# A Material Flow Analysis of Paris and its Region

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# A MATERIAL FLOW ANALYSIS OF PARIS AND ITS REGION

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## ABSTRACT

Material flow analysis (MFA) is a powerful tool that helps understanding national, regional and urban metabolism. It provides some indicators of (un)sustainability and can contribute to the definition of public environmental policy. The paper presents the results of a research project that aimed 1) to examine the feasibility of MFA at the regional and urban scale in France, 2) to select the most appropriate method, 3) to identify the available data, then 4) to realise the material balance in the specific case of Paris and its region.

On the basis of the Eurostat method, the study was conducted at three levels: Paris (2.2 million inhab.), Paris and its suburbs (6.3 million inhab.) and the whole region (11.3 million inhab.). The data collection revealed the lack of information about solid wastes and energy consumption (a very paradoxical situation!) but was successful enough to allow the realisation of the material balance for the year 2003 (but not to calculate hidden flows).

The results show the need for a multi-scale approach as urban life in Paris depends on the suburbs; the consequence of both concentration of activities in the city centre and urban sprawl on material flows; the poor recycling and the huge flow to nature, etc. They encourage using MFA in the urban context as a basis to material flow management and to dematerialisation.

## INTRODUCTION

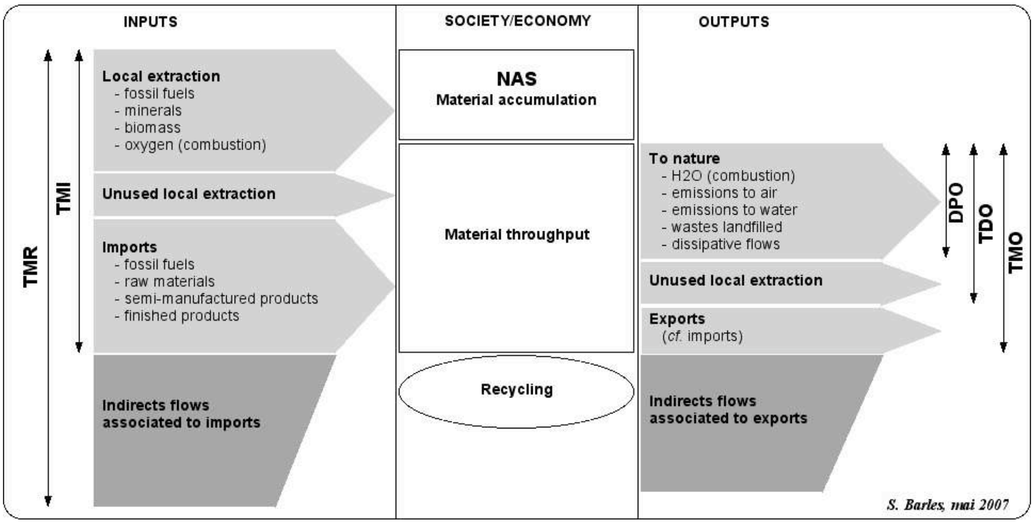
Material flow analysis (MFA) is a powerful tool that helps understanding national, regional and urban metabolism. It provides some indicators of (un)sustainability and can contribute to the definition of public environmental policy [1]. MFA is now widely spread at the national level (see for instance [2]), but remains poorly addressed at the local one, especially in France, despite some encouraging examples abroad (see for instance [3, 4]).

The paper summarises the results of a research project that aimed to examine the feasibility of MFA at the regional and urban scale in France, to select the most appropriate method, to identify the available data (Sect. 1), then to realise the material balance in the specific case of Paris and its region and to discuss the results (Sect. 2). More details are available in the research report [5].

## METHOD, DATA, CASE STUDY

### Method

Few methods exist in order to realise a material balance. In this project, the method developed by the Statistical Office of the European Communities (Eurostat) has been chosen, although it was not implemented for local or regional case studies but for national accounts. The Eurostat method [6] is widely spread, so it allows comparisons (between different territorial levels – national account *versus* regional or urban account –, or between cities or regions). It is based on available national data and we can suppose that those data exist – at least some of them – at the regional level. It lies on the determination of main inputs and outputs for the considered system, and does not need the description of material circulation within the system, so it is quite easy to perform. It can then provide some indicators in the context of sustainability policies. Figure 1 presents the principles of the method, the main flows to be determined and the main indicators proposed by Eurostat.




NB. 1) According to the simplified equation: (fuel+oxygen) → (carbon dioxide+water), material balance needs to weight oxygen consumed and water produced by combustion. 2) Water balance is not included (except water mentioned above).

Indicators mentioned in Fig. 1:

TMI: Total Material Input TMR: Total Material Requirement TMO: Total Material Output

TDO: Total Domestic Output DPO: Direct Processed Output NAS: Net Addition to Stock

Other indicators: DMI: Direct Material Input (local extraction (used)+imports)

DMO: Direct Material Output (DPO + exports) DMC: Direct Material Consumption (DMI – exports)

**TMI = NAS + TMO** **DMI = NAS + DMO**

*Figure 1: Main flows in material balance according to the Eurostat method [6].*

## Case study

The administrative region Île-de-France is currently divided into three zones (Fig. 2): 1) Paris; 2) its dense suburb, called *Petite couronne* (PC) in French, the reunion of three administrative *départements* (Hauts-de-Seine, Seine-Saint-Denis, Val-de-Marne); and 3) the rest of the region, called *Grande couronne* (GC), an area characterised by urban sprawl, industrial activities and intensive agriculture, and composed by four *départements* (Seine-et-Marne, Yvelines, Essonne, Val-d'Oise).

During the first phase of the research, the focus was on Paris area, but it appeared soon that such a choice was very restrictive. Paris, within its administrative limits, does not contain the urban area as a whole. It just represents the very dense city centre of a large urban zone. One can suppose that urban shape (density *versus* sprawl) and variety of activities (residential, tertiary, industrial, agricultural) can impact material flows. Those considerations led to define three concentric areas and three MFA: 1) Paris, 2) Paris and its suburb (PPC) that represent the dense urban zone of the region, 3) the entire region (IdF).

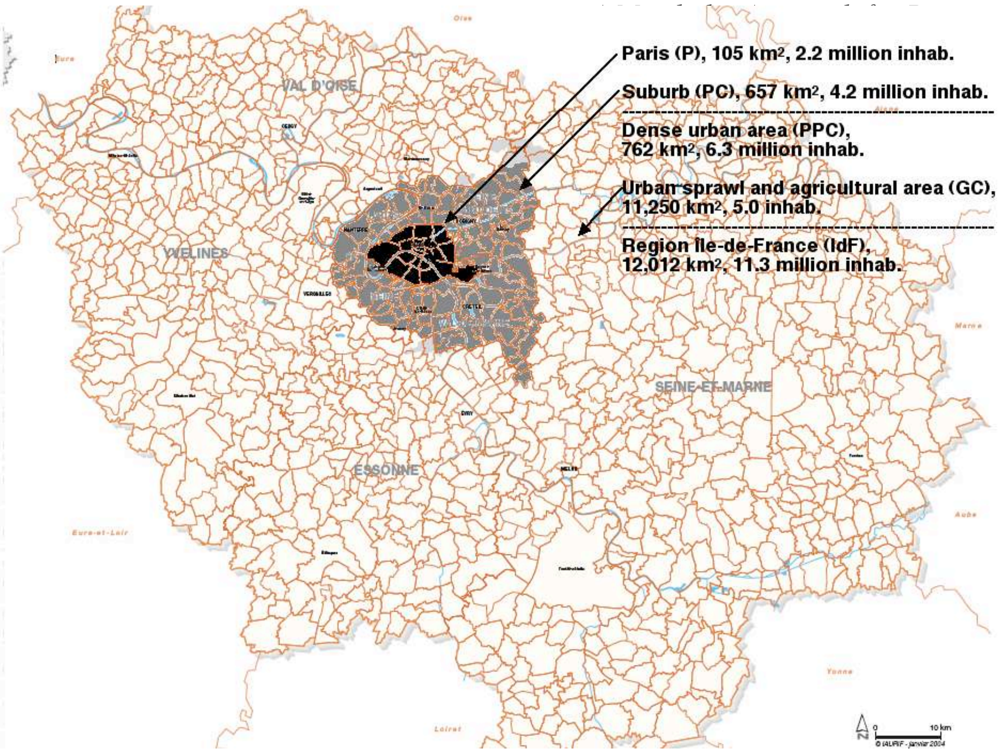



*Figure 2: Study areas (map: IAURIF).*

## Data collection

Data concerned with MFA are mainly available at the regional and, to less extent, departmental level. In this case, we benefited from the particular administrative situation of Paris: it is both a municipality and a *département*, so nearly all data are available at this level (that won't be the case for other cities in France).

The more precise, continuous, homogenous data concern agricultural production (local extraction of biomass in MFA), freight (imports and exports in MFA), household wastes. Data about local extraction of minerals, imports and local extraction of fossil fuels, other solid wastes and liquid wastes, emissions to air are of less quality, or not entirely compatible with MFA. Despite those limits, data collection was proved successful for direct flows, but it was not possible to capture hidden flows. 2003 was chosen as the reference year.

# RESULTS AND DISCUSSION

## General results

Table 1 summarises the main results of MFA. In the following text, all figures except oxygen consumed and water produced by combustion.

Local DMI and DMC can be first compared to national figures [2]. Local DMI ranges from 8.8 t/cap (Paris) to 12.3 t/cap (IdF), while French DMI amounts 17.6 t/cap in 2001. Local DMC ranges from 5.0 t/cap (Paris) to 7.1 t/cap (IdF), while French DMC reaches 14.4 t/cap. The main reason for these differences lies in the fact that, albeit its industrial and agricultural activities, the region extracts, produces and transforms less material than the rest of the country. These steps of material anthropogenic cycles lead to lots of emissions and wastes, and, as a consequence, to higher DMI and DMC. Another reason could be that the increase in stock is less important in Île-de-France than in other French regions. Nevertheless and unsurprisingly, the three concentric areas are proved unsustainable. From a biogeochemical point of view, DMC is the sum of net addition to stock within the study area and of flows to nature: the more the DMC, the less sustainable the system.

| | **Paris (2,166,000 inhab.)** | | **PPC (6,321,000 inhab.)** | | **IdF (11,259,000 inhab.)** | |
|---|---|---|---|---|---|---|
| | kt | t/cap | kt | t/cap | kt | t/cap |
| **INPUT** | | | | | | |
| **Local extraction** | | | **0** | **0.0** | | |
| Fossil fuels | 0 | 0.0 | 0 | 0.0 | 540 | 0.0 |
| Minerals | 0 | 0.0 | 0 | 0.0 | 16,994 | 1.5 |
| Biomass | 0 | 0.0 | 30 | 0.0 | 6,013 | 0.5 |
| Oxygen (combustion) | 6,561 | 3.0 | 24,011 | 3.8 | 52,653 | 4.7 |
| **Total Local Extraction** | **6,561** | **3.0** | **24,041** | **3.8** | **76,200** | **6.8** |
| Total Local Extraction without $O_2$ | 6,561 | 3.0 | 30 | 0.0 | 23,547 | 2.1 |
| **Imports** | | | | | | |
| Fossil fuels | 3,914 | 1.8 | 13,048 | 2.1 | 26,095 | 2.3 |
| Others | 15,242 | 7.0 | 56,453 | 8.9 | 88,350 | 7.8 |
| **Total Imports** | **19,156** | **8.8** | **69,500** | **11.0** | **114,445** | **10.2** |
| **Direct Material Input (DMI)** | **25,717** | **11.9** | **93,541** | **14.8** | **190,645** | **16.9** |
| DMI without $O_2$ | 19,156 | 8.8 | 69,530 | 11.0 | 137,992 | 12.3 |
| **OUTPUT** | | | | | | |
| **To nature** | | | | | | |
| Emissions to air | 6,714 | 3.1 | 24,469 | 3.9 | 53,839 | 4.8 |
| Water (combustion) | 3,281 | 1.5 | 12,006 | 1.9 | 26,327 | 2.3 |
| Waste landfilled | 0 | 0.0 | 2,498 | 0.4 | 20,013 | 1.8 |
| Emissions to water | 0 | 0.0 | 8 | 0.0 | 42 | 0.0 |
| Dissipative flows | 150 | 0.1 | 436 | 0.1 | 2,398 | 0.2 |
| **Direct Processed Output (DPO)** | **10,145** | **4.7** | **39,416** | **6.2** | **102,618** | **9.1** |
| DPO without $H_2O$ | 6,864 | 3.2 | 27,410 | 4.3 | 76,291 | 6.8 |
| Exports | | | | | | |
| Emissions and wastes exported | 4,096 | 1.9 | 9,610 | 1.5 | 69 | 0.0 |
| Others | 8,378 | 3.9 | 40,406 | 6.4 | 58,502 | 5.2 |
| **Total Exports** | **12,474** | **5.8** | **50,017** | **7.9** | **58,571** | **5.2** |
| **Direct Material Output (DMO)** | **22,619** | **10.4** | **89,433** | **14.1** | **161,189** | **14.3** |
| DMO without $H_2O$ | 19,338 | 8.9 | 77,427 | 12.2 | 134,862 | 12.0 |
| Total to nature (TTN) without $H_2O$ | 10,960 | 5.1 | 37,020 | 5.9 | 76,360 | 6.8 |
| **RECYCLING** | | | | | | |
| Local | 0 | 0.0 | 4,211 | 0.7 | 7,320 | 0.7 |
| Outside | 1,854 | 0.9 | 444 | 0.1 | 0 | 0.0 |
| **Total Recycling** | **1,854** | **0.9** | **4,656** | **0.7** | **7,320** | **0.7** |
| **NET ADDITION TO STOCK (NAS)** | **3099** | **1.4** | **4,109** | **0.7** | **29,457** | **2.6** |
| **DIRECT MATERIAL CONSUMPTION (DMC)** | **10,778** | **5.0** | **29,094** | **4.6** | **79,490** | **7.1** |

*Table 1: Main results of the material flow analysis, 2003.*

Furthermore, we can examine the total flows to nature (local and exported). TTN (an indicator that does not exist in standard MFA) ranges from 5.1 t/cap (43% of DMI) in Paris, 5.8 t/cap (53% of DMI) in PPC and 6.8 t/cap (55% of DMI) in IdF: about half DMI is given back to nature, mainly by means of emissions to air (63% of TTN in Paris, 67% in PPC, 71% in IdF). This clearly illustrates the stakes of dematerialisation and decarbonisation and can be compared to the very low recycling: less than 1 t/cap, and less than 10% of DMI.

It is also possible to compare the three study areas. Every flow, except DMC and recycling, increases with the area (it is the same for NAS, but this figure is not reliable). A first reason for this is that activities, in particular primary and secondary sectors, are all the more developed and diversified since the study area around the city centre is large. Those activities, as already stated, need and create huge material flows. Another reason is that IdF comprises the urban sprawl area whereas Paris and PPC are dense zones.

City centre nearly entirely depends on other areas for inputs and flows to nature. These are, except emissions to air and dissipative flows, exported to other parts of the region. This dependence slightly decreases in the dense urban zone (PPC), mainly because some solid waste incinerators and wastewater treatment plants are located in the *Petite couronne* (Fig. 2). The region is self-sufficient with regard to flows to nature (or, more precisely, does not directly export them), but is not, of course, with regard to inputs: local extraction represents only 17% of DMI. Then, in view of sustainability, it would be important to replace imports (and their hidden flows) by local recycling.

**Detailed results**

The detailed results partly explain the observed differences and can help policy making. Figure 3 gives such details for DMC and for Paris, PC, GC and IdF.

As a result of both repartition of various activities and urban sprawl, fossil fuel consumption is higher in GC than in PC, in PC than in Paris. Furthermore, DMC is considerable for construction minerals in GC: about 5 t/cap, ten times more than anywhere in the region. Urban sprawl again is responsible for this. In 2003, construction minerals consumption amounts 590 t per new inhabitant in GC, and 80 t/new inhab. in PPC. On the other hand, the region is not self-sufficient with regard to construction minerals: local extraction represents only 1.5 t/cap, while regional consumption amounts 2.6 t/cap and demolition wastes landfilled 1.5 t/cap (Table 2). This helps defining two targets for dematerialisation: first, control of urban extension (which is generally connected to the sole energy issue), second recycling demolition wastes.

Food consumption is higher in Paris than anywhere else. Paris is both an employment and tourist area so there are more mouths to feed than inhabitants: MFA faithfully pictures the functioning of the urban area. The consequence is probably that organic wastes are also of great importance. Production of fertiliser should then be a good way to use this part of urban wastes, an option that is rarely considered in city centre because agricultural issues are not supposed to be relevant.

Due to wide use of incineration, the amount of wastes landfilled remains low, if we except demolition wastes (Table 2). But the figures clearly show that the emphasis on household wastes that characterises French waste policy is insufficient.

| | **Paris** | **PC** | **GC** | **IdF** |
|---|---|---|---|---|
| Households wastes and related wastes | 98 | 83 | 150 | 116 |
| Ordinary industrial wastes | 115 | 67 | 64 | 75 |
| Demolition wastes | 1654 | 1746 | 1301 | 1533 |
| Agricultural wastes | 0 | 0 | 32 | 14 |
| Dangerous industrial wastes | 0 | 18 | 63 | 34 |
| Wastewater treatment wastes | 4 | 4 | 7 | 6 |
| **Total** | **1872** | **1919** | **1617** | **1778** |

*Table 2: Wastes landfilled, 2003 (kg/cap).*

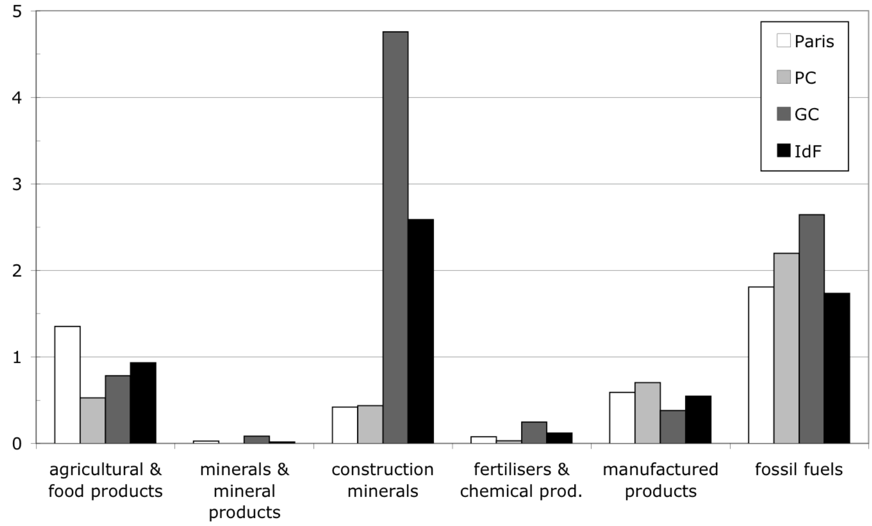



*Figure 3: Direct material consumption (DMC), 2003 (t/cap).*

### CONCLUSION

The results show the need for a multi-scale approach as urban life in Paris depends on the suburbs; the consequence of both concentration of activities in the city centre and urban sprawl on material flows; the poor recycling and the huge flow to nature, etc. They encourage using MFA in the urban context as a basis to material flow management and to dematerialisation. A further step should be to determine hidden flows, to add energy and water balance to MFA, and to implement other case studies in order to compare results.

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### REFERENCES

1. Bringezu, S., et al.: Analysis for action: support for policy towards sustainability by material flow accounting. Wuppertal Institute for Climate, Wuppertal, 1998.
2. Welsz, H. (ed.): Development of material use in the EU-15: 1970-2001. IFF-Department of Social Ecology, Vienne, 2005.
3. Faist Emmenegger, M., Frischknecht, R.: Métabolisme du canton de Genève. Phase 1. Uster, ESU service, Uster, 2003.
4. Hammer, M., Giljum, S., Hinterberger, F.: Material Flow Analysis of the City of Hamburg. Sustainable Europe Research Institute (SERI), Vienne, 2003.
5. Barles, S.: Mesurer la performance écologique des villes: Le métabolisme de Paris et de l'Île-de-France. Laboratoire TMU (UMR CNRS AUS 7136), Champs-sur-Marne, 2007. [http://www.univ-mlv.fr/~www-ltmu/groupe_documents/doc_pdf/Barles-EI-Paris.pdf].
6. Eurostat: Economy wide material flow accounts and balances with derived resource use indicators. A methodological guide. Office for Official Publications of the European Communities, Luxembourg, 2001.