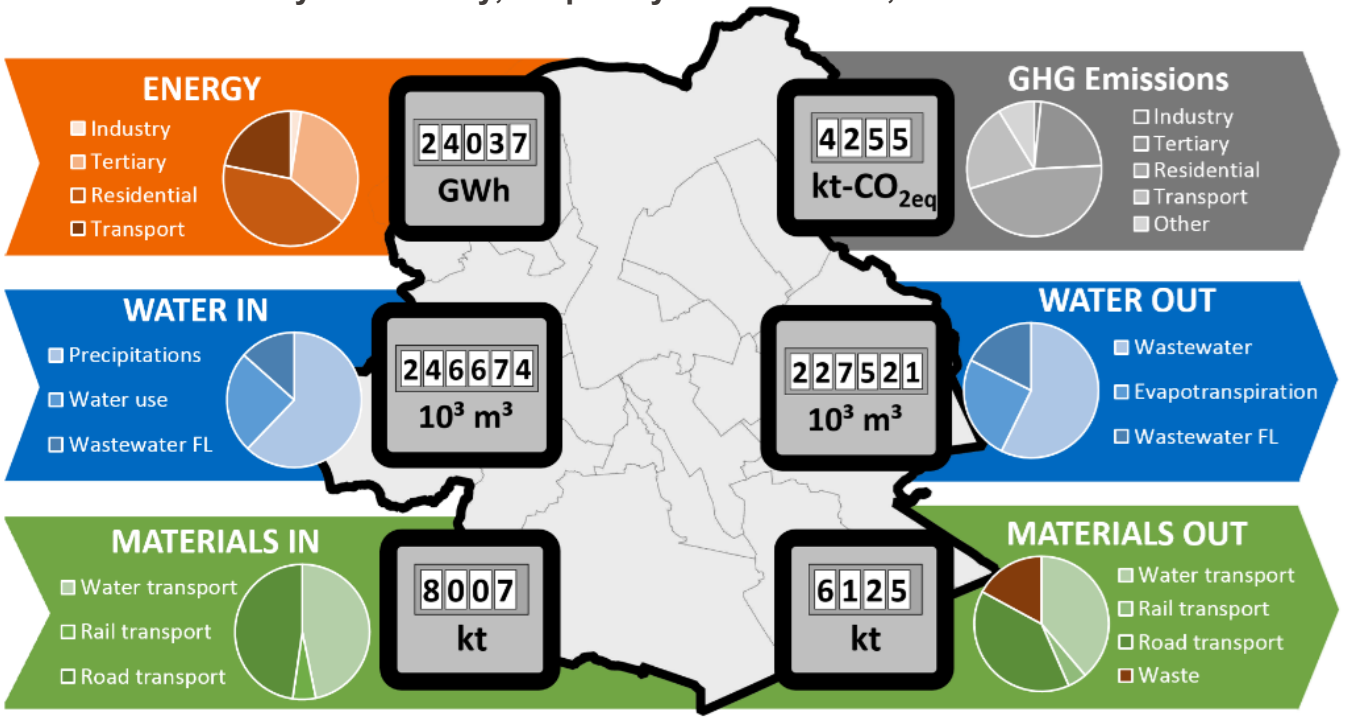
Territorial/production vs Consumption-based accounting

Brussels, 2010

Focused on your territory, frequently available data, sometimes accurate data



Source : Athanassiadis, et al., 2017

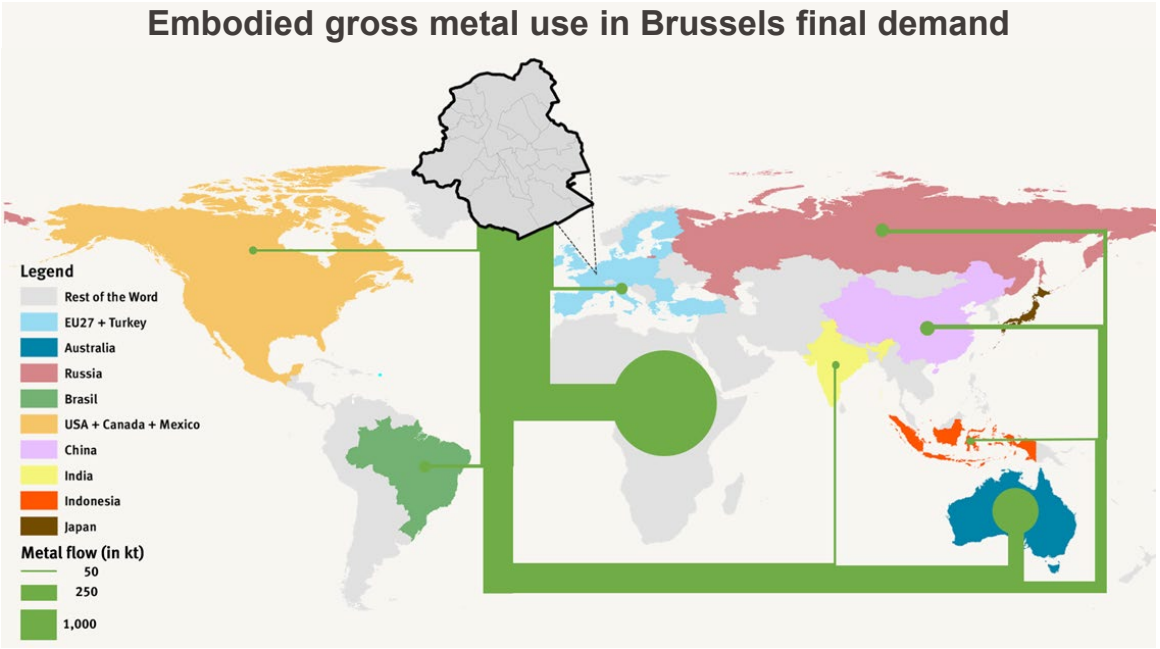
Binder, Félix Martín del Campo, Hecher, Campfens

Consumption-based accounting

Brussels, 2010

Binder, Félix Martín del Campo, Hecher, Campfens

Indirect/embodied flows, hinterland, need of local IO tables

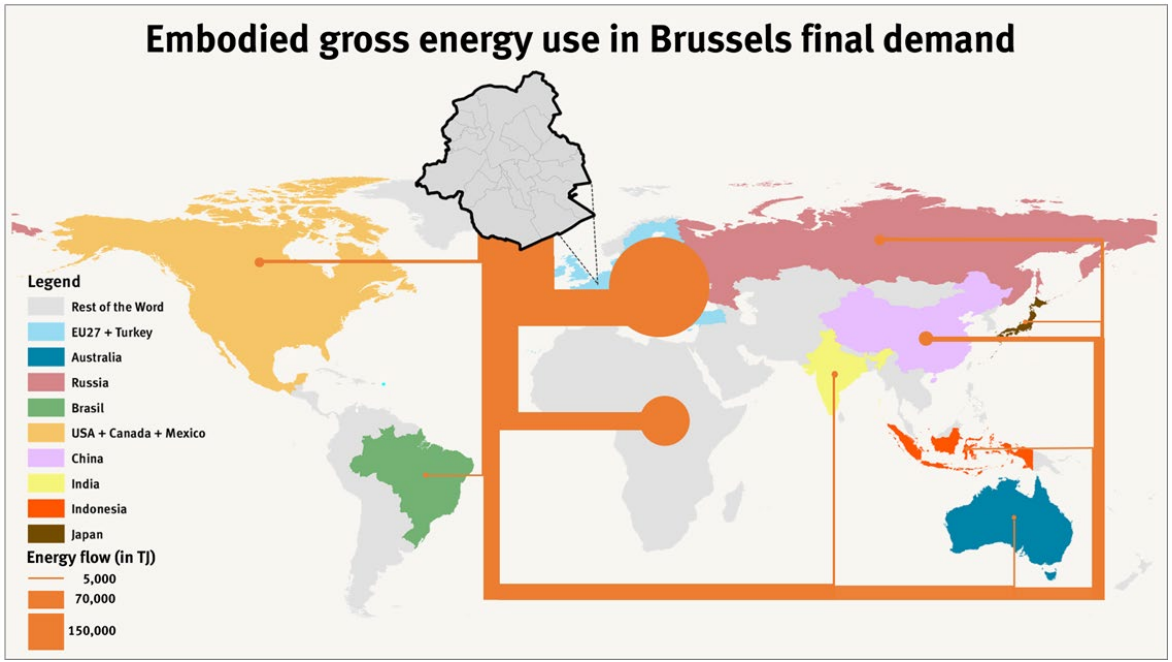


Source : Athanassiadis, et al., 2017

Consumption-based accounting

Brussels, 2010

Indirect/embodied flows, hinterland, need of local IO tables



Source : Athanassiadis, et al., 2017

Territorial/production vs Consumption-based accounting

Pro's of "territorial"

- Accurate data
- Frequently published data
- Enables time series
- Appropriate at urban scale
- Easy to use
- Large pool of case studies
- Available spatial data

Pro's of "consumption"

- Indirect flows
- Spatialises hinterland
- Link global-local
- Systemic overview

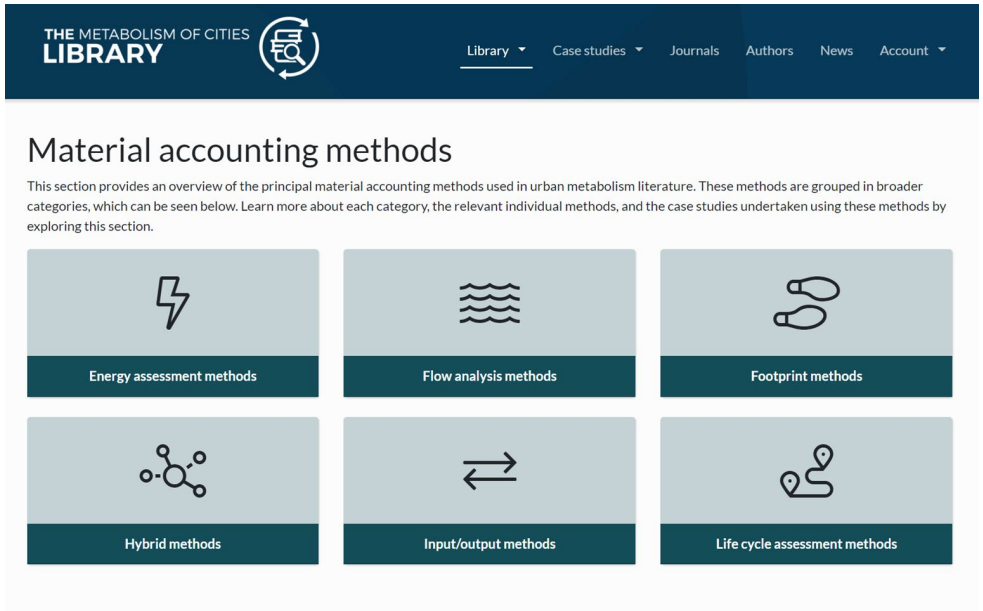
Con's of "territorial"

- No indirect flows
- No standard methodology
- Some flows are not available

Con's of "consumption"

- Uncertainties
- No IO tables at urban level
- Needs experts to use them

No unique accounting method



- **Depending on the available data** (bottom-up, top-down, local IO tables, etc.)
- **Depending on the research question** (what are you trying to answer?)

Source : Metabolism of Cities

No unique accounting method

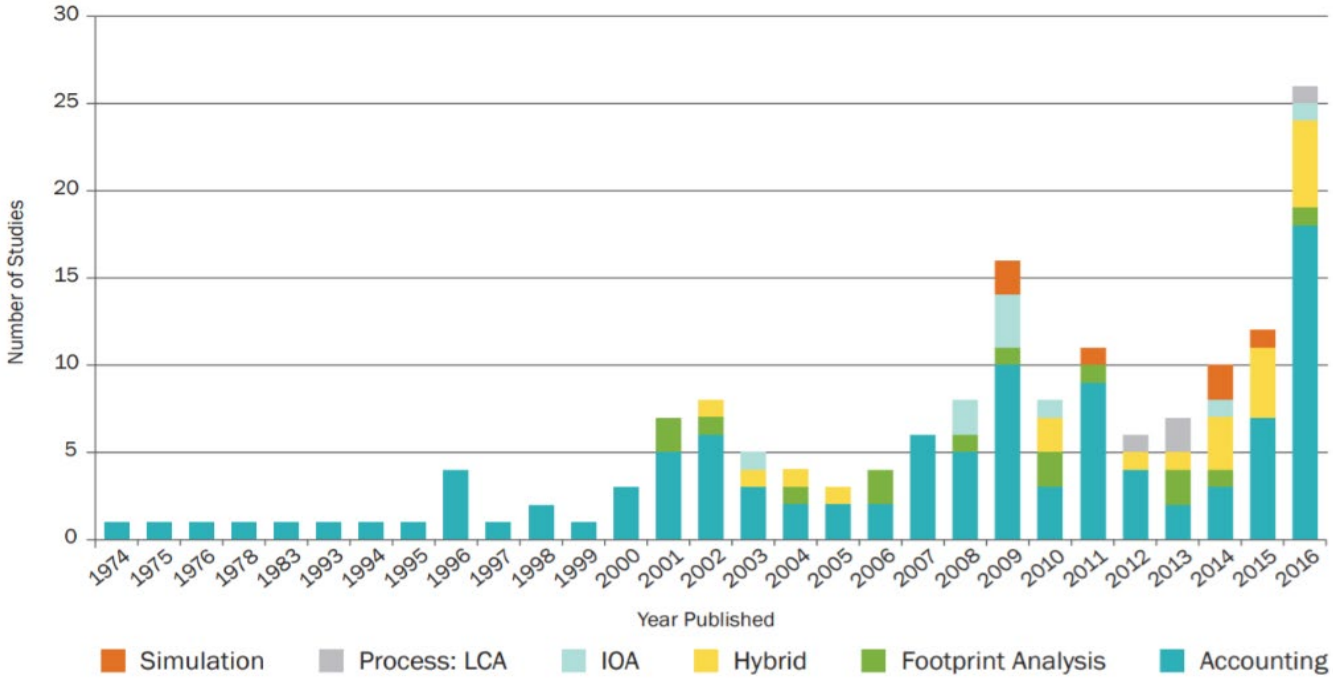


Figure 5: Number of urban metabolism assessment studies over time, showing the increasing diversity of approaches utilised.

Source : Musango et al.., 2017

Where to find data?

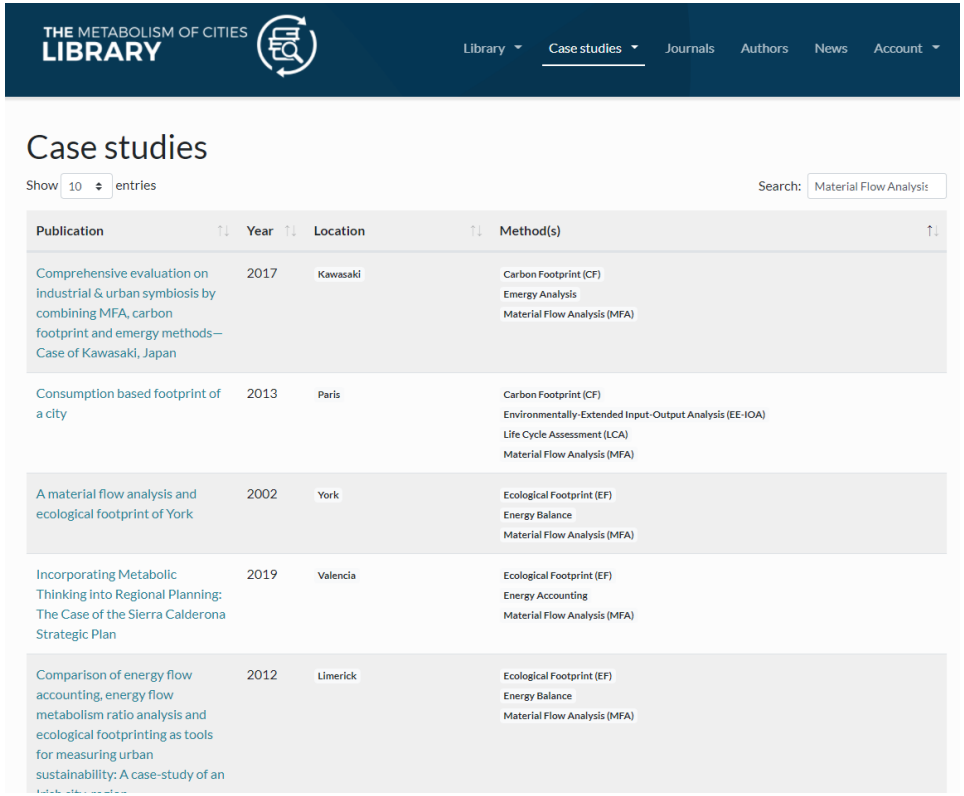
Urban metabolism studies

- **Laboratory on Human-Environment Relations in Urban Systems**

Source : Metabolism of Cities

Where to find data?

- Approx. 70 urban metabolism studies using specifically MFA methods



THE METABOLISM OF CITIES LIBRARY

Library | Case studies | Journals | Authors | News | Account

Case studies

Show 10 entries

Search: Material Flow Analysis

Publication	Year	Location	Method(s)
Comprehensive evaluation on industrial & urban symbiosis by combining MFA, carbon footprint and emergy methods—Case of Kawasaki, Japan	2017	Kawasaki	Carbon Footprint (CF) Emergy Analysis Material Flow Analysis (MFA)
Consumption based footprint of a city	2013	Paris	Carbon Footprint (CF) Environmentally-Extended Input-Output Analysis (EE-IOA) Life Cycle Assessment (LCA) Material Flow Analysis (MFA)
A material flow analysis and ecological footprint of York	2002	York	Ecological Footprint (EF) Energy Balance Material Flow Analysis (MFA)
Incorporating Metabolic Thinking into Regional Planning: The Case of the Sierra Calderona Strategic Plan	2019	Valencia	Ecological Footprint (EF) Energy Accounting Material Flow Analysis (MFA)
Comparison of energy flow accounting, energy flow metabolism ratio analysis and ecological footprinting as tools for measuring urban sustainability: A case-study of an	2012	Limerick	Ecological Footprint (EF) Energy Balance Material Flow Analysis (MFA)

Source : Metabolism of Cities, 2024

Where to find data?

Lausanne
Switzerland

212 documents
Context
Biophysical characteristics
Infrastructure
Stocks and flows
83% data collection completion

Explore city | Contribute

Geneva
Switzerland

266 documents
Context
Biophysical characteristics
Infrastructure
Stocks and flows
97% data collection completion

Explore city | Contribute

Zurich
Switzerland

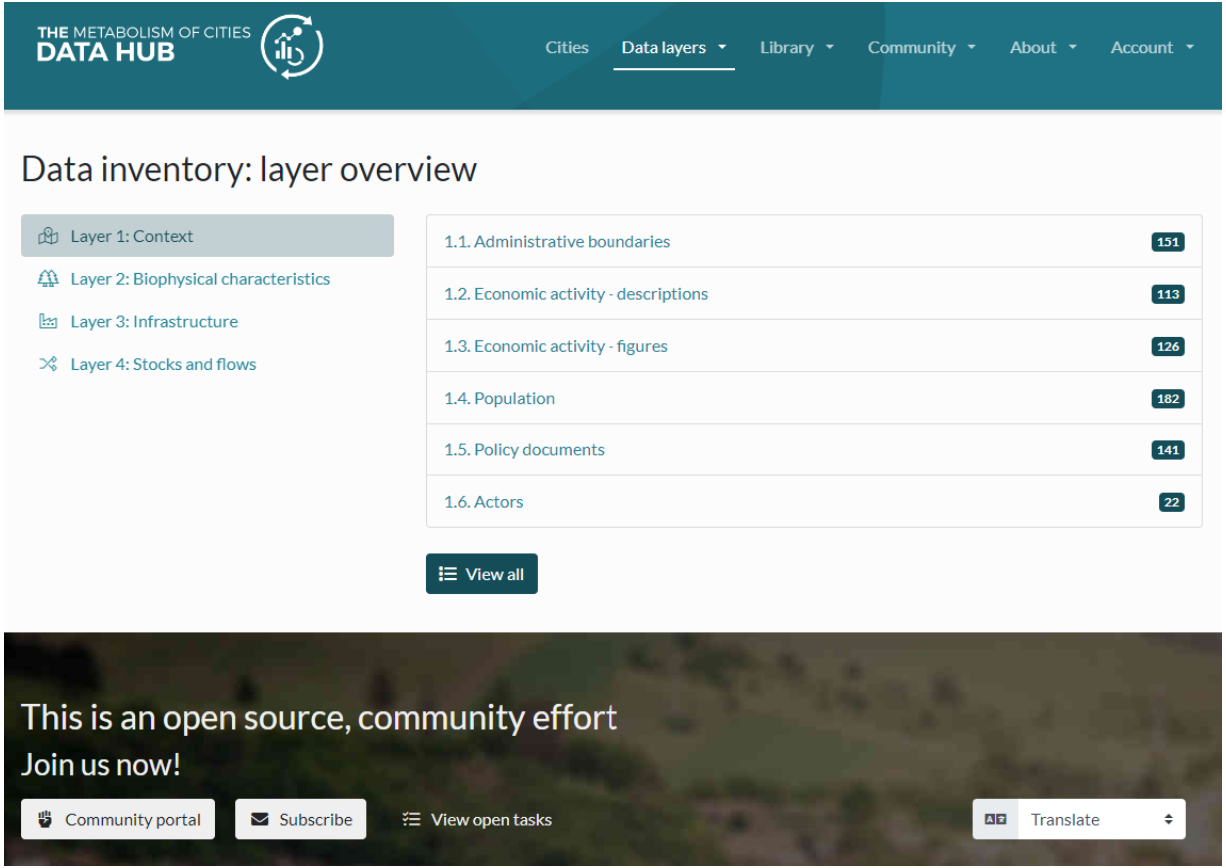
69 documents
Context
Biophysical characteristics
Infrastructure
Stocks and flows
51% data collection completion

Explore city | Contribute

Source : Metabolism of Cities

Binder, Félix Martín del Campo, Hecher, Campfens

Where to find data?



Source : Metabolism of Cities

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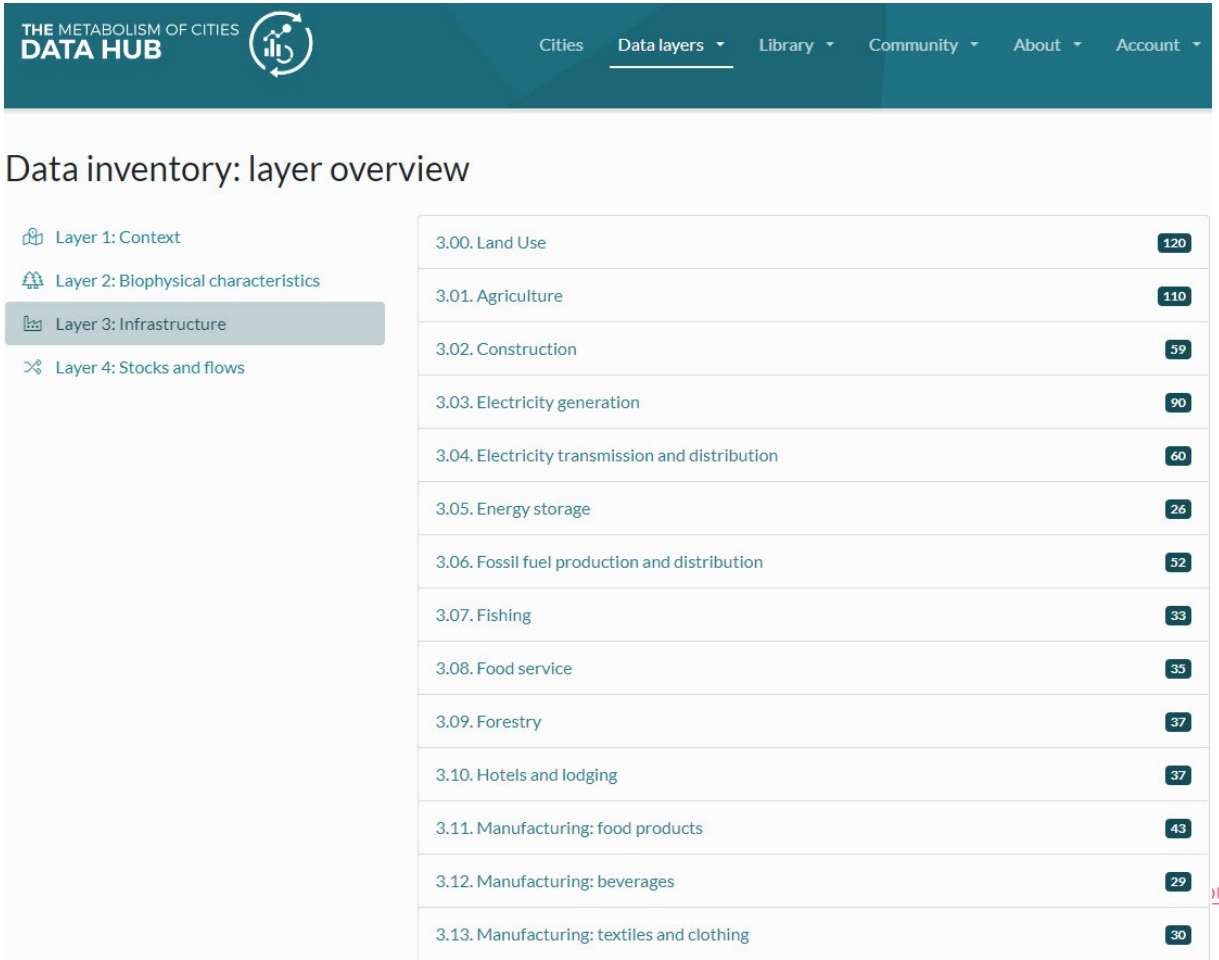


ource : Metabolism of Cities

Binder, Félix Martín del Campo, Hecher, Campfens

Examples MFA at Urban/City scale

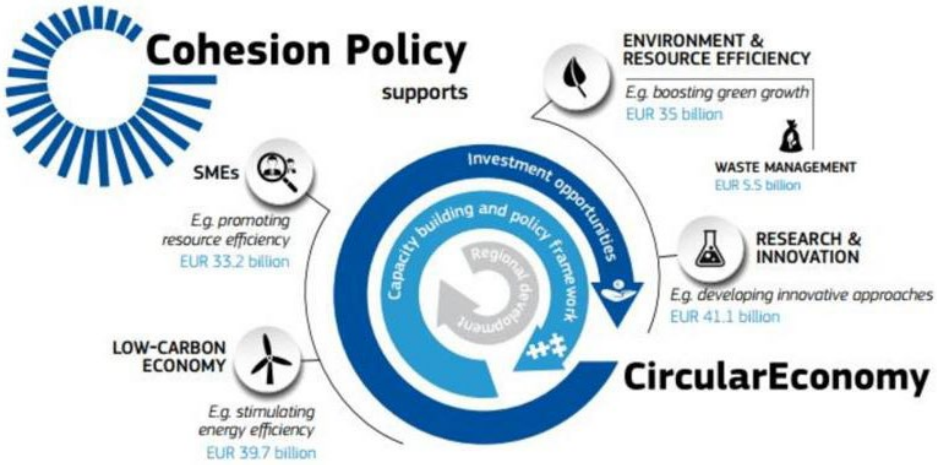
Table 6 Comparison between Cape Town, Paris, Hamburg, Vienna and Leipzig. All indicators are t/cap

	Hamburg 2001	*Vienna 2001*	*Leipzig 2001*	*Paris (PPC) 2003*	*Paris (Île-de-France) 2003*	*Cape Town 2010**	*Cape Town 2013*
Total population (million)	3.26	2.12	1.09	6.32	11.3	3.50	3.85
Total km^2	8,616	4,596	4,386	762	12,012		2,461
Density (capita/km^2)	379	461	249	8,295	937	12,059	1,564
Domestic material consumption	11.4	8.8	25.3	4.6	7.1	11.3	3.5
Domestic extraction used				0.0	2.1		1.6
Imports				11.0	10.2		5.8**
Exports				7.9	5.2		3.9**
Domestic processed output				4.3	6.8		2.3
Physical trade balance				3.1	5.0		1.9
Direct material input				11.0	12.3		6.2**
Direct material output				12.2	12.0		7.3**
Net addition to stock				0.7	2.6		2.5

Note: *This study was published in 2010 but the data sources date back to previous years. **These figuresinclude throughput.

Source : Hoekman, & von Blottnitz, 2017

Insights from Urban MFA's and policies



Source: European Comission, 2015

Insights from Urban Metabolism

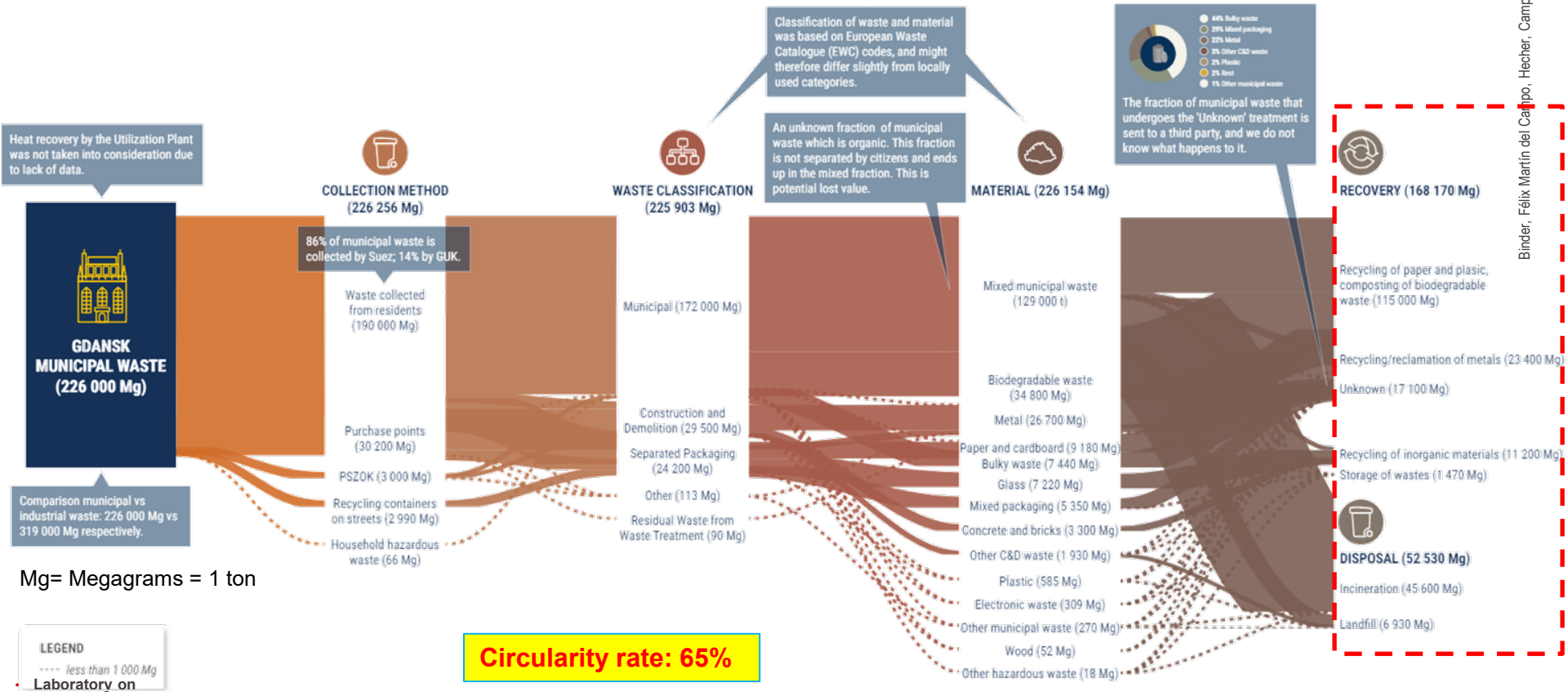
- Cities are **not** at all **self-sufficient**
  - This reliance on external flows highlights the vulnerability of cities to disruptions in supply chains and resource availability, especially as population growth and urbanization continue
- **Scale** matters
  - To optimize resource management and urban planning, it's crucial to understand the specific context of the scale at which material flows are being assessed
- Difficult to make **circular**
  - To create more circular systems, cities would need to redesign production, consumption, and waste processes. This includes strategies that prioritize infrastructure for material recovery, encouraging modular and reusable design, and shifting economic incentives toward resource conservation

Binder, Félix Martín del Campo, Hecher, Campfens

Urban Metabolism

City of Gdansk, Poland, 2021

Binder, Félix Martín del Campo, Hecher, Campfens



Mg= Megagrams = 1 ton

LEGEND

---- less than 1 000 Mg

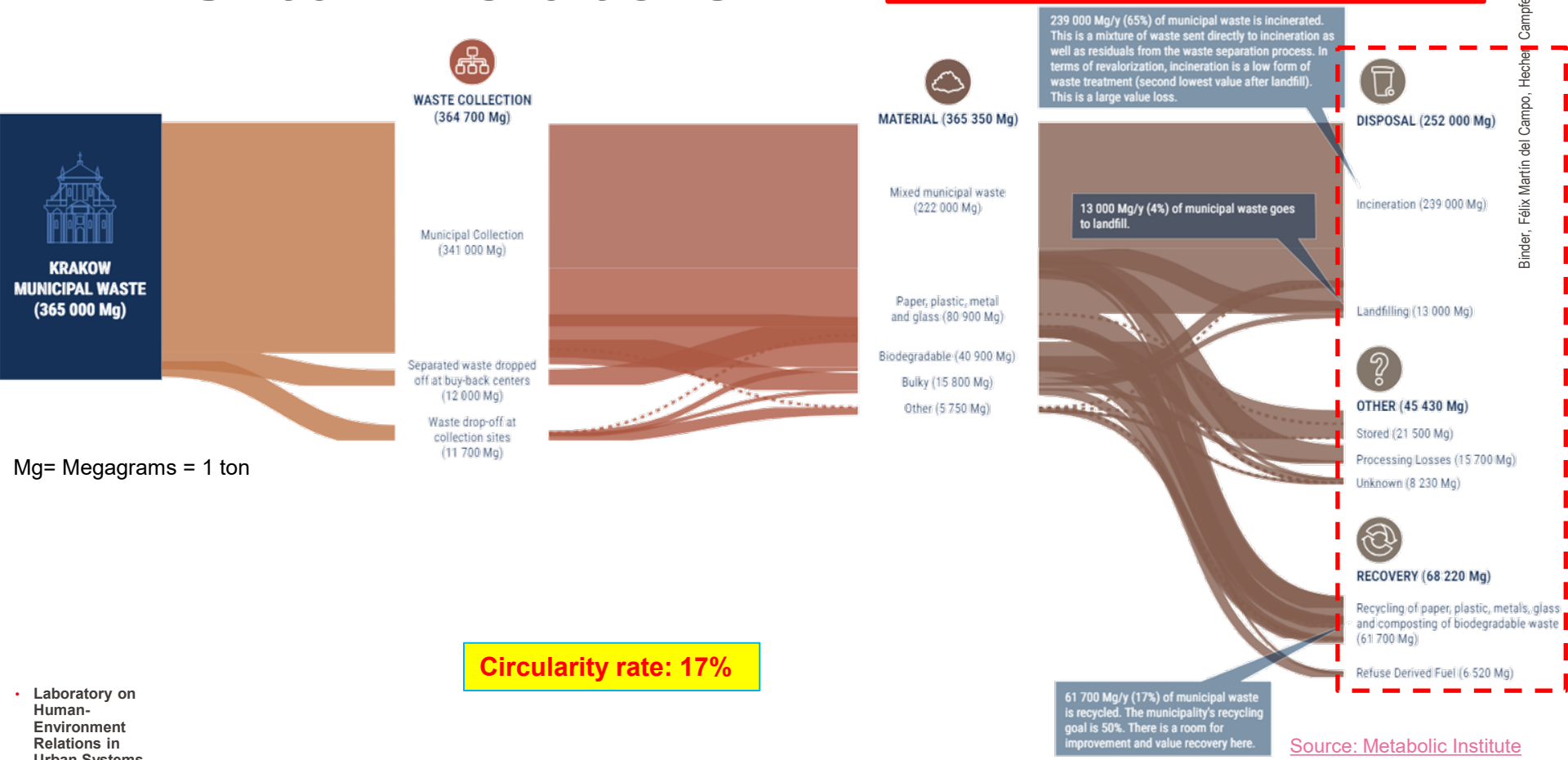
Circularity rate: 65%

Laboratory on Human-Environment Relations in Urban Systems

Source: Metabolic Institute

Urban Metabolism

City of Krakow, Poland, 2021



Mg= Megagrams = 1 ton

Circularity rate: 17%

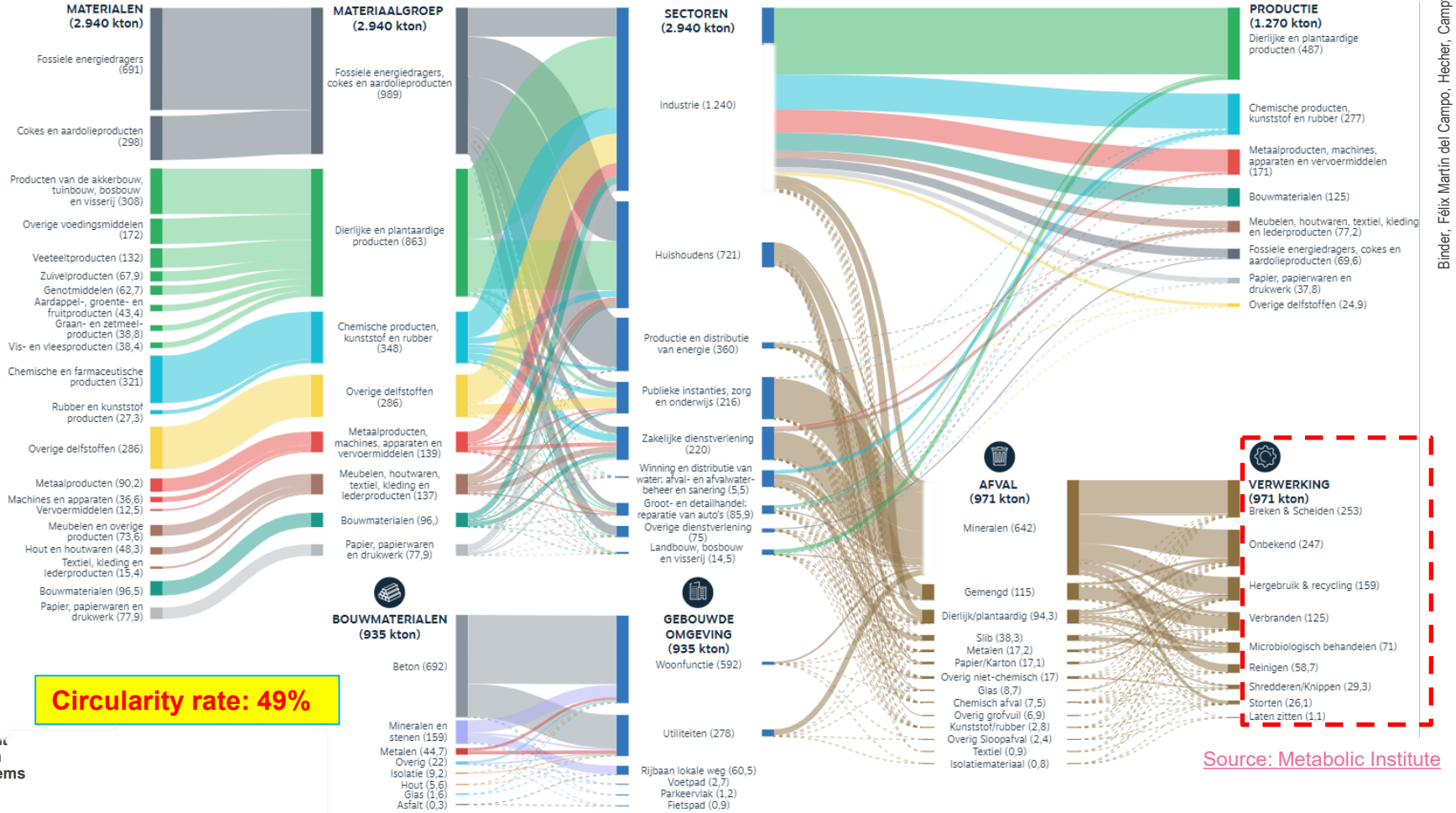
Source: Metabolic Institute

Binder, Félix Martín del Campo, Hecher Campfens

- Laboratory on Human-Environment Relations in Urban Systems

Urban Metabolism

City of Utrecht, Netherlands, 2021



Circularity rate: 49%

Source: Metabolic Institute

- Laboratory Human-Environment Relations in Urban Systems

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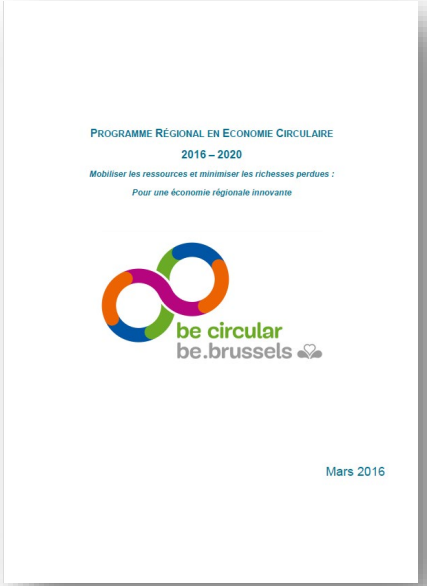
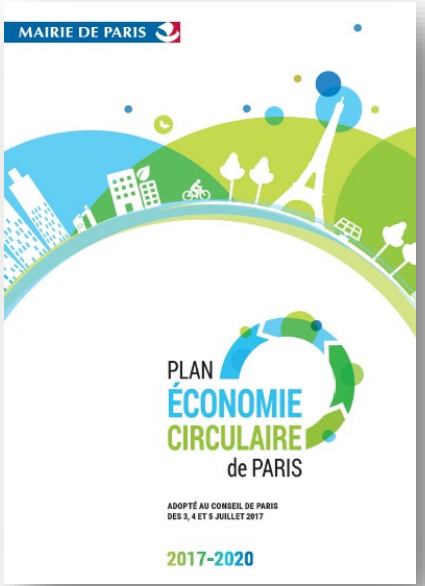
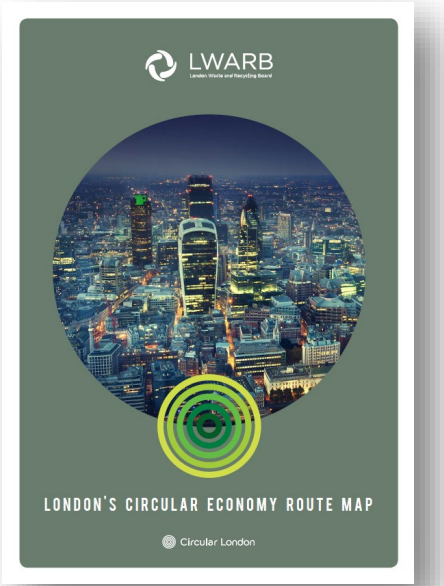
Insights from Policies

- Cities are **not** at all **self-sufficient –** Need to prioritize local resources.
  - Policies that support localized systems for **food, energy, and material recovery** can significantly enhance urban resilience.
- **Scale** matters - Adapt Circular Economy strategies
  - A city-level strategy might prioritize **household recycling** and **community-based resource recovery**, while regional policies might target **industrial by-products** and broader recycling infrastructure
- Difficult to make **circular -** Support Circular Design and Waste Infrastructure.
  - Circular economy policies can drive **eco-design** and **modular construction** approaches, which reduce waste at the source and allow materials to be recovered more easily.

Circular Economy policies at city scale







Sources: Gosuin, Fremault & Laanan, 2016; Mairie de Paris, 2017; LWARB, 2017

Circular Economy policies - Brussels

- **Urban metabolism study in 2014-2015**
- **3 ministries, 4 administrations**
- **4 strategic themes**
  - Transversal (43 measures): define a favorable normative and legal framework
  - Sectoral (48 measures): Construction (13), resources and wastes (24), logistics (7), retail (4)
  - Territorial (8 measures)
  - Governance (12 measures)

Source: Gosuin, Fremault & Laanan, 2016

Circular Economy policies - Paris

- **Urban metabolism study in 2007**
- **Etats Généraux de l'Economie Circulaire in 2015** (120 organisation proposed 65 initiatives)
- **First roadmap in 2017** (15 actions for 3 scales)
  - Planning and construction (3)
  - Reduction, reuse and repair (4)
  - Support for actors (5)
  - Public procurement (2)
  - Responsible consumption (1)
- **Second roadmap from 2018 to 2019**

Source : Mairie de Paris, 2017

Circular Economy policies - London

- **Urban metabolism study in 2002**
- **ReLondon (formerly LWARB) governmental entity, CE Route map**
  - Built environment (13 actions): CE design (5), managing building materials (4), operation of buildings (4)
  - Food (9 actions): preventing avoidable food waste (3), valuing food waste and food surplus (3), maximising use of urban space for food growing (3)
  - Textiles (10 actions): design (1), embedding CE into the textile supply chain (6), re-use and recycling
  - Electricals (11): design (2), extending the life of products (6), and effective collection and recycling (3) aspects.
  - Plastics (7 actions)

Source: LWARB, 2017

Thank you for your attention!