Universitat Autònoma de Barcelona

Integrated assessment of Municipal Solid Waste Metabolism

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Integrated assessment of

Municipal Solid Waste Metabolism

The case of the Metropolitan Area of Naples, Italy

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A Teresa e Pino,
per essere sempre presenti a distanza

A Tony, Maurizio ed Angelo,
per amarmi in maniera tanto differente

A Camilla, Giuseppe, Michela, Francesco e Giulia Sofia,
per riempire il mio cuore ogni volta che vi vedo

A te Nonna,
per accompagnarmi anche se non ci sei più

"The Earth does not belong to man;
Man belongs to the Earth"

"La Terra non appartiene all'uomo;
è l'uomo che appartiene alla Terra

Native American Indian quote

PREFACE

The work reported in this PhD thesis is the output of three years of the intense work carried out within the MARSS project at the ICTA-UAB under the supervision of Professor Mario Giampietro.

The research process has gone through many cycles, changes in direction and adaptation to the emerging ideas, doubts and reflections dealing with a very complex issue: urban waste management.

This adventure started when, after about 6 years of international consultancy in renewable energy solutions, I felt the strong desire to move my vision from consultancy towards academia. Until then, I had not thought about doing a PhD at all…

I was looking for a multi-disciplinarian research project on the same line both with the work that I have been involved during my professional experience and with my interest in sustainable issues. When I met Mario at the bar of ICTA and after the first talk, I understood that I was in the right place and starting a PhD in his "social metabolism group" was the best option.

Well, I didn't know what I was doing…

I must admit that it was a challenging task to learn about MuSIASEM or dealing with complex social-ecological issues or more in general with social sciences so different from my educational background in Environmental Engineering. However, I have to admit that this academic experience provided me a complementary way of thinking and opened my mind to new flexible scientific approaches.

Participating in the MARSS Project was a wonderful opportunity for developing my PhD research. As matter of fact, this project provided the necessary financial support during those years and it was perfectly in line with the scope of my thesis. Furthermore, I tested the tool-kit I developed to assess urban waste management systems in Naples, my city of origin. I like the idea that my work may contribute in generating a holistic understanding of the urban waste framework in my city where trust between local inhabitants and the government has been considerably damaged because of the past corruption and mismanagement in the governance of waste management.

I spent last four months writing this dissertation, trying to put together all the pieces of a puzzle, reviewing all the excel files, mails, reports, my publications, unpublished material, Mario's schemes and ideas on several pieces of papers found between my folders, adapting and completing the conceptual framework.

I hope to have succeeded in making a story easy to follow and that you enjoy and learn with it as much as I did.

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The biggest thank you goes to my nieces and nephews Camilla, Giuseppe, Michela, Francesco and Giulia Sofia for giving me, even though we haven't spent much time together, a big smile on my face any time that I think about them.

I am really happy to share this important achievement with all of you. Each of you has contributed in different ways to this accomplishment.

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Sono realmente contenta di condividere il prodotto di tre anni di lavoro accademico con tutti voi. Ognuno ha contribuito in maniera differente a questo laborioso risultato.

SUMMARY

In my thesis I develop a procedure for the integrated assessment of the performance of Municipal Solid Waste Management System (MSWMS) across dimensions and scales interfacing the quantitative analysis of biophysical flows with the socio-economic analysis. The usefulness and the shortcomings of this procedure have been tested in a real case study (The Metropolitan Area of Naples, Campania Region, Southern Italy).

This procedure can be used as decision support system for carrying out an informed choice, based on the simultaneous consideration of different criteria of performance, when deciding about technological choices.

The proposed decision support system combines two elements:

(a) a holistic framework of analysis making it possible to carry out a multi-scale and multi-criteria analysis of: (i) the performance of a given MSWMS (ii) the option space of future changes in the existing network; (iii) the changes implied by the introduction of innovative technologies.

(b) an integrated package of indicators referring to different criteria and scales that can be selected "à la carte" by relevant social actors through participatory processes increasing the quality of the information used in the process of governance.

The innovative holistic framework builds on the theory of metabolic networks and the Multi-Scale Integrated Analysis of Societal and Ecosystem Metabolism (MuSIASEM) accounting method.

In this approach a MSWMS is perceived as an organ of a socio-ecological system that modulates the interaction between the metabolic processes of the urban area, which consume a flow of inputs and generate a flow of wastes, and those of the embedding ecosystems providing both some of the inputs used by the MSWMS and local sink capacity.

Building on these premises, the tool-kit for integrated analysis can characterize: (i) the waste flows produced by the urban system in terms of quantity and quality; (ii) the mix of inputs required for the operation of the different stages of the waste management process, such as technology, employment, energy, water and material flows; (iii) the degree of openness of the system, that is, the imports and exports of urban waste flows in the different stages of its operation; (iv) the final outputs released into the local environment.

Preliminary data from the MAN case study have been used to develop and illustrate the proposed theoretical framework in a way that is generic enough to be applied in different contexts. The metabolic network approach is then used to generate: (i) a multi-scale integrated representation of the current performance of the MSWMS of the MAN and (ii) a decision support tool to be used to explore the policy option space and to guarantee better-informed policy decision-making. In relation to the last point, an application used to illustrate the potentiality of the approach explores the trade-offs between “exporting wastes” (currently a crucial issue in the MAN) versus “building and operating more processing capacity in the area”. The tool-kit has been used to generate scenarios referring to two policy options - (i) the complete internalization of waste processing; and (ii) increasing recycling rate.

When assessing and comparing the performance of different technological options it is not only important to have an integration of different dimensions of analysis – i.e. bridging the biophysical, socioeconomic and political-cultural factors - but also to check whether the chosen narratives chosen to define the performance of the MWSMS are shared by the local social actors and are relevant for them.

For this reason, the developed decision-support system has been validated through participatory processes with various social actors (policymakers, voters, political parties, experts, associations, NGOs and grassroots movements). Interviews with local stakeholders in Naples were undertaken in the fall of 2015 and the results of these interviews were used to check the: (i) the definition of a "grammar" used to represent across scales and dimensions the different processes taking place in the MSWMS of the MAN (in relation to the identity of the metabolic network used to represents the various processes in the system); (ii) the robustness of the framing of the muti-criterial analysis (in relation to the choice of indicators); and (iii) the robustness of the choices made in the quantitative characterization based on the chosen grammar (in relation to the choice of data and technical coefficients used in the model).

The use of participatory processes makes it possible to tailor the proposed holistic framework to the specific circumstances of the case under study identifying the variety of different perceptions found among social actors. This step guarantees the quality of the choice of narratives used to characterize advantages and disadvantages of different types of MSWMS in a multi-criteria setting.

The approach proposed in this thesis can be considered a meta-tool for carrying out a quantitative characterization of the metabolic pattern of complex waste management systems. It is essentially a semantically open framework that can accommodate various

indicators related to the socio-economic aspects (viability and desirability) and those related to environmental impact/stress (feasibility), and therefore allows an informed discussion among the various stakeholders over the performance of MSWMS. As argued by (Scholz, R.W. & Steiner 2015), the construction of proper meta-levels of reflection, validation, and integration is expected to play an important role in the future development of sciences.

Keywords: municipal solid waste management system; participatory process; integrated assessment; metabolic network; performance indicators; MuSIASEM; Naples.

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Acronyms and abbreviations

MSW - Municipal Solid Waste
MSWMS - Municipal solid Waste Management System
EI - Environmental Impact
SES - Socio-Ecological System
MAN - Metropolitan Area of Naples
MARSS - Material Advanced Recovery Sustainable Systems
MCN - Metropolitan City of Naples
MuSIASEM - Multi-Scale Integrated Analysis of Societal and Ecosystem Metabolism
NAIADE - Novel-Approach-Imprecise-Assessment-And-Decision-Environments
MCA - Multi-Criteria Analysis
MRW - Metabolic Rate of Waste
DW - Density of Waste
DWD - Density of Waste to be Disposed

CM - Mixed Collection
CS - Separated Collection
MBT - Mechanical Biological treatment
STIR - Stabilimento Tritovagliatura ed Imballaggio Rifiuti = MBT
Lf - Landfilling
Inc - Incineration
WW - Waste Water Treatment
PTSP - Presorting Transfer and Storage Platforms
Comp - Composting
AD - Anaerobic digestion;
R - recycling centers;
R_{EX} - External Recycling Centers;
SRMR -Secondary Raw Material Recovery
Rv - Recovery

W - Waste
TSWT -Total Municipal Solid Waste
WM - Mixed Municipal Solid Waste
FST - Frazione Secca Tritovagliata
WS - Separated Municiapl Solid Waste
W_{EX} - Waste exported outside the system
W_{IM} - Waste imported inside the system
Met - Metal
PC - Private waste treatment Companies
FUT - Frazione Umida Tritovagliata (Humid Fraction from MBT)
FUTS - Frazione Umida Tritovagliata Stabilizzata (Stabilized Humid Fraction)

INTRODUCTION

Problem formulation

(i) In the third Millennium, because of the global phenomenon of urbanization Municipal Solid Waste Management is becoming an important issue for all the governments of the world in developed and developing countries.

(ii) The definition of the performance of a Municipal Solid Waste Management System (MSWMS) is complex since it refers to different dimensions of analysis that should be considered observing the system at different scales of analysis. This fact is important because the risk of failures in the proper management of wastes can translate into the emergence of ecological, economic and health problems leading to social conflicts over the issue.

(iii) An effective governance of MSWMS would require the ability of carrying out participatory processes in which scientific experts can help the local communities and their administrators to do informed choices about robust policies in this field.

An effective governance of MSWMS implies a wise choice of institutional settings, technologies and required citizen behavior, plus the ability to monitor the efficacy of the operations in time. For this reason, an effective governance requires participatory processes of integrated assessments based on a wise selection of criteria of performance integrating robust information about environmental impact, socio-economic impact, economic viability, technical performance.

It should be noted, that at the moment the choice of policies, including those referring to waste management, is based on the “evidence based policy” approach. In this approach, a set of quantifiable indicators is first selected by experts and then used to define objective functions to be optimized or minimized. This approach has many drawbacks: (i) within it the complexity of real problems is simplified and reduced by the choice of a finite set of numerical indicators. This simplification of complexity raises a series of questions: Who has the legitimacy to decide about this simplification? What are the implications of this simplification? How important are the aspects not considered in the optimizing functions determined by the simplification?; (ii) the validity of the particular view chosen for the quantitative representation is always contested - each situation is special!; (iii) the validity of the particular view chosen for the quantitative representation will expire in time - socio-economic systems are evolving in time, both in terms of physical process and cultural values.

These three points imply that it is impossible to adopt a set of indicators of performance "one size fits all" whose validity has been determined "once and forever". Each MSWMS is operating within a specific ecological and socio-economic context that makes it special and that will change in time. That is why, it is important to develop new analytical tools that are: (i) semantically open - they must explicitly require an input from the users for their quantification at the moment of tailoring the analysis on the specificity of the considered system; and (ii) based on a quantitative accounting framework which is flexible – a framework that can be patched and adjusted during the scientific analysis.

The structuring of the activities of my thesis has been determined by a wonderful opportunity that was given to me by the participation in the activities of an EU Life Project called MARSS[1] (Material Advanced Recovery Sustainable Systems LIFE11

[1] http://www.marss.rwth-aachen.de/cms/front_content.php

ENV/DE/000343). Within this project I had the task of *developing and testing a framework of integrated assessment of the performance of a Municipal Solid Waste Management system to be used to assess the convenience of adopting a new technological process developed in Trier Germany* (the "MARSS plant" separating and reusing the organic fraction - up to 60% of the solid wastes - into a renewable energy fuel). The testing should be carried out in Naples, my city of origin, representing a famous case of failure in the governance of the waste management problem determining ecological, economic and health problems leading to social conflicts over the issue.

To achieve this result I applied the methodological approach of MuSIASEM (Multi-Scale Integrated Analysis of Societal and Ecosystem Metabolism). A method of integrated assessment based on several theoretical concepts taken from complexity theory developed specifically in order to avoid the pitfalls of reductionism. It was the first time that the MuSIASEM accounting scheme was applied to the development of a decisions support tool for handling waste management problems.

When combining the *problem formulation* expressed above and the tasks to be carried out within the MARSS project I individuated the following research questions that had to be addressed in the activities of my PhD:

Research Questions

1. What type of accounting procedure should be used to generate an integrated quantitative assessment of the performance of a municipal solid waste management system? In my PhD I should use such a procedure to establish a bridge across different scales of analysis making it possible to assess how the characteristics of an individual typology of plant (e.g. this approach could be used to assess the proposed MARSS plant) could affect the performance of the whole management system of the city.

2. What type of characterization should be used to handle simultaneously different types of variables capable of considering technical, economical, social, demographic and ecological dimensions and to integrate them into a coherent and comprehensive accounting framework useful for studying the performance of municipal solid waste management systems? In my PhD I should be able to generate an integrated set of indicators covering the different dimensions of performance of the waste management system of Naples in order to assess the pros and cons of different scenarios.

3. How to use the results of integrated assessments to build a decision support tool useful for discussing policies? In my PhD I should generate an interactive decision support tool to be used to help the decision about policies and technical innovations in the solid waste management system.

4. Can we define a procedure for participatory integrated assessment based on this decision support tool that can be successfully applied in different

contexts? In my PhD I should test the analytical tools developed in actual participatory process.

5. What results can be achieved in applying this procedure to a real case study? In my PhD I should develop enough experience about the potentiality of the analytical tools developed and their usefulness in participatory process to be able to answer this question.

6. What are the problems to be faced in such an attempt? In my PhD I should learn enough lessons to be able to answer this question.

General Objective

The scope of the thesis is: (i) the development of a tool-kit for the integrated assessment of municipal solid waste management systems capable of generating an integrated set of indicators covering the environmental, institutional, socioeconomic, biophysical and socio-cultural dimensions of waste management and that can be used as support decision system; and (ii) the test of the usefulness of this tool-kit in a real world situation (The Metropolitan Area of Naples, Italy).

In this sense, the goal of the thesis is to develop a system of representation of the interaction of socio-economic systems and ecological systems which can be used in participatory processes to characterize the performance of such an interaction in relation to various indicators, which can be chosen "à la carte" by the users of the model to increase the quality of the information used in the process of governance.

Dissertation structure

The text of the dissertation is organized as follows: after the definition of the research objective and questions, Chapter I – The problem definition - illustrates the relevance of the issue and identifies the main challenges faced in tackling it.

Then Chapter II – The methodological framework - describes the theoretical basis of the proposed holistic approach of analysis. In particular, it illustrates with examples how to integrate the analysis based on socio-economic impacts with the analysis based on indicators of environmental impact. Preliminary data from a case study of the Metropolitan Area of Naples are presented.

Chapter III – Naples case study – presents the results of an application of the theoretical framework illustrating how it is possible to characterize the option space associated with the choice of different policies (alternatives) in relation to the selected set of criteria of performance.

Chapter IV – Participatory Integrated Assessment of the performance of municipal solid waste management systems – provides a series of lessons learned in relation to the participatory processes used to test the proposed tool-kit.

The final chapter of conclusions presents a few reflections on the potential and shortcomings of the developed approach.

CHAPTER I - Problem definition

1.1 Summary

This first chapter illustrates the importance of developing robust procedures for assessing the performance of a municipal solid waste management system (the goal of the thesis) starting from an overview of the literature in this field.

The main challenges faced in relation to the mentioned goal are: (i) the lack of a flexible analytical framework that can be used as decision support to guarantee an informed deliberation when choosing policies; (ii) the problematic adoption of participatory processes in a politically sensitive field in which decisions have a direct effect on the living standards of voters.

This analysis shows that the characterization and the comparison of alternatives of municipal waste management (i.e. policy options) should be based on a tool-kit capable of: (i) reflecting different points of view - the definition of the integrated set of indicators of performance should be open; and (ii) using quantitative and qualitative information expressed in different units of measure to cover criteria considered as relevant by the social actors affected by the choice - the definition of the integrated set of indicators of performance should be contextualized on the specificity of the considered socio-economic system. The tool-kit should be transparent making it possible for the user to scrutinize the assumptions and the data used for generating the analysis. The goal of this tool-kit is to guarantee the quality of the deliberation through better informed choices. Therefore, this approach to decision-making is not aimed at generating the "best" policy but "robust" and "fair" policies.

1.2 The state of the play in literature

1.2.1 Introduction

Waste production and management have been plaguing humanity since the appearance of the first non-nomadic societies around 10,000 BC. In fact, the first documented waste-processing facility is dated 2,000 BC (Worrell & Vesilind 2011). Yet waste management is still a problem of primary importance in both rural and urban contexts today. In 2014, 54 per cent of the world population was reported to live in urban areas and, according to UN projections, this percentage could reach 66 per cent by 2050 (United Nations 2015). The large increase in urban population determined by a generalized increase in affluence is associated with a growing quantity and complexity in the composition of Municipal Solid Waste (MSW) (Vergara & Tchobanoglous 2012). This represents a severe challenge for Municipal Solid Waste Management System (MSWMS). In fact, the choice of a specific municipal solid waste management system directly affects the metabolic pattern of a city and, as a consequence, the surrounding environment and the quality of life of its urban dwellers. Not surprisingly then municipal solid waste management has become a crucial issue in the agenda of local and national governments both in developed and developing countries. European Commission, as other institutions around the globe, has defined ambitious recycling and waste reduction goals for European Union member. (European Parliament and Council, 2008)[2]. The establishment of integrated waste management systems is a common goal for most of European cities (McDougall F, White P, Franke M 2001). However, many municipalities in the European Union are dealing with the impossibility to fulfill the legislative

[2] Directive 2008/98/EC of the European Parliament and of the Council of 19 November 2008 on waste and repealing certain directives (Waste framework. LexUriServ. do 3–30). doi:2008/98/EC.; 32008L0098).

requirements at the national level coupled to practical problems due to inefficient municipal solid waste management leading to conflicts at the local level (e.g., Bhuiyan, 2010; D'Alisa et al. 2010; Guerrero et al., 2013; Santibañez-Aguilar et al., 2013; Mazzanti & Zoboli 2008; Lami & Abastante 2014). In Italy, and in particular in the Campania region, there are high levels of discontent with current waste management (D'Alisa et al. 2010); De Feo et al. 2013; Di Nola & Escapa 2012). The waste problem in this region has been characterized by illegality, inefficiency, irresponsibility and indecision; it is a much more complex phenomenon than it seems and unfortunately has been inadequately addressed by official decision-making bodies (D'Alisa et al. 2015).

Analyzing complex adaptive socio-ecological systems such as municipal solid waste management systems represents a serious epistemological challenge. Scientific research on the performance of municipal solid waste management systems (MSWMS) has seen an upsurge of models and indicators proposed to support decision-making in municipal solid waste management (see, for example Pires et al. 2011; Chang et al., 2011; Contreras et al., 2008; Hung et al., 2007; Moy et al., 2008; Rigamonti et al., 2016; Thorneloe et al., 2007; Zaman et al., 2016; Mazzanti et al., 2009; Carlos Afonso et al. 2000; Eriksson & Bisaillon 2011; Fiorucci et al. 2003; Greene & Tonjes 2014; Haastrup et al. 1998; Hanan et al. 2013; Hanandeh & El-Zein 2010; Hanandeh & El-Zein 2009). This proliferation of efforts has resulted in a body of widely different types of qualitative and quantitative methods proposing individual and composite indicators within more or less deterministic models.

1.2.1 An overview of the principal quantitative approaches proposed for assessing municipal solid waste performances

System-analysis tools for supporting decision making in waste management have a long history, with the first approaches dating back to 1970. Specifically, two categories can be easily identified: system engineering models and system assessments (Chang et al. 2011). Other authors have proposed a different classification (Morrissey & Browne 2004), subdividing the methodologies according to the approach adopted. Historically, a shift from mere optimization problems to different types of models has been observed.

System assessments are mostly based on three kinds of approaches: cost benefit analysis; life-cycle assessment; and multi-criteria analysis (Juul et al., 2013; Karmperis et al., 2013). In addition, hybrids of the above-mentioned categories have also been published in the literature.

A recent proposed classification (Juul et al. 2013) subdivides system engineering models in five classes: optimization models, cost-benefit analyzes, multi-criteria decision models, simulation models and forecasting models. Recently, also more variegated sorting criteria have been proposed (Allesch & Brunner 2014).

* **Optimization models** are in general based on mathematical modeling, characterized by variable degrees of complexity and formalism, aimed at minimizing/maximizing one variable or parameter, such as cost, environmental impacts as well as risk perception (Ahluwalia & Nema 2007). The approach has been applied to quantitative indicators referring to several dimensions such as the overall cost of the waste management sector as long as the related environmental impacts (Costi et al., 2004; Lu et al., 2009; Cucchiella et al. 2014)

* **Cost-benefit analysis** is a specific form of optimization model aimed at the optimization of just a problem dimension (i.e. costs, economic efficiency) (Broitman et al. 2012; Juul et al. 2013; Massarutto et al. 2011). This aspect often represents the overriding element in the assessment to the detriment of other characteristics such as the environmental and social aspects (Morrissey & Browne 2004). In line with their criticism, Marshall and Farahbakhsh, (2013) plead for a complex systems approach, but do not make any attempt to quantification.

* **Life Cycle Analysis** has been criticized for not-properly accounting the localized environmental impacts: assessing only the total emissions and not evaluating local emissions in relation to the carrying capacity of the context where they are actually getting into does not allow a proper accounting of the local impacts (Ekvall et al. 2007). Also, LCA models (Banar et al. 2009; Bovea et al. 2010) only calculate potential (and not the real) environmental impacts, using technical coefficients affected by both: (i) epistemic uncertainty - how do we know that the process determining the output/input ratio used in the LCA calculation is the same as the process that is described using this information? That is, are we applying LCA values describing an apple to describe an orange?; and (ii) stochastic uncertainty - how do we know that the characteristics of the process used for estimating a given output/input ratio refers are constant in space and time? That is how sure that the apples can all be described with the same set of expected values?

The relevance and magnitude of these two types of uncertainty are rarely quantified and included in the assessments (Clavreul et al. 2012). In addition, when dealing with the quantitative assessment of joint production (the joint production dilemma: how to deal with processes in which the same input generates several different outputs), LCA approaches adopt questionable/arbitrary assumptions such as the substitution or the partition method (Heijungs & Guinée 2007).

* **Multi-Criteria Analysis** (MCA) this methodology characterizes the performance of waste management using an finite set of criteria and indicators (see Achillas et al., 2013; Caballero & Go 2010; Cheng et al. 2003; Gomes et al. 2008; Korucu & Erdagi 2012; Milutinović et al. 2014; Soltani et al. 2015; Vaillancourt & Waaub 2002). The methodology generally addresses different domains and variable, such as economical, technical, social and environmental dimensions (Bana e Costa 1990; Bell et al., 2001; Figueira et al., 2005; Janssen, R. and Munda, 1999; Munda, 2004, 2005, 2006, 2008; Nijkamp, P. and Ouwersloot, 1997; Roy, 1996; Zeleny, 1982; Vincke, 1992). The final output of a process of MCA is a quantitative or qualitative representation of the problem in the form of either an impact matrix or a graphic representation in the form of a performance space (e.g. a radar diagram with multiple indicators) (Giampietro et al. 2006; Giampietro, 2015). In general, the problem with this approach is determined by the incommensurability of the quantitative assessments referring to different factors (Munda 2004). The incommensurability of quantitative representations – the impossibility to define in quantitative terms direct trade-offs between: (i) an economic gain; (ii) a reduction of biodiversity and (iii) a loss of cultural traditions – implies a major problem in relation to policy choices: quantitative indicators referring to non-reducible criteria when used for decision making require a process of weighting. But how can we weight indicators referring to non-reducible criteria? The problem of how to weight non-reducible criteria is determined by the incommensurability of values: different social actors can express legitimate but contrasting views about what should be considered as an improvement (Munda 2009). A sensitivity test trying to check the consistency of

commensurable scales (Chung & Poon 1996) used to handle incommensurable values still represents an oversimplification. Multi-criteria methods can also been coupled with geographical-information-systems (GIS) assessment to develop a thorough spatial decision support system (Demesouka et al. 2013). In relation to this point the application of the approach presented in Chapter II (published in a co-authored paper[3]) is based on the use of different variables with spatial relevance. They can be used for discussing the location of landfills, for addressing the implications of hydrogeologic analysis, geology and morphology of the area; for making it possible environmental considerations (such as the presence of environmentally protected areas, the surface-water protection and so on).

* **Integrated Approaches** have been proposed to assess waste performances (Antonopoulos et al. 2014; Fabbricino 2001; Finnveden et al. 2013) . For example Daskalopoulos et al., (1998) proposes the integration of several processing plants/steps of the overall waste management system accounting different types of costs involved in the waste management. However, this work does not provide a multi-dimensional. As result, the choice of policy depends again only on a single optimizing criterion: overall cost minimization. Another tentative towards the integration of different indicators - coupling waste management and energy production from incineration - has been performed by Eriksson and Bisaillon (2011). The authors have coupled two different models implicitly expanding the analytical border of their investigation. A bolder attempt at characterizing and comparing the performance of both 'hard' physical components and 'soft' governance aspects is found in the choice of an integrated set of indicators presented by Wilson et al., 2015 . The set of "sustainable waste management indicators" proposed in this publication

[3] This paper is reported in the Appendix – Annex 4

allows benchmarking a city's solid waste management performance. In this way, it becomes possible to compare different cities and monitor changes of performance over time. In their analysis the authors use quantitative and qualitative indicators for the three main physical components – collection, recycling and (treatment and) disposal - and qualitative indicators to assess three main aspects of governance (inclusivity of stakeholders, financial sustainability, sound institutions and proactive policies).

* **Other approaches** based on other methodologies and principles include **dynamic waste management** (Rojo et al. 2013) developed in analogy with the water network distribution and hydraulics principles. **Game theory** proposed as an approach to address the characteristics of the stakeholders and their requests, considering them as utility agents with different and potentially contrasting requirements, in order to find the best-possible solution to the waste management in a defined context (Karmperis et al. 2013).

1.2.3 Reflecting on the effectiveness of conventional approaches

Conventional approaches to waste-management systems are all sharing a common characteristic: **reductionism** - i.e. they identify, analyze and measure separately the characteristics of single parts of the process (e.g. collection, processing and disposal). Because of this choice they lack of an adequate holistic view and system-thinking approach (Seadon 2010).

Quantitative models by definition represent a **simplification** of reality (Box 1979). Economic models assess future trends using data reflecting past trends and assume a perfect economic rational behavior from the involved actors (Finnveden et al. 2013).

Quantitative models tend to assume a general validity of their analysis (extensive applicability). As result of this fact, in-depth **analysis of the local context** as well as **detailed waste material analysis and balance** are quite rare in the literature. This is a serious shortcoming because it is essential to gather information about the local specificities for the implementation of a viable waste management system. An exception is represented by (Font Vivanco et al. 2012) who analyzed the biodegradable-fraction waste flows in the Catalonia region. In this paper, the different sources of waste have been individuated and connected to the processing facilities, with the relative technology involved in the handling of wastes.

Another important piece of information missing in almost all the examined papers is an **environmental-impact list** to be considered at the moment of deciding the set of indicators to be used in the assessment. One of the exceptions is represented by Hokkanen and Salminen, (1997), who took into account a full range of emissions into air as well as leachate production in landfills. Another example is given by Shmelev and Powell, (2006) suggesting a local environmental damage accounting based on the relevance of the emission output determined through a participatory process. They checked the robustness of the coefficients of emissions using the DELPHI approach. Unfortunately, their choice of adopting a single indicator for assessing “environmental damage”, defined in very general terms, implies neglecting the available information about the complexity of the implications determined by the mixture of pollutants.

Finally, last but certainly not least another crucial aspect to take into account in relation to the robustness of the assessment of the performance of an MSWMS is **Social Participation**. As a matter of fact, policies aimed at improving the performance of a local waste management system must acknowledge the central role of the social actors, whose perceptions, narratives and values must play a key role in the choice. An approach based on post-normal science (Funtowicz & Ravetz 1993) – acknowledging the unavoidable presence of uncertainty on both the descriptive and the normative side - has been invoked in the literature (Marshall & Farahbakhsh 2013) for the development of an adequate evaluation of the performance of an UMWS. In this approach the stakeholders have to be involved from the beginning in the process of production and use of quantitative information for decision making. In turn, this implies developing methods of participatory integrated assessments capable of integrate legitimate perceptions, narratives and values proposed in the social actors in both the problem structuring and in the deliberation over different alternatives. Unfortunately, the essential role of stakeholders in guaranteeing the quality of the discussion of policies is neglected by the conventional approached used to assess the performance of MSWMS. As discussed earlier in Multi-Criteria Analysis the questionable use of numerical weighting factors (one size fits all) is used to claim the possibility of integrating different analyses based on the adoption of different criteria. However, the technicality of the weighting of factors is used to hide under the carpet the real problem represented by the incommensurability of values – who decides and how what are the criteria to be included in the analysis and how to weight them

In the literature of assessment of waste management systems the use of participatory processes is rare and limited to the application of the DELPHI method (limited to the control of the quality of the representation based on a consultation of technical experts). One example is found in Zakaria et al., (2012), whereby numerous experts have been consulted about the relevant criteria for the location of a hazardous waste disposal facility according to different parameters, such as environmental, engineering, economic and social ones.

1.3 Challenges and solutions

An integrated quantitative assessment of MSWMS performance presents a major epistemological challenge as it involves the simultaneous consideration of several dimensions (ecological, economic, technical, socio-cultural and political) and scales of analysis (spatial: household, urban zone, municipal, regional, national, and global; temporal: short-term versus long-term concerns).

Moreover, the information generated by the assessment has to be relevant and useful for different stakeholders having legitimate but contrasting points of view about the performance of MSWMS.

A decision support system helping the assessment of alternative strategies of municipal solid waste management must not only provide a system of accounting capable of giving coherence to the quantitative analysis, but also generate an integrated system of indicators that can be used within a process of participatory integrated assessment to guarantee the quality of the choice of relevant stories and the transparency of the decisional process.

To develop a decision support system, first of all, one has to individuate relevant story-telling about the MSWMS. This first step provides a coherent semantic context to the quantitative assessment. To achieve this result participatory processes are fundamental. However, effective participatory processes require a methodology capable of tailoring the quantitative analysis (the quantitative representation) to the semantic inputs (about the relevance of the narrative to be used for the analysis) given by the social actors.

In relation to this goal, in order to have a holistic view of the issue, it is essential to generate first a meta-analytical framework of the functioning of a MSWMS that can be used to structure an integrated analysis of the relations between environmental, economic and social aspects. This meta-analytical framework can be later on tailored on the specificity of geographical areas and socio-economic contexts through participatory processes. As discussed in Section 1.2 it is rare to find in literature examples of participatory integrated assessment used to individuate relevant criteria and indicators to be used for characterizing the performance of an MSWMS.

Implementing a participatory integrated assessment of policies related to MSWMS requires facing two important challenges: (i) a decision support useful to guarantee an informed deliberation over alternative policies must be based on a flexible analytical framework; (ii) the organization of local participatory processes in a very politically sensitive field such as the MSWMS, having direct effect on voters, is risky.

Moreover, conventional decision support systems tend to be based on a multi-criteria analysis (MCA) of the performance of the system using an integrated set of indicators. The risk of this approach is to fall into an excessive focus on the development of technocratic protocols where both the criteria and the weights of criteria are chosen by experts. To avoid this risk, the decision support system presented in this thesis to evaluate MSWMS performance proposes to combine two elements:

(i) a holistic framework of analysis capable of handling simultaneously different types of variables considering technical, economic, social, demographic and ecological dimensions. The coherent and comprehensive accounting framework proposed for characterizing the performance of MSWMSs integrates these different dimensions across scales.

(ii) an integrated package of indicators referring to different criteria and scales that can be selected “à la carte” by relevant social actors through participatory processes.

When dealing with the sustainability of complex systems – e.g. the performance of a municipal solid waste management system, which is a component of a socio-ecological system - it is unavoidable to face “wicked”[4] problems (Rittel, H. and Webber, 1973; Checkland, 1981; Checkland, P. and Scholes, 1990). This fact implies a situation in which science falls into the predicament of Post-Normal Science (Funtowicz, S.O. and Ravets, 1990, 1991, 1993, 1994; Funtowicz, S.O., Ravets, J.R., and O’Connor, 1998). In this situation: (i) “what is relevant” should be considered as a semantically open information space that can be continuously changed because the inclusion of new social actors in the discussion or because the reflexivity typical of social systems; (ii) “what should be considered as a fact” is contested because of the complexity of the issues considered; (iii) “what should be done” cannot be determined on the basis of scientific analysis alone, because the urgency of decision making (Munda, 2005; Funtowicz, S.O. and Ravets, 1990, 1993; Röling, 1994; Jasanoff, 1995). Because of this combination the definition of any integrated assessment to be used for governance in the form of a finite set of indicators and optimizing functions generates a phenomenon called “hypocognition” – i.e. a finite and semantically closed problem definition unavoidably misses relevant aspects of the complex system under analysis that were not included in the chosen set of quantitative indicators (Lakoff

[4] “Wiched” problems are typical of sustainability science and represent a class of problem very difficult to handle in relation to governance.

2010). This is the challenge that we have to face when carrying out a process of Participatory Integrated Assessment.

As matter of fact, as is the case with any sustainability issue, a participatory integrated assessment of MSWMS must address (G. Munda 2008):

- Social incommensurability: What should be considered a relevant criterion of performance? How to handle legitimate but contrasting views? Who decides about that and how?
- Technical incommensurability: How to handle the co-existence of non-equivalent indicators of performance that refer to different dimensions and scales of analysis?
- Temporal incommensurability: How to weigh the interests of current and future generations under conditions of uncertainty?

A problem can be defined as a discrepancy between an expectation and a perception of a given state of affairs. This distinction is at the heart of the issue of scale, the epistemological implications of which have been explored extensively in the field of complex systems theory, especially by those working on hierarchy theory (Simon, 1962; Koestler, 1968, 1978; Allen, T.F.H. and Starr, 1982; Salthe, 1985, 1993; O'Neill et al., 1986; O' Neill, 1989; Allen, T.F.H. and Hoekstra, 1992; O'Neill, 1989; Giampietro, 1994, 2003; Ahl, V. and Allen, 1996; Giampietro and Mayumi, 2004).

This implies that in a given social context the individuation of "relevant problems" should reflect the expectations and the perceptions of local social actors in relation to the issue to be tackled. This implies that problems cannot be properly identified without carrying out participatory processes. Participatory processes are also essential for checking the plausibility of the narratives used to compare the pros and cons of possible solutions.

In turn participatory processes requires a proper understanding of the broader cultural, historic, socio-economic, institutional and ecological context in which the MSWMS is operating. This contextualization is needed to: (i) identify the main stakeholders and the narratives they endorse; (ii) recognize conflicting narratives and storytelling; and (iii) define the criteria/attributes of performance required to be included in an integrated package of indicators in order to reflect the different perceptions of performance of a MSWMS found in its socio-ecological context.

This pre-analytical analysis is crucial because when the performance of the MSWMS is framed using different story-tellings it becomes necessary to adopt different set of attributes of performance. With story-telling I mean a narrative or a set of narratives that have been selected as useful for guiding action by a typology of actors (Giampietro et al. 2006). Several stakeholders are involved in the waste sector and each of them has different visions. Furthermore, it is unavoidable to find conflicting values, interests and requirements. For these reasons it is important to develop non-equivalent integrated sets of indicators capable of characterizing the different perceptions and definitions of performance relevant for the different stakeholders.

The issue of social commensurability can be illustrated using Fig. 1.1: there are several dimensions – e.g. Economic, Social and Environmental – within which different objectives can be defined. Clearly, it is improbable (or hardly possible) to find a solution that simultaneously maximizes all objectives. Moreover, different stakeholders would suggest different ways for individuating a compromise solution. This is a typical example of social incommensurability.

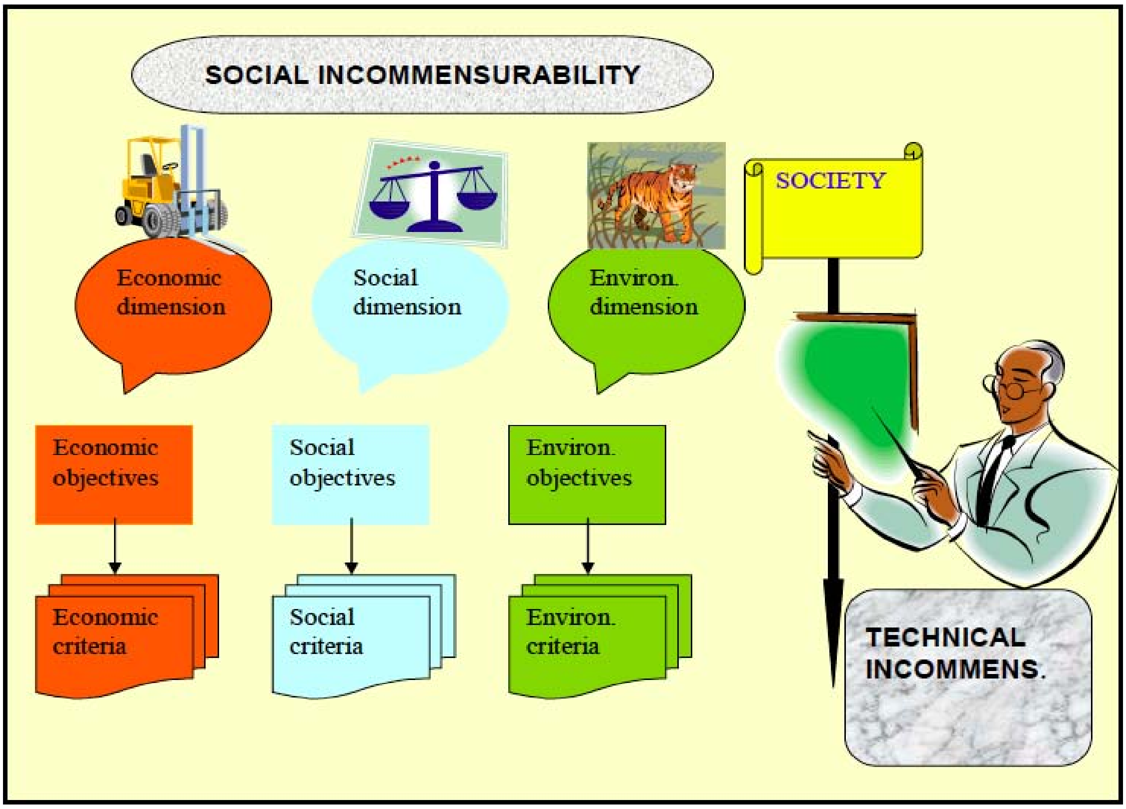

Figure 1.1 *- The co-existence of non-reducible criteria providing motivations for action*

An overview of the broader procedure of participatory integrated assessment within which to fit the proposed approach of multi-scale integrated analysis presented in Chapter II is illustrated in Fig. 1.2. The organization of the procedure in three steps follows the rationale of social multi-criteria evaluation proposed by Munda (2008), and serves to guarantee a quality check on the production and use of quantitative information for decision making.

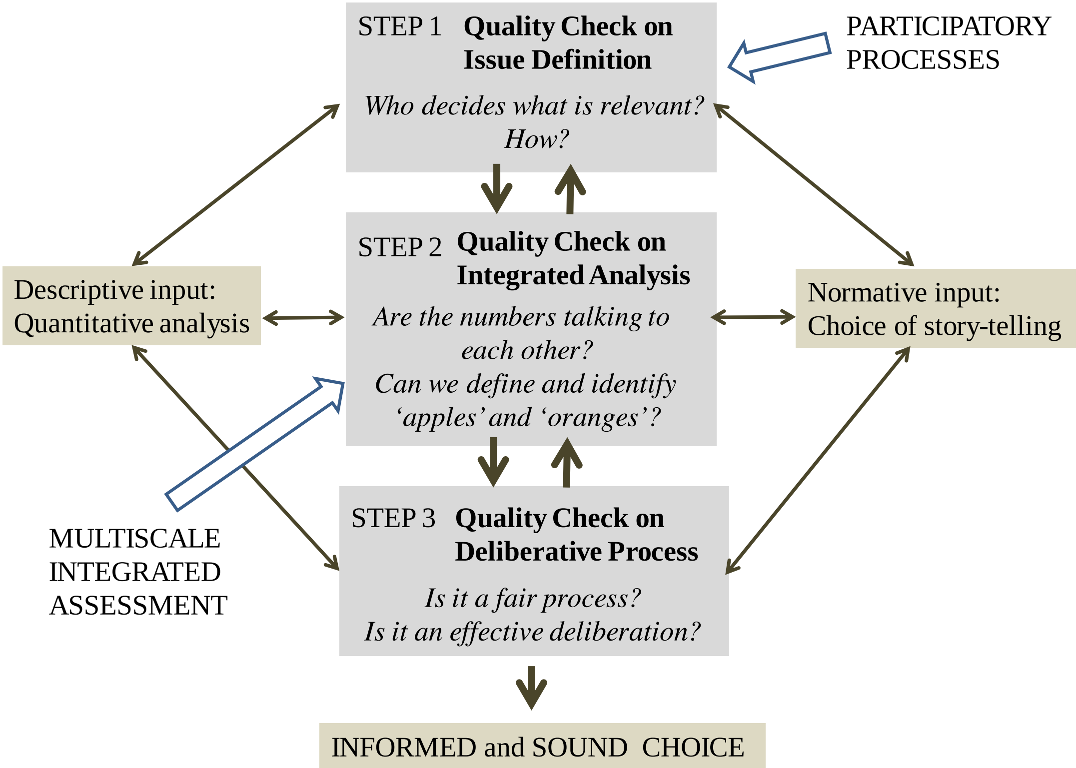

Figure 1.2 *- Three-step quality check on the production and use of quantitative information for decision making*

As shown in Fig. 1.2, participatory processes are required to guarantee the quality of the issue definition (choice of useful story-tellings) in relation to normative uncertainty (STEP 1). Once the main stakeholders in waste sector have been defined, using an institutional analysis, they have to be involved using participatory processes to discuss the quality of the problem definition, to participate in the choice of the set of indicators to be used to characterize the performance of MSWMS.

After this first step it is possible to carry-out a multiscale integrated assessment based on the application of the approach MUSIASEM presented in Chapter II. This application has the goal to guarantee the quality of the quantitative representation of performance, checking the congruence of the quantitative indicators across different dimensions and scales of analysis (STEP 2). The proposed system of accounting is used to establish a link between quantitative assessments referring to economic analysis, socio-economic analysis, technical coefficients, using data obtained by observations done at different levels and scales: (i) at the level of individual plants – when considering the technical coefficients related to the processing of wastes; (ii) at the level of the functional elements of the network used to process wastes; (iii) at the level of the whole MSWMS in its interaction with the socio-ecological context. The ability to handle and integrate in a coherent accounting quantitative analysis referring to different hierarchical levels using data gathered at different spatio-temporal scales is one of the key features of MuSIASEM. In this way, the quality of the quantitative analysis is checked in different ways by relevant actors controlling the relevance of the problem structuring, by biophysical, economic, ecological analysis controlling the viability and feasibility of the discussed policies, and by technical analysis controlling the robustness of the data inputs. Without an integrated analysis numbers used in different indicators are just "not talking to each other" and then the risk is to compare apples with oranges.

The third phase, shown in Fig. 1.2 (STEP 3), is required to guarantee a quality check on the deliberation process. This requires the ability to evaluate the effectiveness and fairness of the process generating informed and sound choices in decision making. The three steps indicated in Fig. 1.2 need an iterative process in which the chosen perceptions of relevance affect the chosen representations, and the chosen representation will, in turn, influence the perception of what should be considered as relevant.

CHAPTER II - The methodological framework[5]

2.1 Summary

The objective of this part is to present a holistic methodological framework that can be used to organize and integrate quantitative information for the characterization of the performance of Municipal Solid Waste Management Systems (MSWMS) across dimensions and scales. The chapter first explains the theoretical concepts that underlie the proposed semantic framework for the integrated characterization of MSWMS based on the MuSIASEM (Multi-Scale Integrated Analysis of Societal and Ecosystem Metabolism) accounting method. This framework makes it possible to generate an integrated package of indicators referring to different aspects of the socio-economic performance of the MSWMS (viability and desirability) and to environmental impact/stress (feasibility). Then the chapter illustrates a practical application of the MuSIASEM analysis to the study of the performance of a MSWMS using preliminary data of the Metropolitan Area of Naples case study.

2.2 Introduction

The proposed methodological framework builds on Multi-Scale Integrated Analysis of Societal and Ecosystem Metabolism (MuSIASEM) accounting method and the theory of metabolic networks.

MuSIASEM is an accounting framework based on a new philosophy of analysis developed using theoretical concepts developed in complexity theory (Giampietro and

[5] The text presented is mainly based on the scientific article "Chifari, R., Lo Piano, S., Bukkens, S.G.F., Giampietro, M., 2016. A holistic framework for the integrated assessment of urban waste management systems. Ecol. Indic. doi:10.1016/j.ecolind.2016.03.006 dalkey1963.pdf, n.d.".

Mayumi, 2004; Giampietro et al., 2013, 2014). In particular, the description of the network of processes taking place in an MSWMS is built on the concept of "grammar". A grammar is a set of expected relation among semantic and formal categories, which is quantified using dictionaries. This makes it possible the tailoring of quantitative representation of semantic categories in specific contexts – transportation of waste can be done using trucks in a modern city and using donkeys in a low income city. The relations over the elements of the network (flows and nodes) are determined by production rules providing an expected set of relations between the inputs and outputs of the nodes. Grammars are semantically open, since the same semantic element (a rich person, a corn field) can be formalized in different ways in different contexts (in China and in the USA).

This is the first attempt to apply the methodological approach MuSIASEM to the integrated assessment of the performance of MSWMSs. Therefore, before getting into the gathering of data and the crunching of number as required for a quantitative analysis, the starting point has been the definition of grammar useful for analyzing the performance of MSWMSs.

Building a "grammar" involves two steps: (i) selection of a set of relevant semantic categories – functional processes within the MSWMS - and definition of expected relations among these categories – the connections over nodes describing the movements of the various flows within the MSWMS; and (ii) formalization of the semantic framework into a set of structural elements – fund and flow elements – making it possible a quantitative characterization.

2.2.1 The construction of the grammar for the analysis of waste metabolism

The use of grammars in the MuSIASEM accounting systems has been illustrated in many publications (Giampietro et al., 2007, 2009, 2013, 2014; Serrano-Tovar and Giampietro, 2014; Sorman and Giampietro, 2013; Ramos-Martín et al., 2009; Velasco-Fernández et al., 2015). In particular in (Giampietro et al. 2014) specific chapters are dedicated to the illustration of specific grammars to be used to characterize the metabolic pattern of socio-ecological systems: (i) food grammar (Giampietro et al. 2013); (ii) energy grammar (Diaz-Maurin & Giampietro 2013); (iii) water grammar (Madrid et al. 2013).

However, when looking at the grammars built for the other applications it is possible to note that a grammar useful to study waste metabolism requires a radically different approach: whereas food, energy and water are inputs to the metabolic pattern of a society, the metabolism of wastes has to do with the processing of an output. In the waste grammar the society becomes the "source" of an output (generation of waste) and the environment is forced to be the "consumer" of it. In fact, the environment receives what the waste management system is treating, transforming and disposing of: solid residues, liquid discharges and emissions to the air. In this case, the performance of the waste management system is not about guaranteeing an adequate supply of inputs to society but it is about: (i) taking care of the waste without interfering too much with the daily activities of people; (ii) processing the input of waste received by society transforming it into materials easy to handle; (iii) trying to recover as much as possible useful material found in the waste; (iv) dispose of the waste into the environment minimizing the impact on the health of both people and ecosystems.

The generation of a grammar useful to study the metabolic pattern of a MSWMS requires two pre-analytical decisions:

1. *definition of the boundary of the system* - Where do we define the boundaries of the system? What is the best level to assess the performance of our MSWMS when adopting administrative boundaries – the region, the province, the city? Depending on this decision are wastes treated in the same area where generated? How to deal with the accounting of exports and imports?

2. *definition of a metabolic identity for the MSWMS* - Which are the fund and the flow elements needed to describe the metabolic pattern of the system? Which are the functional processes? How those functional processes linked to each other? Which is the mix of technologies used in each node of the network to express the expected functional process? Where those plants are located?

It should be noted that before arriving to the final version of the "grammar" illustrated in the rest of this chapter many attempts have been formulated in the first year of the thesis. An illustration of the evolution of the grammars considered is presented in Fig. 2.1, Fig. 2.2; Fig. 2.3; Fig. 2.4. The final version of the grammar providing the semantic framework to assess the performance of municipal solid waste management system is detailed later on in the chapter.

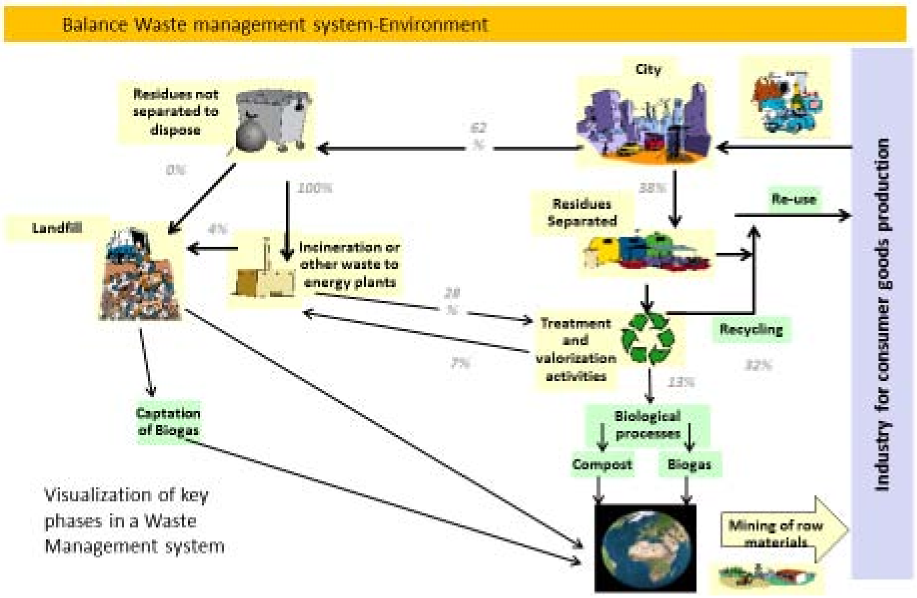

Figure 2.1 *- Evolution of the "Grammar" for waste metabolism: first attempt.*

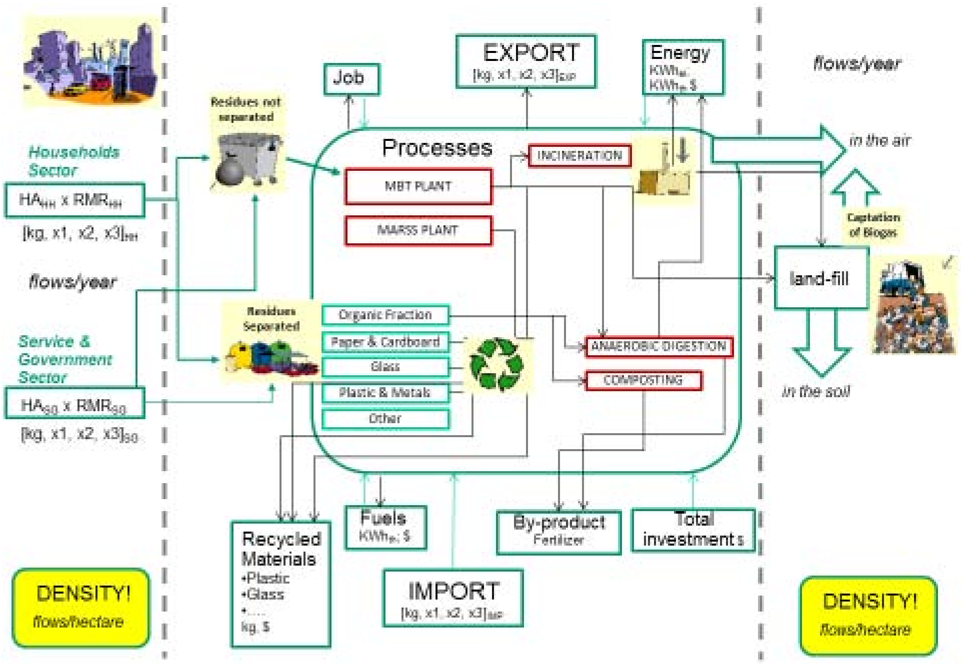

Figure 2.2 *- Evolution of the "Grammar" for waste metabolism: second attempt.*

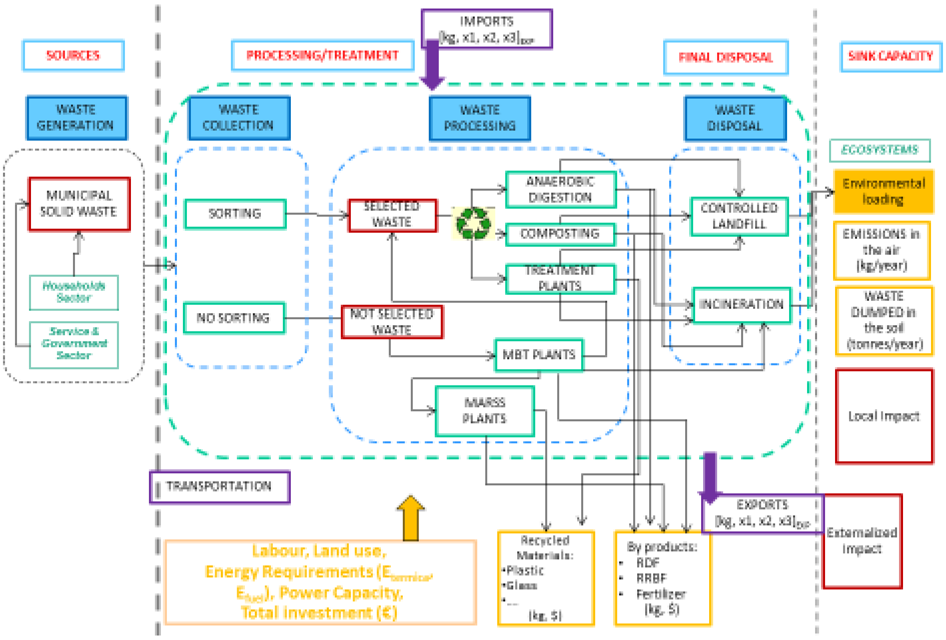

Figure 2.3 *- Evolution of the "Grammar" for waste metabolism: third attempt.*

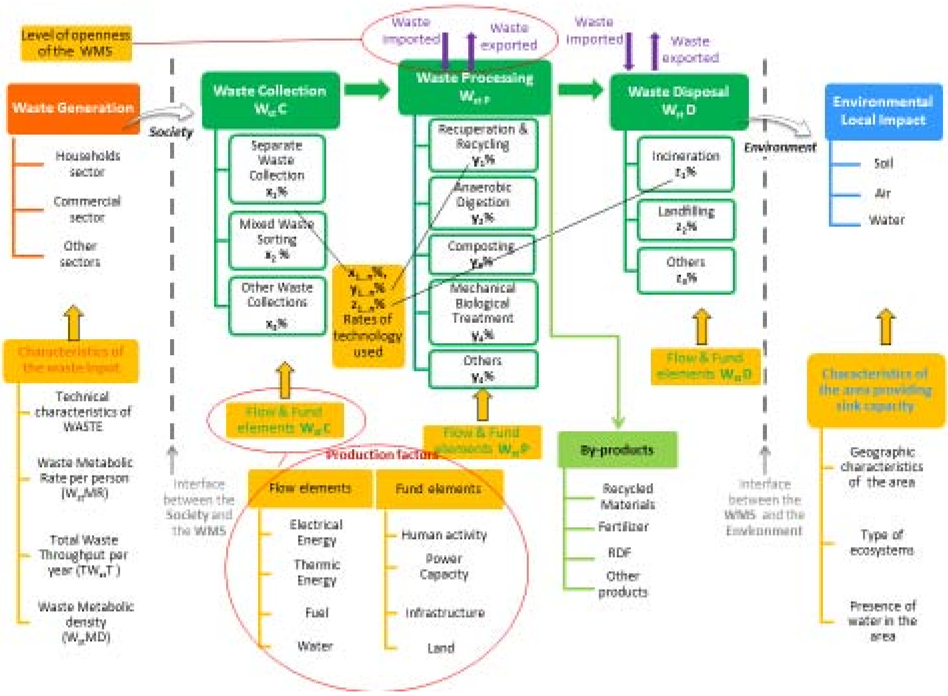

Figure 2.4 *- Evolution of the "Grammar" for waste metabolism: fourth attempt.*

2.2.2 Previous use of MuSIASEM to generate unconventional indicators for the analysis of waste metabolism

Before this thesis the MUSIASEM accounting scheme has been applied to study urban waste patterns (D'Alisa et al. 2012) to propose two new indicators capable of integrating the set of conventional indicators used in the field:

(i) MRW - Metabolic Rate of Waste – an intensive variable measuring the amount of solid waste (in kg) generated per person per day depending on the mix of activities and the size of the population [Waste Flow/person-days]. This factor is determined by socio-economic processes and therefore relevant for a socio-economic analysis. The effect of the environment of this factor depends on the fraction of this flow that is separated[6] and recycled (the performance of the MSWMS) and the density of the population.

(ii) DW - Density of Waste – it represents the flow of solid waste (in kg) generated by a given socio-ecological system per unit of area – it depends on the mix of activities and the density of the population in a given area [Waste Flow/area]. It represents the amount of waste disposed, in a landfill, or through the incineration process, per year in a given region. This factor is affected not only by socio-economic and technical factors - the characteristics of the activities carried out in the city and the characteristics of the MSWMS - but also by the demographic pressure. This factor is an essential piece of information to study the environmental impact that a MSWMS has to mitigate on the basis of the characteristics of the ecosystems providing sink capacity. This factor provides a clear explanation to the fact that in case of densely populated urban settings

[6] The separated waste affects the quantity of incoming waste which is processed and transformed in valuable by-products.

MSWMSs tend to externalize the pressure on the local environment by exporting waste flows.

These two indicators are crucial to compare the flow of solid waste produced and to be handled (characteristics of the society) to the sink capacity the context (characteristics of the embedding environment).

According to D'Alisa et al., 2012, conventional indicators for waste generation often fail in detecting situations of potential waste crisis because are not capable of describing this link between the characteristics of the society and its environment.

The example given in Fig. 2.5 supports the author's point. When making a quantitative comparison of the region Campania with other Italian regions we can get completely different results depending on the choice of variables.

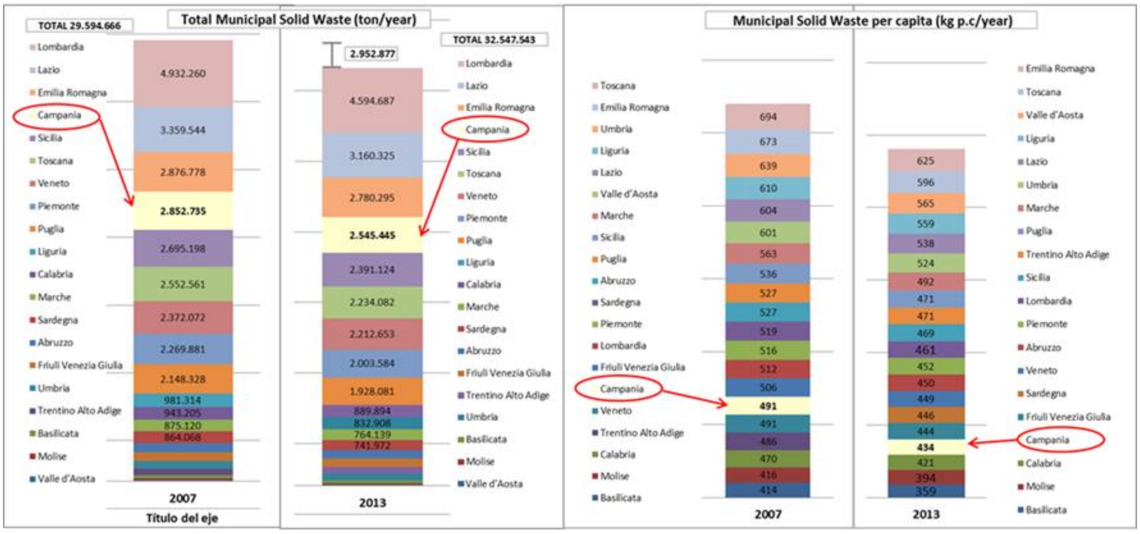

Figure 2.5 - *Total and per capita generation of Municipal Solid Waste in the Italian regions. Source: Elaboration on ISPRA report 2014 and 2008 data.*

When considering the total municipal solid waste (an extensive variable – whose values are represented on the left) both in 2007 and 2013 Campania was ranking 4th among the 20 Italian regions. On the other hand, when considering the Municipal Solid

Waste per capita (an intensive variable – whose values are represented on the right) Campania was ranking 15th in 2007 and 17th in 2013. These two quantitative characterizations would provide a completely different ranking if used one at the time. Moreover none of these two types of information makes it possible to identify the key factor that determines the situation of crisis in waste management.

On the contrary when adopting the indicators suggested by D'Alisa et al. (2012) the density of waste generation - DW - can be considered as a key factor to study the metabolism of waste in a Socio-Ecological System (SES), integrating the conventional indicators such as separated collection rate and total waste generation.

Fig 2.6 shows in fact that the reduction of Density of Waste to be Disposed (DWD) is highly correlated both with the increment of separation rate and with the changes in total municipal solid waste generated in Campania over the time window 2007-2013.

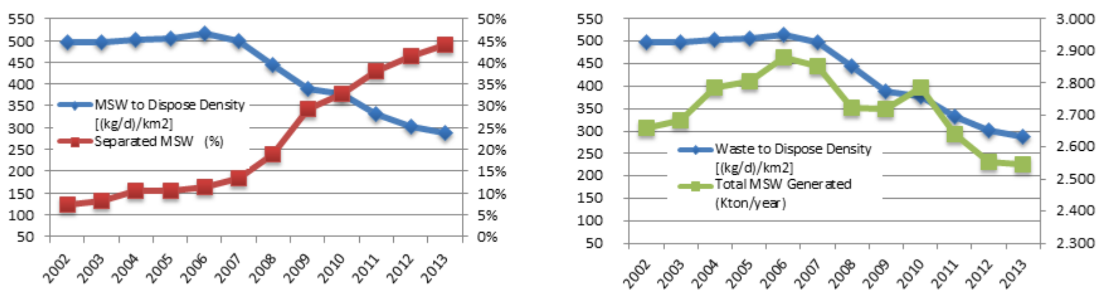

Figure 2.6 *- Correlation of DWD with % of separated MSW and Total MSW in Campania. 2007-2013.*

A second example in Figure 2.7 illustrates the values of DWD at regional level in Italy. In this figure we can see that the Italian regions experiencing serious crisis of waste management – Liguria, Lazio and Campania – are the regions where a high density of population implies a resulting high density of solid waste generation and waste to dispose (D'Alisa et al. 2012). This confirms that it is the density of waste generation and waste to dispose that may generate crisis and not the quantity or the rate of generation per person.

The regions Campania, Lazio[7], and Liguria had the highest value of Waste Metabolic Density to be Disposed in 2007 and in those years they experienced serious difficulties in waste management which were not detectable using the conventional set waste indicators. Official indicators missed the "elephant in the room" – that in this example is the role of population density influencing on the biophysical pressure (i.e. the density of waste to be disposed).

Figure 2.7 *- Map of the DWD in the Italian regions.*
(D'Alisa et al. 2012)

Those examples show that some of the conventional indicators used for representing waste patterns, when used outside a holistic framework addressing the characteristics of

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7 http://www.ilcorriereitaliano.it/emergenza-rifiuti; http://www.ilgiornaleditalia.org/news/da-roma--dal-lazio/863285/Rifiuti-nel-Lazio--emergenza-alle.html

the metabolic pattern of socio-ecological systems, may miss relevant information about potential challenges in waste management.

In this thesis, DW and MRW have been used as intensive variables together with the extensive variable Total Solid Waste Throughput per year (TSWT[8]) to characterize the generation flows of municipal solid waste.

TSWT and DW can be used as indicators of 'environmental loading' and are related to MRW as follows:

TSWT = MRW x population x 365; DW = MRW x population density x 365.

2.2.3 The first attempt based on the logic of 'flow analysis in a distillation column'

At the beginning of the thesis the approach to the definition of a grammar representing the functioning of the MSWMS in biophysical terms was based on the logic of 'flow analysis in a distillation column'. According to this rationale the different flows were characterized using two pieces of information: (i) the amount of matter (size of the flow expressed in tons); and (ii) data arrays (numbers organized in the form of vectors) describing the composition of the flows in terms of the different fractions. This choice made it possible to identify the expected characteristics of flows getting into or coming out of different technical processes and to carry out mass balance across the system. This analytical approach (implemented with a method of calculation based on

[8] Total amount of solid waste (in tons) generated in a year in a given community (over its total population).

matrix algebra) is presented in detail in the first scientific publication in Appendix-Annex 3[9].

However, during the first round of the DELPHI exercise it has been realized that the approach was too complicated, difficult to explain to local experts and decision makers, so the theoretical framework needed to be changed into something earier to handle and to explain. From the logic of an analysis of mixed flows taking place in a distillation column the grammar moved to the logic of an analysis of mixed flows taking place in a metabolic network. In the interaction with the experts in Naples it was immediately evident that by adopting this different method it was much easier to explain the model, check the data, and to receive feed-back.

It should be noted, both grammars developed using different logics were going beyond the conventional idea of quantitative analysis of efficiency (or productivity). That is the MuSIASEM accounting does not calculate ratios over an output and an input at the time (e.g., labor productivity, energy efficiency) but describes patterns of profiles of outputs and inputs that can be scaled across levels.

2.2.4 Final approach: metabolic network theory

The final approach rooted in the logic of theoretical ecology (metabolic networks) considers the MSWMS as part (organ) of a larger socio-ecological system (e.g. the Metropolitan Area of Naples). This theoretical framework provides a holistic view of the metabolic pattern of the MSWMS in the form of a set of expected relations that are

[9] Chifari, R. and Giampietro, M. (2015). "Participatory integrated assessment of urban waste management systems" published in the book of proceedings: O. Kordas and S. Ulgati (Eds.), Proceedings of the 9th Biennial International Workshop Advances in Energy Studies, Energy and Urban Systems, Stockholm, Sweden, 4-7 May 2015. Verlag der Technischen Universität Graz, Graz, Austria, pp. 115-125.

described in quantitative terms simultaneously across different hierarchical levels and scales.

The analysis of the network is based on a combination of quantitative and qualitative assessments: (i) quantitative assessments characterize the size of the throughput in each flow and the size of the structural elements (technologies) operating in the nodes; (ii) qualitative assessments are obtained by defining a vector of ratios of different inputs per unit of throughput, calculated at each node of the network (how much labor, electricity, fuel, area, water, power capacity is required per ton of flow processed). This combined accounting reflects the obvious fact that in order to express a given function in a node of the network the processing of a given flow does not require just an input of energy or water or an amount of hours of labor. Rather, the processing of a given flow requires the right combination of these inputs in the right quantity at the right time.

In conclusion, by applying the MuSIASEM accounting to the analysis of the performance of MSWMS, it is possible to characterize:

(i) the quantity and quality of the flow of municipal solid waste produced by the urban system (rate and density);

(ii) the mix of technical inputs (i.e., technology, labor, energy, water and materials flows) required for the operation of the different stages of the MSWMS and the various economic outputs generated in this process (i.e., recycled and recovered materials, energy);

(iii) the level of openness of the MSWMS (i.e., inflows/outflows crossing system boundaries in the different stages of its operations); and

(iv) the output of waste (gas, liquid and solid) disposed of into the local environment (within the system's boundaries) within a geographic information system. This localized information makes it possible to consider the characteristics of the embedding ecosystems providing sink capacity. When adopting a spatial analysis of the metabolic pattern the characterization of the rate and the density of the flows released into the environment permits the calculation of the relative environmental loads.

The proposed framework can accommodate indicators representing a wide range of domains and conceptually classify them into three non-equivalent sustainability criteria:

1. Feasibility in relation to external constraints – characteristics of the boundary conditions that cannot be controlled by the agents and technologies operating in the MSWMS (biophysical limits to sink capacity, thresholds of environmental loading dangerous for the stability of ecosystems and the framework of laws and regulations insisting on the area under study);

2. Viability in relation to internal constraints - characteristics of the process that are controlled by the agents and technologies operating in the MSWMS (the viability can be referring to economic variables or technical coefficients);

3. Desirability in relation to normative values expressed by social actors.

Preliminary data from the Naples case study are used in this chapter to illustrate and validate the proposed theoretical framework.

2.3 Methodology

2.3.1 Metabolic networks

The concept of metabolic network was originally developed for ecosystems in the field of theoretical ecology, but is equally well applicable to other types of complex metabolic systems. Complex systems are organized over different hierarchical levels (e.g., individual organisms, species, functional compartments, whole ecosystem) and express predictable patterns of interaction among its components and with its context (Tansley 1935; Lindeman 1942).

As it is illustrated in Fig. 2.8, a scientific analysis of such systems therefore necessarily requires a characterization of its expected characteristics across levels and scales (E. P. Odum 1959, 1969; H. T. Odum, 1971, 1983, 1996; Margalef 1968; Ulanowicz 1986, 1997).

In graph A of Fig. 2.8 the ecosystem is represented as a network of interactions among different functional components or nodes quantified by flows of energy (in joules) of different types and forms. The taxonomy of elements, provided in graph B, allows us to distinguish between interactions with the context ('energy losses' and 'source') and interactions inside the network ('store', 'consumption', 'production', 'generic flow'). With this method of analysis the expected patterns that are expressed by the metabolic network in terms of relative size of the functional components/nodes and their relative metabolic rates (determining the flows) can be identified. These expected relations can then be used to develop indices referring to different aspects of the network (graphs C, D in Fig. 2.8) or expected relations over aggregate values (graphs E, F, G in Fig. 2.8).

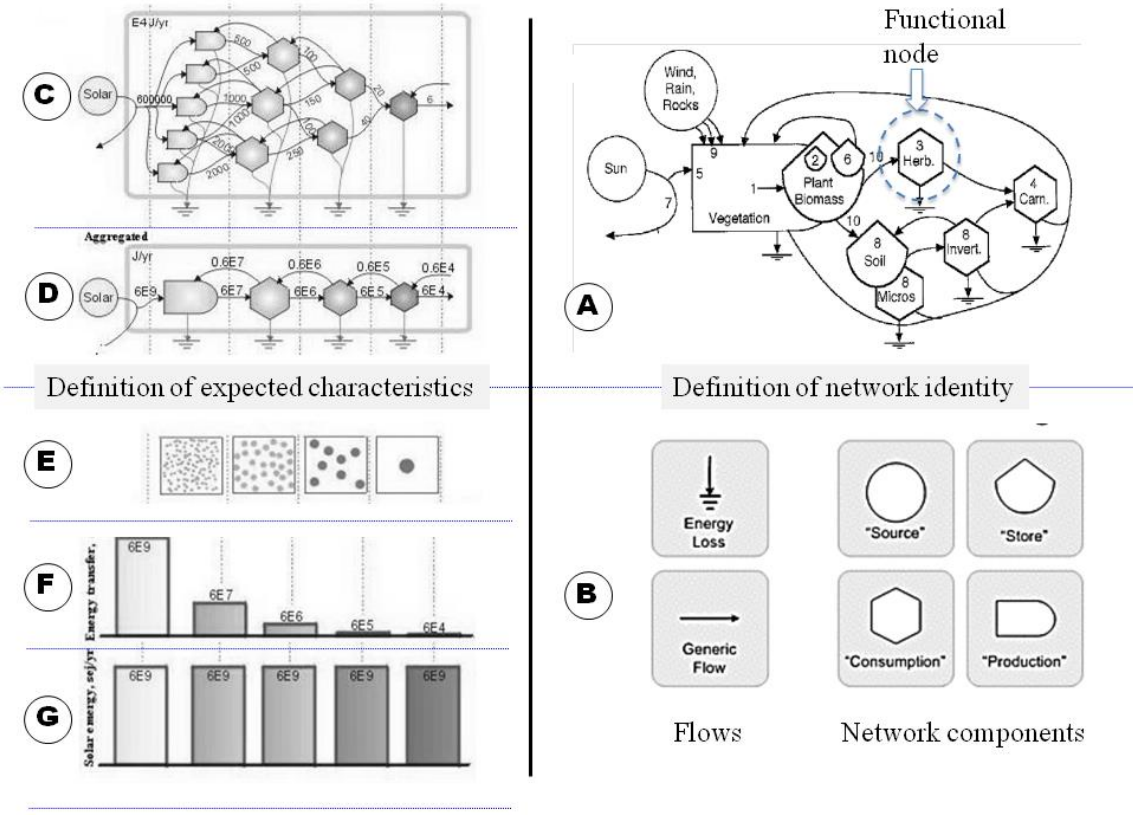

Figure 2.8 - *Quantitative relations over components and flows in an ecosystem according to H.T. and E.P. Odum.*

A detailed look at graph A of Fig. 2.8 shows that the main flow of energy feeding the ecosystem enters from outside in the form of solar energy (left side). This energy input is then transformed into plant biomass (another form of energy) by the primary producers (vegetation). The plant biomass constitutes the flow of energy input for the next node (herbivores), where it is then transformed in herbivore biomass and used by other functional components of the network. By quantifying these relations over all the components of the system, the following can be characterized: (i) the structure of the network; (ii) the properties of its components (what flows they use as input and what flows they generate as output); and (iii) a set of expected relations regarding the size of the network nodes and the flows they metabolize. With the latter information it can be further defined the required size of the structural elements that compose the functional nodes to guarantee the stability of the network in relation to the relative size of the flows.

This type of analysis thus establishes a bridge between: (i) the performance of the whole system; (ii) the characteristics of the individual elements composing the system; and (iii) the effects the system has on its context (the level of openness of the network, the inputs/outputs flowing from/to the external boundary).

Ecological network analysis has been further developed by, among others, Hannon (1973, 1985) and Fath et al. (2007) in an attempt to standardize the method of accounting (for an overview, see Fath and Patten (1999)). Important epistemological contributions were made by Rosen, Georgescu-Roegen and Koestler, and are briefly described below.

Rosen (1958, 1959) pointed out that a quantitative representation of a metabolic network requires two types (sources) of information referring to different scales and levels of analysis (the outside and inside perspective):

1. Information about the network, needed to specify the topological relations over the nodes and the qualitative characteristics of the different flows. This concerns the question: What is an admissible input? For instance, carnivores can metabolize herbivore and carnivore biomass but not solar radiation or plant biomass. In the same way, when dealing with an MSWMS, the input entering an incinerator is different from that feeding a plant of anaerobic digestion.
2. Characteristics of the structural elements making up the nodes, observed at a lower level. Are they able to express the function expected by the rest of the network, consume the admissible input that is the output from other nodes, and generate a known output that, in turn, has to be an admissible input for the next

node? In the same way, technologies making up a node of a MSWMS must be able to process the expected input flow of material and generate the required inputs for the successive nodes.

Georgescu-Roegen (1971) proposed the flow-fund model of analysis for networks of biophysical transformations and introduced the idea that metabolic networks are based on flow-fund relations. The flow-fund model[10] postulates an expected relation between the structural elements (the funds) making up the nodes (defined at a lower hierarchical level of analysis) and the flows that are consumed (inputs) and produced (outputs). It thus requires a definition of: (i) the size or capacity of the (lower-level) fund elements (extensive variable), and (ii) their metabolic rate or flow throughput per unit of fund (an intensive variable). In the proposed representation, the size of the fund is described by the conversion capacity of the plants that compose the node. It follows that flow/fund ratios are the technical coefficients describing the operation of a given plant of defined size capable of processing a certain amount of inputs and generating a certain amount of outputs.

Koestler (1968, 1978) proposed the concept of 'holon' to address the unavoidable complexity associated with metabolic networks (see also Ahl, V. and Allen (1996); Allen, T.F.H. and Starr (1982)). The holon is an elusive epistemic device used by humans to perceive complex systems. It blends together the perception of functional types (e.g., the presidency of the USA being an office) and that of structural types (e.g., Mr. Barack Obama being the current incumbent). These two perceptions are associated simultaneously to the description of any given instance (see Mario Giampietro, Mayumi, and Munda (2006)). Therefore, any analysis of metabolic networks must

[10] Funds are the entities or physical structures that transform, consume, or produce flows. Funds preserve their identity over the duration of the analysis, while flows appear or disappear over the duration of the analysis.

combine the perception of functional network nodes (e.g., herbivores; incineration as a waste treatment process) with that of their structural composition (herbivorous species; different typologies of incinerators). Thus, the special ecosystem or MSWMS to study represents an instance of an integrated set of holons or a so-called ‘holarchy’ (Allen, T.F.H. and Starr 1982).

Building further on these epistemological considerations, the characteristics of a network node can be defined in two independent ways, top-down and bottom-up (see Fig. 2.9).

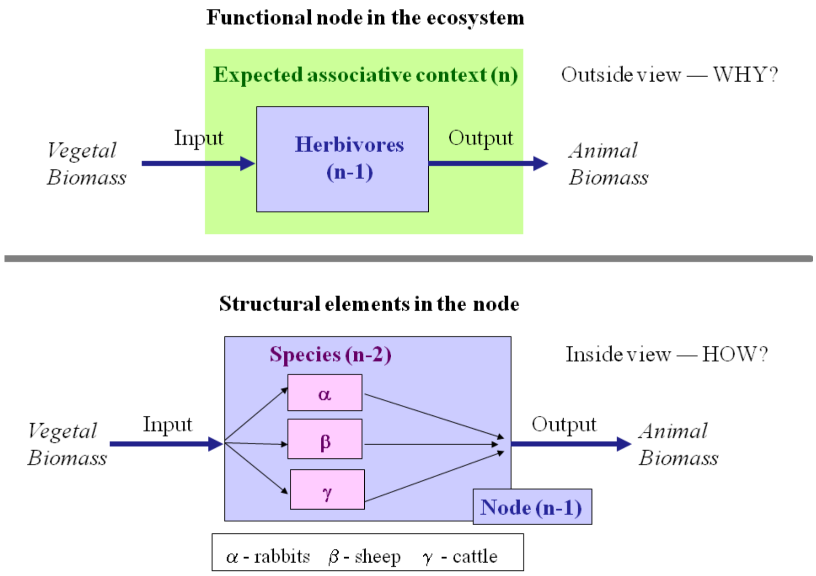

Figure 2.9 *- Top-down (upper graph) and bottom-up definition (lower graph) of the metabolic characteristics of a node, across the various hierarchical levels of the system.*

The metabolic network is defined as level n, the nodes as level n-1, and the structural components composing the nodes as level n-2

The top-down definition or outside (external) view looks at the network niche: what the metabolic network (level n) expects, so to speak, from the node (level n-1) in order to keep the network stable and preserve its identity or essence. (The concept of network identity assumes that the taxonomy of nodes, their topological relations and the expected flow/fund ratios remain stable over the duration of the analysis). This translates into a definition (a set of expected characteristics) of: (i) what has to be processed as input and generated as output, both in quality (the nature of the admissible inputs and outputs) and quantity, by the nodes operating inside the network; and (ii) what has to be taken from or discarded into the environment by the nodes interacting with the context.

The bottom-up definition or inside (internal) view, on the other hand, studies the metabolic capacity of the node (defined at level n-1) starting from the conversion processes carried out at the local scale (level n-2). It looks at the relative composition of the structural elements making up the node, and their characteristics (metabolic rate or technical coefficients of each of these elements).

The successful operation of a metabolic network is thus based on a forced relation of congruence between the top-down definition of the nodes, providing their functional description at the interface of levels n and n-1, and the bottom-up definition of the nodes providing their structural description (defined at the interface of levels n-1 and n-2). As shown in Fig. 2.9, there is no direct mapping between the top-down and bottom-up definition: the same characteristics of a given functional node can be obtained by different combinations of lower-level structural elements. This is an important observation that is usually overlooked in life cycle assessment (LCA): an output/input flow ratio referring to a given node cannot be extrapolated and applied to the analysis of other similar metabolic networks without checking how it is obtained (the mix and the characteristics of the structural elements).

Using the metabolic network approach it can be thus established a bridge among the information referring to different hierarchical levels and scales of analysis:

1. The interactions of the network as a whole with its context. This implies considering simultaneously three hierarchical levels of analysis: (i) level n, referring to the whole network; (ii) level n+1, referring to the context of the network; (iii) level n-1, referring to the functional components of the network (the nodes of the network);
2. The functioning of the internal parts of the network. This requires congruence of the expected characteristics of the functional nodes (determined in quantitative and qualitative terms at the interface of levels n and n-1) with those of the structural elements making up these nodes (determined in quantitative and qualitative terms at the interface of levels n-1 and n-2).

In conclusion, the specific characteristics of any instance of a metabolic network can be explained by a combination of information referring to three different hierarchical levels (scales) of analysis: (i) the interaction with the context, (ii) the identity of the network; (iii) the identity of lower-level components. The purpose of the proposed framework of analysis is to bridge the quantitative information referring to these different scales and the corresponding non-equivalent, non-reducible descriptive domains (Giampietro et al. 2006). The price to pay for doing so is that it is needed to work with:

- *impredicativity* – given a quantitative representation it cannot be defined whether it is the top-down constraint (the characteristics of the functional element) or the bottom-up constraint (the characteristics of the structural elements) that determines the observed pattern;
- *semantic approximation* – an exact mapping between functional and structural elements is impossible because they are defined across different hierarchical levels of organizations. In ecology, functional nodes are made up of species,

made up of populations, made up of organisms that may express an important variability (gender, age, activity patterns) at different levels of analysis. The result of these differences may be either important or negligible depending on the goal of the analysis. In an MSWMS functional nodes are made up of a combination of lower-level technologies (plants of different sizes and technological coefficients) that may express important variability with regard to utilization factor, ageing (deterioration), and effective management.

The theoretical concepts of metabolic networks have been applied to the analysis of MSWMS, using MuSIASEM accounting scheme and drawing on preliminary data from my case study in Naples.

2.3.2 MuSIASEM application

In this thesis the application of MuSIASEM has the specific goal of integrating the external (top-down) and the internal view (bottom-up) of the metabolic pattern of socio-ecological systems across scales, and has already been successfully applied to the analysis of the energy sector of society (Mario Giampietro et al. 2012, 2013, 2014)

Within the rationale of the metabolic pattern of Social-Ecological Systems an MSWMS is perceived as an organ of a socio-ecological system that modulates the interaction between the metabolic processes of the urban area, which consume a flow of inputs and generate a flow of wastes, and those of the embedding ecosystems providing both some of the inputs used by the MSWMS and local sink capacity (capacity of absorbing effluents without insurgence of environmental problems). A basic skeleton of the generic semantic framework, including the external and internal view of the MSWMS, is shown in Fig. 2.10.

(A) The *outside view* focuses on the interaction of the MSWMS (seen as a black box) with its context. The outside view provides relevant information on the environmental impact of the MSWMS and the consequences for human health.

(B) The *inside view* (inside the black box) focuses on the functions and the structures of the parts that make up an MSWMS. This view provides relevant information on the performance of the MSWMS in relation to criteria such as economic costs, employment, and local development. This view includes all processes that determine the 'capacity of managing waste' of the system.

The combination of two not equivalent views: external (interaction between MSWMS and its context) and internal view (functions and structures – technologies - of the parts making the MSWMS) gives a better picture to evaluate the performance of a MSWMS.

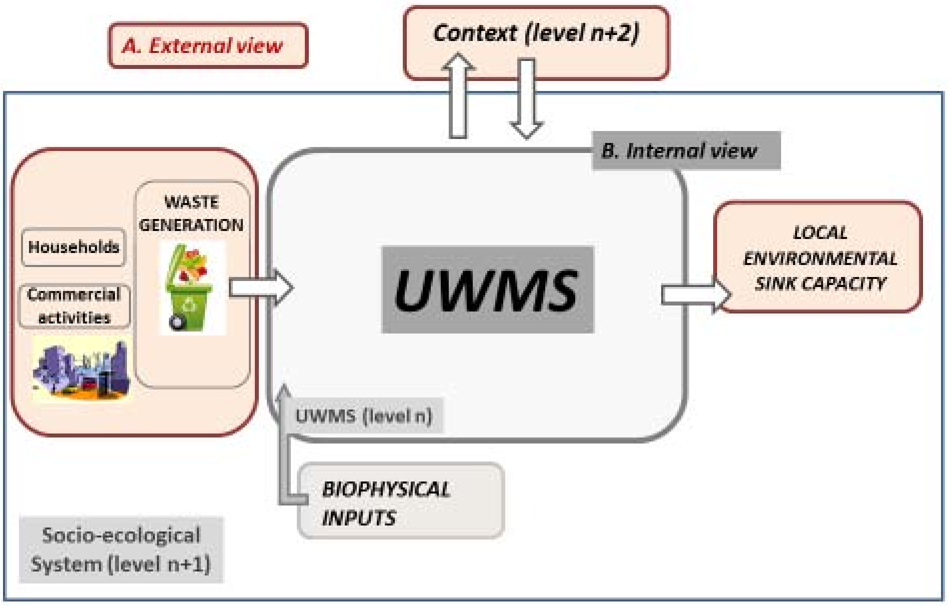

Figure 2.10 - *Skeleton of the generic semantic framework to represent MSWMS metabolism.*

Opening the black box MSWMS in Fig. 2.10, a simplified semantic framework to characterize the metabolism of municipal solid waste management systems (MSWMS) is proposed. In Fig. 2.11, there are represented:

- The society (level n+1) generating the municipal solid waste throughput that is the input for the MSWMS system (focal level n) (left side of Fig. 2.11);
- Other socio-ecological systems (level n+2) importing/exporting waste (top of Fig. 2.11).
- The local environment (level n+1) absorbing the physical flows disposed of (right side of Fig. 2.11);
- The society (level n+1) re-using material generated by the MSWMS (bottom of Fig. 2.11);

All the stages of municipal solid waste management (collection, processing, disposal and so on) taking place within the waste management system to study are considered as internal (e.g., the local environment falls within this border[11]). Any waste flux directed out of this area or entering the area from outside, regardless of the processing stage at which this is occurring, is considered as, respectively, exported or imported.

[11] In the representation of the MSWMS of the Metropolitan Area of Naples, the analytical border adopted is based on an administrative/geographic criterion.

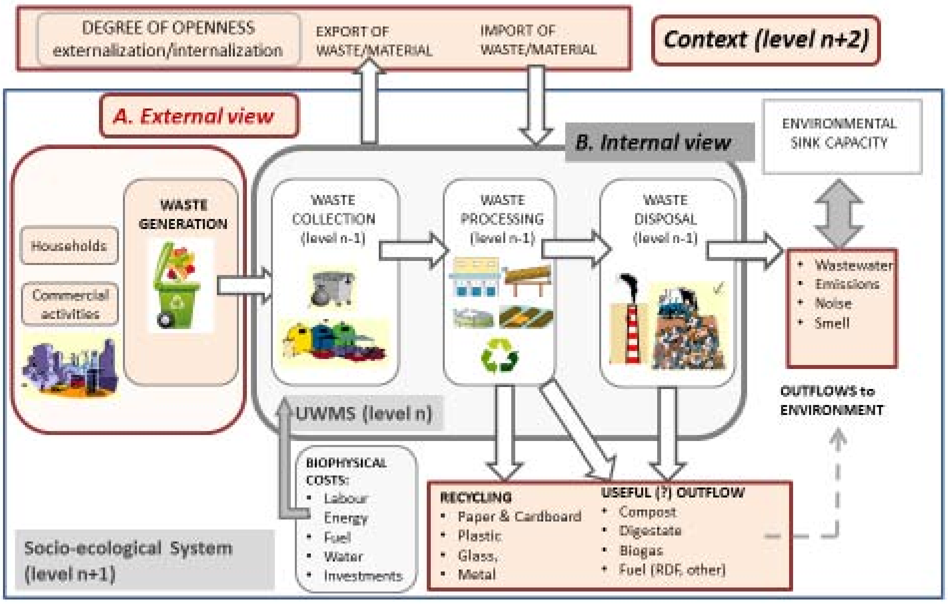

Figure 2.11 *- Conceptual semantic framework to characterize the metabolism of municipal solid waste management systems (MSWMS) in relation to their context*

The external view of the MSWMS covers four crucial aspects:

1. The quantity and quality of the waste generated by the urban society that has to be processed by the MSWMS;
2. The level of openness of the system as determined by the inflows (import) and outflows (export) of the different forms of waste during the various steps of the waste management process. This information is essential to assess the degree of externalization (or internalization) of environmental problems to (from) other socio-ecological systems;
3. The final quantity and quality of wastes, particles and pollutants (solid, liquid and gaseous) that result from the overall functioning of the MSWMS and that are disposed of into the local environment. Together with the given sink capacity of local ecological funds this determines the environmental impact of the MSWMS;
4. The effects that the operation of the MSWMS has on the socio-economic context. These can be measured in terms of: economic costs (fixed and

circulating) of the structural elements needed to operate the MSWMS; benefits of the recovery and recycling of useful material; costs of exporting waste for processing elsewhere (or gains in the opposite case); employment; well-being of citizens; socio-economic 'side-effects' on other sectors, such as impacts on tourism, health care and so forth.

The internal view focuses on a detailed analysis of the various functional nodes/compartments that make up the MSWMS. Three major steps can be distinguished: waste collection, processing and disposal (see Fig. 2.11). These steps can be carried out in different ways, and the chosen modalities will determine the identity of the metabolic network: What functional nodes and what topological relations are established over the different flows across the nodes. In turn, the network identity determines the 'processing capacity' demanded from the structural elements operating within the functional nodes.

- Step 1, waste collection takes place at the interface between the MSWMS (level n) and the urban context (level n+1). Municipal solid waste may be collected in different ways (door-to-door, street containers, underground containers), separately (e.g., recyclables, organic waste) or mixed (and sorted afterwards);
- Step 2, waste processing concerns the internal activities taking place within the MSWMS. Waste processing can be done in different ways using different technologies. The specific processing technologies adopted (structural elements) will imply different degrees of recycling and a different handling of organic waste. Inside the network, solutions adopted for processing depend on the choices made for waste collection (in Step 1), and will affect the possible solutions for final waste disposal (in quality and volume in Step 3). In the step of waste-processing it is essential to distinguish between waste flows that: (i) are

processed by a successive functional node (remaining in the network at level n); (ii) are returned to society (recycled; re-used at level n+1); and (iii) are exported (as by-products) outside of the socio-ecological system boundaries (externalization at level n+2); (iv) are escaping into the local environment as emissions (percolate, particles, etc., at level n+1) (see Fig. 2.11).

- Step 3, waste disposal takes place at the interface between the MSWMS (level n) and the embedding local ecosystems (level n+1). Virtually any MSWMS has a certain share of waste going to landfills and/or incineration plants. However, one should be aware that externalization of waste can also represent an important form of disposal (as is the case for the Metropolitan Area of Naples).

The generic representation of the MSWMS shown in Fig. 2.11 obviously implies ambiguity in the relation between functional nodes and the composing structural elements. The same three steps can be realized with different combinations of functional nodes, and the same functional nodes can be operated with different technologies. For this reason, in the next section, a concrete case has been used, the Metropolitan Area of Naples (Italy), to further elaborate and illustrate the proposed framework of analysis.

2.4 Quantitative characterization of the MSWMS

Data on the MSWMS of the Metropolitan Area of Naples were collected from local statistics (ARPAC[12], ISPRA[13]), and through interviews with various actors[14] of the

[12] Agenzia Regionale per la Protezione Ambientale Campania (Regional Agency for Environmental Protection).

[13] Istituto Superiore per la Protezione e la Ricerca Ambientale (Institute for Environmental Protection and Research).

[14] Municipal Government of Naples, Environmental Authority Department - Campania Region, ARPAC, Campania Region, ASIA (Azienda Servizi Igiene Ambientale – waste collection company); Metropolitan Area of Naples, SAPNA (Sistema Ambiente Provincia di Napoli – Environmental System Naples Province), Cittadini Campani per un Piano Alternativo dei Rifiuti (Campanian citizens for an alternative plan for waste), Hotel/Restaurant Zero Waste/ Zero Waste Campania, Lets do It! Italy.

Neapolitan waste management scene. They included members of the regional and municipal administrations; private and public companies operating in MSWMS; local NGOs; activist groups; and consumer organizations. The interviews with relevant actors were carried out in September and October of 2015 within the framework of the MARSS project[15]. The aim of the interviews was to corroborate the proposed metabolic network structure, estimate waste-flows quantities and economic costs, and identify relevant social and political issues.

2.4.1 The Neapolitan case: preliminary data

In this paragraph the case of the Metropolitan Area of Naples has been used to further elaborate and validate the idea of the MSWMS as a metabolic network. A top-down characterization of the metabolic pattern of the Neapolitan MSWMS is provided in Fig. 2.12. It shows the functional nodes and their topological relations, as well as a quantification of the flows (in metric tons per year) entering and exiting the individual nodes. A close-up of this characterization of the 'network niche' is illustrated for the node Mechanical Biological Treatment (MBT) in Fig. 2.13.

[15] http://www.marss.rwth-aachen.de/cms/front_content.php?idcat=1&lang=2&changelang=2

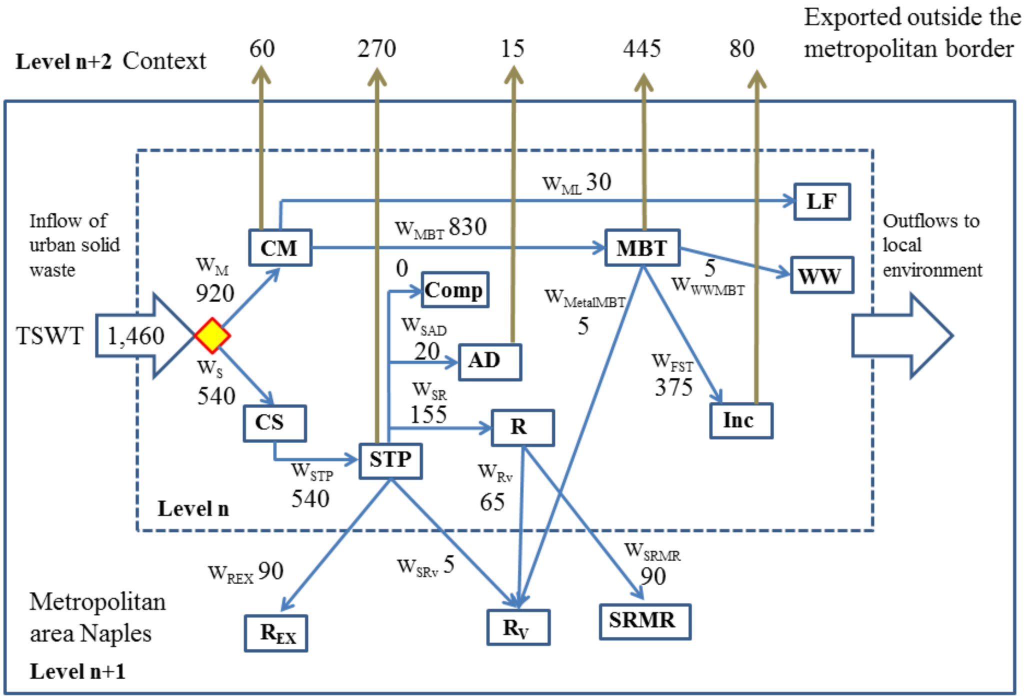

Figure 2.12 *-The network of functional nodes of the MSWMS of the Metropolitan Area of Naples (external view) and quantification of the related waste flows.*

Data (in 103 metric tons per year) refer to 2012. Abbreviations are listed in Box 1.

BOX 1 - Labels identifying nodes and flows in the metabolic network shown in Figures 2.12 and 2.13

Functional nodes: CM: mixed collection; CS: separated waste collection; MBT: mechanical biological treatment; LF: landfilling; Inc: incineration; WW: waste water treatment; STP: sorting transfer; Comp: composting; AD: anaerobic digestion; R: recycling centers; R_{EX}: External recycling; SRMR: secondary raw material recycling; Rv: recovery)

Flows: *TSWT:* Total Municipal Solid Waste Throughput; W_M *:* Mixed Municipal Solid Waste; W_{MBT} *:* Mixed Municipal Solid Waste sent to Mechanical Biological Treatment; W_{ML} *:* Mixed Municipal Solid Waste sent to Landfill*;* W_{FST} *:* Dried Fraction coming from MBT sent to Incineration; W_{WWMBT} *:* Waste Water coming from MBT sent to waste water treatment plants; $W_{MetalMBT}$*:* Recovered metals from MBT; W_S *:* Separated Municipal Solid Waste; W_{STP}*:* Separated Municipal Solid Waste sent to Sorting Transfer Platforms; W_{SAD} *:* Biodegradable Waste from separated collection sent to Anaerobic Digestion; W_{SR} *:* Dried Separated Municipal Solid Waste sent to Recycling Centers; W_{REX}*:* Dried Separated Municipal Solid Waste sent to Recycling Centers outside the MAN; W_{SRMR} *:* Recycled Material coming from Recycling Centers sent to Secondary

Raw Material Recycling; W_{Rv} : Processed Separated Waste coming from Recycling Centers sent to Recovery; W_{SRv} : Refuse from Separated Municipal Solid Waste Sorting Platforms sent to Recovery.

W_{FUTLF}: Unstabilized Organic Fraction coming from MBT sent to Lanfill; W_{MBTww} : Waste Water coming from MBT sent to waste water treatment plants; W_{FUTS} : Stabilized Organic Fraction coming from MBT; W_{FST} : Dried Fraction coming from MBT sent to Incineration; W_{FUT}: Unstabilized Organic Fraction coming from MBT sent to other treatments;

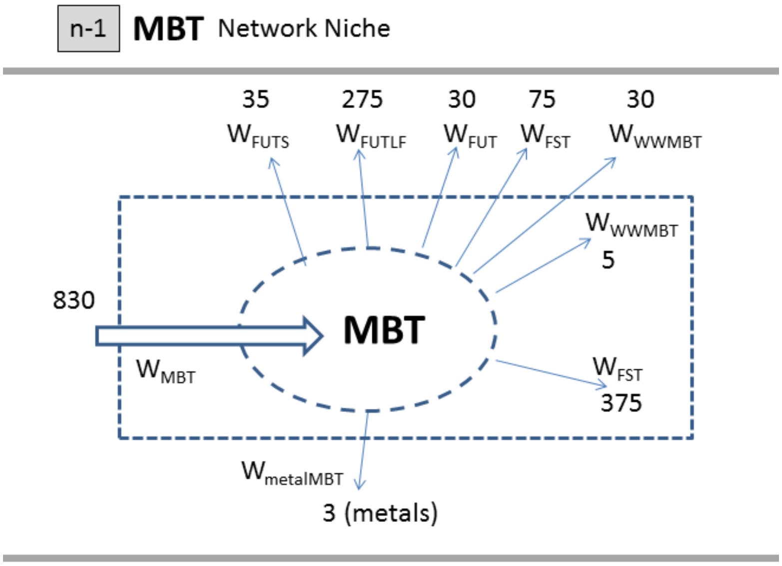

Figure 2.13 *- Quantitative representation of the node Mechanical Biological Treatment (MBT) based on the outside view. Abbreviations are explained in Box 1.*

Data are in 10^3 metric tons/year and refer to the Metropolitan Area of Naples and the year 2012.

It can be also possible to open up the 'black box' and look at the characteristics of the structural elements that make up the node and determine its properties in terms of: (i) the composition of the material flows; and (ii) the relations between inputs and outputs. An example of a bottom-up representation of the characteristics of the structural elements operating within the node MBT is given in Fig. 2.14. In the case of Naples, there are three structural elements: (i) 2 MBT plants of type α, each with a capacity of 473×10^3 metric tons/year, which have been operating at 59% of their capacity in 2012; (ii) 1 MBT plant of Type β, with a capacity of 607×10^3 metric tons/year, which has been operating at 45% of capacity in 2012. The relation between the actual processed throughput and the processing plant capacity is a service performance indicator recommended by UNEP (2005). Note that the expected relations between the input and outputs of the different typologies of plant in Fig. 2.14 are expressed as technical coefficients (per thousand metric tons of input).

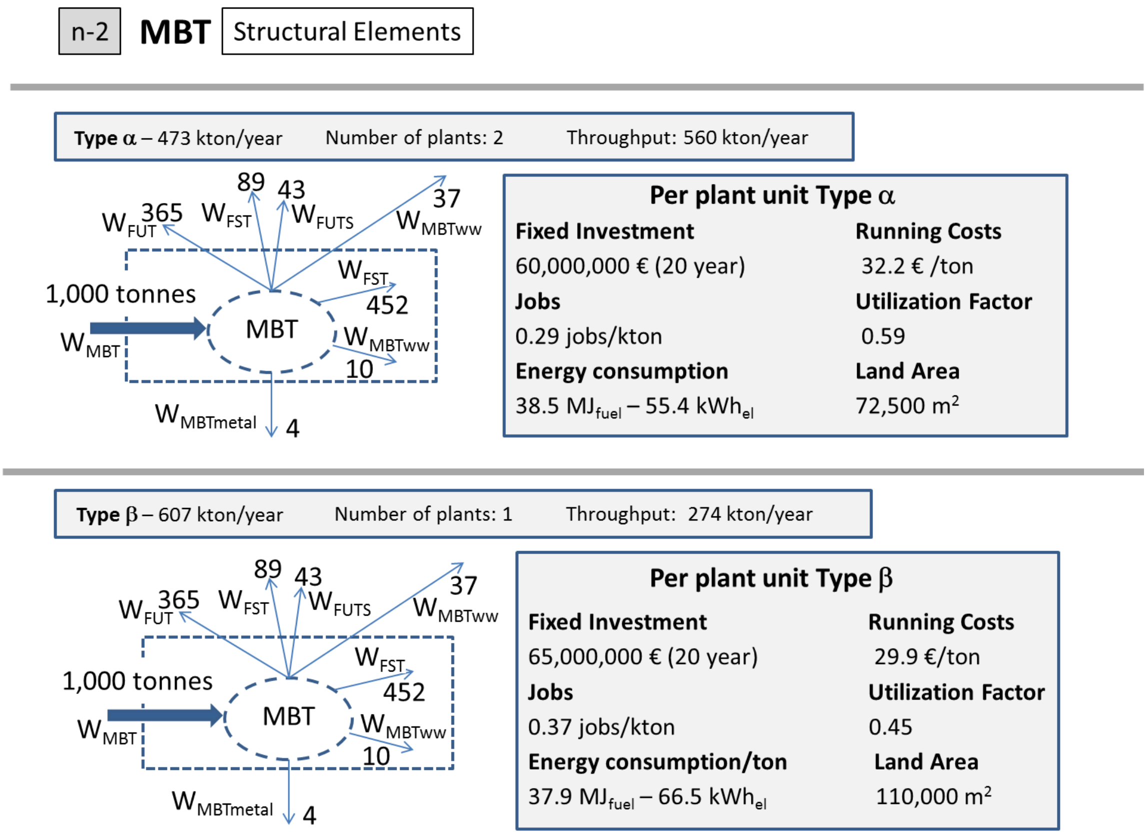

Figure 2.14 - *Quantitative representation of the node MBT looking at its structural elements and their characteristics (inside view).*

Flows are reported in metric tons.

The two views presented in Figs. 2.13 and 2.14 are analogous to those presented in Fig. 2.11. Note that for each of the waste flows reported in Figs. 2.12, 2.13 and 2.14, the composition by specifying the mix of different fractions (e.g., biodegradable, paper & cardboard, plastic, glass, metal, other) can be detailed. For instance, in Fig.2.15 the average composition of the collected waste in the Metropolitan Area of Naples is illustrated. Detailed information about the composition of all the different flows from/to the different nodes is beyond the scope of this paper and will be published elsewhere.

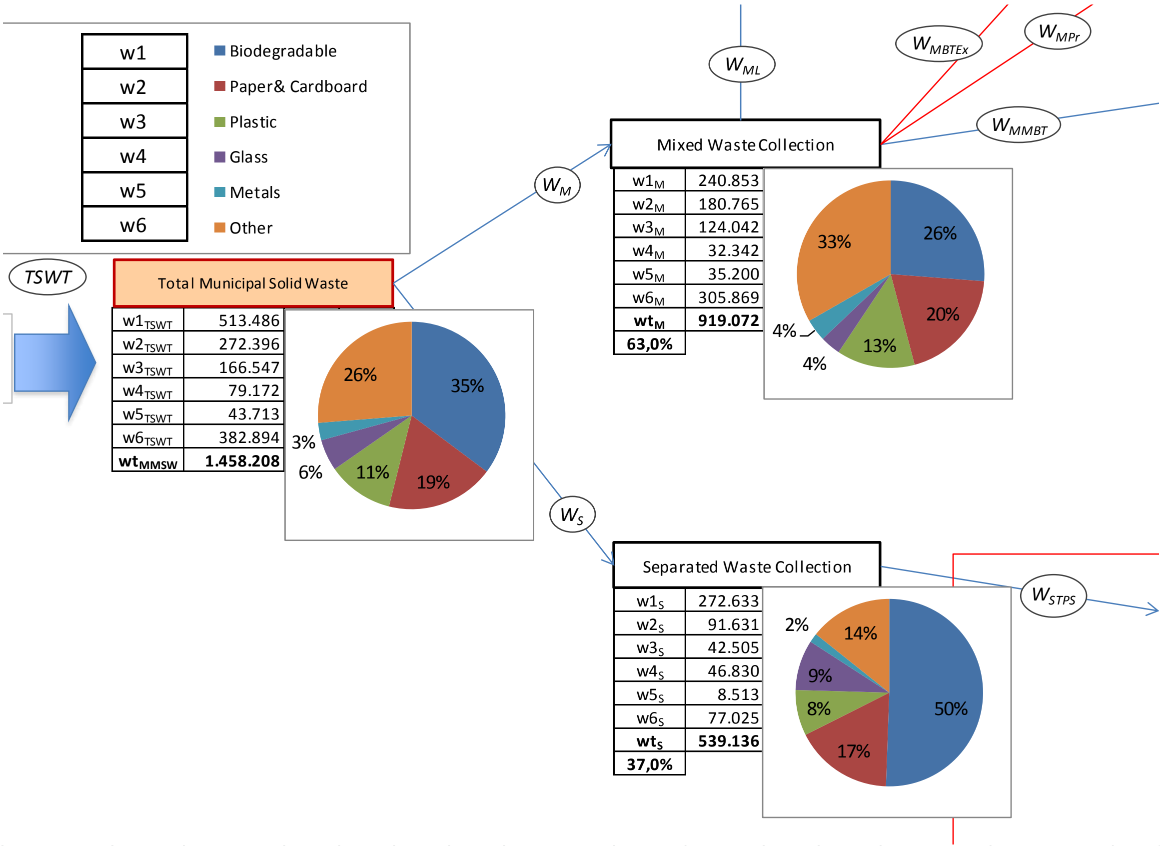

Figure 2.15 *- Composition of waste flows in the collection stage of the network of the MSWMS of the Metropolitan Area of Naples in 2012.*

Data are in metric tons/year.

2.4.2 Indicators characterizing the performance of the MSWMS

2.4.2.1 Openness of the network

Starting out from the description of the metabolic network (Fig. 2.12) the nodes from which flows are leaving the MSWMS into the context can be identified. This analysis is important because flows exiting the network signal either an excess of input relative to the capacity of the node in question (saturation of the capacity of lower-level structural elements) or economic convenience (the cost of exporting the flow is lower than that of processing within the network), or both. An example of an analysis of the openness of the system is given in Fig. 2.16.

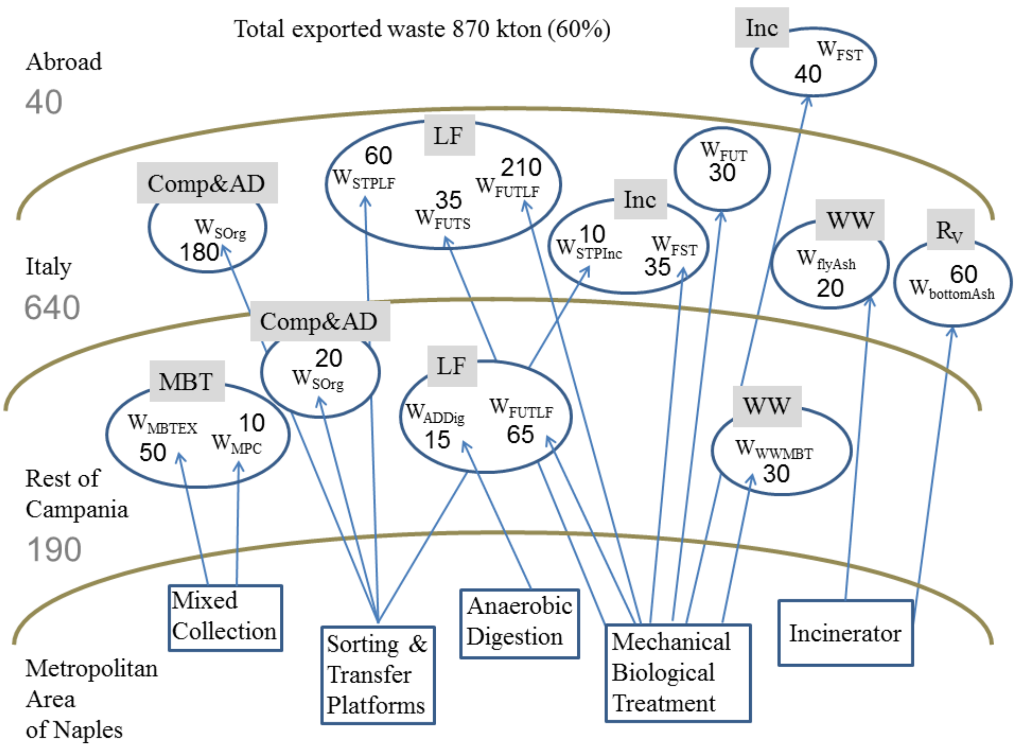

Figure 2.16 *- Analysis of the flows released into the context from specific nodes of the MSWMS network of the Metropolitan Area of Naples.*

Data are in 10^3 metric tons/year and refer to the year 2012.

In Fig. 2.16, the destination of the flows is represented on the basis of: (i) a spatial criterion (flows are entering a node elsewhere in the region of Campania, in other regions of Italy, or abroad), and (ii) a functional criterion (individuating the type of processing capacity required by the characteristics of the flow). For example, WFUTLF (unstabilized organic fraction coming from MBT sent to landfill) requires land-fill capacity, independently of the location of the landfill. It is important to combine these two criteria in the organization of the information as it makes the system of accounting more useful for discussing policies and scenarios at different scales. For instance, administrators of the Region Campania can easily see the connections between the local and the regional network. Also, it can help administrators to estimate trade-offs between increasing the capacity of selected local nodes and exporting in relation to projected changes in population size and/or solid waste throughput (quantity and quality) per person.

The percentage of waste (on the total throughput) that is exported outside of the system is an indicator of the 'degree of openness' of the system. In the year 2012, in the Metropolitan Area of Naples 60% of the municipal solid waste generated was exported outside of its borders. Only 13% of the exported flow was actually treated within the region (Campania), the remaining 47% was exported to other Italian regions or abroad. These figures stand in stark contrast to the ambitious goal of regional self-sufficiency in waste treatment and disposal laid down in the 2007 Regional Plan for Waste Management of the Campania Region (PRGRC[16]) as well as in the Italian legislative decree 152/2006.

2.4.2.2 Socio-economic impact of the network

Combining the information on (i) operating costs and labor requirements for the structural elements within the individual functional nodes (see Fig. 2.14); (ii) recycling of material and production of useful outputs for society; and (iii) export of wastes (a cost for the local administration of the Neapolitan MSWMS), the monetary flows associated with the operation of the MSWMS as well as the number of jobs created can be estimated, as illustrated in Fig. 2.17. In the case of Naples, also the maintenance and safeguarding of 5.7 million tons of 'eco-balle', a temporary storage of waste excess generated in the crisis period of 2001-2009 needs to be included. In this way, a check on the *viability* of processes under human control, both in relation to technical viability

[16] PIANO REGIONALE per la GESTIONE dei RIFIUTI URBANI della REGIONE CAMPANIA – legge regionale 4/2007.

(compatibility of the technical characteristics of the elements of the metabolic network) and economic viability (the resulting monetary flows) can be carried out. Note that the data provided in Fig. 2.17 are rough estimates and only serve to illustrate the approach.

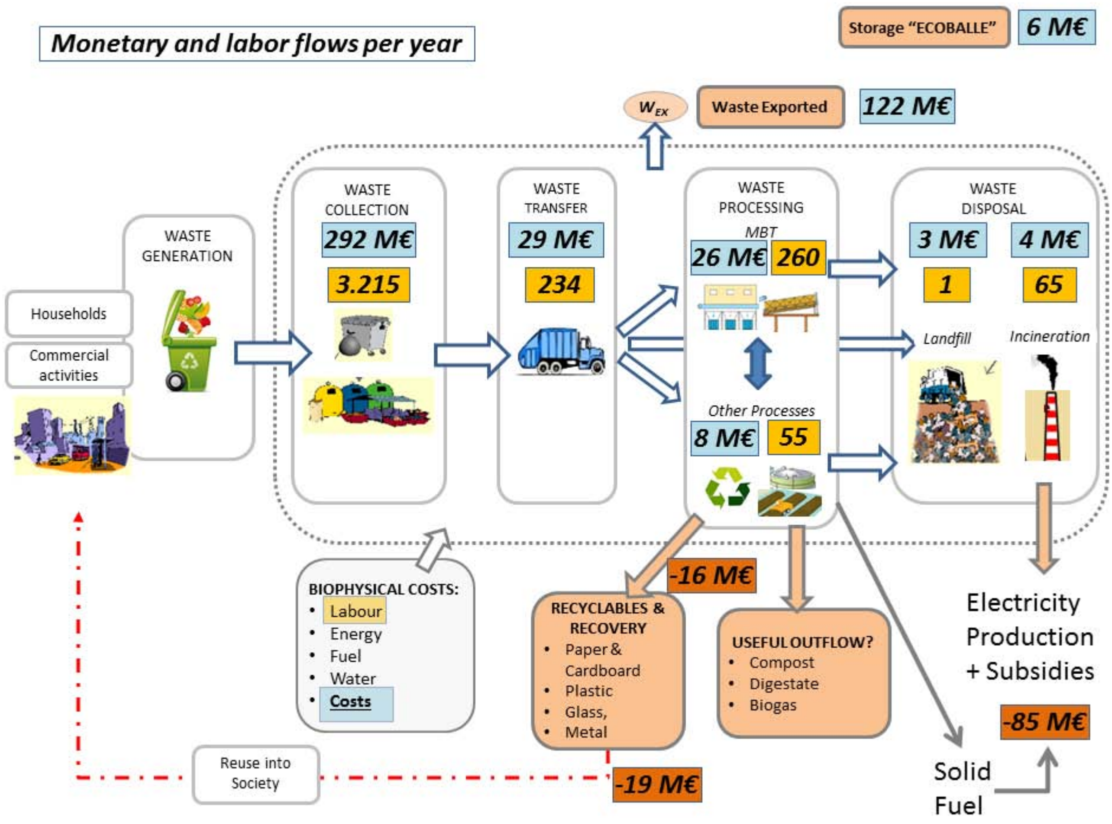

Figure 2.17 - *Preliminary assessment of the monetary flows (at 2012 market prices) and jobs created (in units of full-time positions) for the MSWMS of the MAN based on metabolic network analysis.*

Fig. 2.17 shows that in the Metropolitan Area of Naples, waste collection accounts for the larger part of the economic costs of the MSWMS (292 M€/year). However, an important part of this monetary flow remains in the city in form of wages for local workers and revenues for local operators. Waste export also represents a significant economic burden for the local administration (122 M€/year). The large flow of export is a result of shortage of processing capacity at the level of structural elements in key nodes. Using the proposed approach, one can analyze the processing capacity and relative economic investments in the different nodes for generating alternative network configurations (by changing characteristics of functional nodes, e.g. through the adoption of new technologies and/or changing connections over nodes) to achieve a planned reduction of waste export.

The monetary values illustrated in Fig. 2.17 can be interpreted as costs or benefits depending on the perspective adopted. For instance, labor represents a monetary cost for the local administration but benefit (wages) for the community. The same reasoning applies to other monetary flows between interacting economic agents in the MSWMS. The flows indicated in the bottom part of Fig. 2.17, such as recycled material or useful output like biogas, fuels or compost, provide an economic return for the local administration, although in the case of Naples the revenue is relatively small compared to the costs. In 2012, the local administration received around 16 M€ for delivering recycled materials to private companies. In this case, the 16M€ is a benefit for the local administration, but a cost for the companies. The added value generated by the private companies processing the recycled material has been evaluated at 19 M€.

A similar situation is found for the operation of the incinerator, the benefits of which are equally shared between the Campania Region (regional public administration) and the private operator of the plant. The estimated value of 85 M€ reported in Figure 2.17 includes the sale of the net quantity of electricity produced by the incineration plant and subsidies received from the central government. The monetary flow coming from sale of electricity is around 25 M€ and has been calculated on the basis of the average cost of 1kWh in Italy in 2012 applied to the electricity generated with the fuels. The remainder consists of public subsidies (approximately 60 M€, estimated from data published by D’Alisa et al. (2010).

The ambiguity in the assessment of economic costs and benefits for the MSWMS shows the importance of discussing pre-analytical decisions with those using the results of the quantitative analysis for decision-making. Costs and benefits for whom? When it comes to the criterion 'desirability' it is important to recognize that different social actors do adopt different, but equally legitimate definitions of economic costs and benefits. This means that the choice of an integrated set of indicators of socio-economic performance should always include a participatory phase in which the pre-analytical choices of story-telling (how to reflect the monetary flows in a system of indicators) are checked with those that will use the results of the model.

2.4.2.3 Environmental impact of the network

To assess and monitor the environmental impact of the emissions generated by the MSWMS, the level of disturbance that the metabolic pattern of the MSWMS generates on the metabolic pattern of the embedding ecological system needs to be studied. A discussion of how to use a multi-scale characterization of the metabolic pattern of socio-ecological systems to develop indicators of environmental impact organized in an environmental impact matrix has been described elsewhere (Giampietro, M. and Lomas 2014). An overview of the proposed approach, applied to the Neapolitan MSWMS, is illustrated in Fig. 2.18. Briefly, the information need to be organized as follows:

1. Individuate and categorize the nodes generating significant emissions into the environment, and represent them in quantitative and qualitative terms both in space and in time;
2. Individuate and categorize the local ecological systems in the context and, for each of them, identify and describe the attributes to define threshold values of critical environmental loading;

3. Select a mix of indicators of Environmental Impact (EI) capable of characterizing the level of stress caused by the selected emissions. This integrated set of EI indicators must be able to observe processes taking place at different scales. It is important that indicators of environmental impact are specific to the characteristics of local ecological funds. This implies the need of using spatially geo-referenced data that can be used to both characterize and monitor in time the environmental performance of the MSWMS.

Participatory processes are useful to check the quality of the choices made with regard to nodes, indicators and ecosystem funds, and of the relative system of monitoring (e.g., location and number of control units, definition of emission limits).

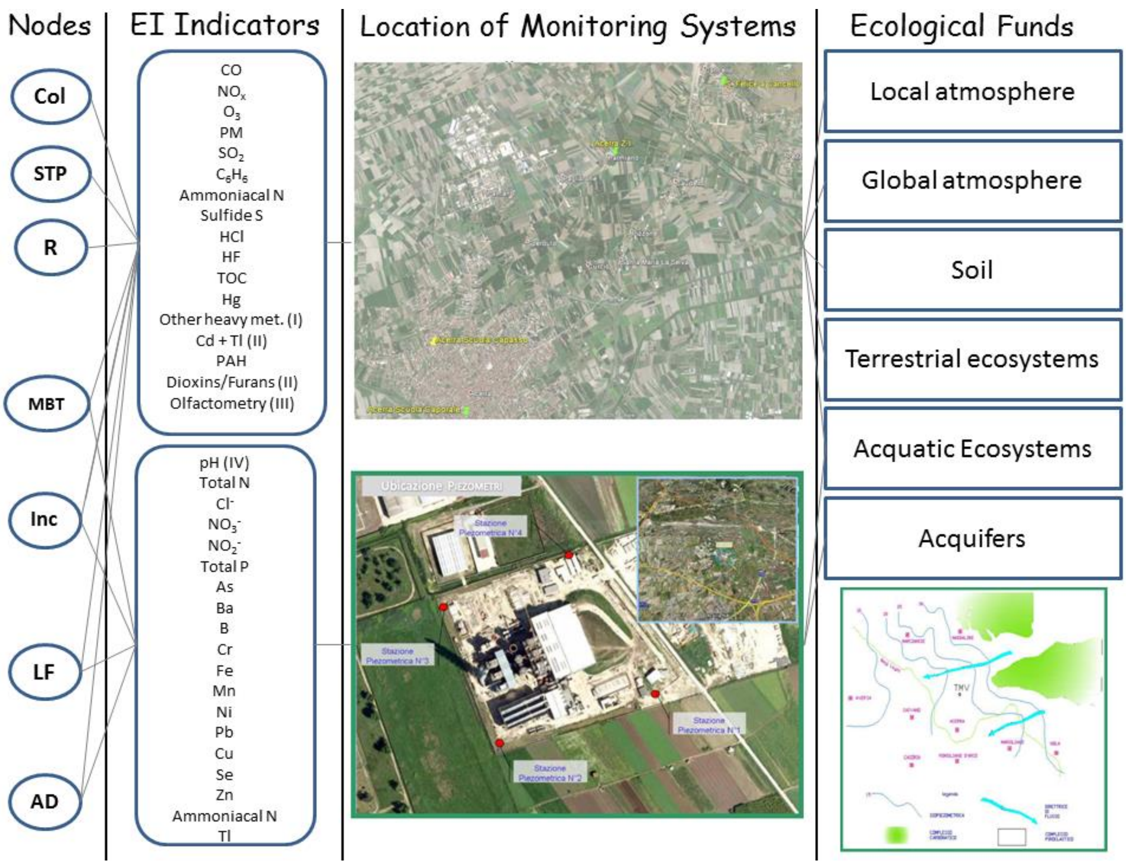

Figure 2.18 *- Example of environmental impact indicators for the case of Naples: Air and water emissions from specific nodes of the network in relation to relevant ecological funds in the context.*

The corresponding legislative framework consists of: European directive 2008/50/EC; Italian legislative decree 152/2006; "Ordinanza commissariale 258/2003" specific for MBT plants; "Autorizzazione Integrata Ambientale" (AIA) from ARPAC specific for the Acerra incinerator; the AIA and "Ordinanza *commissariale" 289/2009 specific for the Terzigno landfill. Notes and abbreviations: (I) Other heavy metals: Sb, As, Pb, Cr,Co, Cu, Mn, V, Ni, Zn, Sn; PAH: Poly-Aromatic Hydrocarbons; PM: Particulate Matter; TOC: Total Organic Carbon.*

In the example shown in Fig. 2.18, there are indicated: (i) in the far left column: the nodes whose activity could potentially generate relevant emissions (in this case waste collection is treated as a unique system, including both CS and CM); (ii) in the second column: the indicators of environmental impact (upper set: air emission; lower set: water emission); (iii) in the third column: the location of the nodes generating emissions and the relative monitoring systems (the example shows the incinerator of Acerra in the Metropolitan Area of Naples and the location of the air-quality control units in the surrounding area [upper photo], and the positions of the upline and downline observation wells [lower photo]); (iv) the far right column: typologies of vulnerable ecosystem funds (the example shows groundwater flows in the Acerra microregion affected by local effluents from the incinerator). The most controversial facilities, that is, the incinerator, the landfill and the MBT plants, installed and erected despite the aversion of the local population, are subordinated to specific higher standards, with lower concentrations of the effluents allowed. The environmental performance of the above-mentioned plants has generally been within the prescribed limits, with the exception of the landfill in Terzigno, which has been accused of exceedances in water emissions for metals such as manganese and zinc as well as other species[17].

2.4.2.4 Integrating indicators of MSWMS performance

The holistic framework illustrated in this paper is useful to bridge information referring to different levels of analysis (local and meso scale) and different data sources (bottom-up information about the characteristics and use of technologies versus top-down statistics describing the functional compartments). Starting from a general

[17] Report accusing: http://www.comune.boscotrecase.na.it/files/Microsoft%20Word%20-%20Relazione_tecnica_finale.pdf, report denying: http://www.altrestorie.org/Allegato%207.pdf.

semantic characterization of the MSWMS (Fig. 2.11), a representation of the metabolic network (Fig. 2.12) based on the identification of functional nodes and their topological relations inside the system (level n-1) (Fig. 2.13) and with its context (levels n+1 and n+2) (Fig. 2.16) can be reached. Flows exiting or entering the network (exported or imported flows) are accounted for because of their economic relevance and externalization of impact (Fig. 2.17). For example, the analysis of the nature and source of exported waste flows for the Neapolitan MSWMS (Fig. 2.16) clearly shows the typologies of technological capacity that are externalized, as well as the implications of the choice of system boundary for the analysis (e.g., the Metropolitan Area of Naples versus the whole region of Campania).

The proposed framework also makes it possible to interface the analysis of the performance of the MSWMS with an analysis of environmental impact, that is, the feasibility of the operation of the MSWMS in relation to the carrying capacity of the embedding ecosystems and the related regulations imposed by the local, regional and central governments (Fig. 2.18). For example, the massive export of waste material (for composting, for land-fills, including both the fly and the bottom ash from the incinerator) outside of the Metropolitan Area of Naples has been an emergency strategy to provide for the severe lacking of local processing and disposal capacity. Within this framework, it is proposed to track the flows of emissions from each node into the ecological funds likely to be affected. Linking emissions and other environmental problems to specific network nodes not only makes it possible to study the environmental impacts of proposed scenarios (simulating different network configurations), but also to carry out a transparent discussion about the monitoring of environmental impacts. The proposed framework facilitates the use of geographic information systems to localize and visualize emissions (as illustrated in Figure 2.18), which is extremely useful for a transparent communication with the public.

As shown by the preliminary findings in the Naples case study, the proposed holistic framework for the integrated assessment of the performance of MSWMS can generate a set of relevant indicators reflecting the concerns and goals of different stakeholders. Other indicators, such as proposed by Armijo, et al. (2011) and UNEP (2005), can also be accommodated within the framework.

For each typology of stakeholders interviewed in Naples, different storytelling about the performance of the MSWMS have been found. The public administration expressed its concern about the high economic costs (including labor costs) of the operation of the waste management system. In contrast, the creation of jobs was considered positive by the unemployed councils. Citizens, NGOs and activists were basically concerned with the (lack of) transparency and effectiveness of the monitoring of emissions from the plants and the resulting environmental harm. This diversity of storytelling, associated to different goals and concerns, can be handled by generating a series of dashboards as illustrated in Fig. 2.19. Note that the current local environmental impact reported in Fig. 2.19 is relatively low considering the high population density in the area (2600 inhabitants/km^2). As mentioned earlier, this is due to the fact that almost 60% of waste produced is being exported. This massive externalization of environmental impacts implies high economic costs for the operation of the MSWMS.

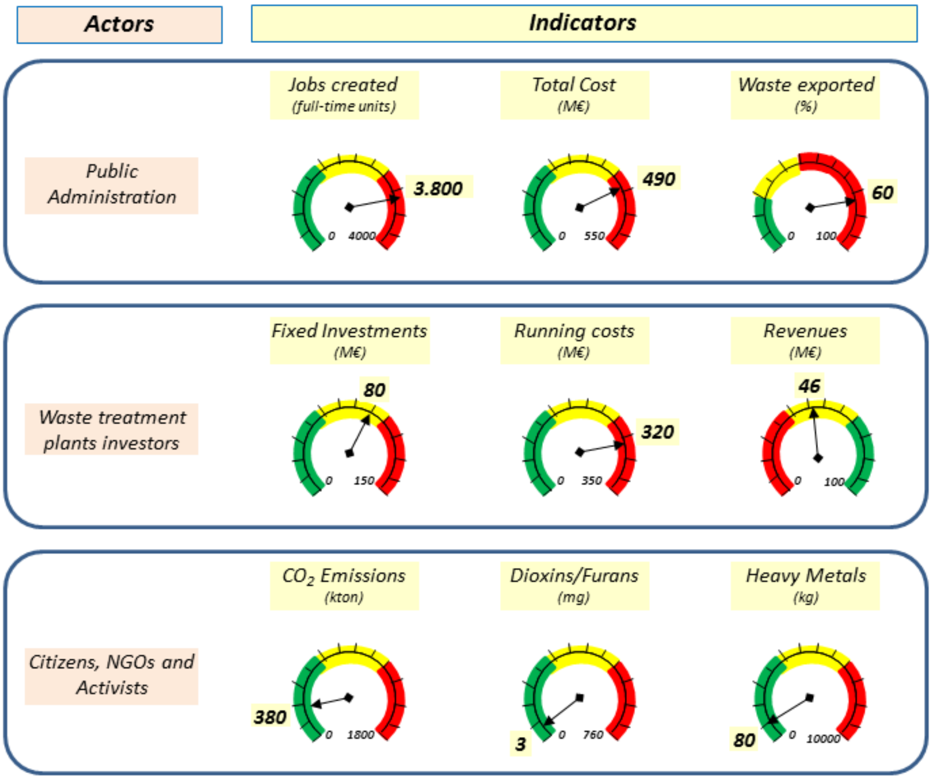

Figure 2.19 *- Relevant indicators of MSWMS performance for different story-telling by stakeholders in the Metropolitan Area of Naples.*

Indicators refer to the operation of the entire MSWMS and represent the sum over the various network nodes. The color code red, yellow and green corresponds to bad, average and good performance respectively. Data presented are preliminary and only serve to illustrate the proposed approach.

2.5 Conclusions

The approach presented in this chapter is innovative in that it is based on theoretical concepts from complexity theory (metabolic network, flow-fund model, holons and holarchy). It is the first attempt to apply the MuSIASEM accounting framework to the development of a decision support tool for the integrated assessment of the performances of MSWMS. I believe that the proposed framework has the potential to integrate different type of indicators –social, economic; environmental– across different scales and dimensions of analysis.

The advantages of constructing a semantic framework for the MSWMS are manifold:

Facilitation of participatory problem structuring. A semantic definition of the MSWMS is helpful to identify and compare the different perceptions and narratives of social actors involved. Even though different stakeholders will describe in details "different things" when referring to "waste collection", "waste treatment", "waste disposal", the ambiguity of the semantic definitions makes it possible to establish a coherent set of relations over these different terms and in this way can be used to explain the existence of bifurcation of meanings when considering the narrative adopted by different social actors or by different academics;

Awareness of potential environmental problems. The semantic framework makes it possible to build a common understanding of the perception and representation of key aspects to be considered to study the interaction of the USWM with its context, in terms of a common agreement on: (i) how to assess the quantity and quality of waste to process (in terms of pace per hour and density per hectare); (ii) the characteristics of the ecological context to be considered when checking the impacts (in terms of critical thresholds of environmental loading); (iii) the level of openness of the system (in terms of externalization/internalization of waste flows during the various operations of the waste management system);

Insight into the functioning of the MSWMS. The semantic framework establishes a relation between the overall performance of the MSWMS considered as an organ of the city and the technical characteristics of the specific processes taking place within the system (the parts operating inside the organs). The hierarchical organization of the different processes and corresponding functional compartments, that together express the overall function of the MSWMS, can be tracked in quantitative terms by adopting an appropriate set of accounting categories.

The proposed methodological framework has important features:

(1) It can be used to evaluating "scenarios" associated with potential policies. The quantitative relations between the outside and inside view of network nodes (functional element of the network–network niche versus structural elements of the node–technical coefficients) are not deterministic. Therefore, it has to be decided, node by node, what can be done to obtain congruence in the simulation: exporting (when capacity to process the new input flow is insufficient) or increasing capacity by adding new/changing structural elements. As soon as we decide what to do with a node, this choice will be reflected in the flows reaching successive nodes, which, in turn, will have to be adjusted to the new input flows in a similar way. Rather than generating simulations of deterministic dynamic trajectories, this approach explores the option space, providing for the proposed alternatives an analysis of the pros and cons in relation to the chosen indicators. Clearly, this exploration requires a continuous input from the end-users with regard to: (i) relevant hypotheses of network identities; (ii) relevant indicators for characterizing the performance of the MSWMS; (iii) solutions for dealing with lack of congruence in individual nodes.

(2) It represents a semantically open framework that can be used to structure a discussion about how to improve the analysis. Different relevant storytelling demands correspondingly different integrated characterizations. Hence, to be useful in different geographic and cultural contexts, the holistic framework for the integrated assessment of MSWMS must be able to accommodate performance indicators tailored to specific local situations. The use of performance indicators of the type 'one size fits all' simply

does not work. The approach proposed in this section can be considered a meta-tool for carrying out a quantitative characterization of the metabolic pattern of complex waste management systems. It is essentially a semantically open framework that can accommodate indicators related to the environmental, legal, political, economic, technical, public health, and socio-cultural spheres, and therefore allows an informed discussion among the various stakeholders over the performance of MSWMS. As argued by Scholz, R.W. & Steiner (2015), the construction of proper meta-levels of reflection, validation, and integration is expected to play an important role in the future development of sciences.

(3) It makes it possible to generate a quantitative story-telling tailored on the specificity of the situation. The holistic approach to integrated assessment presented in this chapter makes it possible to improve the quality of the process of production and use of quantitative information for MSWMS-related policies. It can be used in combination with participatory processes to identify the different perceptions and narratives (story-telling) of the social actors involved and characterize the advantages and disadvantages of different types of MSWMS in a multi-criteria setting. This new way of using quantitative analysis, that can be called quantitative story-telling, implies a new level of collaboration between the producers and users of quantitative information. The two sides have to work together from the outset in order to guarantee the quality of the process, integrating different types of available information in order to obtain the big picture of the problems at stake.

(4) It guarantee the transparency of the pre-analytical decisions made at the moment of generating the analysis. The proposed representation of the functioning of the MSWMS and the characterization of its performance reflecting the different interests of different social actors increases the transparency of the process of evaluation

and decision making. In the case of Naples, this transparency is badly needed to restore the credibility and legitimacy of decision makers.

Obviously, the proposed methodological framework has also shortcomings:

(1) It requires large amounts of data that have to be retrieved from multiple and variegated sources. Given the peculiarity of the Neapolitan UMWS (scandals and waste crisis in the recent past) it has been difficult to obtain reliable data and information on the numerous network nodes.

(2) It requires time and the commitment of the different social actors defined as relevant for the Participatory Integrated Assessment. To obtain reliable results it is necessary to continuously integrate statistical data (which are not necessarily easy to obtain) with the expertise of practitioners (for double checking the credibility of the data with expert estimations).

(3) last but certainly no least another problem is that the method is **too transparent**. As it will be discussed in Chapter IV when dealing with decision making implying important political implications, politicians and administrators are not happy to take part in a process in which every decision about how to frame the problems, how to interpret the data and how to decide on the policy is as transparent as possible . . .

CHAPTER III - The case study

3.1 Summary

This chapter presents an application of the metabolic network approach – illustrated in Chapter II (Chifari et al. 2016) – for an integrated characterization of the performance of the municipal solid waste management system (MSWMS) of the Metropolitan Area of Naples (MAN). The characterization has the aim to: (i) describe across scales and dimensions the current metabolic pattern of municipal solid waste in the MAN, and (ii) develop a decision-support tool that can be used in participatory processes to explore the policy option space and to guarantee better-informed decision-making. Naples was selected as the case study for practical reasons because of the activity of the EU MARSS project in which I have been working for my PhD. This choice was very appropriate because Naples has been in the past the quintessential example of waste mismanagement in Europe. Interviews with local stakeholders in Naples were undertaken in the fall of 2015 and the results of these interviews were used to check the: (i) the definition of the grammar used to represent the different processes taking place in the UWM of MAN (in relation to the identity of the metabolic network used to represents the various processes in the system); (ii) the robustness of the framing of the muti-criterial analysis (in relation to the choice of indicators); and (iii) the quantitative characterization based on the chosen grammar (in relation to the choice of technical coefficients used in the model).

The same application of the MuSIASEM approach is first used to generate a multi-scale integrated representation of the current performance of the municipal solid waste management system. Then it is used to generate a decision support tool to be used for

taking more informed policy decisions. In fact, the proposed decision support tool can be useful to inform the different social actors (policymakers, voters, political parties, associations, NGOs and grassroots movements) about the factors determining the option space (what can be done) and the pros and cons of different possible waste arrangements. In particular, the decision support can be used to study the trade-offs between exporting wastes (currently a crucial issue in the MAN) versus building and operating more processing capacity within the area. In relation to this point two policy options were analyzed in detail: (i) the complete internalization of waste processing; and (ii) changing from a predominantly unsorted to a predominantly sorted waste-collection scheme.

3.2 Introduction

The Italian region of Campania and particularly its capital Naples have experienced a serious waste mismanagement during the last several decades, the environmental and health consequences of which are still under investigation (D'Alisa et al., 2015; Armiero and D'Alisa, 2013; Barba et al., 2011; Rivezzi et al., 2013; Di Costanzo and Ferraro, 2013; Martuzzi et al., 2005; Fazzo et al., 2008; Triassi et al., 2015; Greyl et al. 2013). The onset of the waste crisis can be dated back to the early 1980s, when Campania became a cheap dumpsite of illegally-imported hazardous waste (Ferrara et al. 2012). In 1994, a formal state of emergency was declared in the Campania region due to the saturation of regional solid municipal solid waste treatment facilities (De Feo & De Gisi 2010a). From 1996 onwards, the Italian government, ignoring the law 387/2003[18] and in breach of any notion of sustainable waste cycle management, started

[18] Legislative Decree no 387/2003 of the Italian Regulatory Authority for Electricity Gas and Water, subsidized only the electricity produced by using biodegradable fractions. http://www.normattiva.it/uri-res/N2Ls?urn:nir:stato:decreto.legislativo:2003-12-29;387!vig=

subsidizing energy generated by burning both organic and inorganic waste. This resulted in the construction of new incinerators in already heavily polluted areas and further contributed to environmental disaster. New incineration facilities, providing an inefficient and non-renewable electricity supply, were clearly not needed in a grid where excess electricity production had led to the closure of many power stations. This choice only created local economic profit through CIP 6[19] incentives -'the more you burn, the more you earn' (Fregolent et al. 2015).

The illegal waste trafficking, the lack of an appropriate municipal solid waste management plan, and the subsidizing of energy generation from indiscriminate waste incineration generated social unrest and a continuous paralysis of waste services throughout much of the late 1990s and early 2000s (D'Alisa and Germani, 2013; De Feo and De Gisi, 2010; D'Alisa et al., 2010; Armiero and D'Alisa, 2012; Arena et al., 2003; Di Costanzo and Ferraro, 2013; Mastellone et al., 2009; Dines, 2013; Capone, 2013; D'Alisa et al., 2012).

Legacy of the waste management crisis is the significant amount of waste accumulated in Campania, waiting to be processed, in a temporary storage made of bales of approximately 1 tonne each, colloquially named "ecoballe", from the Italian *'balla' (bale)* (Belgiorno & Panza 2008). The total mass accumulated amounts to 5.6 million metric tons (D'Alisa & Armiero 2011). The largest one of the three main storage sites is located in the Taverna del Re area in between the municipalities of Villa Literno (adjacent to the MAN) and Giugliano (inside the MAN), covering an area of approximately 130 hectares and storing roughly 3.5 Mt of ecoballe (Fig. 3.1). The bales have undergone a degradation process that implies high dryness and flammability, which makes that the hazard potential of the storage sites is high. However, the

[19] CIP 6: Deliberation No 6 of 29 April 1992

“ecoballe question” has been ‘untouchable’ up to date because of the huge amount of incentives that potentially could be captured if used to produce electricity.

Figure 3.1 *- The storage site at Taverna del Re. View from above and details of one of the “ecoballe” pyramids.*

The European Court of Justice repeatedly condemned the Italian government for its inability to face the waste emergency in Campania and its infringement of European waste legislation (The Court of Justice of European Union Judgments: 4/03/2010[20]; 2/12/2014[21]; 16/07/2015[22]). The ruling of 2014 showed that the declaration of the end of the waste emergency in Campania in 2009[23] by the then Italian Prime Minister Silvio Berlusconi was premature. In the same way, even if newspapers keep reporting new illicit toxic waste dumping areas[24], Neapolitan policy-makers still prefer to believe that waste management is no longer a critical issue (Raffaele Del Giudice, personal communication, 2015). In any case there is a shared common sense that the municipal solid waste management system in Campania is in a very precarious equilibrium because of the strong dependence on waste treatment facilities located outside the region.

The rest of this chapter is organized as follows: Section 3.3 describes the main characteristics of the area under study; Section 3.4 describes the methodological framework adopted and the sources of data used in the analysis; Section 3.5 presents and discuss the main findings of the analysis in relation to: (i) the current UWM situation; (ii) a policy having the goal of increasing the recycling rate; and (iii) a policy having the goal of introducing new waste processing capacity inside the MAN making it possible to treat locally the waste that is currently exported.

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[20] Judgment in Case C-297/08 Commission v Italy. The Court of Justice declares that Italy has not adopted all the measures necessary for the disposal of waste in the region of Campania. http://europa.eu/rapid/press-release_CJE-10-20_en.htm?locale=en

[21] Judgment in Case C-196/13 Commission vs Italy. Italy is ordered to pay financial penalties for failing to complywith a 2007 judgment of the Court establishing failure to fulfil obligations under the waste directives. http://curia.europa.eu/jcms/upload/docs/application/pdf/2014-12/cp140163en.pdf

[22] Judgment in Case C - 653/13 Commission vs Italy. As a result of its incorrect application of the Waste Directive in the region of Campania, Italy is ordered to pay a lump sum of €20 million and a daily late payment penalty of €120000 http://curia.europa.eu/jcms/upload/docs/application/pdf/2015-07/cp150086en.pdf

[23] The Prime Minister declared "waste emergency in Naples is now over since the piles of rotting garbage that had filled the streets are gone". http://www.edie.net/news/5/Berlusconi-Naples-waste-crisis-over/15016/

[24] Fabbriche clandestine e rifiuti «invisibili» Brucia la Campania felix. http://video.corriere.it/fabbriche-clandestine-rifiuti-invisibili-brucia-campania-felix/909748a6-9c33-11e5-9b09-66958594e7c5?refresh_ce-cp

Terra dei fuochi, maxi discarica abusiva a Calvi Risorta: "La più grande d'Europa". I pm: "Analisi per stabilire dannosità". http://www.ilfattoquotidiano.it/2015/06/16/terra-dei-fuochi-maxi-discarica-abusiva-a-calvi-risorta-la-piu-grande-deuropa-i-pm-analisi-per-stabilire-dannosita/1782945/

3.3 The study Area

The choice of boundaries is a well-known conceptual problem in multi-scale analysis (Allen, T.F.H. and Starr 1982; Giampietro 2003). In fact, the same set of indicators can provide radically different conclusions when "the process" under analysis is assessed at different scales (e.g., national, regional, provincial, municipal). The application presented here is based on the adoption of the administrative borders of the Metropolitan Area of Naples (provincial level) as system boundaries for the analysis. This choice has been based on the balancing of the following criteria:

(i) Homogeneity of municipalities in terms of waste production and processing patterns;

(ii) Inclusion of the majority of the municipal solid waste treatment facilities utilized within the geographical boundaries of the system, as well as presence of most if not all types of facilities used;

(iii) Relevance of the chosen administrative boundaries for decision-making about waste management.

The Metropolitan Area of Naples (MAN) (formerly, Province of Naples) is located in the Campania Region in Southern Italy (see Fig. 3.2). With a population of about 3 million people and an area of around 1200 km^2 MAN has an average population density of around 2600 habitants per km^2. This makes it the most densely populated area of Italy and the 10th-most populous urban area of the European Union (EUROSTAT 2013).

The MAN consists of 92 different municipalities. With its almost 1 million inhabitants, the municipality of Naples is by far the largest and represents 35% of the total population of the MAN.

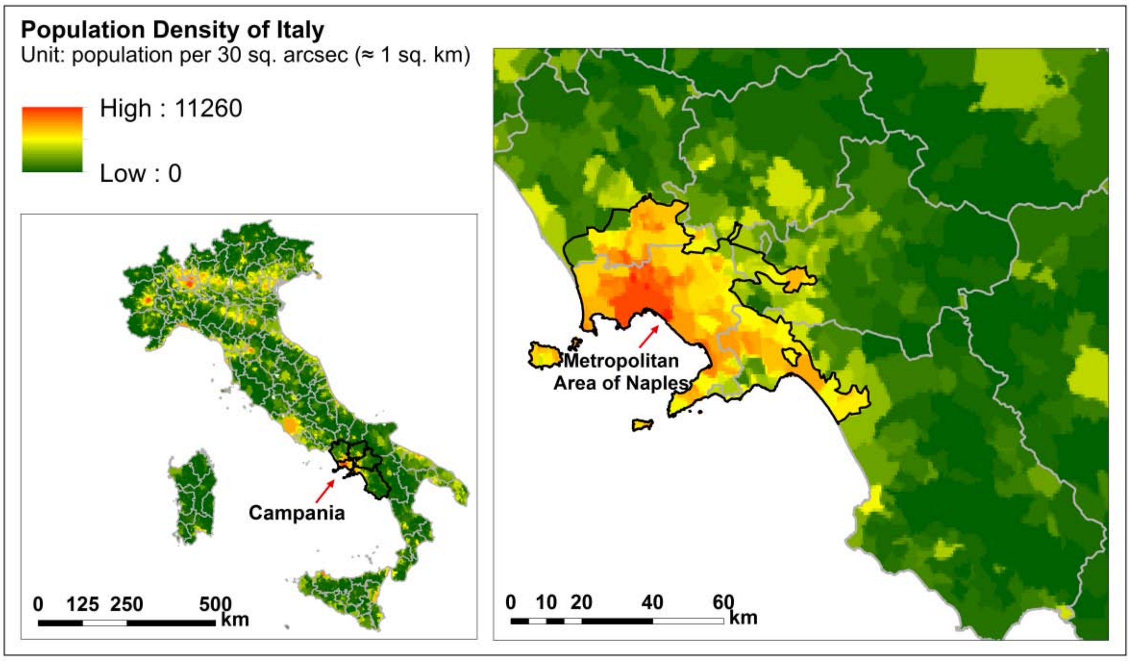


Figure 3.2 - *Population density of the Metropolitan Area of Naples, Campania, Italy. Own elaboration of data from the Center for International Earth Science Information Network, 2015; Global Administrative Areas, 2012.*

Municipal solid waste production in the City of Naples, in the MAN and in the Campania region in the year 2012 is shown in Tab. 3.1. The density of waste produced in Naples (12 t/day/km^2) is, respectively, almost four and 20 times that of the MAN and the region, while the separate waste collection rate is about half that of the MAN and even less that of Campania. Indeed, the Campania Region is heterogeneous with regard to recycling. In the large urban agglomeration of Naples the separate collection rate is only around 18%, while in many of the smaller municipalities it exceeds 35% and in some cases it is even higher than 70%[25].

Table 3.1 - *Characteristics of municipal solid waste production in the City of Naples, the MAN and the Campania region in the year 2012 (elaboration of data from* (Ispra 2013).

Waste Indicators	Territorial Ambit		
	City of Naples	**MAN**	**Campania region**
Total waste generation (10^9 kg/year)	0.5	1.45	2.55
Per capita waste generation (kg per year)	540	480	440
Per capita waste generation rate (kg/day)	1.5	1.3	1.2

[25] http://www.sapnapoli.it/amministrazione/aree-tematiche/raccolta-differenziata-in-campania.html

Waste density (10^3 kg/day/ km^2)	12	3.4	0.5
Separate collection rate	18%	37%	42%

All typologies of urban waste treatment plants but composting are present at the provincial level (Tab 3.2). Inside the municipal territory of Naples only waste collection service is provided (Tab. 3.2).

Table 3.2 *- Waste facility types existing in different territorial ambits in the year 2012 (elaboration of data from ARPAC).*

Structural elements of the waste management system	**Territorial Domain**		
	City of Naples	**MAN**	**Campania Region**
Collection	x	x	x
Presorting Transfer and Storage Platforms		x	x
Mechanical Biological Treatment		x	x
Anaerobic Digestion		x	x
Composting			x
Recycling Centers		x	x
Incineration		x	x
Landfill		x	x

Municipal solid waste (MSW) collection in the MAN is based on a combination of two different schemes: “door-to-door” and “dumpster collection”. The 92 municipalities composing the MAN differ in some organizational functions, such as the type and extent of separate collection. The main technology used to process the unsorted municipal solid waste in the MAN is the mechanical biological treatment (MBT). Dry fractions obtained from MBT are sent to the incineration facility located in Acerra (inside the MAN). Presorting storage and transfer platforms and recycling centers placed within the metropolitan borders treat sorted urban waste coming from separated collection but their managing capacity is insufficient to treat the total amount generated. Also waste-processing capacity for the organic fraction is limited. In fact, there are no composting plants within the MAN and just one anaerobic digestor. Finally, the landfill in Terzigno (inside the MAN) was still operative in 2012, our year of reference, to dispose municipal solid waste without any treatment, but it was closed in 2013. Even though almost all the main types of municipal solid waste treatment plants are installed within the metropolitan territory (provincial level), waste processing and disposal capacity is insufficient to manage the totality of MSW generated in the area. Therefore, as it will be shown later, a huge amount of municipal solid waste generated inside the MAN is exported outside of the system boundaries.

As established by Italian law, public administration of municipal solid waste management takes place at different levels. While decisions about landfills are taken at the regional level, each municipality of the MAN organizes its own waste collection system by relying on different private and/or public companies. For example, ASIA[26] is responsible for the waste collection of the Municipality of Naples but not for the other municipalities within the MAN. Two of the three MBT plants (both owned by Campania region) in the MAN are managed at the provincial level through SAPNA[27] while a private company manages the third MBT plant as well as the incinerator in Acerra (also owned by the Campania region). ARPAC[28] controls the environmental performance of the waste treatment plants at regional scale, but self-monitoring at the level of individual plants also takes place as established by regional and national laws. Tab 3.3 shows the main responsibilities within the municipal solid waste management system at different administrative levels.

Table 3.3 *- Competences at different administrative levels according to national law (D. Lgs 152/2006)* (D'Alisa & Armiero 2013).

Territorial Domain	Main responsibilities
City of Naples	○ Manage the waste collection and transport service. ○ Collect the tax or tariffs for the provision of the waste services.
MAN	○ Implement the disposal planning and organization. ○ Control the waste management and trade activities. ○ Identify suitable areas to locate disposal and recovering plants.

[26] ASIA - Azienda Servizi Igiene Ambientale – waste collection company
[27] SAPNA – Sistema Ambiente Provincia di Napoli (Environmental System of Naples Province)
[28] ARPAC - Agenzia Regionale per la Protezione Ambientale Campania (Regional Environmental Authority)

Campania Region	○ Issue the regional low on waste management ○ Draw up management and treatment plans. ○ Set the number and type of new plants. ○ Approve the projects of new plants.

3.4 Methodology

The metabolic network approach presented in Chapter II is used here in two different ways. It is used first as a diagnostic tool to characterize the current metabolic pattern of the MSWMS of the MAN. Later on the same characterization will be used as decision-making support tool through the generation of an integrated set of performance indicators. Therefore, in the first stage of the analysis the metabolic network has been described using information describing the existing facilities and the processes of waste collection and processing. This information was gathered from public data-bases and technical reports. Where necessary for the quantification of flows (technical coefficients), additional data were retrieved from grey literature and from similar processing plants elsewhere. At the end of this process of gathering of data, a consultation with local stakeholders [29] was performed to validate the chosen representation of the network and the associated quantification of the network flows. The same consultation was also used to discuss relevant performance indicators and policy options. Two policy options were selected and a purposefully-designed software program (based on the rationale of the metabolic network) was used to generate an integrated package of performance indicators checking their viability and feasibility.

[29] Municipal Government of Naples, Campania Region, ARPAC, ASIA, Metropolitan Area of Naples, SAPNA, Cittadini Campani per un Piano Alternativo dei Rifiuti (Campanian citizens for an alternative plan for waste), Hotel/Restaurant Zero Waste/ Zero Waste Campania, Lets do It! Italy.

3.4.2 Performance indicators

Indicators to characterize MSWMS performance were checked for their relevance with local stakeholders, and can roughly be divided into required production factors (referring to biophysical variables and economic costs) and environmental impact factors (referring to "ecological costs"):

(i) Production factors: these include biophysical funds (requirement of land, labor, and power capacity [machinery and infrastructure]), biophysical flows used inside the systems (consumption of electricity, process heat, fuel and water), biophysical flows imported/exported or sold. These production factors and exchanged flows can also be described using economic variables. The use of production factors implies fixed investment and running costs, exports imply additional costs, useful output such as recycled material and electricity production do include revenues;

(ii) Environmental impact variables: include 15 emission flows used as environmental indicators. They include air effluents and emissions in water bodies and soil.

Assumptions used in the assessment of the above performance indicators are explained in Box 3.

BOX 3

Biophysical funds:

*Occupied land from the plants including covered and uncovered area;

*Labor requirement/employment - a working time of 1,878 $h \cdot y^{-1}$ is assumed for each full-time position;

* Power capacity represents the sum of the machinery providing processing capacity in the various nodes;

Biophysical flows:

* Fuel consumption refers to the overall consumption of gasoline both for transport and machineries. In the evaluation of the fuel use for transport we include the combustible needed to move waste from the analyzed node to the next one. For exported waste, we consider the fuel needed to reach the border of the MAN. The same criterion is adopted for the evaluation of the emissions released because of waste transport and machineries implied for the waste treatment;

* Waste water/leachate represents the water discharged in superficial/underground water bodies; it derives primarily from washing cycles and percolating rain water.

Economic variables:

* Fixed investment represents the fraction required for the building of the plants as well as the purchase/rent of the machinery (amortization included). The annual values reported in the results section have been obtained considering a discount period of 30 years;

* Running costs represent the operating costs such as salaries, purchase of the bags, diesel fuel and so forth; all what is related to the internal treatment of waste fractions;

* Cost of exports represents the sum of the fees paid by the local (provincial) public administration in order to export and treat at facilities located in other provinces, regions or abroad. Unitary costs paid per tonne of waste depend on the type of waste and its final destination.

* Revenues due to recycling (deriving from the trade of the secondary material at the entrance of the recycling centers).

* Revenues from produced electricity (from the incinerator as well as the anaerobic digester) considering the unitary tariff of the electricity market price reported by GSE.

* Subsidies for electricity production paid by the central government to the owner of the plants producing electricity.

Costs and investments have been indicated with a positive sign, revenues and subsidies with a negative sign (negative costs).

The above-mentioned set of performance indicators has been used to characterize the current situation of the MSWMS of the MAN, and has been later on contrasted with the results of the simulations done for the two different policy options.

It is important to underline that the definition of monetary flows as 'costs' or 'benefits (or revenues)' depends on the choice made by the observer. In this study, economic costs and benefits are define in relation to the local public administration given that it owns most of the facilities of the waste management system studied. However, the reality is much more complex than that. For example, the anaerobic digestor is owned and managed by a private company, while the incinerator is publicly owned but managed by a private company. Especially the assessment of cost/benefit from electricity production by the incinerator is ambiguous (see Tab. 3.4).

***Table 3.4** - Evaluation of cost/benefit for electricity production from incineration according to three different story tellers (observers).*

Cost/benefit from electricity production from the incinerator	**(€/MWh$_{el}$)**	**Source**
All-inclusive subsides (CIP 6)	a. 0 b. 250 c. -175	Termovalorizzatore-Acerra
Economic value of produced electricity*	a. 0 b. 75 c. 0	Data 2012 GSE[30]
Subsidies	a. 0 b. 175 c. -175	Own elaboration

(a) local public administration; (b) private investor/owner of plant; (c) Italian taxpayer. *The economic value of the electricity is obtained by multiplying the kWh produced by the market price of electricity. The subsidies are paid by the Italian Government using taxpayers' money.

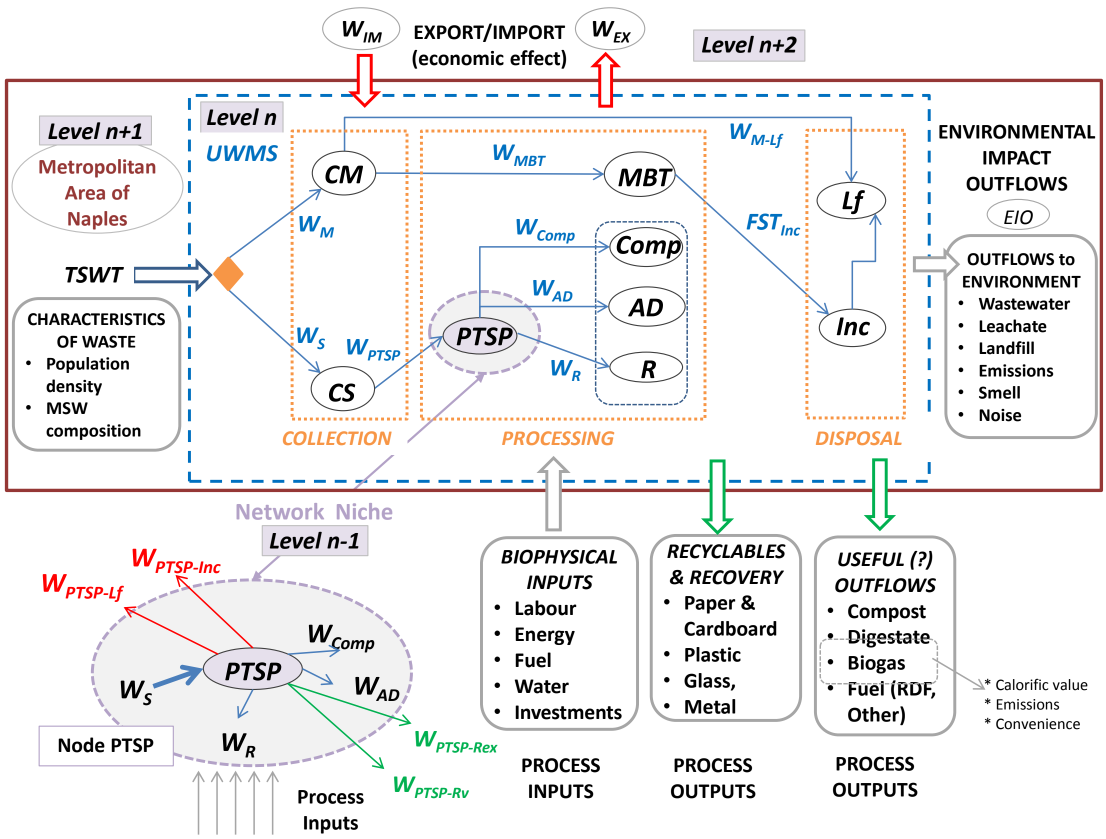
[30] GSE -Gestore dei Servizi Energetici

3.4.1 Representation of the MSWMS as an open metabolic network

The MSWMS is represented as an open metabolic network receiving inputs from society - local municipal solid waste and imports - and generating outputs - emissions into the local environment within the system boundaries and exports of waste fractions, secondary materials and by-products outside of the system's boundaries. For each node composing the network the representation defines both a functional and a structural metabolic profile. As explained in Chapter II the two representations can be described as follows: (1) the functional representation refers to the 'network niche', that is, it describes what the node is expected to do in relation to the topological relations that it has with the rest of the network – i.e. what is expected to get in and out of the node in the interaction with the rest of the network; (2) the structural representation of the node refers to the different typologies of plants/facilities that, inside the node, carry out that function – i.e. the profile of inputs and outputs associated to the technical coefficients of the technological plants processing the flows within the nodes. This impredicative definition of the node (from the outside and from inside) implies that the identity of each node is defining and is defined by the network in which the node is embedded (Giampietro and Bukkens, 2015; Giampietro, 2003).

The MSWMS of the MAN is defined as the focal level *n* of the analysis (it includes all the waste facilities located within the MAN); the MAN intended as made up by the population, technology and infrastructures and local embedding environment is therefore level *n+1*. Anything beyond the MAN – its "context" or "outside" - is considered to be level *n+2*. In this framework, the characteristics of the nodes making up the network and the structural elements making up the nodes are observed at lower levels (level *n-1* and *n-2*, respectively). That is, the set of constraints from outside (boundary conditions) are defined at level *n+2* and the set of constraints from within (initiating conditions) are defined at level *n-2*. After having framed the hierarchical structure of the analysis in this way it becomes possible to defining the functional identity of the network: the typologies of transformations and the links between the nodes. The functional identity makes it possible to study the conditions of congruence across the different levels of analysis (level *n+2*/level *n+1*/level *n*/level *n-1*/level *n-2*) when describing the metabolic pattern of the network. Put in another way, the combination of plants (level *n-2*) used within the same functional node (level *n-1*) has to express the function expected by the rest of the network (level *n*). That is, the plants have to process, at the right pace, the admissible inputs - the output generated by the previous node(s) to which they are connected - and they have to generate the expected output - the admissible input for the next node. Within this structure of constraints a crisis can be generated if the flows determined by the characteristics of the network as input to a node (something described at the level *n-1*) overcomes the capacity of processing that flow referring to the characteristics of the technical processes taking place at the lower level *n-2*.

The basic functional representation of the metabolic network of the MSWMS of the MAN, based on the existing facilities in the area, is presented in Fig.3.3. The various stages of the waste management system, covering collection, processing and disposal, are depicted from the left hand-side to the right. The fluxes entering into and exiting from the system are also indicated: waste production, waste imports and exports, environmental impact outflows, recyclable and recoverable material and other potentially useful outflows. For example, W_{EX} in the central upper part of Fig. 3.3 represents the total amount of waste coming from the different functional nodes and going to plants (landfill, biological and mechanical-biological treatment, incineration and wastewater treatment) outside of the system's boundaries (outside the MAN).



LEGEND

Functional Nodes			
CM	Mixed Collection	**CS**	Separated Collection
MBT	Mechanical Biological Treatment	**PTSP**	Presorting Transfer and Storage Platforms
Lf	Landfill	**AD**	Anaerobic Digestion
Inc	Incineration	**Comp**	Composting
		R	Recycling Centers

Flows	
TSWT	Total Municipal Solid Waste
W_{M}	Mixed Municipal Solid Waste
W_{MBT}	Mixed Municipal Solid Waste to Mechanical Biological Treatment
$W_{M\text{-}Lf}$	Mixed Municipal Solid Waste to Landfill
FST_{Inc}	Dried fraction coming from MBT sent to Incineration
W_{S}	Separated Municiapl Solid Waste
W_{PTSP}	Separated Municiapl Solid Waste to Presorting Transfer and Storage Platforms
$W_{PTSP\text{-}Lf}$	Waste from PTSP to landfill
$W_{PTSP\text{-}Inc}$	Waste from PTSP to Incineration
$W_{PTSP\text{-}Rv}$	Waste from PTSP to Recovery
$W_{PTSP\text{-}Rex}$	Waste from PTSP to Recycling Centers ex
W_{AD}	Biodegradable Waste from CS sent to Anaerobic Digestion
W_{R}	Dried Separated Municipal Solid Waste sent to Recycling Centers
W_{EX}	Waste exported outside the system
W_{IM}	Waste imported inside the system

Figure 3.3 *- The metabolic network representing the MSWMS of the MAN. The node Presorting Transfer and Storage Platforms (PTSP) is zoomed out as an example of a network niche.*

This representation makes it possible to establish a relation across several variables (see Figure 3.3), such as:

1) The quantity and quality of the flow of municipal solid waste produced by the population of the MAN (*waste characteristics*);
2) The *process inputs* (labor, energy, water and materials flows) required for the operation of individual plants, individual nodes, the different stages of the MSWMS, the whole MSWMS; and the *process outputs* generated (i.e., recycled and recovered materials, compost, electricity and so on). These flows determine the economic costs and revenues related to the waste management system for the various actors involved.
3) The level of self-sufficiency of the system as well as the requirement of processing capacity as a function of the export/imports of waste fractions; and
4) Outflows (gas, liquid and solid) into the local environment (within the MAN).

3.4.3 Quantification of network flows: Data sources

Given that a functional node is composed of structural elements (plants, facilities) of different types the relevant data to characterize network nodes must include: (i) the specific mix of plant types included in the same functional node; (ii) characteristics of each plant type, such as processing capacity and technical coefficients (e.g. inputs per unit of throughput); (iii) utilization factor for each individual plant. This characterization is therefore based on two different typologies of information: (a) intensive variables or technical coefficients (e.g., production factors required by the plant type per tonne of waste processed) and (b) extensive variables (total input of production factors per year, and total tonnes of waste processed per year).

Quantities of waste-flows and technical coefficients were retrieved from local statistics/databases, publicly-available reports - ARPAC database 2013, (Ispra 2013)and SAPNA website[31] - and data made available by local operators and experts (see section 3.3.3). Where specific information could not be obtained in this way, we used benchmarks from the literature or similar plants/facilities operating elsewhere. Relevant assumptions and data sources for specific network nodes and flows, for which local data were unavailable, are explained in Box 2.

BOX 2

Mixed and separate collection nodes (CM and CS):

Total waste production (TSWT in Fig. 3.3) has been divided according to the European Waste Catalogue (EWC) into two main fractions: mixed (unsorted) municipal solid waste (hereinafter referred to as MMSW) (W_M in Fig. 3.3), and separated municipal solid waste (W_S in Fig. 3.3). The latter includes different waste fractions such as biodegradable waste destined for organic treatments and paper, plastic, glass, metal and other (e.g. textile residues, wood waste, bulky waste, batteries, etc.) waste flows going to recycling centers. The ratio mixed/separate collection is different for the two dominant waste collection schemes employed in the MAN: dumpster collection has a CM:CS ratio of roughly 75:25 whereas door-to-door collection has a CM:CS ratio of roughly 25:75. These values are based on the average national and regional figure for the two collection schemes in the year of reference (Campania Regional Council Report 2012). The contribution of the so-called “amenity civil centers” or “bringing banks” is quantitatively negligible in the region, and has not been included. The technical coefficients estimated for the collection stage are based on the technical document elaborated by the municipality of Frattaminore (a municipality within the MAN) for the

[31] http://www.sapnapoli.it/

collection system (Comune di Frattaminore 2008). Data for fuel consumption are from Miralles Tejedor (2010), data on electricity use from Cherubini et al. (2008), vehicle emissions from Nahlik et al. (2015) and data on operational costs from Cossu & Masi (2013). Detailed data related to *CM* and *CS* nodes are reported in Tab. 3.6 and Tab. 3.7.

Presorting Transfer and Storage Platforms node (PTSP):

The data for the Presorting Transfer and Storage Platforms are based on a facility located in Paolisi, Benevento (Comune Paolisi 2007), located outside of the MAN, but inside the Campania Region. The processing capacity of the facility is 35×10^3 tonnes of waste/year, a standard size for the area. The percentage of refused waste produced in the PTSP and its final destination have been assessed for the different waste fractions coming from separated collection according to the data provided by ARPAC. No refused waste coming from the fraction "other" has been considered (see Tab. 3.8).

Mechanical-biological treatment node (MBT = STIR):

The mechanical-biological treatment node consists of three plants: (i) 2 plants of type α, represented by STIR [32] of Giugliano and Tufino (processing capacity 470×10^3 tonnes/year) publicly owned by SAPNA; (ii) 1 plant of type β, represented by a plant located in the municipality of Caivano (610×10^3 tonnes/year) managed by a private company. The data for water, fuel consumption and leachate production have been retrieved from another publication related to a plant of similar characteristics based in Greece (Abeliotis et al. 2012). The proportions of the flows (outputs of the mechanical and biological treatment) produced by the STIRs are based on the average value of the 7 STIR plants in the Campania region, as individual data for the three STIRs in the MAN were not available. Costs per tonne for exporting waste outputs produced by STIR plants vary according to the type of fraction and its final treatment and geographical

[32] STIR: "Stabilimento Tritovagliatura ed Imballaggio Rifiuti" is equivalent to a mechanical-biological treatment (MBT) plant.

destination. Those values have been provided by SAPNA through interviews. Detailed data related to the *MBT* node are reported in Tab. 3.9.

Anaerobic Digestion treatment node (AD):

The Anaerobic Digestion (AD) node is composed of a single plant based in Caivano (inside the MAN). The processing capacity of the digester is 33×10^3 tonnes of biodegradable waste per year. In 2012, roughly 20×10^3 tonnes of biodegradable material have been treated in the plant. The figure for water consumption, requisite investments, and environmental impacts has been integrated with data for similar-size facilities (Blengini and Fantoni, 2009; Bonomo and Consonno, 2008; Mata-álvarez, 2015). The ratios related to the production of biogas, solid digestate sent to recovery, and wastewater from AD going to treatment plants have been retrieved from personal communication and the ARPAC database. Data were checked with the literature on the anaerobic digestion process. No reliable data were available for the final destination of the total amount of produced digestate and it was assumed that all of it (100%) is sent to landfills. The revenues from central government subsidies (incentives) to encourage electricity production from biogas have been evaluated considering the all-inclusive feed-in tariff national scheme applicable to biogas-producing plants that have a nominal real power of less than 1 MW. Detailed data related to the *AD* node are reported in Tab. 3.10.

Recycling plant node (R):

The recycling node consists of various recycling facilities of different sizes within the MAN. However, the technical coefficients used in the quantification refer to the one plant processing the largest share. The overall processing capacity of this facility is 130 $\times10^3$ tonnes of separated waste per year. The revenues for the secondary materials, both at the plant entrance and gate, have been taken into account considering the average composition of the several recyclable waste fractions and the different tariffs established by CONAI[33]. The total revenue for recyclables represents the income for recyclables irrespective of the location of the recycling centers (either inside or outside the MAN). The benefits for selling recyclables go directly to the municipalities of the MAN. See Tab. 3.11 for detailed data related to the *R* node.

Incineration node (Inc):

The incineration node consists of a single plant, located in Acerra, publicly owned, but managed by a private company. The total processing capacity of its three furnace lines amounts to approximately 690×10^3 tonnes/year. The largest part of the output consists of three streams: bottom ashes, fly ashes and emissions. Technical coefficients are derived from the elaboration of data from personal communication with ARPAC and (Ripa et al. 2016). The revenues for electricity generation have been evaluated considering the average value of the tariff paid for generation of electricity in 2012 according to the GSE[34] data. In addition, Acerra Incinerator receives a yearly subsidy tariff according to the so-called CIP6 scheme. Detailed data related to *Inc* node are reported in the Tab. 3.12.

Landfilling node (Lf):

Also the node landfilling is composed of a single facility: the landfill of Terzigno. The facility was operative until 2012. The quantity of waste disposed in 2012 amounted to about 32×10^3 tonne/year. The data on the environmental impact is from (Baig 1999). For fuel consumption only the fuel requirement for machinery is considered as the fuel for inter-plant transport is already included in other nodes. The amount of leachate generated by the landfill is estimated from the average value for areas having similar yearly rainfall and landfill of comparable size. See Tab. 3.13 for detailed data related to *Lf* node.

[33] CONAI: The Italian “National Packaging Consortium” (*Consorzio Nazionale Imballaggi*)
[34] http://www.gse.it

3.4.4 Participatory processes: validation phase

Local stakeholder pools were involved in September and October 2015 with the goal to check the robustness of the chosen representation of the metabolic network and the resulting quantification of the flows. In the same occasion we also discussed the performance indicators and policy options. The stakeholders contacted in this phase were part of a larger set of stakeholders involved in an earlier consultation[35] on municipal solid waste management in Naples (April 2015) within the framework of the MARSS project[36] (Hornsby et al., 2016; Ripa et al., 2016). In this case, only one representative per organization/per competent authority was contacted following the 2014 stakeholder consultation guidelines of the European Commission[37].

3.4.5 The policy option-space assessment and simulations

Two policy options were considered in this study. The first one is about an increase in recycling rate. It considers what happens if the current ratio "mixed to separated" waste collection is reversed from 75/25 to 25/75. This option follows up on the EU directive 2008/98/EC that commits member states to prioritize the recycling of post-use materials over thermal recovery and finally as last resort landfilling.

The second policy option is about self-sufficiency. It assumes that all the waste produced within the MAN is also processed there (no waste export). In this option the current ratio of mixed/separated collection remains at 75/25 whereas it is the processing capacity of the network that is dramatically increased. The motivation for this second

[35] http://www.marss.rwth-aachen.de/cms/front_content.php?idart=129
[36] http://www.marss.rwth-aachen.de/cms/front_content.php?idcat=1&lang=2&changelang=2
[37] http://ec.europa.eu/smart-regulation/impact/docs/scgl_pc_questionnaire_en.pdf

choice resides in the national legislative decree 205/2010[38] that emphasizes regional self-sufficiency of waste management.

Simulations of these two policy options have been run with proprietary system analysis software developed by Renner, (2016). The software allows for the creation of a network topology (determining the metabolic identities of functional nodes and their linkages). As described earlier each functional node in the network represents one or more module (e.g. a processing plant, a collection scheme), and each module is associated with a set of technical coefficients (e.g. jobs produced, fuel consumed per ton of throughput processed). These technical coefficients are represented as intensive values, which are scaled by the quantity of waste arriving at the module, up to the module's extensive capacity. The resultant extensive technical attribute values may be assessed on a module-to-module, node-to-node or network-wide basis. Modules and nodes may be added or subtracted, flows redirected and flows to a node with multiple modules may be redistributed to those internal modules at will. In this manner, simulations of alternative waste management paradigms have been explored.

[38] http://www.sistri.it/Documenti/Allegati/Decreto_Legislativo_205_del_3_dicembre_2010.pdf

3.5 Results and discussion

3.5.1 Current metabolic pattern of the MSWMS of the Metropolitan Area of Naples

The quantification of the network flows for the MSWMS of the MAN is illustrated in Fig. 3.4. Each node receives a specific input of municipal solid waste, which is defined in quantity and quality, and transforms this input into a set of outflows that are also characterized in quantity and quality. For instance, the anaerobic digestion plant (AD) receives 20×10^3 tonnes of biodegradable waste coming from separated collection (W_{AD}) and converts 3×10^3 tonnes of organic waste into biogas (2,400 Nm^3/year) and 15×10^3 tonnes of digestate ($W_{ADDig\text{-}Lf}$).

Flows represented in red are exported outside of the system's boundaries (MAN). The cost of exporting these flows is accounted for along with the variable costs to run the waste management system. Flows depicted in green represent recyclables for which the MSWMS gets revenue. The waste flows managed within the MAN are indicated in blue, and emissions (gaseous or liquid) going to the local environment in light salmon.

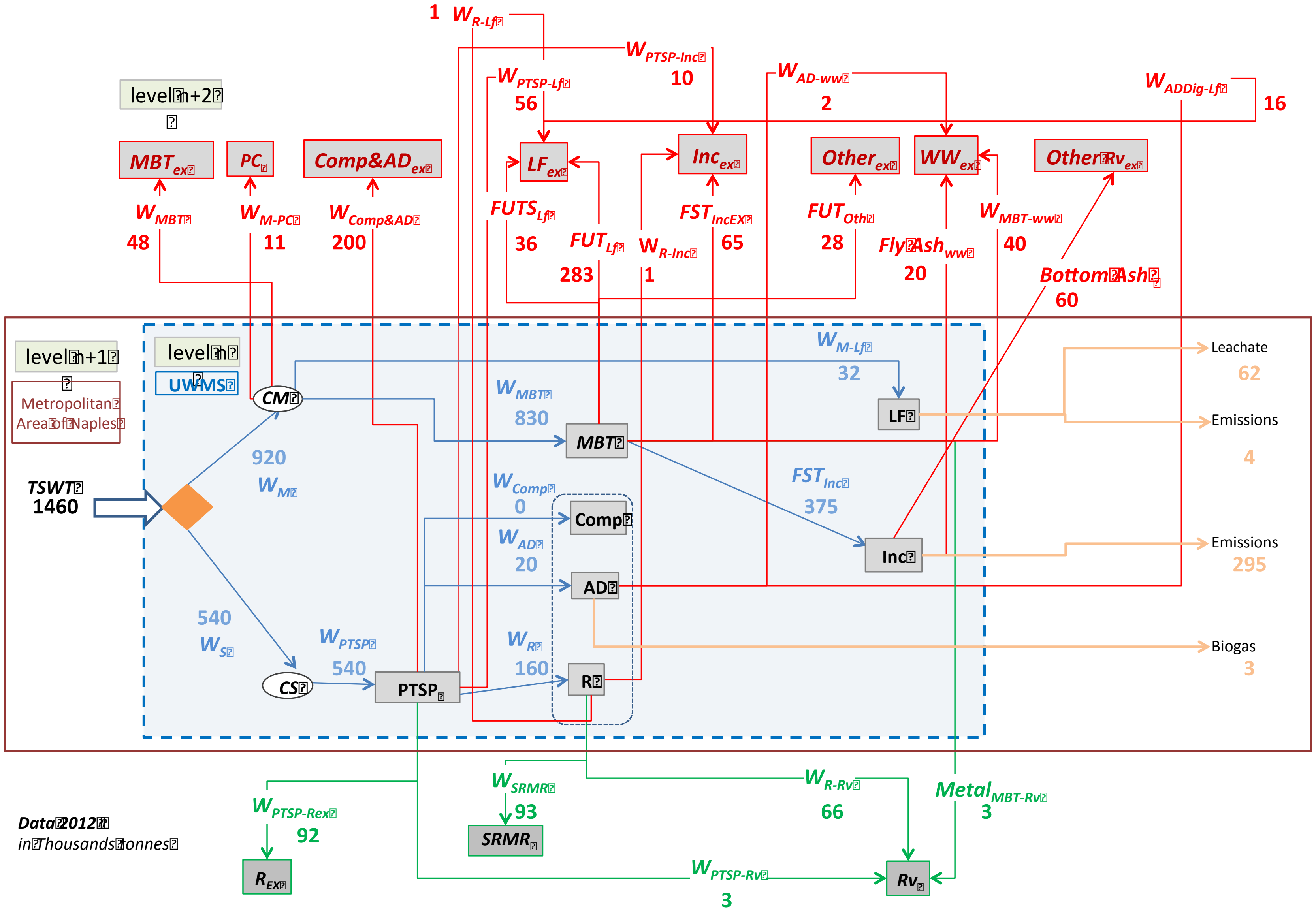


Figure 3.4 - *Quantification of network flows for the MSWMS of the MAN.*
Abbreviations are explained in the legend of Figure 3.3; additional new abbreviations are explained in the legend below the present diagram. Data in thousands tonnes (reference year: 2012).

LEGEND

Flows	
$W_{PTSP-Rex}$	Waste from PTSP to Recycling Centers ex
$W_{PTSP-Rv}$	Waste from PTSP to Recovery
Met_{MBT-Rv}	Metal coming from MBT to Recovery
W_{SRMR}	Recyclables from Recycling Centers sent to Secondary Raw Material Recovery facilities
W_{RRv}	Waste from Recycling centers sent to Recovery facilities
W_{MBTex}	Mixed Waste to MBT Plants ex
W_{M-PC}	Mixed Waste to Private waste treatment Companies
$FST_{Inc\ EX}$	Dry Fraction sento to Incineration ex
FUT_{Lf}	Humid Fraction sento to Landfill
$FUTS_{Lf}$	Stabilized Humid Fraction sento to Landfill
W_{MBT-ww}	Waste Water from MBT going to Waste Water Treatment plants
FUT_{Oth}	Humid Fraction sento to Other treatments
$W_{Comp\&AD}$	Biowaste to Composting & Anaerobic Digestion ex
$W_{PTSP-Inc}$	Refuse from PTSP to Incineration ex
$W_{PTSP-Lf}$	Refuse from PTSP to Landfill ex
W_{R-Inc}	Refuse from Recycling Centers going to Incineration ex
W_{R-Lf}	Refuse from Recycling Centers going to Landfill ex
$W_{ADDig-Lf}$	Digestate from AD going to Landfill
W_{AD-ww}	Wastewater from AD going to Landfill
Fly ashes$_{-ww}$	Fly ashes from Incineration going to wastewater treatment ex
Bottom ashes $_{Rv}$	Bottom ashes from Incineration going to other Recovery facilities ex
W_{Inc-ww}	Other fractions from Incineration going to wastewater treatment ex

The quantification of flows in Fig. 3.4 shows that the major part (63%) of the total solid waste throughput (TSWT) generated in the MAN is not sorted. Approximately 90% of this unsorted (mixed) waste (W_M), corresponding to 57% of total municipal solid waste, is sent to STIR facilities inside the MAN (W_{MBT}). The rest of unsorted municipal solid waste is directly disposed in the local landfill (3.5% of the unsorted waste or around 2% of total waste) or treated in STIR plants or private waste facilities outside the system (6.4% of the unsorted waste or 4% of total waste) (see also Tab. 3.6). Of the final outputs of the local STIR facilities (MBT node) around 40% ends up in landfills outside the MAN (FUT_{lf} and $FUTS_{lf}$), 45% and 8%, respectively, are burned in internal and external incinerators (FST_{Inc} and FST_{IncEX}), and 8.6% ends up as wastewater, humid fraction sent to other treatments and additional recycling downstream of the MBT node (W_{MBT-WW} FUT_{Oth} and Met_{MBT-Rv}).

As regards separated (sorted) waste (W_s), almost 50% of dried separated waste is processed in recycling centers located in the metropolitan area (W_R), while the remaining part is sent to plants outside the MAN ($W_{PTSP\text{-}Rex}$). The major part (90%) of the organic fraction coming from separated waste collection is exported outside the MAN ($W_{Comp\&AD}$). Only 11% of the biodegradable waste exported is treated in the Campania due to the lack of regional waste treatment plants.

On the whole, only 40% of the total generated waste is finally disposed in facilities inside the MAN, 60% of the total being exported either to other provinces within the Campania region (13%), other Italian regions (44%), or abroad (2%).

In addition to the mass balance shown in Fig. 3.4, the composition of waste flow has been further divided into six subcomponents (Tab. 3.5), namely biodegradable, paper, plastic, glass, metal and the so-called “other waste” including both the non-recyclable fraction as well as the materials not included in the above-mentioned categories (e.g. textile residues, wood waste, bulky waste, batteries, etc.). The fraction “other” from separated waste (representing less than 9% of total waste generation) has not been accounted for in this analysis due to lack of reliable data. This analysis assumes the flows as averaged over the year and therefore neglect the buffering effect of local storage (that can be filled or emptied in different periods). Therefore, flows directed or coming from storage have been redistributed among the subsequent nodes according to a specific-weight criterion. Precisely, the redistribution was directly proportional to the actual flows. All the waste flows have been mapped through all the stages, from collection to processing and the final disposal. The location of the facilities has been taken into account to check whether waste treatments were taking place out of the border of the MAN.

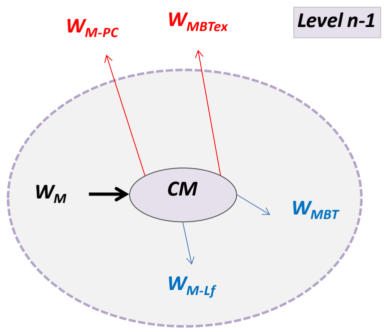
Required quantities of production factors as well as environmental impacts for individual network nodes are reported in Tables 3.6 – 3.13.

Table 3.5 *- Amount and distribution of the six subcomponents of waste flow within the network of the MSWMS in the MAN*

NODE	FLOWS	Amount		Waste fractions											
				Biodegradable		Paper& Cardboard		Plastic		Glass		Metals		Other	
Acronym		10^3tonne/year	ratio	10^3tonne/ year	ratio	10^3tonne/ year	ratio	10^3tonne/ year	ratio	10^3tonne/ year	ratio	10^3tonne/ year	ratio	10^3tonne/ year	ratio
Input	***TSWT***	**1,460**	**1.00**	**511**	**0.35**	**277**	**0.19**	**161**	**0.11**	**88**	**0.06**	**44**	**0.03**	**380**	**0.26**
CM	W_{M}	920	0.63	239	0.26	184	0.20	120	0.13	37	0.04	35	0.04	304	0.33
	W_{M-Lf}	32	0.02	8.3	0.26	6.4	0.20	4.2	0.13	1.3	0.04	1.2	0.04	11	0.33
	W_{MBT}	830	0.57	216	0.26	166	0.20	108	0.13	33	0.04	32	0.04	274	0.33
	W_{MBTex}	48	0.03	12	0.26	10	0.20	6.2	0.13	1.9	0.04	1.8	0.04	16	0.33
	W_{M-PC}	11	0.01	2.9	0.26	2.2	0.20	1.4	0.13	0.44	0.04	0.4	0.04	3.6	0.33
MBT	W_{MBT}	830	0.57	216	0.26	166	0.20	108	0.13	33	0.04	32	0.04	274	0.33
	FST_{Inc}	375	0.26	71	0.19	79	0.21	56	0.15	15	0.04	14	0.04	139	0.37
	FST_{IncEX}	65	0.05	12	0.19	14	0.21	10	0.15	2.5	0.04	2.5	0.04	24.1	0.37
	FUT_{Lf}	283	0.19	255	0.90	13	0.05	12	0.04	1.5	0.01	0.18	0.00	1.5	0.01
	$FUTS_{Lf}$	36	0.03	32	0.90	1.7	0.05	1.5	0.04	0.19	0.01	0.0	0.00	0.2	0.01
	W_{MBT-ww}	40	0.02	40	1.00	0.0	0.00	0.0	0.00	0.0	0.00	0.0	0.00	0.0	0.00
	FUT_{Oth}	28	0.02	25	0.90	1.3	0.05	1.2	0.04	0.15	0.01	0.0	0.00	0.1	0.01
	Met_{MBT-Rv}	3.0	0.00	0.0	0.00	0.0	0.00	0.0	0.00	0.0	0.00	3.0	1.00	0.0	0.00
CS/PTSP	W_{S}	540	0.37	275	0.51	92	0.17	43	0.08	47	0.09	8.6	0.02	75.6	0.14
	W_{PTSP}	540	0.37	275	0.51	92	0.17	43	0.08	47	0.09	8.6	0.02	75.6	0.14
	$W_{Comp\&AD}$	200	0.14	200	1.00	0.0	0.00	0.0	0.00	0.0	0.00	0.0	0.00	0.0	0.00
	$W_{PTSP-Inc}$	10	0.01	7.4	0.75	0.6	0.06	1.5	0.15	0.20	0.02	0.20	0.02	0.0	0.00
	$W_{PTSP-Lf}$	56	0.04	42	0.75	3.6	0.06	8.4	0.15	1.12	0.02	1.1	0.02	0.0	0.00
	W_{Comp}	0.0	0.00	0.0	1.00	0.0	0.00	0.0	0.00	0.0	0.00	0.0	0.00	0.0	0.00
	W_{AD}	20	0.01	20	1.00	0.0	0.00	0.0	0.00	0.0	0.00	0.0	0.00	0.0	0.00
	W_{R}	160	0.11	0.0	0.00	74	0.46	19	0.12	11	0.07	6.4	0.04	49.6	0.31
	$W_{PTSP-Rex}$	92	0.06	0.0	0.00	14	0.15	13	0.14	35	0.38	1.1	0.01	29.4	0.32
	$W_{PTSP-Rv}$	3.0	0.00	2.3	0.75	0.19	0.06	0.45	0.15	0.06	0.02	0.06	0.02	0.0	0.00
R	W_{R}	160	0.11	0.0	0.00	74	0.46	19	0.12	11	0.07	6.4	0.04	49.6	0.31
	W_{SRMR}	93	0.06	0.0	0.00	52	0.56	7.4	0.08	11	0.12	2.7	0.03	19.5	0.21
	W_{R-Rv}	66	0.04	0.0	0.00	21	0.32	12	0.18	0.10	0.00	3.3	0.05	29.5	0.45
	W_{R-Inc}	0.8	0.00	0.0	0.00	0.80	1.00	0.0	0.00	0.0	0.00	0.0	0.00	0.0	0.00
	W_{R-Lf}	0.8	0.00	0.0	0.00	0.50	0.63	0.23	0.29	0.06	0.08	0.0	0.00	0.0	0.00
Inc	FST_{Inc}	375	0.26	71	0.19	79	0.21	56	0.15	15	0.04	14	0.04	139	0.37
	Bottom $ashes_{Rv}$	60	0.04	0.0	0.00	0.0	0.00	0.0	0.00	3.7	0.06	11	0.19	45.0	0.75
	Fly $ashes_{ww}$	20	0.01	0.0	0.00	0.0	0.00	0.0	0.00	0.0	0.00	0.0	0.00	20.0	1.00
	W_{Inc-ww}	0.5	0.00	0.0	0.00	0.0	0.00	0.0	0.00	0.0	0.00	0.0	0.00	0.50	1.00
Lf	W_{M-Lf}	32	0.02	8.3	0.26	6.4	0.20	4.2	0.13	1.3	0.04	1.2	0.04	11	0.33

Table 3.6 - *Waste flows, production factors and environmental indicators for the network node Mixed Collection (CM).*

CM = Mixed Collection of Municipal Solid Waste **920** **10^3 tonne/year**



In red waste flows going outside the MAN

In blue waste flows treated inside the MAN

FLOWS	Amount (10^3tonne/year)	%	Destination
W_M	920	100%	Mixed Collection
Door-to-door	220	25%	DdD Mixed Collection
Dumpster	700	75%	Dumpster Mixed Collection
$W_{M\text{-}Lf}$	32	3.5%	Landfill Terzigno
W_{MBT}	830	90%	STIR Plants in
W_{MBTex}	48	5.2%	STIR Plants ex
$W_{M\text{-}PC}$	11	1.2%	Waste treatment Private Companies

W_M = Mixed Municipal Solid Waste (MMSW)

$W_{M\text{-}Lf}$ = Mixed Waste directly to Lanfill in

W_{MBT} = Mixed Waste to MBT Plants in

W_{MBTex}= Mixed Waste to MBT Plants ex

$W_{M\text{-}PC}$ = Mixed Waste to Private waste treatment Companies

in = inside MAN

ex = outside MAN

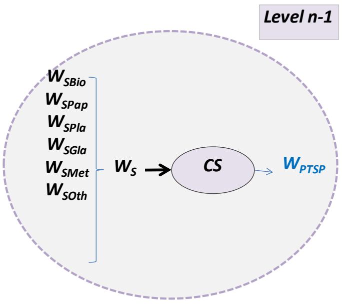
Production Factors		Intensive Values	Units	Extensive Values	Units per year
BIOPHYSICAL FUNDS	Occupied land	N.A.	m^2/tonne	N.A.	hectares
	Employment	2.0	full-time people/1000 tonne	1,800	full-time people
	Power Capacity Electrical machineries	N.A.	kW-el/tonne	N.A.	MW-el
	Power Capacity Thermal machineries	0.2	kW-th/tonne	190	MW-th
BIOPHYSICAL FLOWS	Process heat consumption	N.A.	TJ-th/tonne	N.A.	TJ-th
	Electricity consumption	6.3	kWh-el/tonne	5,800	MWh-el
	Fuel consumption	2.7	L/tonne	2.5	ML
	Water consumption	4.3	L/tonne	3.9	ML
ECONOMIC VARIABLES	Fixed Investments (discounted over 30 years)	34	€/tonne	31	M€
	Running costs	130	€/tonne	120	M€
	Cost of exports	120	€/tonne	7.4	M€
	Electricity Revenues	0.0	€/tonne	0.0	M€
	Recyclables Revenues	0.0	€/tonne	0.0	M€
	Subsidies for electricity production	0.0	€/tonne	0.0	M€

Environmental Indicators	Intensive Values (kg · $tonne^{-1}$waste)	Extensive Values (kg)
CH_4	-	-
CO_2	5.18E-02	4.77E+04
Heavy metals*	-	-
PCBs	-	-
PAHs	-	-
Dioxines/Furans	-	-
PM10	1.93E-05	1.78E+01
PM2.5	1.46E-06	1.34E+00
VOCs	1.44E-05	1.32E+01
CO	5.89E-05	5.42E+01
NO_x	3.77E-07	3.47E-01
SO_x	4.48E-07	4.12E-01
HF	-	-
HCl	-	-
Waste water/leachate	-	-

*Heavy metals: Sb, As, Pb, Cr, Co, Cu, Mn, V, Ni, Zn, Sn, Cd, Tl, Hg

Table 3.7 *- Waste flows, production factors, and environmental indicators for the network node Separated Collection (CS).*

CS = Separate Collection of Municipal Solid Waste			**540**	**10^3 tonne/year**



FLOWS	**Amount (10^3tonne/year)**	**%**	**Destination**
W_S = W_{PTSP}	540	100%	
Door-to-door	410	76%	DdD Separated Collection
Dumpster	130	24%	Dumpster Separated Collection
W_{SBio}	270	51%	Separated Collection
W_{SPap}	92	17%	Separated Collection
W_{SPla}	43	7.9%	Separated Collection
W_{SGla}	47	8.7%	Separated Collection
W_{SMet}	8.5	1.6%	Separated Collection
W_{SOth}	77	14%	Separated Collection
W_{PTSP}	540	100%	Presorting Transfer and Storage Platforms

W_{SGla} = Glass fraction of Separated Waste

W_{SMet} = Metal fraction of Separated Waste

W_{SOth} = Other fraction of Separated Waste

W_{PTSP} = Separated Waste to Presorting Transfer and Storage Platforms

W_S =Separated Municipal Solid Waste

W_{SBio} = Biodegradable fraction of Separated Waste

W_{SPap} = Paper & Cardboard fraction of Separated Waste

W_{SPla} = Plastic fraction of Separated Waste

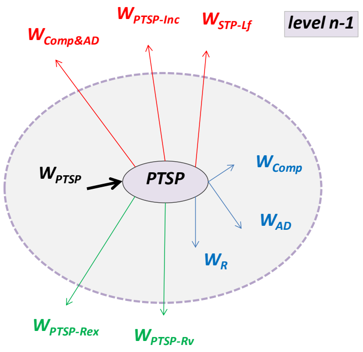
Production Factors		**Intensive Values**	**Units**	**Extensive Values**	**Units per year**
BIOPHYSICAL FUNDS	Occupied land	N.A.	m^2/tonne	N.A.	hectars
	Employment	2.3	full-time people/1000	1,200	full-time people
	Power Capacity Electrical machineries	N.A.	kW-el/tonne	N.A.	MW-el
	Power Capacity Thermal machineries	0.2	kW-th/tonne	120	MW-th
BIOPHYSICAL FLOWS	Process heat consumption	N.A.	TJ-th/tonne	N.A.	TJ-th
	Electricity consumption	6.3	kWh-el/tonne	3,400	MWh-el
	Fuel consumption	3.0	L/tonne	1.6	ML
	Water consumption	4.3	L/tonne	2.3	ML
ECONOMIC VARIABLES	Fixed Investments (discounted over 30 years)	37.0	€/tonne	20	M€
	Running costs	160.0	€/tonne	84	M€
	Cost of exports	-	€/tonne	-	M€
	Electricity Revenues	-	€/tonne	-	M€
	Recyclables Revenues	-	€/tonne	-	M€
	Subsidies for electricity production	-	€/tonne	-	M€

Environmental indicators	**Intensive Values (kg · $tonne^{-1}$waste)**	**Extensive Values (kg)**
CH_4	-	-
CO_2	5.72E-02	3.09E+04
Heavy metals	-	-
PCBs	-	-
PAHs	-	-
Dioxines/Furans	-	-
PM10	2.13E-05	1.15E+01
PM2.5	1.61E-06	8.70E-01
VOCs	1.59E-05	8.56E+00
CO	6.50E-05	3.51E+01
NO_x	4.16E-07	2.25E-01
SO_x	4.94E-07	2.67E-01
HF	-	-
HCl	-	-
Waste water/leachate	-	-

*Heavy metals: Sb, As, Pb, Cr, Co, Cu, Mn, V, Ni, Zn, Sn, Cd, Tl, Hg

Table 3.8 *- Waste flows, production factors and environmental indicators for the network node Presorting Transfer and Storage Platforms (PTSP).*

PTSP = Presorting Transfer and Storage Platforms for Separated Collection — **540** — **10^3 tonne/year**



FLOWS	Amount (10^3tonne/year)	%	Destination
W_{PTSP}	540	100%	Presorting Transfer and Storage Platforms
$W_{Comp\&AD}$	200	37%	Composting & AD plants ex
$W_{PTSP-Inc}$	10	1.8%	Incineration ex
$W_{PTSP-Lf}$	56	11%	Landfill ex
W_{Comp}	-	0%	Composting plants in
W_{AD}	20	3.6%	AD plants in
W_R	160	29%	Recycling plants in
$W_{PTSP-Rex}$	92	17%	Recycling plants ex
$W_{PTSP-Rv}$	3.0	0.5%	Recovery facilities

W_{PTSP} = Separated waste to Presorting Transfer and Storage Platforms

in = inside MAN

ex = outside MAN

$W_{Comp\&AD}$ = Biowaste to Composting & Anaerobic Digestion ex

$W_{PTSP-Inc}$ = Refuse from PTSP to Incineration ex

$W_{PTSP-Lf}$ = Refuse from PTSP to Landfill ex

W_{Comp} = Biowaste to Composting in

W_{AD} = Biowaste to Anaerobic Digestion in

W_{S-R} = Separated Waste to Recycling Centers in

$W_{PTSP-Rex}$ = Waste from PTSP to Recycling Centers ex

$W_{PTSP-Rv}$ = Waste from PTSP to Recovery

In red waste flows going out of the MAN

In blue waste flows treated inside the MAN

In green flows going to Recovery facilities

Refuse Waste from PTSP		
Refuse per fraction	%	Amount (tonne/year)
$Refuses_{S-Bio}$	20%	53,000
$Refuses_{S-Pap}$	5.0%	4,600
$Refuses_{S-Pla}$	24%	10,000
$Refuses_{S-Gla}$	3.0%	1,400
$Refuses_{S-Met}$	19%	1,600
$Refuses_{S-Oth}$	0%	-
$Refuse_{STotal}$		71,000

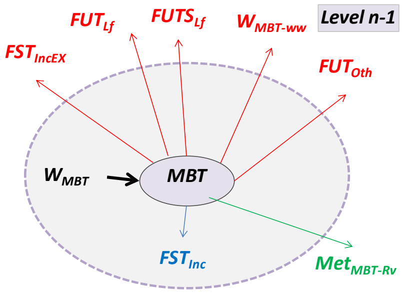
Production Factors		Intensive Values	Units	Extensive Values	Units per year
BIOPHYSICAL FUNDS	Occupied land	0.31	m^2/tonne	17	hectars
	Employment	0.43	full-time people/1000 tonne	230	full-time people
	Power Capacity Electrical machineries	0.0016	kW-el/tonne	0.85	MW-el
	Power Capacity Thermal machineries	0.059	kW-th/tonne	35	MW-th
BIOPHYSICAL FLOWS	Process heat consumption	N.A.	TJhe/tonne	N.A.	TJ-th
	Electricity consumption	6.3	kWhel/tonne	3,400	MWh-el
	Fuel consumption	30	L/tonne	16	ML
	Water consumption	44	L/tonne	24	ML
ECONOMIC VARIABLES	Fixed Investments (discounted over 30 years)	16	€/tonne	8.5	M€
	Running costs	47	€/tonne	25	M€
	Cost of exports	130	€/tonne	35	M€
	Electricity Revenues	-	€/tonne	-	M€
	Recyclables Revenues	- 190	€/tonne	- 0.55	M€
	Subsidies for electricity production	-	€/tonne	-	M€

Environmental Indicators	Intensive Values (kg · $tonne^{-1}$waste)	Extensive Values (kg)
CH_4	-	-
CO_2	5.85E-01	3.16E+02
Heavy metals	-	-
PCBs	-	-
PAHs	-	-
Dioxines/Furans	-	-
PM10	2.18E-04	1.18E-01
PM2.5	1.65E-05	8.90E-03
VOCs	1.62E-04	8.75E-02
CO	6.64E-04	3.59E-01
NO_x	4.25E-06	2.30E-03
SO_x	5.05E-06	2.73E-03
HF	-	-
HCl	-	-
Waste water/leachate	-	-

*Heavy metals: Sb, As, Pb, Cr, Co, Cu, Mn, V, Ni, Zn, Sn, Cd, Tl, Hg

Table 3.9 *- Waste flows, production factors and environmental indicators for the network node Mechanic-Biological Treatment (MBT= STIR).*

MBT Plants (STIR-Stabilimenti di Tritovagliatura ed Imballaggio Rifiuti) **830** **10^3 tonne/year**



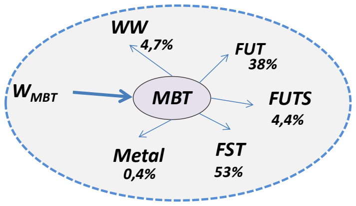
FLOWS	Amount (10^3tonne/year)	%	Destination
W_{MBT}	830	100%	MBT plants inside MAN
FST_{Inc}	375	45%	Incineration plant in Acerra
FST_{IncEX}	65	7.9%	Incineration Plants ex
FUT_{Lf}	283	34%	Landfill ex
$FUTS_{Lf}$	36	4.4%	Landfill ex
W_{MBT-ww}	40	4.7%	Wastewater treatment plants
FUT_{Oth}	28	3.4%	Other treatments ex
Met_{MBT-Rv}	3	0.4%	Metal Recovery facilities

W_{MBT} = Mixed Municipal Solid Waste sent to MBT
FST_{Inc} = Dry Fraction sento to Acerra Incinerator
Met_{MBT-Rv} = Metal coming from MBT to Recovery

FST_{IncEX} = Dry Fraction sento to Incineration
FUT_{Lf} = Humid Fraction sento to Landfill
$FUTS_{Lf}$ = Stabilized Humid Fraction sento to Landfill
W_{MBT-ww} = Waste Water from MBT going to Waste Water Treatment plants
FUT_{Oth} = Humid Fraction sento to Other treatments

in = inside MAN
ex = outside MAN

In red waste flows going out of the MAN
In blue waste flows treated inside the MAN
In green flows going to Recovery facilities



Outputs from MBT treatment	% in weight of the input
FST = Dry Fraction (Frazione Secca Tritovagliata)	53%
FUT = Humid Fraction (Frazione Umida Tritovagliata)	38%
FUTS = Stabilized Humid Fraction (Frazione Umida Tritovagliata Stabillizzata)	4.4%
Metal = Recovered Metal	0.4%
WW = Waste Water	4.7%

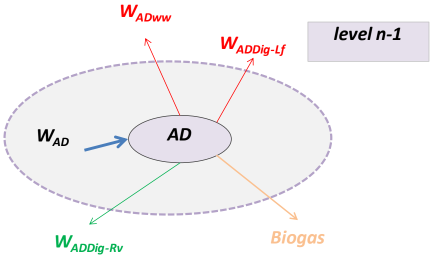
Production Factors		Intensive Values	Units	Extensive Values	Units per year
BIOPHYSICAL FUNDS	Occupied land	0.31	m^2/tonne	26	hectars
	Employment	0.31	full-time people/1000 tonne	260	full-time people
	Power Capacity Electrical machineries	0.004	kW-el/tonne	3.5	MW-el
	Power Capacity Thermal machineries	0.03	kW-th/tonne	25	MW-th
BIOPHYSICAL FLOWS	Process heat consumption	N.A.	TJ-th/tonne	N.A.	TJ-th
	Electricity consumption	59	kWh-el/tonne	49,000	MWh-el
	Fuel consumption	0.53	L/tonne	0.44	ML
	Water consumption	540	L/tonne	440	ML
ECONOMIC VARIABLES	Fixed Investments (discounted over 30 years)	11	€/tonne	8.8	M€
	Running costs	31	€/tonne	26	M€
	Cost of exports	150	€/tonne	70	M€
	Electricity Revenues	-	€/tonne	-	M€
	Recyclables Revenues	- 190	€/tonne	- 0.57	M€
	Subsidies for electricity production	-	€/tonne	-	M€

Environmental Indicators	Intensive Values (kg · $tonne^{-1}$waste)	Extensive Values (kg)
CH_4	-	-
CO_2	1.02E-02	8.48E+03
Heavy metals	-	-
PCBs	-	-
PAHs	-	-
Dioxines/Furans	-	-
PM10	3.81E-06	3.16E+00
PM2.5	2.88E-07	2.39E-01
VOCs	2.83E-06	2.35E+00
CO	1.16E-05	9.64E+00
NO_x	7.43E-08	6.17E-02
SO_x	8.83E-08	7.33E-02
HF	-	-
HCl	-	-
Waste water/leachate	5.36E+02	4.45E+08

*Heavy metals: Sb, As, Pb, Cr, Co, Cu, Mn, V, Ni, Zn, Sn, Cd, Tl, Hg

Table 3.10 *- Waste flows, production factors and environmental indicators for the network node Anaerobic Digestion (AD).*

AD = Anaerobic Digestion	**20**	**10^3 tonne/year**



FLOWS	Amount (10^3tonne/year)	%	Destination
W_{AD}	20	100%	Anaerobic Digestion plant
$W_{ADDig\text{-}Lf}$	16	78%	Composting & AD plants ex
W_{ADww}	1.5	6.7%	Wastewater treatment plants
$W_{ADDig\text{-}Rv}$	0.0	0.09%	Digestate Recovey
Biogas (Nm^3/year)	2,400	15%	CHP plant

Biogas density (kg/Nm^3) 1.2

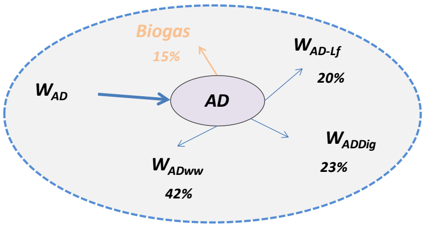
W_{AD} = Biowaste to Anaerobic Digestion

$W_{ADDig\text{-}Lf}$ = digestate from AD going to Landfill

W_{ADww} = wastewater from AD going to Landfill

$W_{ADDig\text{-}Rv}$ = solid digestate from AD going to recovery plants

Biogas = biogas generated from AD



Outputs from AD treatment	% in weight
Biogas	15%
Digestate	85%
$W_{AD\text{-}Lf}$ = Refuse waste from AD	20%
W_{ADDig} = Solid Digestate from AD	23%
W_{ADww} = Wastewater (Liquid Digestate) from AD	42%

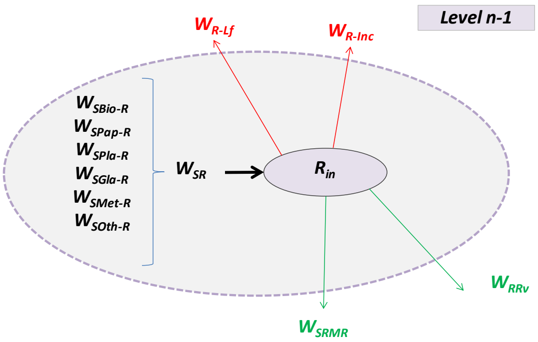
Production Factors		Intensive Values	Units	Extensive Values	Units per year
BIOPHYSICAL FUNDS	Occupied land	0.50	m^2/tonne	1.0	hectars
	Employment	0.25	full-time people/1000 tonne	4.9	full-time people
	Power Capacity Electrical machineries	0.051	kW-el/tonne	1.0	MW-el
	Power Capacity Thermal machineries	0.22	kW-th/tonne	4.3	MW-th
BIOPHYSICAL FLOWS	Process heat consumption	N.A.	TJ-th/tonne	N.A.	TJ-th
	Electricity consumption	73	kWh-el/tonne	1,400	MWh-el
	Fuel consumption	49	L/tonne	1.0	ML
	Water consumption	0.089	L/tonne	0.0017	ML
ECONOMIC VARIABLES	Fixed Investments (discounted over 30 years)	73	€/tonne	1.4	M€
	Running costs	75	€/tonne	1.5	M€
	Cost of exports	89	€/tonne	1.5	M€
	Electricity Revenues	- 19	€/tonne	- 0.37	M€
	Recyclables Revenues	-	€/tonne	-	M€
	Subsidies for electricity production	- 52	€/tonne	- 1.0	M€

Environmental Indicators	Intensive Values (kg · $tonne^{-1}$waste)	Extensive Values (kg)
CH_4	-	-
CO_2	4.29E+02	8.58E+06
Heavy metals	-	-
PCBs	-	-
PAHs	-	-
Dioxines/Furans	-	-
PM10	3.53E-04	7.06E+00
PM2.5	2.67E-05	5.34E-01
VOCs	3.28E-03	6.56E+01
CO	1.08E-03	2.15E+01
NO_x	6.89E-06	1.38E-01
SO_x	8.18E-06	1.64E-01
HF	-	-
HCl	-	-
Waste water/leachate	8.90E+01	1.78E+06

*Heavy metals: Sb, As, Pb, Cr, Co, Cu, Mn, V, Ni, Zn, Sn, Cd, Tl, Hg

Table 3.11 *- Waste flows, production factors and environmental indicators for the network node Recycling Centers (R).*

R = Recycling Centers **160** **10^3 tonne/year**



FLOWS	Amount (10^3tonne/year)	%	Destination
W_{SR}	160	100%	Recycling Centers
W_{SBio-R}	-	0.0%	
W_{SPap-R}	73	46%	
W_{SPla-R}	19	12%	
W_{SGla-R}	12	7.4%	
W_{SMet-R}	5.6	3.6%	
W_{SOth-R}	47	30%	
W_{SRMR}	93	59%	Secondary Raw Material Recovery
W_{R-Rv}	66	41%	Recovery facilities
W_{R-Inc}	0.8	0.36%	Incineration Plants ex
W_{R-Lf}	0.8	0.36%	Lanfill ex

W_{SGla-R} = Glass fraction of Separated Waste sent to Recycling Centers

W_{SMet-R} = Metal fraction of Separated Waste sent to Recycling Centers

W_{SOth-R} = Other fraction of Separated Waste sent to Recycling Centers

W_{R-Inc} = Refuse from Recycling Centers going to Incineration ex

W_{R-Lf} = Refuse from Recycling Centers going to Landfill ex

W_{SR} = Total Separated Municipal Solid Waste sent to Recycling centers

W_{SPap-R} = Paper & Cardboard fraction of Separated Waste sent to recycling

W_{SPla-R} = Plastic fraction of Separated Waste sent to recycling centers

W_{SRMR} = Recyclables from Recycling Centers sent to Secondary Raw Material Recovery facilities

W_{RRv} = waste from Recycling centers sent to Recovery facilities

Production Factors		Intensive Values	Units	Extensive Values	Units per year
BIOPHYSICAL FUNDS	Occupied land	0.31	m^2/tonne	4.8	hectars
	Employment	0.31	full-time people/1000 tonne	44	full-time people
	Power Capacity Electrical machineries	0.0031	kW-el/tonne	0.48	MW-el
	Power Capacity Thermal machineries	0.038	kW-th/tonne	6.0	MW-th
BIOPHYSICAL FLOWS	Process heat consumption	N.A.	TJ-th/tonne	N.A.	TJ-th
	Electricity consumption	180	kWh-el/tonne	28,000	MWh-el
	Fuel consumption	0.50	L/tonne	0.08	ML
	Water consumption	15	L/tonne	2.3	ML
ECONOMIC VARIABLES	Fixed Investments (discounted over 30 years)	8.0	€/tonne	1.2	M€
	Running costs	32	€/tonne	5.0	M€
	Cost of exports	50	€/tonne	0.028	M€
	Electricity Revenues	-	€/tonne	-	M€
	Recyclables Revenues	- 63	€/tonne	- 16	M€
	Subsidies for electricity production	-	€/tonne	-	M€

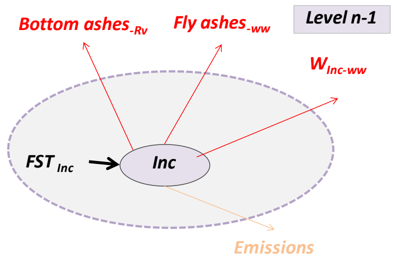
Environmental indicators	Intensive Values (kg · $tonne^{-1}$waste)	Extensive Values (kg)
CH_4	-	-
CO_2	9.65E-03	1.50E+03
Heavy metals	-	-
PCBs	-	-
PAHs	-	-
Dioxines/Furans	-	-
PM10	3.60E-06	5.60E-01
PM2.5	2.72E-07	4.24E-02
VOCs	2.68E-06	4.17E-01
CO	1.10E-05	1.71E+00
NO_x	7.02E-08	1.09E-02
SO_x	8.34E-08	1.30E-02
HF	-	-
HCl	-	-
Waste water/leachate	-	-

*Heavy metals: Sb, As, Pb, Cr, Co, Cu, Mn, V, Ni, Zn, Sn, Cd, Tl, Hg

Recycling Centers								
Recyclables Fractions	**Inside MAN**	**Outside MAN**				**TOTAL**	**Recyclables tariffs (€/tonne)**	**Total Revenues (M€)**
10^3 tonne/year	MAN	Campania	Italia	Abroad	Total	**250**	0	**-16.0**
Paper& Cardboard	73	13	0.92	0.38	14	87	-28	-2.4
Plastic	19	12	0.96	0.00	13	32	-215	-6.9
Glass	12	3.2	31.00	0.00	34	45	-5	-0.23
Metals	5.6	1.3	0.02	0.00	1.3	6.9	-96	-0.66
Other	47	20	10.00	0.00	30	77	-70	-5.4

Table 3.12 *- Waste flows, production factors and environmental indicators for the network node Incineration (Inc).*

Inc = Incineration — **375** — **10^3 tonne/year**



FLOWS	Amount (10^3tonne/year)	%	Destination
FST_{Inc}	375	100%	MBT plants inside MAN
Fly ashes$_{-ww}$	20	5.1%	Wastewater treatment plants
Bottom ashes$_{-Rv}$	60	16%	Other Recovery Facilities ex
$W_{Inc\text{-}ww}$	0.5	0.10%	Wastewater treatment plants
Emissions	295	79%	Local Environment

in = inside MAN
ex = outside MAN

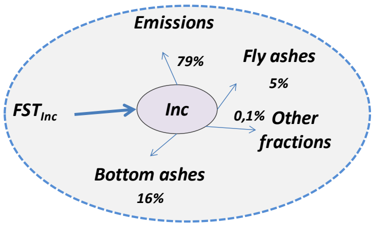
FST_{Inc} = Dry Fraction sento to Incineration

Fly ashes$_{-ww}$ = Fly ashes from Incineration going to wastewater treatment ex

Bottom ashes$_{-Rv}$ = Bottom ashes from Incineration going to other Recovery facilities ex

$W_{Inc\text{-}ww}$ = Other fractions from Incineration going to wastewater treatment ex

Emissions = emissions due to the combustion in the incineration process



Outputs from Incineration	% in weight of the input	Amount (10^3
Bottom ashes	16%	60
Fly ashes	5.1%	20
Other fractions	0.12%	0.50
Total solid-liquid outputs	21%	81
Emissions	79%	295

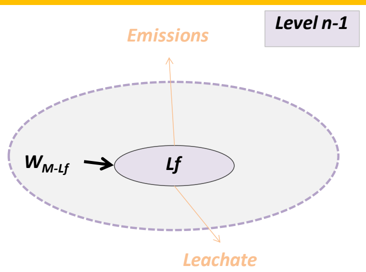
Production Factors		Intensive Values	Units	Extensive Values	Units per year
BIOPHYSICAL FUNDS	Occupied land	0.24	m^2/tonne	8.8	hectars
	Employment	0.29	full-time people/1000 tonne	110	full-time people
	Power Capacity Electrical machineries	0.00048	kW-el/tonne	0.18	MW-el
	Power Capacity Thermal machineries	0.33	kW-th/tonne	120	MW-th
BIOPHYSICAL FLOWS	Process heat consumption	590	TJ-th/tonne	220	TJ-th
	Electricity consumption	93	kWh-el/tonne	35,000	MWh-el
	Fuel consumption	0.54	L/tonne	0.20	ML
	Water consumption	960	L/tonne	360	ML
ECONOMIC VARIABLES	Fixed Investments (discounted over 30 years)	32	€/tonne	12	M€
	Running costs	70	€/tonne	26	M€
	Cost of exports	200	€/tonne	16	M€
	Electricity Revenues	- 67	€/tonne	- 25	M€
	Recyclables Revenues	-	€/tonne	-	M€
	Subsidies for electricity production	- 150	€/tonne	- 58	M€

Environmental Indicators	Intensive Values (kg · $tonne^{-1}$waste)	Extensive Values (kg)
CH_4	-	-
CO_2	1.00E+03	3.75E+08
Heavy metals	2.50E-04	9.38E+01
PCBs	1.40E-12	5.25E-07
PAHs	2.90E-07	1.09E-01
Dioxines/Furans	7.90E-12	2.96E-06
PM10	2.60E-03	9.76E+02
PM2.5	2.00E-03	7.50E+02
VOCs	7.50E-03	2.81E+03
CO	1.10E-01	4.13E+04
NO_x	4.00E-01	1.50E+05
SO_x	2.00E-02	7.50E+03
HF	9.10E-04	3.41E+02
HCl	9.50E-03	3.56E+03
Waste water/leachate	3.30E+02	1.24E+08

*Heavy metals: Sb, As, Pb, Cr, Co, Cu, Mn, V, Ni, Zn, Sn, Cd, Tl, Hg

Table 3.13 *- Waste flows, production factors and environmental indicators for the network node landfill (Lf).*

Lf = Landfill — **32** — **10^3 tonne/year**



FLOWS	Amount (10^3tonne/year)	%	Destination
W_{M-Lf}	32	100%	MBT plants inside MAN
Emissions	4.5	14%	Wastewater treatment plants
Leachate	62	190%	Other Recovery Facilities ex

FST_{Inc} = Dry Fraction sento to Incineration — in = inside MAN

Emissions = emissions produced from the landfill — ex = outside MAN

Leachate = leachate produced from the landfill

Production Factors		Intensive Values	Units	Extensive Values	Units per year
BIOPHYSICAL FUNDS	Occupied land	0.11	m^2/tonne	0.35	hectars
	Employment	0.036	full-time people/1000 tonne	1.2	full-time people
	Power Capacity Electrical machineries	N.A.	kW-el/tonne	N.A.	MW-el
	Power Capacity Thermal machineries	0.0038	kW-th/tonne	0.12	MW-th
BIOPHYSICAL FLOWS	Process heat consumption	N.A.	TJ-th/tonne	N.A.	TJ-th
	Electricity consumption	16	kWh-el/tonne	510	MWh-el
	Fuel consumption	0.12	L/tonne	0.0039	ML
	Water consumption	N.A.	L/tonne	N.A.	ML
ECONOMIC VARIABLES	Fixed Investments (discounted over 30 years)	18	€/tonne	0.59	M€
	Running costs	73	€/tonne	2.4	M€
	Cost of exports	-	€/tonne	-	M€
	Electricity Revenues	-	€/tonne	-	M€
	Recyclables Revenues	-	€/tonne	-	M€
	Subsidies for electricity production	-	€/tonne	-	M€

Environmental Indicators	Intensive Values (kg · $tonne^{-1}$waste)	Extensive Values (kg)
CH_4	8.30E+01	2.66E+06
CO_2	5.50E+01	1.76E+06
Heavy metals	-	-
PCBs	-	-
PAHs	-	-
Dioxines/Furans	-	-
PM10	8.68E-07	2.78E-02
PM2.5	6.57E-08	2.10E-03
VOCs	6.46E-07	2.07E-02
CO	1.60E-03	5.13E+01
NO_x	1.69E-08	5.42E-04
SO_x	2.01E-08	6.44E-04
HF	1.60E-03	5.12E+01
HCl	7.80E-03	2.50E+02
Waste water/leachate	1.92E+03	6.14E+07

*Heavy metals: Sb, As, Pb, Cr, Co, Cu, Mn, V, Ni, Zn, Sn, Cd, Tl, Hg

***Table 3.14** - Production factors and environmental indicators for the MSWMS in the MAN (breakdown of the different nodes).*

Production factors MSWMS of the MAN (data 2012)		**Stages and Nodes of the MSWMS**												**Total MSWMS**
		Units	**Collection**	CM	CS	**Processing**	PTSP	STIR (MBT)	AD	R	**Disposal**	Inc	Lf	
BIOPHYSICAL FUNDS	Occupied land	hectares	N.A.	N.A.	N.A.	49	17	26	1.0	4.8	9	8.8	0.35	**58**
	Employment	full-time people	3,000	1,800	1,200	539	230	260	4.9	44	111	110	1.2	**3,650**
	Power Capacity Electrical machineries	MWel	N.A.	N.A.	N.A.	6	0.85	3.5	1.0	0	0.2	0.2	N.A.	**6.0**
	Power Capacity Thermal machineries	MWth	310	190	120	70	35	25	4.3	6	120	120	0	**500**
BIOPHYSICAL FLOWS	Process heat consumption	TJ-th	N.A.	N.A.	N.A.	220	N.A.	N.A.	N.A.	N.A.	220	220	N.A.	**220**
	Electricity consumption	MWh-el	9,200	5,800	3,400	81,800	3400	49,000	1,400	28,000	35,510	35,000	510	**126,510**
	Fuel consumption	ML	4.1	2.5	1.60	17	16	0.44	1.0	0.078	0	0.20	0.0	**22**
	Water consumption	ML	6.2	3.9	2.30	466	24	440	0.0	2.3	360	360	N.A.	**833**
ECONOMIC VARIABLES	Fixed Investments (discounted over 30 years)	M€	51	31	20	20	8.5	8.8	1.4	1.2	13	12	0.59	**83**
	Running Costs	M€	204	120	84	58	25	26	1.5	5.0	28	26	2.4	**290**
	Export Costs	M€	7	7	0	107	35	70	1.5	0.0	16	16	0.0	**130**
	Electricity Revenues	M€	0	0	0	0	0.0	0.0	-0.4	0.0	-25	-25	0.0	**-25**
	Recyclables Revenues	M€	0	0	0	-17	-0.6	-0.6	0.0	-16	0	0	0.0	**-17**
	Subsidies electricity	M€	0	0	0	-1	0.0	0.0	-1.0	0	-58	-58	0.0	**-59**

The overall performance of the MSMWS, obtained by integrating the quantitative assessments of the individual network nodes (see Tab. 14), is shown in Tab. 3.15.

Table 3.15 *- Performance of the municipal solid waste management system of the MAN (year 2012) based on the requirement of production factors and environmental impacts.*

Municipal Solid Waste Management System of MAN	**1,460**	**10^3 tonne/year**

Production Factors		**Extensive Values**	**Units per year**
BIOPHYSICAL FUNDS	Occupied land	58	hectares
	Employment	3,650	full-time people
	Power Capacity Electrical machineries	6	MWel
	Power Capacity Thermal machineries	500	MWth
BIOPHYSICAL FLOWS	Process heat consumption	220	TJ-th
	Electricity consumption	127	GWh-el
	Fuel consumption	22	ML
	Water consumption	833	ML
ECONOMIC VARIABLES	Fixed Investments (discounted over 30 years)	83	M€
	Running Costs[39]	290	M€
	Cost of exports	130	M€
	Electricity Revenues	-25	M€
	Recyclables Revenues	-17	M€
	Subsidies for electricity production	-59	M€

Environmental indicators	**Extensive Values**	**Units per year**	
CH_4	2.7×10^3	tonne	Heavy metals*: Sb, As, Pb, Cr, Co, Cu, Mn, V, Ni, Zn, Sn, Cd, Tl, Hg
CO_2	380×10^3	tonne	
Heavy metals*	93	tonne	
PCBs	0.52	mg	
PAHs	0.11	kg	
Dioxines/Furans	3.0	kg	
PM10	1.0	kg	
PM2.5	0.75	tonne	
VOCs	2.9	tonne	
CO	41	tonne	
NO_x	150	tonne	
SO_x	7.5	tonne	
HF	0.39	tonne	
HCl	3.8	tonne	
Waste water/leachate	630×10^3	tonne	

[39] The maintinance costs for Ecoballe is not included in the running costs.

Analyzing the Tab. 3.14 and Tab 3.15 I can summarize the main characteristics of both biophysical, economic and environmental factors of the current MSWMS in the MAN.

Water requirement of the entire system is basically divided among STIR plants (52% of total water consumption) and incineration node (43%). Those nodes together with Recycling centers are also the main electricity consuming waste facilities of current system. Process heat is only requested in the incinerator. Almost 60% of the power capacity using fuels is concentrated in the collection node. In the processing stage almost the totality of electrical power capacity is operating in the STIR node. Approximately 80% of the employment is related to the collection stage (nodes CM and CS).

Moving to economic analysis collection represents around 40% of the total costs of the MSWMS. The total costs (around 500 M€/year) has been calculated by summing: (1) fixed investments (discounted over 30 years) – 17% of the total; (2) running costs - 58% of the total; and (iii) costs for exports 26% of the total without accounting the annual revenues. The total benefits cover around 20% of the total costs and are determined by: (1) net electricity production: 25M€; (2) selling of recyclables: 17M€; and (3) subsidies: 59M€. Subsidies come from the central government and mainly refer to the energy generated in the incineration. Note that overall economic performance of the UMWS of MAN is affected by the additional cost for the protection and maintenance of the bales (ecoballe) of waste stored within the MAN. This cost is about 10 M€/yr, of which 7 M€ for the largest facility only (Del Giudice personal communication, 2015). The recent decision to remove the waste bales from the Taverna del Re facility for treatment elsewhere (outside MAN) would imply an estimated additional cost for the final disposal of around 120 M€[40].

In terms of environmental impacts, the most impacting node is the incinerator. In fact, the flue gas from incinerator furnaces includes almost the totality of gaseous emissions assessed for the total system (see Tab. 3.16). The production of significant amount of dioxin and furan creates the main concern about the incineration of MSW since those substances can be considered a serious health hazards (Giovannini et al. 2013; Rivezzi et al. 2013; Cantoni 2016). Other studies show that other emission sources have also a notable environmental impact on the area under direct influence of the incinerator. However, according to these authors there is no direct correlation between the emissions of dioxins and furans from a municipal solid waste incinerator and the level of contamination and health risk of the area close to the incinerator (Meneses, et al. 2004). Landfill node is the unique responsible of emissions of methane (CH_4) while the main source of waste water and leachate is the STIR node (70% of total) followed by incineration (20%) and landfill (10%).

It is important to underline that the emissions linked to transportation of waste count only the movements within the MAN. The environmental impact associated with the MSWMS of MAN is considered "externalized" when it refers to the handling or the processing of waste transported outside of the borders system. .

Table 3.16 *- Environmental impacts and related most impacting nodes in the MSWMS of the MAN.*

Environmental Indicators	% on the total value	Most impacting node	**Total MSWMS**	Unit per year
CH_4	100%	Lf	2,656	tonne
CO_2	97%	Inc	385,432	tonne
Heavy metals	100%	Inc	94	kg
PCBs	100%	Inc	0.5	mg
PAHs	100%	Inc	0.11	kg

[40] http://www.ilfattoquotidiano.it/2016/03/12/ecoballe-fine-della-storia-118-milioni-per-smaltirle-e-intanto-sono-mummificate/2534845/

Dioxines/Furans	100%	Inc	3.0	mg
PM10	96%	Inc	1,017	kg
PM2.5	99.6%	Inc	753	kg
VOCs	97%	Inc	2,904	kg
CO	99.6%	Inc	41,428	kg
NO_x	100%	Inc	150,001	kg
SO_x	100%	Inc	7,501	kg
HF	87%	Inc	392	kg
HCl	93%	Inc	3,812	kg
Wastewater/leachate	70%	STIR	631,850	tonne

In conclusion, the current MSWMS management in the MAN is characterized by (1) an elevated share (47% of TSWT) of waste treated outside of regional ambit and (2) a low rate of separate collection (37% of TSWT) (Fig.3.4). These are the priorities local authorities are facing, given the two objectives on (i) regional self-sufficiency of urban waste final disposal and (ii) 65% of recycling rate to reach at regional level within 2020 imposed by the regional law 14/2016[41].

3.5.2 Exploring the option space

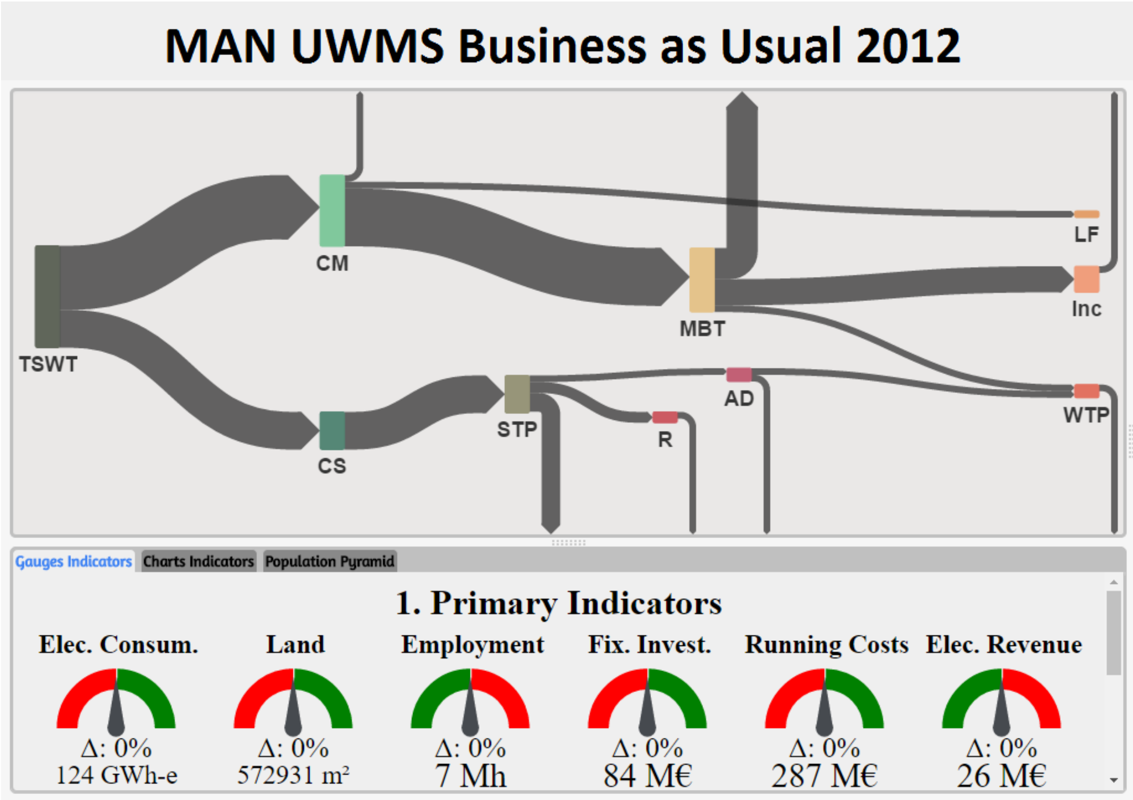
In order to improve the recycling rate, the MAN has recently started to implement ambitious policies. For instance, the percentage of separate collection has already increased from 37% in 2012 to 43% in 2014, according to the directive 2008/98/EC[42] of the European Union, which states that priority should be given to reduction, reuse, recycling and recovery. However, given the combination of geographic and demographic characteristics, the MAN critically lacks processing capacity in the very nodes receiving the growing input determined by the strengthening of the separate-collected branch of the network. This is especially important in relation to the

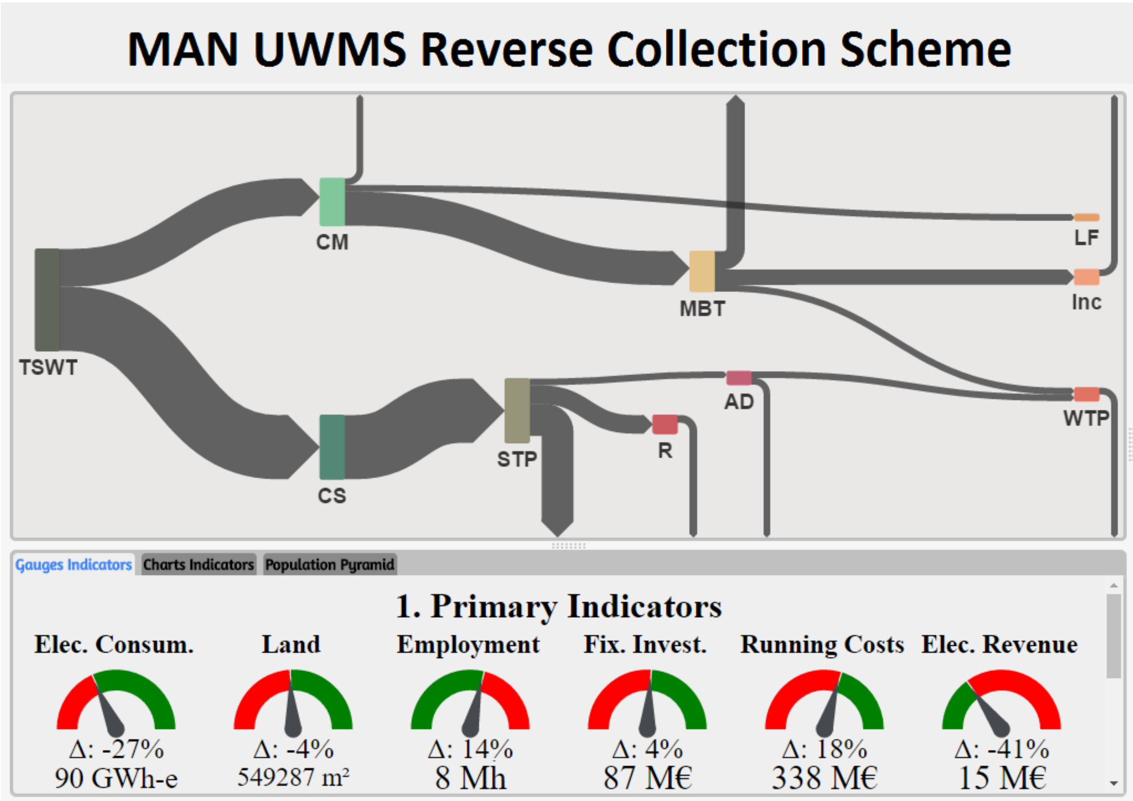
[41] Regional Law 26 May 2016 , n . 14 " Provisions for the enforcement of European and national legislation on waste".

[42]https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/218586/l_31220081122en00030030.pdf

biodegradable fraction. On the contrary, the nodes with a good processing capacity, specifically the MBT plants and the following incinerator are now underused because of this ongoing transformation. That is, the policy towards a more diffuse adoption of the door-to-door collection scheme is determining, paradoxically, an even higher level of export of fluxes because they are implying a lower utilization of the local installed power capacity. For this reason, the local stakeholders are also considering the hypothesis of a reconversion of the MBT plants for the treatment of the biodegradable fraction due to the change of the composition of the allocated flows.

Based on these premises and in consultation with the local stakeholders, two policy options were chosen for further analysis and compared with the 2012 baseline situation ('business as usual'): 'reverse collection scheme' and 'internalization'. The first policy assumes a significant increase in recycling rate, that is, the reversal of the current mixed-to-sorted waste collection ratio from 63/37 to 37/63; the second simulation gives priority to self-sufficiency and assumes that all the waste produced in the MAN is also processed within the MAN (no waste export) by increasing processing capacity, while keeping constant the current ratio of mixed/separated collection of 63/37. The results of the simulation are presented in the following Fig. 3.5 and Tab. 3.17.


MAN UWMS Business as Usual 2012
CM
LF
Inc
MBT
TSWT
AD
WTP
STP
R
CS
Gauges Indicators
Charts Indicators
Population Pyramid
1. Primary Indicators
Elec. Consum.
Land
Employment
Fix. Invest.
Running Costs
Elec. Revenue
Δ: 0%
124 GWh-e
Δ: 0%
572931 m²
Δ: 0%
7 Mh
Δ: 0%
84 M€
Δ: 0%
287 M€
Δ: 0%
26 M€


MAN UWMS Reverse Collection Scheme
CM
LF
Inc
MBT
TSWT
AD
WTP
STP
R
CS
Gauges Indicators
Charts Indicators
Population Pyramid
1. Primary Indicators
Elec. Consum.
Land
Employment
Fix. Invest.
Running Costs
Elec. Revenue
Δ: -27%
90 GWh-e
Δ: -4%
549287 m²
Δ: 14%
8 Mh
Δ: 4%
87 M€
Δ: 18%
338 M€
Δ: -41%
15 M€

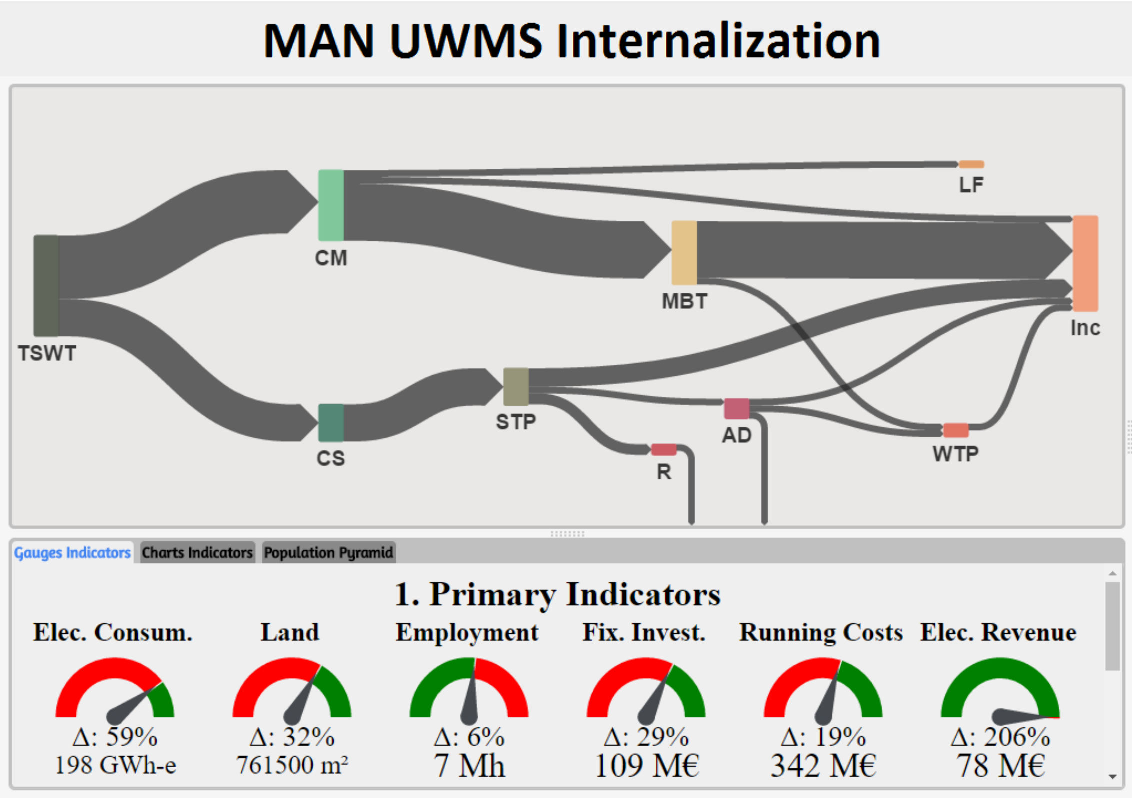


Figure 3.5 *- Side-by-side diagram for illustrative purposes comparing two alternative waste managements among three potential simulations (business as usual, reverse collection scheme, internalization, respectively).*

Table 3.17 *- Performance of the municipal solid waste management system of the MAN in year 2012 and the two simulated alternatives ("reverse collection scheme and "internalization").*

Municipal Solid Waste Management System of MAN - Exploring the option space					
Production Factors		**BAU**	**Option 1**	**Option 2**	**Units per year**
		MSWMS MAN 2012	**Reverse Collection Scheme**	**Internalization**	
BIOPHYSICAL FUNDS	Occupied land	58	55	76	hectares
	Employment	3,650	4,200	3,900	full-time people
	Power Capacity Electrical machineries	6	4.1	5.3	MWel
	Power Capacity Thermal machineries	500	470	750	MWth
BIOPHYSICAL	Process heat consumption	220	130	680	TJ

FLOWS	Electricity consumption	127	90	200	GWh-el
	Fuel consumption	22	34	23	ML
	Water consumption	833	520	1600	ML
ECONOMIC VARIABLES	Fixed Investments (discounted over 30 years)	83	87	110	M€
	Running Costs	290	340	340	M€
	Cost of exports	130	120	0	M€
	Electricity Revenues	-25	-15	-78	M€
	Recyclables Revenues	-17	-17	-17	M€
	Subsidies for electricity production	-59	-35	-180	M€

Environmental indicators	MSWMS MAN 2012	Reverse Collection Scheme	Internalization	Units per year
CH_4	2.7	1.6	2.7	10^3 tonne
CO_2	380	230	1,200	10^3 tonne
Heavy metals	93	55	290	tonne
PCBs	0.52	0.31	1.6	mg
PAHs	0.11	0.06	0.34	kg
Dioxines/Furans	3.0	1.7	9.2	kg
PM10	1.0	0.8	3.2	kg
PM2.5	0.75	0.46	2.3	tonne
VOCs	2.9	1.9	8.9	tonne
CO	41	25	130	tonne
NO_x	150	88	460	tonne
SO_x	7.5	4.4	23	tonne
HF	0.39	0.23	1.1	tonne
HCl	3.8	2.2	11	tonne
Waste water/leachate	630	370	890	10^3 tonne

The assumptions, indicators and abbreviations are the same as adopted in Table 3.6.

Reverse collection scheme (increasing recycling rate)

Analyzing the overall performance of the UMWS of the MAN area under the simulated "reverse collection scheme" it emerges a lower consumption of two types of energy carriers, namely electricity and process heat, but a higher consumption of the third energy carrier: fuel. This is due to an increase of requirement of fuels in the collection stage (Tab. 3.17). More vehicles would be needed, with more stop-and-go collection. This is also the reason for a larger requirement of hours of work/jobs (Greco et al. 2014). The water use is significantly lower in this scenario and this fact can be easily explained by the reduction of operations in functional processes requiring more water, such as the MBT and the incinerator.

When considering economic variables, the economic cost of the operation of the whole MSWMS would be higher. This is due to the increase in the running costs (i.e. usage of fuel and more workers required in the collection stage). In relation to the cost to be paid for export, the exports associated with the handling of the unsorted wastes is diminished but this gain is coupled to a considerable increase in waste deriving from the separate-collection that has to be exported due to the lack of adequate processing capacity. In relation to this point, the availability of an adequate process capacity in the branch of separate-collection is essential. In order to properly handle the increase in the fraction of separated waste assumed in this scenario the MSWMS should have an increase in recycling and anaerobic digestion capacity of up to two-fold and twenty-fold, respectively. Finally, in relation to environmental impacts, the solution of increasing the separate-collection translates into lower local emissions because the most impacting nodes (i.e. incinerator and landfilling) are reducing their operations.

Internalizing the processing of all the exported flows

In the second scenario of "full internalization" the simulation assumes an increase in processing capacity capable of coping, at the local level without using exports, with the entire amount of waste throughput. This simulation implied a re-arrangement of the metabolic network as follows: (i) the set of relations over the functional nodes remained the same; (ii) two additional structural elements - an anaerobic digestion plant and a recycling plant were added in order to be able to process more throughputs in these nodes; (iii) all the waste exceeding processing capacity, that would otherwise have been exported, is sent to the incinerator. This implies sending to incineration: exported waste from the mixed collection, from sorting/transfer platforms, and from mechanical biological treatment plants; (iv) the capacity of the incineration node is roughly doubled, in order to handle the larger flow of internalized waste. It should be noted that a solution capable of internalizing the disposal of all wastes in MAN could have obtained in many different ways. What has been chosen for the simulation is just one of them. For example, another solution would have been to distribute the waste coming from the sorting/transfer platforms among recycling and anaerobic digestion plants (rather than sending them to the incinerator). But then this solution would have implied increasing the processing capacities of these two nodes by as much as two and ten-fold respectively. In this alternative solution almost 30 ha additional hectares would have to be needed in the MAN. Recent history tells us that the selection of an area where to build new waste treatment plants in this region ("not in my back yard effect") is a very delicate topic, especially in a metropolitan area characterized by a very high population density (Fig. 3.2). This fact has indeed played a major role in determining the twenty-year-long "waste crisis".

In relation to this point, it is obvious that participatory processes aimed at establishing a system of governance capable of involving local residents are the only solution to this problem. In this way it becomes possible to individuate, or better negotiate, acceptable solutions. As a matter of fact, the results of this simulation suggest that it would be easier to look for suitable sites for new plants in the surrounding regional areas, rather than within the very-densely-populated metropolitan area of Naples. Moreover, the ‘internalization’ simulation implies higher local consumptions (electricity, fuel and process heat, along with water) and emissions.

In economic terms both the fixed and the circulating investments are definitely higher even though the solution reduces the cost of exports and provides higher return in terms of electricity production. Indeed, if the subsidies would be maintained at the existing levels this solution would generate a net economic benefit (paid with the money of tax payers making it possible the generation of subsidies!). It should be noted that in this assessment the cost of the plants for the processing of the fly and bottom ash generated in the incineration process were not considered. The assessment of the fixed and circulating costs associated with this type of plants was not carried out because of lack of data[43].

3.6 Conclusions

The analysis presented in this chapter illustrates the potentialities of the application of a multi-scale integrated assessment based on metabolic network theory to a specific municipal solid waste management system. The concrete case study is the Municipal Area of Naples analyzed in the year 2012. This approach makes it possible a detailed characterization of the material balance of waste flows through the MSWMS. In particular, it makes it possible to identify the sources of the problems (e.g. excessive export, sources and location of environmental impacts, economic costs) in relation to the definition of the functional processes expressed at the different nodes and the technology used. In this way it becomes possible to individuate the bottlenecks (e.g. shortages of processing capacity) forcing the local administrators to export a significant amount of the waste throughput. With the use of the integrated methodology, it

[43] In Campania there are not such types of plants for bottom ashes. In the whole Italian country there is not a single fly-ashes-treatment plant.

becomes possible to evaluate constraints belonging to different incommensurable dimensions such as social, technical, economic and environmental ones.

There are two points that should be considered when adopting this approach:

(1) the representation of the MSWMS used in the decision support tool used for the simulations, as every representation, represent a simplification of the complexity of the real system. This simplification requires addressing the implications of scaling of the estimation of both production factors (technical coefficients) and the profile of outflow distribution out of each node. For example, let’s assume that in a simulation an additional 20% of waste inflow gets into a given node. Then if there is enough processing capacity, each one of the node’s outflows will also be augmented proportionally of 20%. This increase of the output flows is possible in relation to the assessment of processing capacity of the note (internal view) but, in order to be stable in time it would require that each one of the increased outflows does not exceed the processing capacity of the other nodes supposed to receive and process these outflows. Whenever this occurs, then we cannot assume that the percentage of increase obtained at a given node will be transmitted linearly through the rest of the network. A change in a given node may imply either a: (i) change in the size of the structural elements in the other nodes affected – either we have to use more plants of the same type to process the larger flows, or we have to adopt more efficient plants with better technical coefficients – e.g. economies of scale; or (ii) change in the level of openness of the network (export outside the system) - an increase in the amount of waste that is exported by the node in excess of the available processing capacity. In biophysical terms we can say that this second solution represents an externalization of the requirement of processing capacity to other MSWMS. Either of these two solutions will change the economic performance of the MSWMS changing the profile of circulating, and fixed cost and the cost of externalizing the process elsewhere. Therefore, it is

important to be aware that simulations done with this approach **are not predictions** of what will happen, but rather explorations of possible solutions within the viability domains. The coherence of the quantitative representation of the characteristics of the network across levels and scales has the only goal of visualizing the conditions and the implications of the adjustments needed to keep the viability of the system.

(2) this type of analysis requires a direct input from those that will be using the decision support tool. In fact, a change in the characteristics of a technological process within the network of does not define in a deterministic way what will happen to the rest of the network. As illustrated in the examples of simulations, any change in the characteristics of a node do require a re-arrangement in the rest of the network. But this re-arrangement can take place in many different ways. The possible changes may refer to either: (i) a different level of openness of the network (e.g. exporting extra flows in the case of insufficient processing capacity or leaving processing capacity idle in the case a reduction of the flow getting into a given node); (ii) a change in the technical characteristics of the structural elements of the node, in which the various technical processes have to be changed to make them compatible with the new configuration of the network. Constraints related to the value of technical coefficients (bottom-up information) and to the constraints provided by mass and energy balance (top-down information) define an option space associated with technological changes within the metabolic network. However, this method of analysis does not make it possible to predict what will be the final re-adjustments of the whole MSWMS determined by the introduction technological innovations. The representation of the metabolic network generated with this method of analysis is based on an impredicative relation between bottom-up and top-down information but it requires an input from the outside when deciding which specific combination of changes should be explored in a simulation. This means that this approach has to be used to structure an informed discussion with

experts and other social actors about the effects that different potential choices of re-adjustments may imply depending on the decision taken in the process. Changes in the whole can force changes in the elements or vice versa. That is, starting from the characterization provided by the accounting scheme of the existing situation it becomes possible to discuss the pros and the cons of possible changes exploring the pros and cons of possible options considering the legitimate but contrasting definition of performance that are found among the relevant stakeholders.

CHAPTER IV - Participatory Integrated Assessment of the performance of municipal solid waste management systems

4.1 Summary

This part presents the experience done when trying to use the analytical tool-kit characterizing the performance of MSWMS in a participatory multi-criteria integrated assessment. This part does not address the theoretical aspects of participatory multi-criteria integrated assessment (for details, see, for example, Salter et al., 2010; van Asselt, M.B.A. and Rijkens-Klomp, 2002; Giampietro et al., 2006). Rather this chapter provides a reflection of the type of problems that can be encountered when using a decision support system of the type presented in the previous two chapters. The reflections presented below are based on the experience made during the participatory processes conducted within the activities of the EU MARSS project in the Metropolitan Area of Naples.

The participatory processes carried out in the MARSS project include: (i) a public meeting with different stakeholders at the beginning; (ii) in-depth interviews; (iii) a mini-DELPHI exercise having a double goal (checking the quality of the characterization and deciding about the indicators to be used); and (iv) a NAIADE exercise (NAIADE is a software useful to structure the multi-criteria analysis of a given issue in relation to typologies of relevant stakeholders and resulting potential conflicts). These participatory processes involved stakeholders defined as relevant within the urban waste sector of Naples. This decision was based on the results of an institutional analysis of the issue of waste management in Naples carried out by other members of the MARSS project.

Not all the participatory processes provided the expected results and an analysis of the activities carried out in those participatory process carried out by the group of research in which I was operating (referring to the use of the tool-kit) and the results obtained are the objects of the reflections presented here. In relation to the use of our tool-kit the different objectives of the participatory processes carried out by my group were respectively:

(i) map the existing narratives about the waste crisis in Naples and potential solutions proposed by the different stakeholders; (ii) check with administrative experts and politicians the non-technical framework (the specific narratives of the decision makers); (iii) check with the technical experts the validity of the proposed representation (identity of the functional nodes in the network, data sources, estimation of waste-flows quantities); (iv) check the selection of indicators of performance technical, economic, social, environmental) to be adopted in the integrated analysis; (v) test the usefulness of the decision support system developed starting from the analytical tool-kit for integrated assessment.

4.2 The role of participatory processes in integrated assessment

As discussed in Chapter I a process of integrated assessment aimed at generating scientific information to be used for governance has to guarantee two non-equivalent quality checks. In relation to the scheme presented in Fig. 1.2 (in Chapter I) these two quality checks are represented by:

* *STEP 1 "Quality check on the issue definition":* before getting into the process of identification of the scientific information required for the analysis it is important to identify or, at least, to have a satisficing understanding of: (i) the concerns of the social actors in relation to the issue to be tackled; (ii) their aspirations; and (iii) their normative

values. In fact, a multi-criteria characterization based on an integrated set of indicators represents a static output that is semantically closed: the decisions about what is relevant and what should be considered as an improvement in the integrated assessment are taken in a pre-analytical phase. In this phase data, indicators and quantitative targets are not yet relevant. In this specific case, when representing a MSWMS as a metabolic network one has to get through a series of pre-analytical choices referring to the problem structuring. These pre-analytical choices will determine the usefulness of the analysis in relation to goals, indicators and policy options considered as relevant by society. For this reason, these pre-analytical choices should not be carried out by scientists alone, but they should be co-produced with those that will use the results of the analysis. Without a quality check on the semantic framing of the issue, the quantitative output coming from the Multi-Criteria Analysis - if based on a poor selection of indicators - could result: (i) irrelevant; (ii) misleading; (iii) biased by the influence of powerful lobbies imposing the choice of indicators; (iv) not capable of producing useful inputs to the process of governance;

* *STEP 2 "Quality check on the integrated analysis"* – this check refers to the choices determining the quantification of the network of flows and technical coefficients describing the technologies operating in functional nodes and the calculation of indicators. This quality check starts with a provisional input of representation drawn up by a group of scientists in charge for generating the representation. They can generate this provisional input from public databases, reports, grey and scientific literature. Then, the robustness of the proposed analysis has to be checked through the involvement of local experts in meetings and interviews and by gathering more accurate and robust information expanding the available sources of data and information. Without a quality check on the quantitative representation adopted for the analysis, the quantitative output coming from the Multi-Criteria Analysis - if based on sloppy models or bad data - can

result: (i) misleading; or in the best case scenario (ii) not capable of producing useful inputs to the process of governance;

In conclusion the main role of participatory processes in integrated assessment is to guarantee the generation of a "useful" input of information (relevant and robust) to the process of governance (Giampietro 2015). To achieve this goal multi-stakeholder participatory processes are essential because they make possible the co-production of quantitative information with the different types of expertise (political, administrative, technical) associated with different categories of stakeholders. The involvement of social actors is required both in the phase of production of quantitative information (in the form of inputs of information) and in the phase of use of the quantitative information (in the form of feed-backs on the usefulness of the choices made).

4.3 The experience done in the MARSS project

4.3.1 Preliminary institutional analysis

Before starting any participatory processes it is essential to carry out a preliminary institutional and discourse analysis (Munda, 2008). In relation to this analysis this input has been provided by the University of Parthenope and by the RWTH Aachen University ("MARSS - Local Authorities Report"[44]; "MARSS - Layman Report"[45]). The results of this task were the identification of relevant social actors and their narratives about the problems and the priorities over there. This analysis has provided also essential information about the legislative context, existing and past conflicts, public and private institutions acting within the urban waste sector of Naples. This

[44] http://www.marss.rwth-aachen.de/cms/upload/downloads/MARSSResults/01-marss-local-authorities-report.pdf

[45] http://www.marss.rwth-aachen.de/cms/upload/downloads/MARSSResults/02-laymans-report.pdf

analysis has been carried out by looking at relevant sources of public information (webpages[46], blogs[47], newspapers, public reports[48], videos[49], scientific publications (Basile et al. 2009; Lega et al. 2012; Kosmatka 2010; D'Amato et al. 2011; De Feo & De Gisi 2010a, 2010b; De Feo et al. 2013; De Feo & Williams 2013) and experts[50]' opinion) about municipal solid waste management.

The pool of relevant stakeholders was selected among all the potential groups and individuals affecting and by affected by waste management policy: those who will be involved in the implementation of the policy, those that have stated interest in the policy, those that have knowledge and expertise about the issue and finally the policy makers who have the power to endorse or reject the proposed solutions (European Commission 2014). A list of about 300 stakeholders was identified and grouped into 10 categories (see Tab. 4.1) (Hornsby et al. 2016).

Table 4.1 - *Identification of 10 stakeholder categories relevant in the waste sector*.

1. National Government
2. Local Authority
3. Local Waste Management Authority
4. Waste Emergency Commissioner
5. Companies in charge of collection and recycling urban waste
6. Professional Associations
7. Environmental Associations
8. Local Actors (mainly individuals)
9. Academic and Research Institutions
10. Mass Media

46 Rete salute e ambiente, Donne Acerra, Mamme Vulvaniche, VAS associazione ambientale .
47 La civiltá del sole, CORERI Terra dei fuochi.
48 Reports of Inquiry Parliamentary Commissions ("Commissioni parlamentari d'inchiesta"), Waste Management Plans, Statements (pleadings) made by "camorristi" (Schiavone, Vassallo, Cosentino, Cipriano).
49 "Biutiful country" documentary
50 Marco Armiero, Giacomo D'Alisa, Afredo Mazza, Umberto Arena.

4.3.2 Public meeting in Naples

Then a public meeting with stakeholders was organized and held at the Parthenope University, Naples, in April 2015 (Fig. 4.1) with the aim to discuss the results of a preliminary socio-economic analysis within the MARSS project and to establish a permanent channel of contacts with them. Different stakeholders (managers in the administration, members from European organizations, politicians, technicians, NGOs and activists, as well as a variety of key stakeholders from industry, education and civil society) were invited and participated on a voluntary basis (no payment for their time). Broad events such this one have the purpose to gather input from a larger number of targeted respondents through interactions and direct involvement. So this type of events make easier to coordinate later on specific consultation processes such as stakeholder meetings/workshops/seminars.

Figure 4.1 *– Public meeting in Naples in April 2015*.

4.3.3 In-depth interviews

In September of 2015, 5 months after the public event, our group (Universitat Autonoma de Barcelona) started a series of in-depth interviews (Fig. 4.2) with a subset of the stakeholders individuated in the previous steps. For targeted consultations like in-depth interview it is important to select a limited number of participants. So we included among the contacted people only one representative per organization/per competent authority following the rules included in the stakeholder consultation guidelines of the European Commission. The list of interviewed stakeholders is reported in Tab. 4.2. It is important to notice that it was easy for us to contact these people, who accepted to take part in the interview, because of the preliminary work done by the Parthenope University that established a friendly relation with them. Otherwise, especially when dealing with busy and important people, it is not sure that the strategy of in-depth interview will result always effective.

Figure 4.2 *- In-depth interviews carried out in Naples in September 2015.*

Table 4.2 - *List of relevant stakeholders interviewed in September 2015*

Item	Institution/Association	Surname	Name	Role
1	Comune di Napoli	Del Giudice	Raffaele	Environmental Councilor
2	Ufficio Autorità Ambientale - Regione Campania	Risi	Antonio	Manager
3	ARPAC (2 interviewed)	Marro Grosso	Claudio Alberto	Manager Technician
4	ASIA	Stanganelli	Paolo	Operations Manager
5	ASIA	Iodice	Gianfranco	Manager Local Services
6	Regione Campania	Rampone	Michele	Technician
7	Città Metropolitana di Napoli	Cozzolino	Giuseppe	Manager
8	Cittadini Campani per un Piano Alternativo dei Rifiuti (2 interviewed)	Righetti Martuscelli	Lucio Annamaria	Leaders Activists
9	Hotel/Restaurant Zero Waste/ Zero Waste Campania	Esposito	Antonino	Coordinator
10	Lets do It! Italy	Capasso	Vincenzo	Activist/ Coordinator
11	Rete Commons (Defense against Acerra incinerator)	Kaiser	Serena	Activist

A protocol for the interviews has been elaborated and 11 interviews (9 individual and 2 with 2 actors together) have been carried out. The protocols of the interviews and the notes reporting the answers received in the interviews are available in Appendix. Each interview took around 45/60 minutes.

The interview were organized in four parts:

PART 1 – was a short introduction presenting the team of interviewers (including the institutions), giving a brief overview of the MARSS Project (financing the survey) and explaining goals and giving an estimate of the expected duration time of the interview.

PART 2 – was a guided discussion of issues related to MSWMS in Naples (exploring the narratives). Depending on the typology of the interviewed (a politician, an administrator, an activist, etc.) the discussion was tackling different aspects:

(1) specificity of Naples – individuating the main factors determining the past crisis and actual situation;

(2) urgency of action - asking to rank different potential problems: (i) economic costs not sustainable, (ii) health and environmental impact, (iii) damage to the image of the city (negative impacts on tourism or agriculture), (iv) damage to social cohesion, weakening institutions);

(3) governance and power relations among the actors involved – asking to comment on the influence of EU regulations, Italian State, Campania Region, Province/Metropolitan Area, the Municipality, powerful lobbies, privates, organized crime, NGOs;

(4) economic view of MSWMS as whole (big picture) - asking to assess the approximate profile of economic flows (fixed and circulating money expenditures) and employment over the different functional sectors of the MSWMS. This was an important point used to check the level of understanding of the nexus between economic, technical and ecological variables.

PART 3 – was more focused on the representation of the situation. The idea was to check the quality of the choice of: (i) criteria and performance indicators; (ii) representation of the MSWMS; (3) the alternatives to be explored in the option space - the choice of the set of technical options to be included in the integrated assessment of policies. More specifically:

(1) In relation to criteria and indicators of performance the questions were about: (i) the quality of the service for the citizens (e.g. costs, convenience); (ii) the effect on the health and the environment; the socio-economic effect of changes in the MSWMS (employment, money remaining in the community, etc.); (iii) the economic performance of the MSWMS (taking into account that the performance depends from the observer);

(2) In relation to the technical quality of the representation of the network the questions were about: (i) the validity of the proposed scheme made of functional and structural units and the quantitative data on waste flows; (ii) the proposed guesstimates of the “value” and “revenue” of the recyclable fractions such as metals, plastics, glass and paper and also the real utility of other potential valuable outflows like compost, biogas, digestate and other fuels and their local and external demand; (iii) the proposed characterization of the main environmental problems such as gaseous emissions (dioxins, furans), percolates, and heavy metal concentration.

(3) In relation to the choice and assessment of alternatives, essential in order to be able to tailor the integrated characterization of the chosen alternatives, we asked the interviewed to comment – e.g. discuss pros and cons - about different strategies that can be used to describe what should be done in Naples about the existing situation with the MSWMS:

- Strategy A – “revolutions do not work”: the current MSWMS needs just to be patched and improved;
- Strategy B – “radical technological change is the solution”: the current MSWMS needs the introduction of technological innovations in order to eliminate bottlenecks;
- Strategy C – “change in governance system is needed”: the waste crisis in Naples should be used as an opportunity to build a better system of governance since adopting improved technology will not change the situation.

The discussion of this part was closed asking the interviewer’s personal opinion about the possible solutions to adopt to improve the situation of the waste management in Naples.

PART 4 – represented an open space in which the interviewer at the end of the walk through the 3 parts was asked to provide her/his ideas in the form of a brain-storming. Any type of feed-back was welcome: feelings, suggestions, criticisms and any type of comments.

Before closing the interview we checked the availability of the person to get involved in additional participatory processes (e.g. the mini-DELPHI for the technicians and a possible focus group of public event for all the interviewed).

4.3.4 Mini-DELPHI exercise

In October 2015 a DELPHI exercise (Fig. 4.3) – for details see DELPHI method see (Dalkey & Helmer 1963); Linstone and Turoff, (1975)) – consists to have an iterative set of interviews/interactions with experts with the goal of generating a convergence on an assessment that is based on personal expertise, or in the case of irreducible differences of opinion to identify where the opinions of experts bifurcate about an issue, looking at the reason of the disagreement among them. There have been many cases when the Delphi method produced poor results (Helmer, 1994; Linstone and Turoff, 2011; Rowe and Wright, 2011) - weak results or even lack of results due to the unavailability of the experts in responding to questionnaires (this problem is especially important when the questionnaires are send via mail). Therefore, in order to make the DELPHI exercise more effective, we decided for an adaptation of this technique for use in face-to-face meetings, which is called *mini-Delphi* or Estimate-Talk-Estimate (ETE) (Gustafson et al., 1973; Pan et al., 1996; Fischer, 1981). According to this method a panel of experts is primarily contacted by mail and then the received feedback is confirmed during in-person meetings. The list of interviewed stakeholders in this stage was slightly different from the one used during the in-depth interviews (see Tab. 4.3) because we focused this mini-Delphi only on people that could provide useful opinions about the quantitative representation of the MSWMS of Naples.

Figure 4.3 *- Mini- DELPHI exercise carried out in Naples in October 2015.*

Table 4.3 *- List of relevant stakeholders participating in the mini-Dephi survey in October 2015*

Item	**Institution/Association**	**Surname**	**Name**	**Role**
1	Comune di Napoli	Del Giudice	Raffaele	Environmental Councilor
2	SAPNA	Martina	Vaccariello	Technician
3	Ufficio Autorità Ambientale - Regione Campania	Risi	Antonio	Manager
4	ARPAC	De Palma	Giuseppe	Technician
5	ARPAC	Grosso	Alberto	Technician
6	ARPAC	Marro	Claudio	Manager
7	Regione Campania	Rampone	Michele	Responsabile
8	ASIA	Stanganelli	Paolo	
9	ASIA	Iodice	Gianfranco	Responsabile Servizi Territoriali
10	Hotel/Restaurant Zero Waste/ Zero Waste Campania	Esposito	Antonino	Coordinator
11	Lets do It! Italy	Capasso	Antonio	Activist/Coordinator

The experts participating in the mini-Delphi survey have been asked to give their own assessments in relation to: (i) network flows (quantitative material flows in the different nodes of the system) (Fig. 4.4); (ii) degree of openness of the system (quantitative material flows going outside of the MAN: to Campania region, to other Italian regions or abroad) (Fig. 4.5); (iii) an overview of the costs of the whole

MSWMS (large scale picture) and its breakdown over the different functional sectors (Fig. 4.6); (iv) specific assessments of the costs for the treatment of waste in the different functional nodes (small scale picture) within the MSWMS (Fig. 4.7).

We also asked the interviewed to provide detailed information about the performance of the MSWMS of the MAN using an excel file that we provided through e-mail. The excel file we sent is structured in eight sheets one for each functional node of the network: collection, presorting transfer and storage platforms, recycling, mechanical-biological treatment, anaerobic digestion, composting, incineration and landfill. Then within each sheet there are different sections related to the requirements of the node in terms of biophysical funds (employment, machineries, occupied land), biophysical flows (electricity, fuel, process heat, water), and economic variables (fixed and running costs and revenues for electricity production, subsidies and selling of recyclables). The objective of this data sheet was to gather a more robust input of information about technical coefficients and indicators characterizing the performance of the MSWMS.

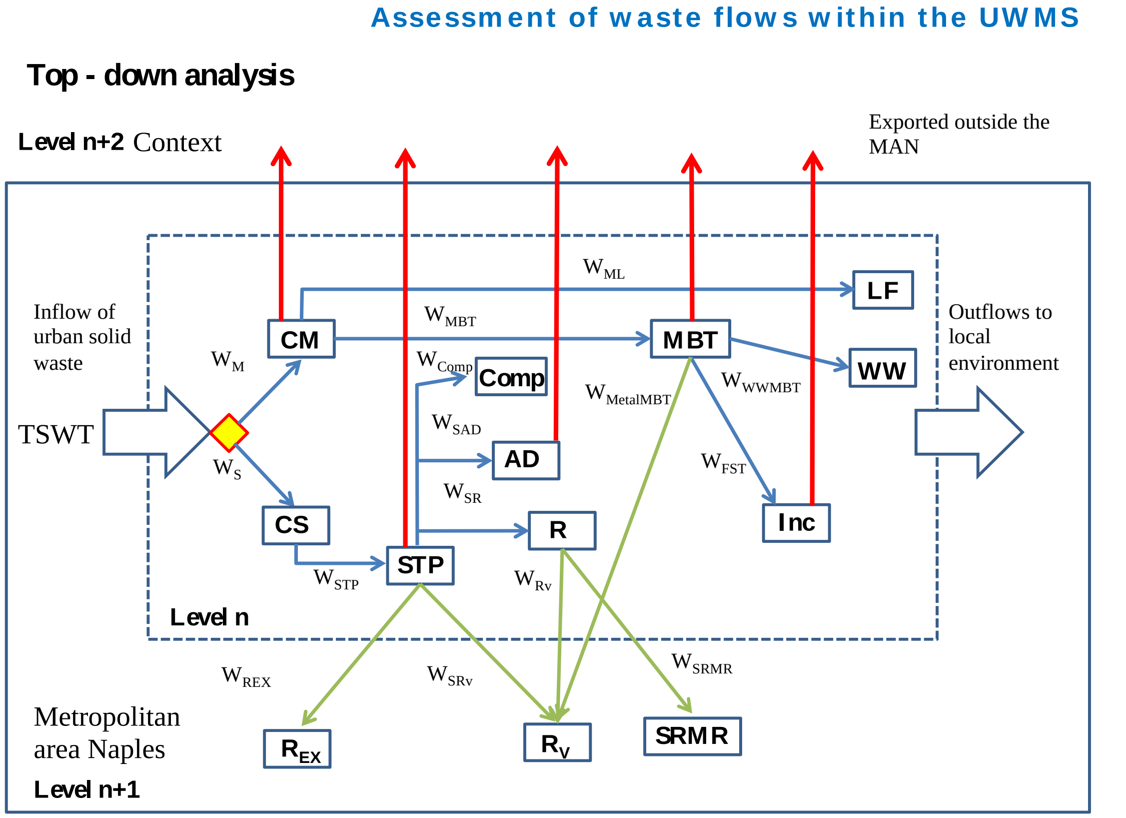


Figure 4.4 *- Diagram used to receive feedback from experts to assess yearly urban waste flows within the MSWMS of MAN.*

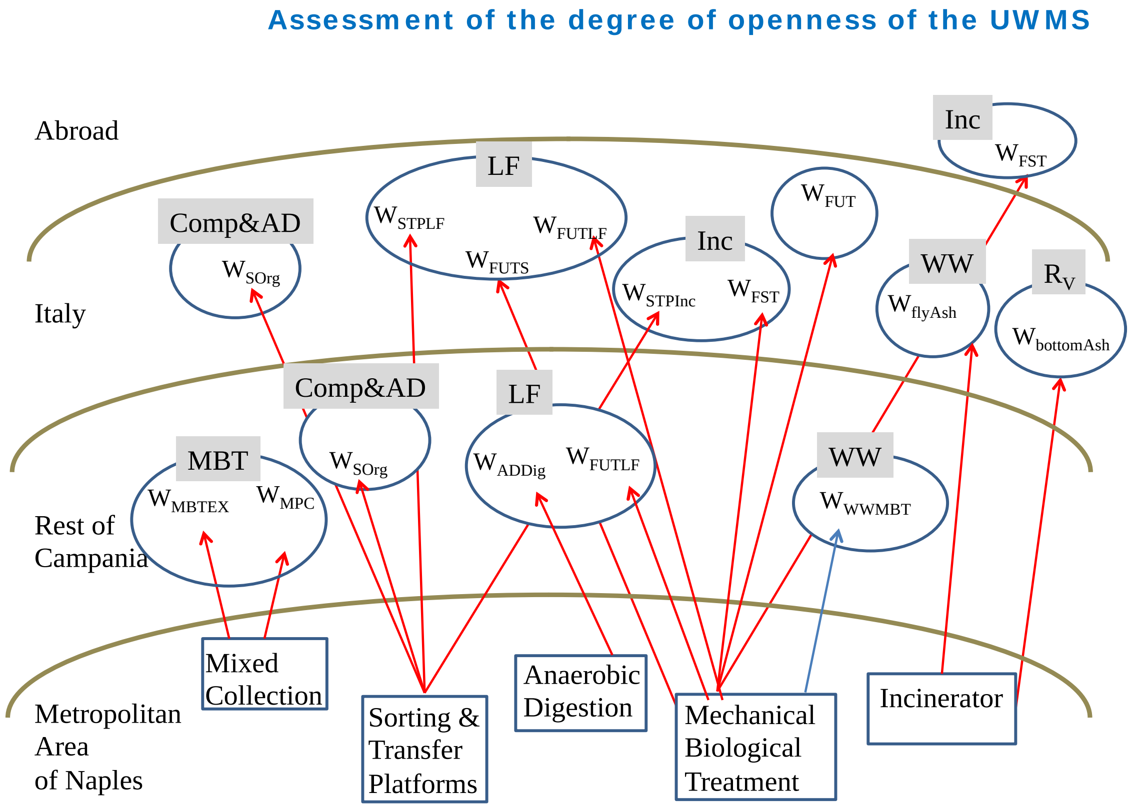


Figure 4.5 *- Diagram used to receive feedback from experts to assess the degree of openness of the MSWMS of the MAN.*

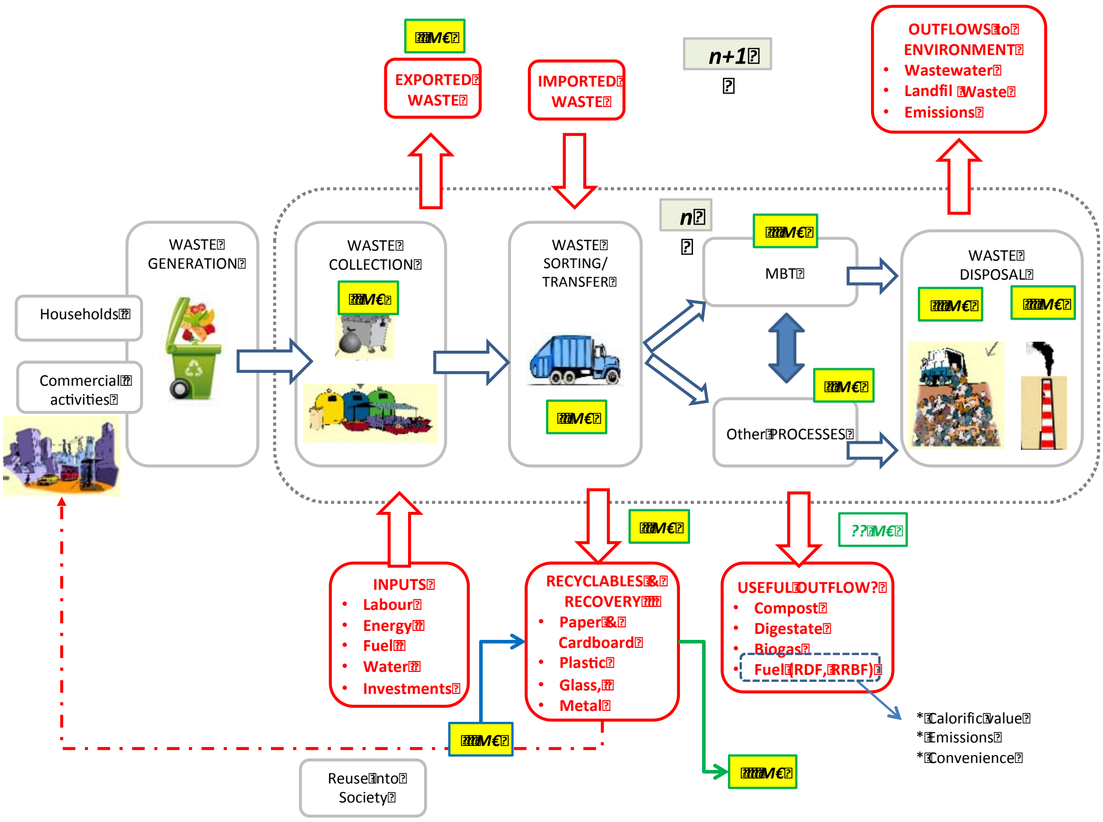


__Figure 4.6__ - Diagram used to receive feedback from experts to assess costs per functional phase of the MSWMS of the MAN.

Compartments of Waste Management System	Proposed Assessment			Assessment proposed by Expert		
	€/ton	kton	M€	€/ton	kton	M€
Waste Collection	200	1458	292			
Waste Transfer	20	1458	29			
Waste MBT_{IN}	150	828	124			
Waste Processing Tot_{IN}		109	-7			
Waste Processing Organic IN	55	19	1			
Recycling Dried fractions		174	0			
Recycled fractions IN (Recycling Centers Gate)	-140	90	-13			
Recycled fractions IN (Recycling Centers Entrance)	-90	90	-8			
Waste Disposal total		406	22			
Waste Landfill	90	32	3			
Waste Inceneration	50	374	19			
Waste exported		798	129			
SC Organic Waste exported		199	33			
to other Italian regions	170	176	30			
to Campania	140	23	3			
SC Dried Waste exported		75	16			
to other Italian regions	160	43	7			
to Campania	140	65	9			
Other Waste		485	76			
to other Italian regions	160	382	61			
to Campania	140	103	14			
Waste exported abroad (boat)	105	39	4			

__Figure 4.7__ - Diagram used to receive feedback from experts to assess treatment costs of the different waste flows within the MSWMS of the MAN.

For this exercise, we sent to the experts diagrams, slides and tables both "with data" based on our estimates and "without data" (looking for their estimates) asking to:

(i) correct our estimates if they were considered not appropriate;

(ii) provide their personal quantitative analysis, explaining the reasons of eventual differences;

(iii) individuate missing assessments needed to have a more complete vision of the system;

(iv) provide any feed-back considered useful to improve the proposed assessment.

4.3.4 NAIADE application

The last application requiring an input from stakeholders was related to the NAIADE approach. NAIADE (Novel-Approach-Imprecise-Assessment-And-Decision-Environments) is a multi-criteria analysis tool developed by Giuseppe Munda in the form of interactive software. The software is open access and can be downloaded at the site: NAIADE Software. NAIADE it is an interesting tool to organize the information generated in participatory processes, because it can provide the following features: (i) ranking of the alternatives according to a set of criteria of performance (i.e. technical compromise solutions described using an impact matrix); (ii) indicating the distance of positions of the various interest groups (i.e. possibilities of convergence of interests or coalition formations); and (iii) ranking of the alternatives according to actors' impacts or preferences (social compromise solution using an equity matrix). In particular we were interested in the NAIADE module of coalition formation analysis that can be used for conflict analysis. This particular feature of the tool has been implied in this thesis with the goal to check whether the characterization of the performance of new technologies (e.g. the MARRS plant studied in the MARSS project) could have a significant impact in reducing the conflicts over waste management.

The inputs for the NAIADE application were obtained during the in-depth interviews (a few questions had the goal to gather this input). The analysis of the possibility of coalition formation (or in alternative of possibility of conflicts) starts with the definition of an Equity Matrix. An equity matrix describe in relation to the chosen set of alternatives "winners" and "losers" for each alternative on the basis of social actors' preferences. That is the information making it possible to study the potential conflicting preferences found among relevant social actors has been obtained to fill the template illustrated in the Fig. 4.8.

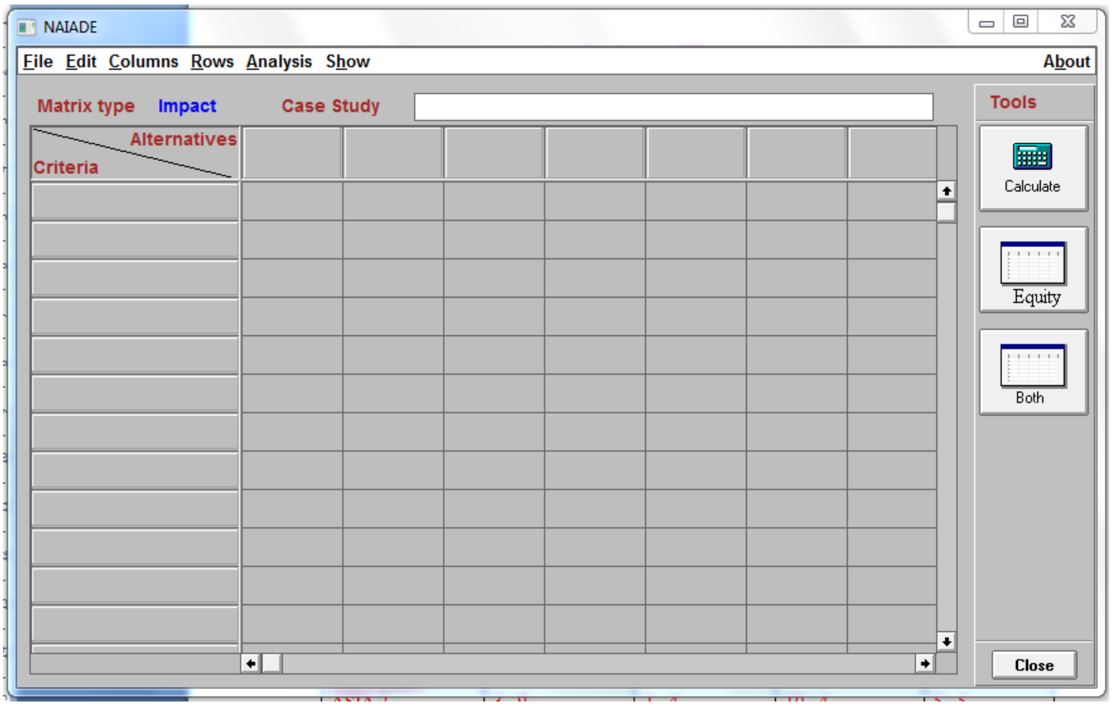


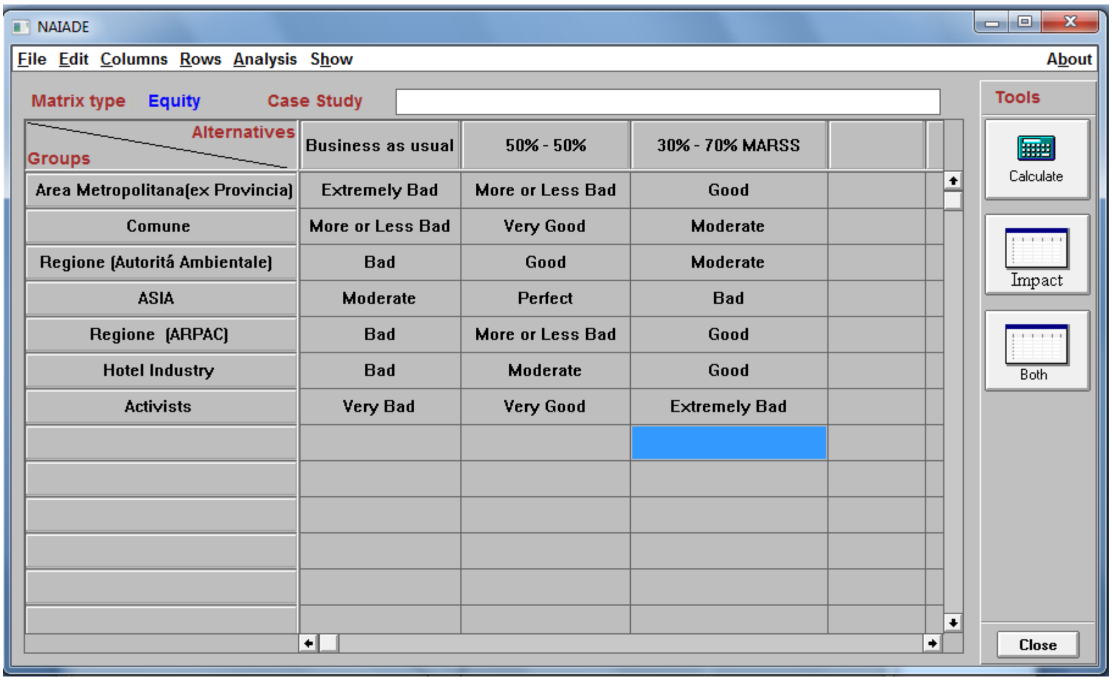
Figure 4.8 *- Selecting Alternatives and Criteria in NAIADE.*

The characterization of the equity matrix can be tailored on the specific problem of decision-making considering for example three different alternatives.

The options considered in the Naples case study: (i) Business as usual; (ii) increasing of separated collection to 50%; and (iii) 30% of separated collection and 70%

of unsorted waste sent to MARSS plant. The last option refers to the introduction of MARSS module[51] that is an innovative technology for processing and recycling municipal solid waste into a product that can be used as fuel in small CHP (Combined Heat and Power) plants.

The results coming out from the preliminary test done with NAIADE are shown in Fig. 4.9 (equity matrix) and Fig. 4.10 (potential coalitions among the social actors).



Groups \ Alternatives	Business as usual	50% - 50%	30% - 70% MARSS
Area Metropolitana(ex Provincia)	Extremely Bad	More or Less Bad	Good
Comune	More or Less Bad	Very Good	Moderate
Regione (Autoritá Ambientale)	Bad	Good	Moderate
ASIA	Moderate	Perfect	Bad
Regione (ARPAC)	Bad	More or Less Bad	Good
Hotel Industry	Bad	Moderate	Good
Activists	Very Bad	Very Good	Extremely Bad

Figure 4.9 - *Equity Matrix Alternatives vs Groups (relevant actors): preliminary test.*

[51] MARSS plant is a utility that processes the output material from MBT plant through a series of cleaning and recovery steps to remove the heavy materials, other contaminants such as metals (ferrous and non-ferrous), stones, glass and plastics in order to produce a quality biogenic solid dry fuel identified as a Refuse Recovered Biomass Fuel (RRBF) (for details see http://www.marss.rwth-aachen.de/cms/front_content.php?idcat=1&lang=2&changelang=2).

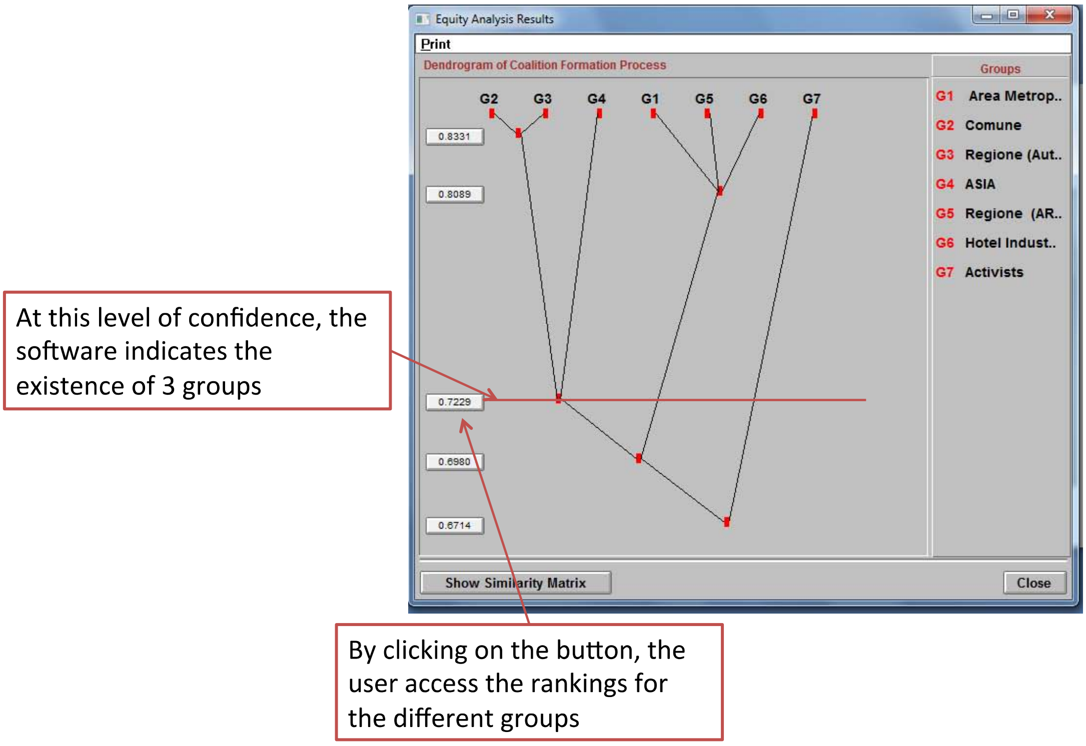


Figure 4.10 - *Dendrogram of Coalition in NAIADE program.*

The different features of NAIADE can be used to carry out a series of sophisticated analysis – e.g. Fig. 4.11 - in the case there are different opinions about the alternatives among the considered set of stakeholders. The software can calculate different rankings in relation to different choices of indicators and weighting factors. The differences between the coefficients (indirectly) indicate the intensity of preference between alternatives for the groups.

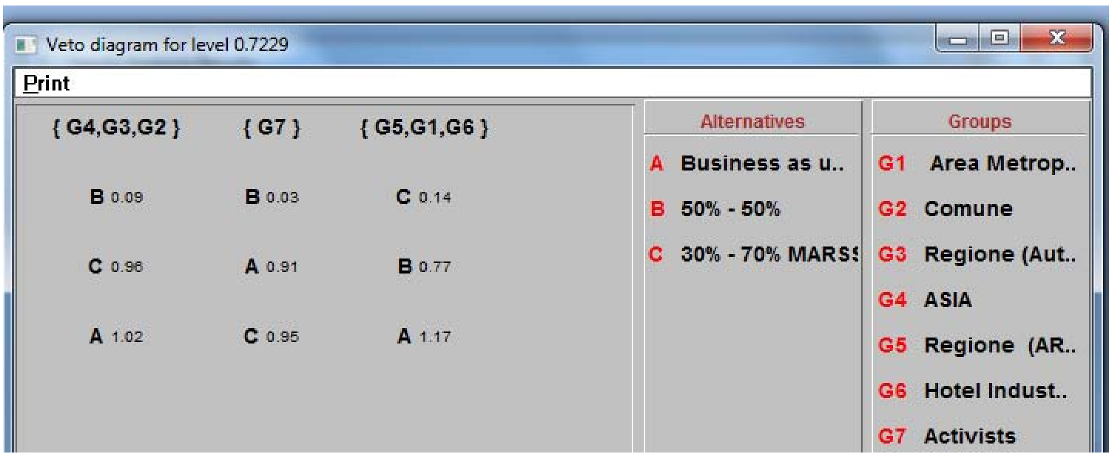


Figure 4.11 - *Ranking coefficients build by NAIADE representing the intensity of preference between alternatives among the groups.*

For example, in the theoretical example given in Fig. 4.11 if two groups were in favor of alternative B (50-50%), and one group of actors were in favor of alternative C (30%-70% MARSS) we could conclude that the alternative B is the less conflictive.

However, in our real application in the case study of Naples, these features of the NAIADE software resulted not particularly relevant. In fact, according to the feedback received, the three alternatives considered did not generate a situation requiring a sophisticated Multi-Criteria Analysis: (i) the Business As Usual is considered not acceptable according to all the groups of stakeholders, it is not an option; (ii) any increase in the level of burning of wastes (the MARSS solution) also is not an option, because it is considered as not acceptable by all groups; therefore basically only one of the three options (iii) increasing the separate collection, is acceptable according to the preferences of all the social actors interviewed.

Results of the application of the software NAIADE to the case of Naples (using the inputs gathered in the in-depth interviews) are presented in Tab. 4.4. The urgency of the action has been ranked from 1 to 10 according to 4 potential issues (economic cost not sustainable; health and environmental impact; negative effect on tourism; damage to social cohesion).

Test done in preparation for NAIADE
Naples, 16, 17, 18 September, 2015

Perception of urgency of action

Actors	Economic cost	Health Environment	Side effect Tourism	Social cohesion
Metropolitan Area of Naples (ex Province)	6	9 Politician	9	8
Comune	n.a.	n.a.	n.a.	n.a.
Regione (Autoritá Ambientale) (2 interviewed separately)	10 - 3	5 - 3 Technician	3 - 5	5 - 3
ASIA (2 interviewed separately)	3 - 9	1 - 4	10 - 4	5 - 5
Regione (ARPAC) (2 interviewed together)	9 - 10	9 - 10	10 - 10	7 - 7
Hotel Industry	8	8	10	8
Different Activists 3 (3 interviewed separately)	3 – 6 - 7	6 – 10 - 10 Activists	8 – 8 - 7	10 – 9 - 9

Interviewed Separated

Interviewed Together

It is interesting to underline that the opinions of experts working in the same organization result similar when they are interviewed together while the results become more divergent when the interviewed people are not interviewed together (see example of ASIA and ARPAC in Tab.4.4). The results shown in Tab. 4.4 indicate also the differences between Politician, Technician and Activists (in red).

The equity matrix that represents the attitude toward the proposed alternatives is shown in Tab. 4.5.

Table 4.5 *- Test done on the attitude toward proposed technological solutions in preparation for NAIADE in Naples (September 2015).*

Attitude toward proposed technological solutions

Actors	Business As Usual	50% - 50%	30% - 70% MARSS
Metropolitan Area of Naples (ex Province)	0	9	0
Comune	3	9	0
Regione (Autoritá Ambientale) (2 interviewed separately)	2	9	0
ASIA (2 interviewed separately)	3 - 5	9 - 9	0 - 1
Regione (ARPAC) (2 interviewed together)	2 - 2	9 - 9	0 - 0
Hotel Industry	2	9	0
Activists (3 interviewed separately)	2 - 0 - 0	9 - 9 - 9	0 - 0 - 0

As already explained in plain English previously, in this equity matrix there is a total dominance of one of the alternatives - the 50%/50% - over the others. This implies that the "Business as Usual" and "the MARSS option" are no longer relevant when considering the NAIADE approach. These results made the application of the NAIADE software useless and confirmed the decision of using a different approach for the organization of the quantitative characterization to be used in the decision support (see Fig. 1.2 in Chapter I).

4.4 Reflections on the results obtained in these participatory processes

4.4.1 The individuation of different sets of indicators of performance relevant for different categories of stakeholders: quantitative story-telling

The first reflection on the lesson learned in the participatory processes carried out in the MARSS project is that different actors interviewed during the consultations have defined as relevant different types of indicators. This may seem trivial but it is a very important reflection. In fact the classic solution adopted in Multi-Criteria Analysis is to mix all the indicators considered as relevant together in a multicriteria performance space. The presentation of the quantitative representation based on a common pool of indicators can take two forms: (i) impact matrix – where the different criteria and indicators are listed in the first column on the left and define the accounting category of the values in the correspondent row; (ii) multicriteria performance space - a graphical representation of indicators with targets – the classical radar diagram used to characterize the performance in relation to the values taken by a set of indicators described as axes coming out of a common origin.

There is a third method of visualization based on a set of indicators that has been proposed for carrying out a different approach to the integrated assessment: Quantitative Story-Telling (Saltelli et al. 2016). In the rationale of Quantitative Story-Telling the indicators of performance are grouped into different sets that are relevant for specific Story-Tellers [= those that will use the indicators for guiding their action and that therefore are the ones having a legitimate say on the usefulness of the choice]. In the example illustrated in Fig. 4.9 the indicators suggested by the stakeholders in the participatory processes are organized over 4 sets reflecting the existence of different story-telling: (i) Waste management costs for the administration; (ii) Waste management as an opportunity for local development; (iii) Waste management performance for citizens; (iv) Waste management as a threat for the environment.

Obviously not all the categories of social actors do consider all these indicators relevant for guiding their action. For example, an entrepreneur not necessary uses in her/his decision space the criterion of "threat to the environment" or the "minimization of the management costs for the administration". In a developed country policies and regulations – outside of the competence domain of the entrepreneur - should be in place to guarantee the protection of the environment and the good management of the administration. Therefore if the entrepreneur respects the laws and the regulations she/he does not need to be worried about these criteria of performance that should be considered as relevant by other actors. For this reason, the organization of relevant indicators in sets referring to different story-telling helps in clarifying the domain of competence of the different actors. At the same time it also helps to individuate the natural occurrence of conflicting criteria of local optimization within non-equivalent story-telling.

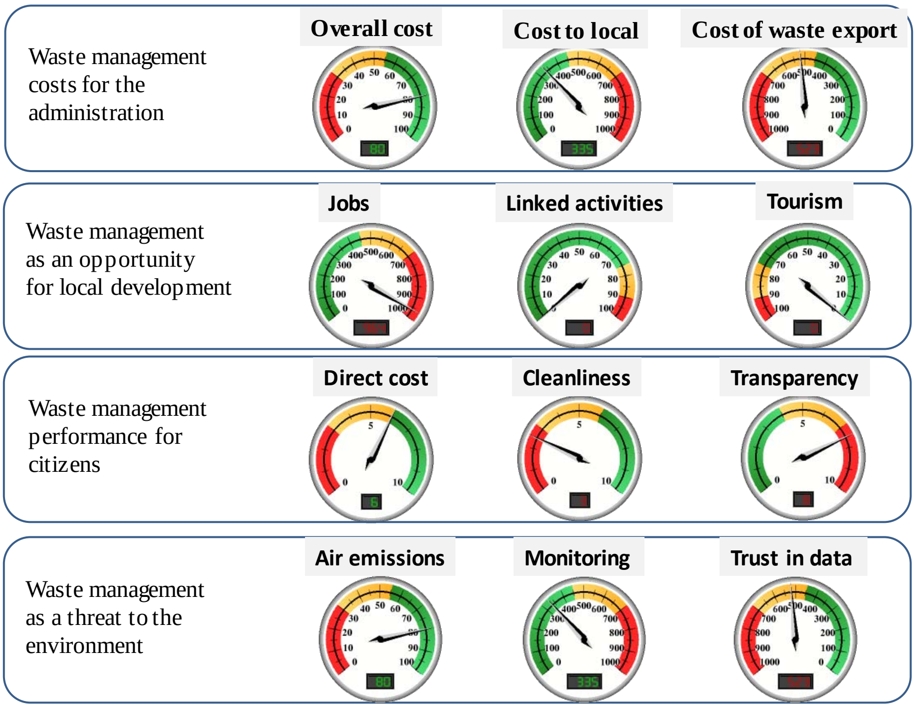


Figure 4.12 *- Relevant indicators of performance for story-telling suggested by various stakeholders in the MAN (values indicated are fictive).*

It should be noted that the example with dashboard in Fig. 4.12 has only the scope to illustrate two features of this visualization: (i) the relevant criteria are included in sets referring to specific story-telling; (ii) colored targets (good is green, medium is yellow, bad is red) are used to give meaning to the values of the indicator. If the dashboards shown in Fig. 4.12 are not presenting real assessments, examples of dashboards with real data have been presented in Fig. 2.14 (Chapter II of this thesis).

The fact that different agents operating at different scales and hierarchical levels follow different strategies implies that they will adopt different story-telling to assess the performance of MSWMS. If we accept this fact then we can also accept that it is impossible to individuate "the best strategy" of waste management and "the best combination of technologies" using mathematical models. The co-existence of different criteria of performance implies not only the co-existence of contrasting definitions of performance over the chosen indicators but also the co-existence of winners and losers among social actors when policies are made. When dealing with participatory integrated assessment in the field of science for governance we can no longer assume that science can predict and control and indicate best courses of action (Pereira and Funtowicz, 2014; Benassia et al. 2016).

For example during the in-depth interview "increasing the number of jobs" (something good for the unemployed) was associated with "increasing the costs of operations" (something bad for the administrator struggling against shrinking budgets). In the same way, "reducing the impact of emissions on the environment" (something good for the environment) using more sophisticated scrubbers and filters was associated with "increasing the cost of operations" (something bad for the operator). For this reason, participatory integrated assessment are needed not only when generating the issue definition and the integrated characterization, but also in the following process of deliberation in which the different indicators and relative story-telling have to be confronted and integrated with each other.

4.4.2 Naples is a special case of MSWMS

The second reflection is that Naples is without any doubt a "special case". The waste mismanagement in Naples has been characterized by illegality, inefficiency, irresponsibility and indecision for too many years. Now it is a phenomenon that would require a much more complex set of analyses and solution than the one provided by the official decision-making bodies (D'Alisa et al. 2015). For example, mistrust about the quality of decision making can be found also in other places inside and outside Italy - everywhere politicians are not trusted blindly. However, the issue of mistrust is really important in the area of study. Past corruption at the local and national level has made possible the dumping of imported industrial wastes (including toxic wastes) in the area together with bad technological investments that wasted important economic resources without solving local problems (see also D'Alisa et al., 2010). According to the activists we interviewed the installation of an incinerator in Acerra (in the MAN) is only one example of inappropriate technological solution in a land already suffering from illegal dumping.

As a result of this history, trust between local inhabitants and the government has been considerably damaged. This was reflected in the results of our interviews: this lack of legitimacy of the process of decision-making about MSWMS emerged as a crucial problem. In fact, environmental activists and representatives of the Neapolitan citizens were not particularly concerned with the specific choice of environmental impact indicators. Rather their principal concern was that the lack of transparency and distrust in organizations in charge for environmental monitoring was making irrelevant any discussion about how to select a set of effective environmental indicators (see Fig. 4.12).

4.4.3 One should be aware of the co-existence of different story-telling

The third reflection is about the divide in terms of perceptions and endorsement of different story-telling between the "experts" and the "decision makers" and the rest of the society. All technicians working in the Municipal Solid Waste Management System of Naples claim that the system works reasonably well now. They say "We had a serious crisis in the past but now it is over" and "illegal dumping of toxic and special wastes has come to a stop" and also that "the MSWMS of Naples does not pose any threat to human health". On the contrary almost all the activists and general public still believe that the situation is totally out of control with serious implications for human health. According to the perception of the local residents, the sink capacity of the environment around Naples should be considered saturated and additional sources of emissions or dumping sites should be moved outside the area.

Also in this case, the different perceptions are generated by a systemic confusion in the definition of the problem. The interviewed experts do not deny problems with human health. But what they say is that the problems with human health are mainly linked to the illegal dumping of toxic and special wastes, *something that they consider unrelated to the current operations of the MSWMS of the city*. Clearly this lack of the big picture in the semantic framing of the issue does not help the communications among different groups. For example, recently newspapers reported the existence of new illicit toxic waste dumping areas and this information is in total contrast with the "waste management is no longer a critical issue" statement, even if the statement in the narrative of the administration is correct.

Given these circumstances, waste management in Naples represents a 'special', time and space-specific situation and, consequently, decision-making in municipal solid waste management in Naples cannot be handled in the same way as in 'any other city'. Waste situation in Naples is a "specific hot spot" that cannot be simply described or explained by theoretical and empirical models or analyses based on conventional waste indicators as if it were just another Italian city (Amato et al., 2014; Mazzanti et al., 2009; D'Alisa et al., 2012). This fact supports the claim that an integrated assessment of the performance of MSWMS requires always the three-step process indicated in Fig. 1.2.

4.4.4 A more holistic vision of the issue is required

Another important finding coming out from interviews is that, surprisingly, both people working in the waste management sector and public officers deciding about waste management policies are unable to "quantify" the "big picture" of the MSWMS. In fact, when asked almost nobody could assess the overall cost of operation of the whole system, let alone assess the profile of costs for the different operations in aggregate terms. Some of interviewed had an excellent knowledge of data "per ton" of waste, or good data for the specific process they are dealing with, but when asked to assess the relative size of the different operations within the "big picture" – including operations that they do not control - they could not provide such an information. To make things worse, different experts assess the same costs – e.g. the cost for handling a specific flow - in different ways. Because of this fact, very often even informed people use numbers that "do not talk to each other". For example, after asking three different experts in Naples about the value of recycled materials we got three quite different assessments: (i) 9 M€ - this is the money the public operator gets by selling them; (ii) 15 M€ - this is the money that private operators get selling the same materials after further treatment; 40 M€ - this is the overall amount of money obtained by selling recycled material including also industrial waste (another flow not included in the analysis of the MSWMS). In this example, the three experts were perfectly competent and provided a very reliable assessment. The problem is represented by the fact that they were using different definitions of what was assessed, mixing apples and oranges. For this reason, some of them were questioning the competence of the others (since they were working in different organizations). Moreover, even when it is possible to obtain an agreement over the numbers – e.g. "this flow has a handling cost of 180€/ton, this other flow costs 90€/ton" - the assessments used by experts are based on the existing situation. If one imagines a scenario in which the activities carried out in the various waste management phases are different because of new technologies or in which the relative sizes of the activities change (e.g., because of a change in the percentage of separate collection) these assessments may become completely useless to estimate the resulting new profile of costs. Also in this case this reflection confirms the importance to have a more holistic vision of the relations of the characteristics of individual plants, functional nodes, level of openness, the whole MSWMS.

4.5 The problems with the second round of DELPHI and the test of the decision support tool

In the original plan we had envisioned a second DELPHI integrated with another public event having the goal to test the possible use of the analytical tool presented in Chapter III as decision support for characterizing and discussing policies about UWM in MAN. The visualization of the decision support capable of simulating management alternatives and generate integrated set of indicators has been developed by Ansel Renner a student of the UAB group that created an ad-hoc software making easier to carry out the procedure proposed in Fig. 1.2 (Chapter I). This tool adopts a system of visualization of the indicators of performance based on the concept of quantitative story-telling. In fact, it can generate different sets of indicators of performance organized in a way that reflects the existence of different "perceptions and narratives" that can be associated with different typologies of social actor.

An example of the working of the software is shown in Fig. 4.13.

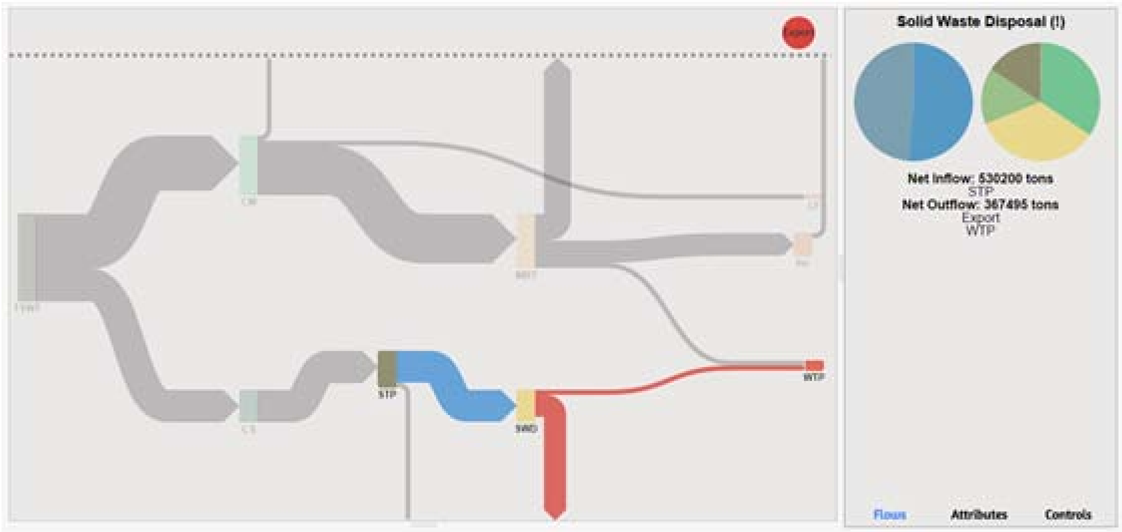


Figure 4.13 - *Example of screenshot of the ad-hoc software*.

The full video can be watched at: Decision support tool for local authorities. The analysis starts with a provisional definition of network topology. In this case, this topology is the one of the Metropolitan Area of Naples waste system presented in Chapter III. Then using the software it becomes possible to change the definition of nodes (for example Solid Waste Disposal groups Recycling and Anaerobic Digestion) within the set of relations over nodes a node can be split into two. The mix and the type of technologies used within a functional node can also be changed. For example, the mechanical-biological treatment node for Naples – a functional node – is at the moment guaranteed by the activity of three plants - two plants of type 'alpha' and one plant of type 'beta'. Each of these plants receives roughly one third of the node's inflow. The technical attributes associated with each these three plants (technical coefficients) are intensive variables, such as energy consumption per tonne of waste processed or methane production per tonne of waste processes. Then these technical attributes are scaled by the quantity of waste directed at that particular plant (depending on the tonnes processed). This feature is important because when in different scenarios it is assumed that flows are changed or re-directed, with this software it becomes possible to assess the impact the consequences that these redirections have on our system: (i) either the processing capacity of a node will be under-utilized when the inflow is below the existing processing capacity; (ii) either waste flows will have to be exported when the inflow exceeds the available processing capacity (with consequent increase in the costs); or (iii) either new processing capacity (requiring more fixed and circulating costs) will be required when in order to avoid exports, it is necessary to match a larger inflow.

Links directed to the diagram peripheries represent waste export. Selecting a node highlights inflows, in blue, outflows, in red, and draws a heads-up display summary of these links. Pie charts allow one to easily interpret proportionally where flows are coming from or going to.

As presented in Chapter III of this dissertation, a characterization of the current situation and a simulation of two possible scenarios have been elaborated using this software: (i) increasing recycling collection and (ii) the complete internalization of waste processing. In the original plan, these two preliminary applications had to be used in a focus group with stakeholders involved in the in-depth interviews and in the mini-DELPHI exercise to illustrate the potentiality of the approach and also to gather additional suggestions on how to improve the quality of the decision support.

However, after entering in the final phase of the participatory process the response of the group of social actors became more and more weak and sporadic, to a point that it became impossible to manage to schedule a meeting in Naples to present our decision support tool. It should be noted that this cooling down of the interest in our project was also due to the period of political campaign that in those months took place for the election of the new mayor in Naples. Needless to say, that since the waste issue is politically very relevant there, getting involved in an open discussion and analyses of the problems and failures of the MSWMS in Naples was not considered as appealing.

Our last attempt to get feedbacks from relevant actors was the elaboration of a video[52] illustrating the decision support tool in action. Again it should be stressed that the quantitative assessments shown in the video are not presenting the results of an actual participatory integrated assessment (the action we wanted to take). Rather, the video presenting the simulations has been generated for illustrating the potentiality of the tool. A real test would have required the involvement of the experts in additional participatory processes in which social actors could play with the software in order to generate a better-informed discussion of the viability and desirability of municipal solid waste management options.

Even after the video was subtitled in Italian[53] - to make easier the comprehension of the decision support tool for those non understanding English - and sent to all the actors involved, we did no received relevant feedbacks. In relation to this point, a last reflection can be done about the difficult use of this type of tools that have as a feature to be extremely transparent in relation to the analysis they provide. For example, looking at the characteristics of the processes at the nodes, one can note that the number of workers in some of the plants operating in Naples is more than the double of the number of workers in similar plants operating in other cities of Italy. Many other anomalies of this type can be individuated when looking at the multi-scale analysis. Probably, under elections nobody wanted to go "on record" providing comments or opinions about what should be changed and how in the actual operations of MSWMS.

For sure the rest of the UAB team and I working in the MARSS project have been very naïve in expecting that politicians, administrators and top-experts would participate in an explicit discussions of these topics organized by a foreign University (the Autonoma University of Barcelona) on which they do not have any control. For this

[52]Link to the video in English
https://www.dropbox.com/s/8eq9el3pc1opxt2/marss%20video%20v2.wmv?dl=0
[53]Link to the video subtitled in Italian:
https://drive.google.com/file/d/0BwWfHRapQnlUSWtfNlJ0OXRkdEk/view?usp=drive_web

reason the lesson learned is that when trying to use these new tools in actual processes of decision making it is essential to address the political and the institutional constraints. An alternative complication has been generated by the fact that these processes are still considered as "news" and therefore potentially dangerous for the establishment (especially in the South of Europe and in critical spots such as Naples). Hopefully, in the future when this new approach to science for governance will be adopted on large scale, it will be easy to achieve the results that we tried to achieve.

4.6 Conclusions

The experience done with participatory processes confirms that involving local stakeholders in a Participatory Integrated Assessment is essential for obtaining a more robust analysis and a better informed discussion of the local waste management system. Thanks to the collaboration with local experts the representation based on the concept of metabolic networks has been implemented and it was possible to associate to the various nodes a reliable characterization of specific requirement of production factors for each process.

A holistic methodology has the advantage to present a comprehensive vision, overcoming the main limitations that are generally found in analysis based on reductionism. Generally, stakeholders are processing information relevant for their specific competences, missing the "big picture". For this reason, it is required an integrated assessment capable of exploring the option space by falsifying narratives such as: (i) individuating solutions that are not possible; (ii) providing a richer understanding of the consequences implied by adopting a given solution: (iii) considering the kind of adjustments that would be required to implement the chosen policies. In is way, it becomes possible for the social actors to check the quality of the narratives used in the process of deliberation. When a simulation shows that a narrative is unrealistic, they have to improve the models referring to it, or they have to find new reasons for defending a narrative that has been shown to have negative implications (Popper 2002). An inability to do develop defendable models or defendable reasons associated with a narrative a red indicates that that narrative should not be used in the discussion of a given policy. Additionally, the integrated assessment of the results of the simulations urges policymakers to acknowledge the unavoidable existence of trade-offs (that translates into winners and losers) inherent to any decision - a presently unfavorable practice in politics and one which services fragile narratives (Latour 1987).

On the other hand, if used without the necessary quality check a decision support of this type could also be used to legitimize a partisan narrative. For this reason it is imperative to maintain transparency in the way the tool is developed and used (Sarewitz 2000). Even more important is that this analytical tool is made available for its use to different social actors.

The proposed holistic tool-kit makes it possible to evaluate simultaneously three major aspects determining the quality of policies:

1. feasibility - the compatibility with the ecological constraints and the legislative framework (constraints outside the control of the agents operating in the MSWMS);
2. viability – the compatibility with socio-economic processes as well as the technical coefficients determining the metabolic network (constraints under the control of the agents operating in the MSWMS); and
3. desirability – the compatibility with the perspectives/values expressed by the involved social actors affecting and affected by the MSWMS.

The aspect of desirability makes the utilization of science for governance even more difficult. For example Neapolitan environmental activists and also epidemiologists in which they underline that even when the legislative limits for environmental emissions are respected, epidemiologic problems cannot be ruled out, due to unknown synergies among different effluents (Cantoni 2016).

The experience with the participatory processes carried out in the MARSS project flagged the existence of a major problem to be considered. When trying to test the validity of the decision support system for MSWMS, we discovered that the interaction of academicians and the other social actors is very wearing, requiring a long series of interview and a very elaborated schedule. Practitioners and administrators are busy people and it is often difficult to engage them in a meticulous and time-consuming cross-check of information. In fact, for roughly a month, for the quality check on the robustness of the representation of the metabolic network, it was possible to keep a participatory process with a high level of commitment from different actors (top administrative officials, local technicians, politicians, NGOs) then the interaction has become less intense and more problematic. Finally, it is also probable that for reaching political compromises an analytical approach providing an excess of transparency may be even considered as counterproductive. In any case, an effective participatory integrated assessment of the type proposed in this thesis would require the involvement of a greater variety of stakeholders over a longer period of time. Something that was not possible with the timing and the budget of the MARSS project. Even more important would be the existence of institutional support for this type of participatory integrated assessment capable of securing the stable involvement of administrators, politicians, and local technicians.

Beside the failure in testing the decision support, the participatory processes provided also very positive feed-back. All social actors involved in these participatory processes found the proposed approach extremely interesting. This fact suggests that participatory processes of integrated assessment require the establishment of an appropriate stable platform making possible an effective co-production and use of quantitative information to be used in decision making.

Clearly I hope that over time participatory research methods will become more commonplace and that once the end-users recognize that they can benefit from the results, these difficulties can be overcome.

CHAPTER V - General Conclusions

The characterization of the performance of a Municipal Solid Waste Management System (MSWMS) is an extremely complex issue since it refers to different dimensions of analysis that should be considered observing the system at different scales of analysis.

An effective governance of MSWMS implies a wise choice of institutional settings, technologies and required citizen behavior, plus the ability to monitor the efficacy of the operations in time. For this reason, an effective governance requires participatory processes of integrated assessments based on a wise selection of criteria of performance integrating robust information about environmental impact, socio-economic impact, economic viability, technical dimensions.

Implementing a participatory integrated assessment of policies related to MSWMS requires facing two important challenges: (i) being able to develop a decision support useful to guarantee an informed deliberation over alternative policies that must be based on a flexible analytical framework; (ii) being able establish effective local participatory processes in a very politically sensitive field such as the MSWMS having direct effect on voters.

The overview of the literature in this field shows that models and indicators proposed to support decision-making in municipal solid waste management are limited and the use of participatory processes is rare. When participatory processes are used then they are essentially consultations with technical experts.

In this thesis I developed an innovative approach for the quantitative characterization of the performance of MSWMS that can be used in a participatory process of integrated assessment. This approach has been applied to the development of a decision support tool based on the simultaneous consideration of different criteria of performance and quantitative analysis referring to different scales. When deciding about technological choices this decision support tool makes it possible better informed choices.

The usefulness of a procedure of Participatory Integrated Assessment based on the adoption of this approach have been tested in a real case study (The Metropolitan Area of Naples, Campania Region, Southern Italy) where actual participatory processes have been carried out to check the quality of the issue definition, the integrated characterization, and the whole process for the final deliberation. This test highlighted the potentialities and the shortcomings of the proposed procedure.

The specific conclusions related to the developed methodology, the case study and application of participatory processes have been presented in the corresponding chapters. So the general conclusions of my thesis address the research questions presented at the beginning of this dissertation.

1. *What type of accounting procedure should be used to generate an integrated quantitative assessment of the performance of a municipal solid waste management system?*

The accounting procedure presented in Chapter II provides an example of organization and integration of quantitative information that can be used for the characterization of the performance of MSWMSs across dimensions and scales. The hierarchical organization of the different processes and corresponding functional compartments, that together express the overall function of the MSWMS, can be tracked in quantitative terms by defining an appropriate set of accounting categories. This integrated approach multi-scale makes it possible to study the effect of changes taking place at different hierarchical levels: (i) in the characteristics of an individual typology of plant - local scale; (ii) in the characteristics of the network (the relations of the flows over the nodes) – meso scale; (iii) in the behavior of the people generating the inflow of wastes to be processes – meso scale; (iv) in the level of externalization of the network (determined by imports and exports of flows) – large scale. The potential effects of these different changes can be integrated and scaled to assess the performance of the whole management system of the city in relation to different dimensions of analysis (economic, social, technical, ecological).

2. *What type of characterization should be used to handle simultaneously different types of variables capable of considering technical, economical, social, demographic and ecological dimensions and to integrate them into a coherent and comprehensive accounting framework useful for studying the performance of municipal solid waste management systems?*

The characterizations presented in the Chapter III provides an example of how it is possible to integrate in a common multi-scale assessment sets of indicators covering the environmental, institutional, socioeconomic, biophysical and socio-cultural dimensions. This characterization can be used not only to study the performance of the current MSWMS of the MAN but also to characterize *"scenarios"* associated with potential policies. Rather than using mathematic models generating simulations of deterministic dynamic trajectories, the proposed approach can explore the option space using a flexible set of expected relations over different elements of a metabolic network that can be defined both in semantic and in formal terms. In this way it becomes possible to analyze the pros and cons of proposed policies using sets of indicators considered relevant by local stakeholders.

3. How to use the results of integrated assessments to build a decision support tool useful for discussing policies?

The results coming from the integrated assessments presented in Chapter III provide an example of how the approach of multi-scale integrated assessment proposed in this thesis can be used to generate an interactive decision support tool in participatory processes. That implies a new level of collaboration between the producers and users of quantitative information, integrating different types of available information (about data, relevance, values, narratives) in order to obtain the big picture of the problems at stake. This new way of using quantitative analysis can improve the quality of the process of production and use of quantitative information for MSWMS-related policies. The overall procedure increases the transparency of the process of evaluation and decision making since the characterization of the performance of the MSMWS reflect the individual interests of the different social actors involved. In a territory such as the Metropolitan Area of Naples, where the quality of the decision making of the local policy makers has been seriously questioned, this kind of transparency is terribly necessary.

4. Can we define a procedure for participatory integrated assessment based on this decision support tool that can be successfully applied in different contexts?

The decision support tool developed in this thesis has been tested in the participatory processes carried out in Naples (see Chapter IV). In relation to this question the experience done shows that this holistic framework can be applied in different geographic and cultural contexts. In fact, the framework is semantically open and for this reason it can accommodates different choices of indicators of performance tailored to specific local situations. As matter of fact, the procedure for participatory integrated assessment does explicitly require an input from the users for the quantification when calibrating the analysis on the specificity of the considered system. In this way, the existence of different relevant storytelling in the socio-economic context can be reflected in the integrated characterization with a variety of different indicators. An additional feature of this decision support tool is given by flexibility that implies the quantitative accounting framework can be patched and adjusted during the entire process of production and use of scientific information for governance.

5. What results can be achieved in applying this procedure to a real case study?

The analysis presented in Chapter III illustrates the potentialities of the application of the proposed procedure to a real case study, in terms of a multi-scale integrated representation of the current performance of the MSWMS of the MAN. In this way, it becomes possible to evaluate the effects of constraints belonging to different incommensurable dimensions such as social, technical, economic and environmental, and non-equivalent scales – micro, meso and macro. As matter of fact, the example of results presented in Chapter III show that the proposed procedure: (i) gives an insight into the functioning of the MSWMS (internal view: functions and structures – technologies - of the parts making the MSWMS): (ii) identifies and measure the dependency of the actual performance on externalization (external view: interaction between MSWMS and its economic context); (iii) identifies potential environmental problems (external view: interaction between MSWMS and its ecological context). The combination of those different views gives a more holistic picture of the performance of a MSWMS and makes it possible to double check this integrated representation through participatory processes.

6. What are the problems to be faced in such an attempt?

The problems faced in the application of the proposed decision support tool in participatory processes in a real case study have been presented and discussed in Chapter IV. Shortcomings about the developed analytical tool-kit have been presented at the end of Chapter II.

Lesson learned from participatory processes:

1. Different actors interviewed during the consultations have defined as relevant different types of indicators so we need to accept that is impossible to individuate "the best strategy" of waste management and "the best combination of technologies" using mathematical models. In relation to this systemic impasse the organization of relevant indicators in distinct sets referring to different story-telling (presented in Chapter IV) helps in clarifying the domain of competence of the different actors.

2. In the case study of Naples trust between local inhabitants and the government has been considerably damaged because of the past corruption and mismanagement in the governance of waste management. As matter of fact, lack of legitimacy of the process of decision-making about MSWMS emerged as a crucial problem for a proper use of the decision support tool.

3. The co-existence of different story-telling endorsed by "experts" , "decision makers" and "rest of the society" reflects their difference in the perceptions of the problems associated with waste management. The resulting systemic confusion in the definition of "the problem" does not help the communications among different groups.

4. The vast majority of social actors - “experts” , “decision makers” and “rest of the society” are unable to give reliable quantitative assessments of the “big picture” (e.g. how much cost the whole MSWMS per year?) or contextualize the relations over the parts (e.g. guess the relative amount of cost per year of the different processes taking part in the MSWMS) or to assess the level of openness of the system (e.g. guess the overall fraction of the waste entering in Naples which is exported). This is a surprising and scaring discovery I made in the participatory processes. This discovery flags again the importance to develop analytical tools providing a more holistic vision of the functioning of the MSWMS, in order to have a more useful input from better informed social actors.

5. Practitioners and administrators are busy people and it is often difficult to engage them in a meticulous and time-consuming cross-check of information. Therefore an effective adoption of these new tools in actual processes of decision making requires a specific expertise on how to engage and work with these stakeholder in the co-production of scientific information for governance.

Shortcomings of the analytical tool-kit:

1. The representation of the MSWMS used in the decision support tool used for charactering the current situation and the “simulations”, as every representation, represents a simplification of the complexity of a real MSWMS system. Therefore, it is important to be always aware that both indicators and simulations generated with the tool-kit unavoidably miss relevant aspects of the complex system under analysis. Therefore the resulting indications are affected by a level of uncertainty.

2. The analytical tool-kit requires large amounts of data that have to be retrieved from multiple and variegated sources. Moreover, the robustness of these data has to be checked in participatory processes. Given the peculiarity of the Neapolitan UMWS (scandals and waste crisis in the recent past) it has been difficult to obtain reliable data and information on the numerous network nodes.

3. A robust quality check of the information requires time and the commitment of the different social actors defined as relevant for the Participatory Integrated Assessment. To obtain reliable results it is necessary to continuously integrate statistical data (which are not necessarily easy to obtain) with the expertise of practitioners (for double checking the credibility of the data with expert estimations).

4. Last but certainly no least another problem is represented by the fact that the tool-kit is "*too transparent*" (!) in terms: (i) how the information is generated; (ii) a detailed characterization of the links between different dimensions and scales; (iii) how the information is used in the process of decision making. As it has been discussed in Chapter IV when dealing with decision making implying important political implications, an excess of transparency can represent a problem for politicians and administrators. In fact, they are not happy to take part in a process in which every decision about how to frame the problems, what should be considered as reliable information, how to interpret the data and how to decide on the policy is not controlled by them and as transparent as possible.

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Appendix

Annex 1 – Protocol for Interviews

NAPLES 16-17-18 September, 2015

INTRODUCTION

Presentation of the team of interviewers (including the institution)
Brief overview of the MARSS Project – and our role in it
Goals of the interview and estimate time (45/60 minutes)

Ask about the possibility of taking a picture and recording the interview
Ask whether they did attend the stakeholder meeting in Naples
Explain the structure of the interview:
1. General discussion of issues related to UWM in Naples (20/25 minutes)
2. Specific questions about the representation of the UWM (20/25 minutes)
3. Comments and feed-backs (5/10 minutes)

A. General discussion of issues (information for NAIADE)

1. Checking the basic story-telling

1.1 The specificity of Naples

1.1.1 What are the factors that make UWM in Naples "special" and that generated the past crisis?

1.1.2 Ranking motivations for action (assessing urgency from 1 to 10):
- a. The economic costs are not sustainable;
- b. Threats to human health and the environment;
- c. Damage to the image of the city (negative impacts on tourism, agricoture)
- d. Damage to social cohesion, de-legitimization of institutions
- e. other?

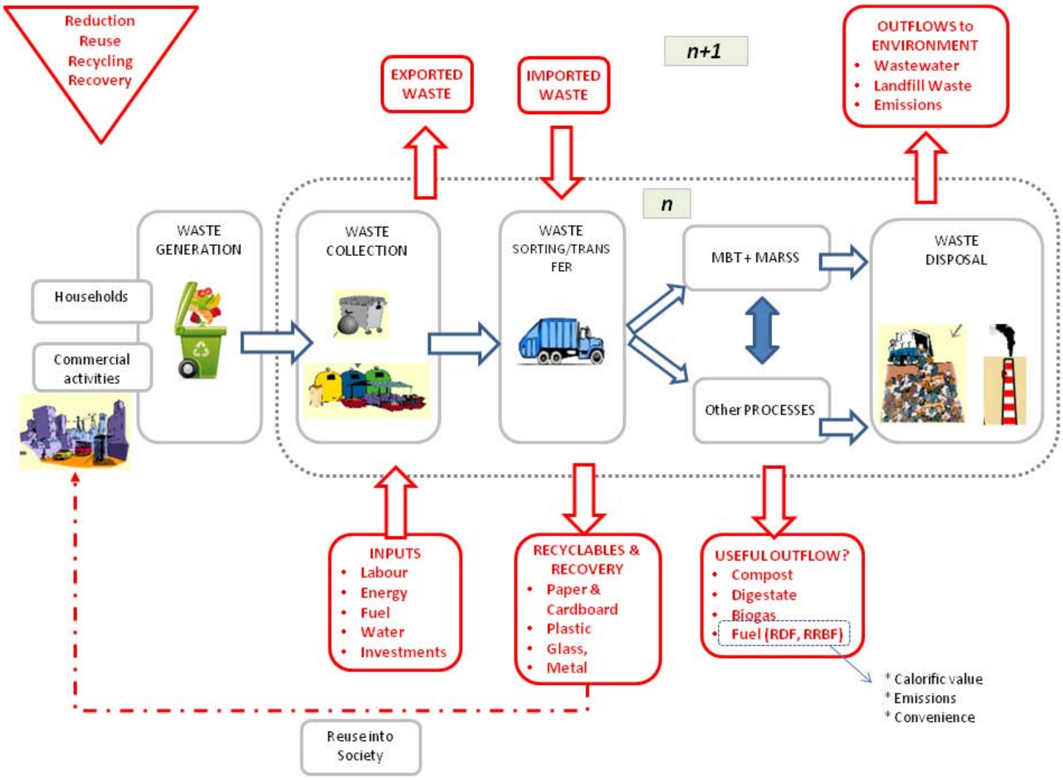
1.2 Governance/actors

1.2.1 Who decides (has power) in relation to changes in the UWM and how?
EU regulations, Italian State, Campania Region, Province/Area Metropolitana, the Municipality, powerful lobbies, privates, organized crime, NGOs

1.2.2 What is the level of integration/coordination across the different institutions?

1.2.3 How should we tailor the information in a Decision Support tool? (what type of clients should we consider? Information useful for whom? Useful for what?)

1.3 Economic View: the big picture (test the existing capability of analysis)



SHOWING GRAPH - Looking at this overview of the Urban Waste Management System can you give us your assessment on:

1.3.1 Approximate profile of economic flows (total and relative importance) over the different functional sectors;

1.3.2 Who pays and who gets the money for doing what

1.3.3 Would you be able to estimate for the different functional sectors: (i) fixed and circulating money expenditures; (ii) JOBS; (iii) what remains in Naples and what goes out

1.3.4 What are the functional sectors that are really bad in terms of cost/effectiveness)?

2. Perceptions about strategies changes to be adopted

2.1 Pros and Cons of the following strategies

2.1.1 Strategy A – revolutions do not work and can generate more damage than improvements, we need just to patch and improve the existing system

2.1.2 Strategy B – getting out from Business As Usual requires technological innovations capable of eliminating bottlenecks (during the discussion ask for the importance of the role of technology)

2.1.3 Strategy C – we need a strong discontinuity and use the crisis as an opportunity to build a better system of governance because technology alone will not solve the problem (during the discussion ask for the importance of the role of technology)

2.2 Criteria and Indicators of performance

Can you suggest criteria of performance (and relative indicators) in relation to:

2.2.1 The quality of the service for the citizens

2.2.2 The effect on the health of people and of the environment

2.2.3 Socio-economic effect of changes in the Waste Management System

2.2.4 Economic performance of the WMS (performance for whom?)

B. Quantitative representation of the UWM (preparation of the DELPHI)

(only if the interviewed has technical expertise)

2.3 Direct questions about the proposed characterization

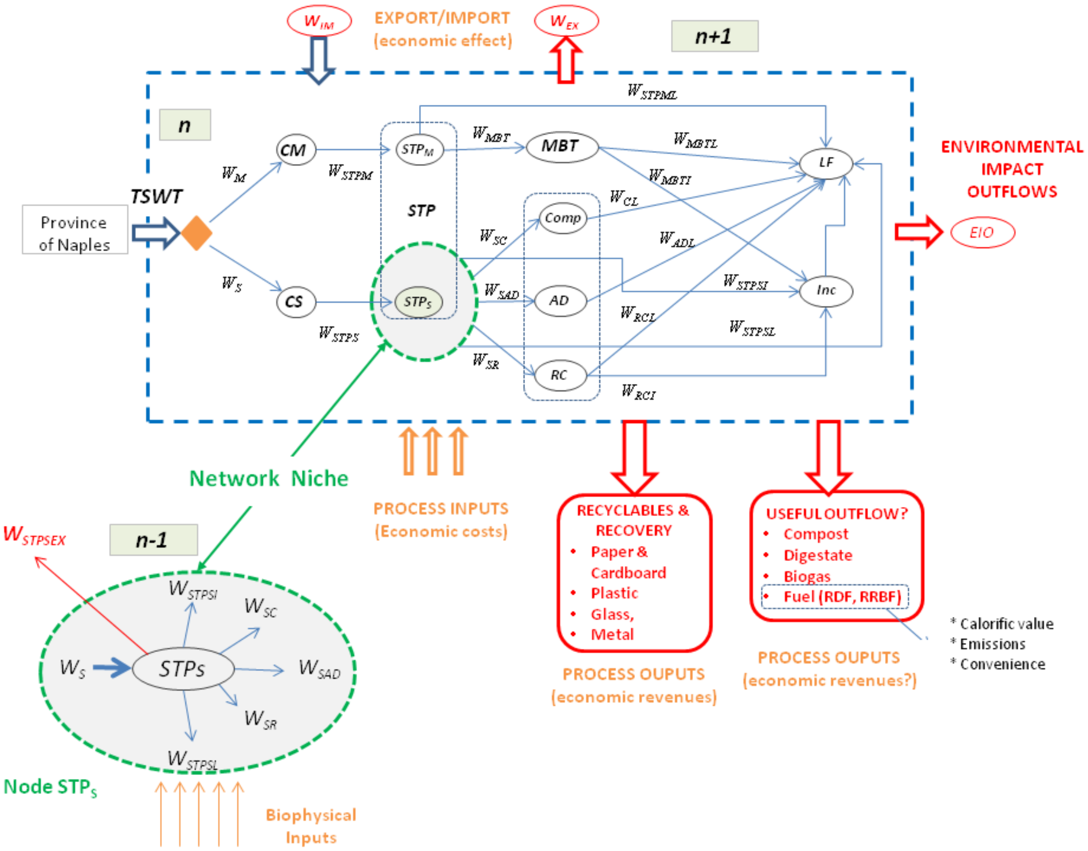
2.3.1 How "useful" are the products of the WMS?

a. Who buy and what is the "value" and "revenue" of the recovered fractions:
(i) Metals; (ii) Plastics; (iii) Glass; (iv) Paper – who gets the money?

b.What is the "value" of other outflows and what are attributes determining their value?
(v) Biogas; (vi) Compost; (vii) Fuels

c. What is the demand (local and/or external) for these outflows?

2.3.2 How "problematic" are the outflows of the WMS?
a. What are the emissions that are more problematic?
b. The issue of percolates
c. Specific problems with heavy metal?
d. Other?
2.3.3 Quality check on quantitative assessment of the WMS of Naples



a. Checking the proposed scheme based on the characterization of functional units and structural units (at two different scales)

b. Checks on the data: quantity of flows, composition, costs

c. how obsolete is this representation referring to the year 2012, ?

2.4 Questions about future collaboration with the person interviewed

2.4.1 Check the contact information (update and expand if needed)

2.4.2 Can we schedule a second interview in the week 19-23 October?
You will be able to have a look at the results of our characterization using NAIADE and participate in a DELPHI about simulations and scenarios.

2.4.3 Can we contact you, via e-mail in the case we need "specific information" referring to your expertise?

2.5 Specific Technical Questions (if there is enough time)

3. Feed-back and Final Comments

3.1 Your suggestions to improve the analysis

3.1 General comments about the goals of our work

3.2 other aspects/factors to be considered in the analysis missing in the proposed approach

3.3 Direct feed-backs on the proposed approach of accounting

3.2 You have the last word: what is your bottom line?

Messages you want to be send through the report about a key point to be considered to improve the situation in Naples

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FINAL NOTE

We will send a copy of the document that we will prepare as deliverable of the MARSS project to get your green-light. In the document we will acknowledge the contribution given by all the people that collaborated in these interviews, but we will avoid to quote directly the specific persons interviewed.

Annex 2 - Record of the interviews

Interview #1

Interviewed: Manager
Institution: Regione Campania - Ufficio Autoritá Ambientale
Address: via Bracco 15/1 – 80133 Napoli
Date: Sept. 16th, 2015 - 9,15 a.m. – 10,30 a.m.

A. General discussion of issues (information for NAIADE)

1. Checking the basic story-telling

1.1 The specificity of Naples

1.1.1 What are the factors that make UWM in Naples "special" and that generated the past crisis?
Naples is not special and there is no crisis now (this is an echo of the past). Waste management in Naples today works better than Rome or many other Italian cities. Yet still there is a shortage of treatment plants. The crisis has been generated by bad management.

1.1.2 Ranking motivations for action (assessing urgency from 1 to 10):
a. The economic costs are not sustainable; 10 but only for the organic fraction
b. Threats to human health and the environment; 5 but only in the province (illegal burning)
c. Damage to the image of the city (negative impacts on tourism, agriculture): 3 the problem is uncontrolled dumping in the streets in periphery.
d. Damage to social cohesion, de-legitimization of institutions: 5
e. other? NO

1.2 Governance/actors

1.2.1 The situation is quite messy: there is a fine given by EU of 120,000 €/day for bad management done by Italy that has to be paid by the Region. In the past we had conflicts over policies (e.g. the incinerator of "Napoli Est") for which the Municipality was in favor and the Region against (due to the fact that the two political majorities were different). There is already an incinerator of 700,000 tons but since there is confusion about the different proponents measure the demand to waste to be incinerated it is difficult to clarify the issue. Particularly serious has been the chaos during the emergence, that implied no respect of rules for a decade. Often ASIA has been by-passed with the externalization of the service to privates.

1.2.2 Beside the state, more important actors are the Regions, Municipality (commune di Napoli) and the Province (now Area Metropolitana). There is a new fact, very recently - Delibera 7 Agosto 2015 – it has been decided to merge the two jurisdictions over UWM of the Municipality and the Area Metropolitana.

1.3 Economic View: the big picture (test the existing capability of analysis)

1.3.1 Approximate profile of economic flows (total and relative importance) over the different functional sectors; The interviewed cannot provide an overall estimate, but he knows estimates of costs per typology of waste flow – e.g. 160€/ton for humid (organic) 120€/ton for bulky waste.

1.3.2 Who pays and who gets the money for doing what SKIPPED

1.3.3 Would you be able to estimate for the different functional sectors: (i) fixed and circulating money expenditures; (ii) JOBS; (iii) what remains in Naples and what goes out SKIPPED

1.3.4 What are the functional sectors that are really bad in terms of cost/effectiveness?
Lack of composting capacity

2. Perceptions about strategies changes to be adopted

2.1 Pros and Cons of the following strategies

2.1.1 Strategy A – revolutions do not work and can generate more damage than improvements, we need just to patch and improve the existing system
Changes are needed, the actual system does not work, it needs more processing capacity (composting plants)

2.1.2 Strategy B – getting out from Business As Usual requires technological innovations capable of eliminating bottlenecks (during the discussion ask for the importance of the role of technology) - technology is needed but it must be a reliable technology (no experiments)

2.1.3 Strategy C – we need a strong discontinuity and use the crisis as an opportunity to build a better system of governance because technology alone will not solve the problem (during the discussion ask for the importance of the role of technology)
SKIPPED

2.2 Criteria and Indicators of performance
Can you suggest criteria of performance (and relative indicators) in relation to:

2.2.1 The quality of the service for the citizens
Cost, frequency of the cleaning, convenience, street cleaning
2.2.2 The effect on the health of people and of the environment
This is relevant for the emissions from Special Wastes
2.2.3 Socio-economic effect of changes in the Waste Management System

Jobs
2.2.4 Economic performance of the WMS (performance for whom?) SKIPPED

B. Quantitative representation of the UWM (preparation of the DELPHI)
(only if the interviewed has technical expertise)

2.3 Direct questions about the proposed characterization

2.3.1 How "useful" are the products of the WMS?

a. Who buy and what is the "value" and "revenue" of the recovered fractions:
(i) Metals; (ii) Plastics; (iii) Glass; (iv) Paper – who gets the money?
One should consider the difference between waste (you pay to get rid of it) and Secondary Primary Source (someone pays for getting it) – but not assessments

b.What is the "value" of other outflows and what are attributes determining their value? (v) Biogas; (vi) Compost; (vii) Fuels
Biogas can just cover the energy spent in the plant; compost – it is already an achievement if you find someone willing to get them (you save the cost of disposing of them); digestate –stabilized waste (either an input for the composting or to the landfill); SKIPPED;

c. What is the demand (local and/or external) for these outflows? Doubtful

2.3.2 How "problematic" are the outflows of the WMS?
SKIPPED for shortage of time, this is not the main expertise of the interviewed
a. What are the emissions that are more problematic?
b. The issue of leachates
c. Specific problems with heavy metal?
d. Other?

2.3.3 Quality check on quantitative assessment of the WMS of Naples

a. Checking the proposed scheme based on the characterization of functional units and structural units (at two different scales) OK He liked the approach very much
He did a similar attempt of analysis (much simpler) and gave us the file in excel

b. Checks on the data: quantity of flows, composition, costs
Some of the required information has been written directly on the figure (but not much)

c. how obsolete is this representation we use, that is referring to the year 2012?
Minor changes took place but the general scheme is still valid

2.4 Questions about future collaboration with the person interviewed

2.4.1 Check contact information (update and expand if needed) - DONE

2.4.2 Can we schedule a second interview in the week 19-23 October?

You will be able to have a look at the results of our characterization using NAIADE and participate in a DELPHI about simulations and scenarios. - OK

2.4.3 Can we contact you, via e-mail in the case we need "specific information" referring to your expertise? YES

2.5 Specific Technical Questions (if there is enough time)
NO TIME

3. Feed-back and Final Comments

3.1 Your suggestions to improve the analysis

3.1 General comments about the goals of our work
Very good. In fact the new "delibera" (decision) of the "Area Metropolitana" is to create a permanent collaboration among experts of the ex-Provincia, Regione and Municipality on how to study the performance of UWM and this could be a good occasion for starting such collaboration (when we will do the DELPHI)

3.2 other aspects/factors to be considered in the analysis missing in the proposed approach This will require a collaboration across different experts

3.3 Direct feed-backs on the proposed approach of accounting
He gave us his model made in excel, that is available as "contributo dell'Autoritá Ambientale della Regione Campania" on . . .

3.2 You have the last word: what is your bottom line?

Messages you want to be send through the report about a key point to be considered to improve the situation in Naples - NONE

Interview #2

Interviewed: Coordinator
Institution: Zero Waste Campania (Feder Hotel, Restaurant)
Address: the meeting took place in the bar of the Central Station
Date: Sept. 16th, 2015 - 12,30 – 13,30

A. General discussion of issues (information for NAIADE)

1. Checking the basic story-telling

1.1 The specificity of Naples

1.1.1 What are the factors that make UWM in Naples "special" and that generated the past crisis?

There is no crisis now, and the problems with UWM are quite generalized in Italy and in many parts of the world – nothing special about Naples.

1.1.2 Ranking motivations for action (assessing urgency from 1 to 10):
a. The economic costs are not sustainable; 8
b. Threats to human health and the environment; 8
c. Damage to the image of the city (negative impacts on tourism, agriculture): 10
d. Damage to social cohesion, de-legitimization of institutions: 7
e. other? YES it is urgent to consider the policies about UWM in relation to the policies for Tourism since the two are strictly related and can generate synergisms

1.2 Governance/actors

1.2.1 Total disaster they did not manage to express an effective management of the problems

1.2.2 Privates – Federalberghi and other private entrepreneurs are not empowered in the process of decision making

1.3 Economic View: the big picture (test the existing capability of analysis)

Whole section SKIPPED the interviewers says he does not have the required expertise
1.3.1 Approximate profile of economic flows (total and relative importance) over the different functional sectors;
1.3.2 Who pays and who gets the money for doing what

1.3.3 Would you be able to estimate for the different functional sectors: (i) fixed and circulating money expenditures; (ii) JOBS; (iii) what remains in Naples and what goes out
1.3.4 What are the functional sectors that are really bad in terms of cost/effectiveness?

2. Perceptions about strategies changes to be adopted

2.1 Pros and Cons of the following strategies

2.1.1 Strategy A – revolutions do not work and can generate more damage than improvements, we need just to patch and improve the existing system
The system requires changes

2.1.2 Strategy B – getting out from Business As Usual requires technological innovations capable of eliminating bottlenecks (during the discussion ask for the importance of the role of technology) - technologies already exist – composting can be done at small scale (machine processing 25 tonnes costs 28,000€) and produced by Italian firm (compostiera.it) directly in the hotel.

2.1.3 Strategy C – we need a strong discontinuity and use the crisis as an opportunity to build a better system of governance because technology alone will not solve the problem (during the discussion ask for the importance of the role of technology) In fact what we need is not more technology to process the existing flow of wastes,

but change the behavior and reduce the flow of wastes – no plastic bottles, composting
"tariff puntuale" – reducing waste (up to 70% in hotels) by using dispensers, giving free water to be used in re-usable bottles, etc. etc.

2.2 Criteria and Indicators of performance
Can you suggest criteria of performance (and relative indicators) in relation to:

2.2.1 The quality of the service for the citizens
Clean Cities (good for the tourism)
2.2.2 The effect on the health of people and of the environment
Fraction of "separate collection" (the higher the better), monitoring the quality of the watertable
2.2.3 Socio-economic effect of changes in the Waste Management System
Jobs
2.2.4 Economic performance of the WMS (performance for whom?) SKIPPED

B. Quantitative representation of the UWM (preparation of the DELPHI)

(only if the interviewed has technical expertise)
SKIPPED – he said he does not have the required expertise
2.4 Questions about future collaboration with the person interviewed

2.4.1 Check contact information (update and expand if needed) - DONE

2.4.2 Can we schedule a second interview in the week 19-23 October?
You will be able to have a look at the results of our characterization using NAIADE and participate in a DELPHI about simulations and scenarios. - OK

2.4.3 Can we contact you, via e-mail in the case we need "specific information" referring to your expertise? YES

3. Feed-back and Final Comments

3.1 Your suggestions to improve the analysis

3.1 General comments about the goals of our work
We have to establish a relation between the cost of the UWM and its performance and the implications on the performance of the Tourist Sector. If the Tourist Sector has a volume of money several times larger than the cost of the UWM it is important to consider the possible effect on tourism (e.g. a reduction on 20%) when considering the costs to be paid in order to obtain an effective UWM. For example, the policy of "blue flags" on the beaches has the effect of increasing or 15% the flow of tourists. In the same way one can imagine a process of Certification of the performance of hotels and restaurants in relation to the recycling of wastes.

3.2 other aspects/factors to be considered in the analysis missing in the proposed approach Formation of the people running hotels and restaurants, tourists, local residents in order to generate synergies

3.3 Direct feed-backs on the proposed approach of accounting SKIPPED

3.2 You have the last word: what is your bottom line?

Messages you want to be send through the report about a key point to be considered to improve the situation in Naples - At the beginning ambitious targets seem impossible (this happened with the fraction that goes into recycling) nobody believed that it was possible to achieve in the Region a fraction of 50% but we did it. In the same way it is possible to achieve a reduction of waste of 60% (up to more than 80%!) in hotels and restaurants. You have to be informed and willing to do your share.

Interview #3

Interviewed: Manager Local Services
Institution: Azienda Servizi Igiene Ambientale
Address: via Ponte dei Francesi 37/d – 80133 Napoli
Date: Sept. 16th, 2015 - 14,30 – 15,45

A. General discussion of issues (information for NAIADE)

1. Checking the basic story-telling

1.1 The specificity of Naples

1.1.1 What are the factors that make UWM in Naples "special" and that generated the past crisis?
Heterogeneity of the city (geographic and cultural). There is a cultural problem in relation to waste collection local citizens do not collaborate (bad behavior)

1.1.2 Ranking motivations for action (assessing urgency from 1 to 10):
a. The economic costs are not sustainable; 3
b. Threats to human health and the environment; 1
c. Damage to the image of the city (negative impacts on tourism, agriculture): 10
d. Damage to social cohesion, de-legitimization of institutions: 5
e. other? NO

1.2 Governance/actors

1.2.1 In the past we had major problems of coordination among institutions but now things are much better

1.2.2 Within the ASIA the coordination works pretty well

1.3 Economic View: the big picture (test the existing capability of analysis)

1.3.1 Approximate profile of economic flows (total and relative importance) over the different functional sectors; NO
1.3.2 Who pays and who gets the money for doing what SKIPPED
1.3.3 Would you be able to estimate for the different functional sectors: (i) fixed and circulating money expenditures; (ii) JOBS; (iii) what remains in Naples and what goes out SKIPPED
1.3.4 What are the functional sectors that are really bad in terms of cost/effectiveness
SKIPPED

2. Perceptions about strategies changes to be adopted

2.1 Pros and Cons of the following strategies

2.1.1 Strategy A – revolutions do not work and can generate more damage than improvements, we need just to patch and improve the existing system
The system work but need adjustments

2.1.2 Strategy B – getting out from Business As Usual requires technological innovations capable of eliminating bottlenecks (during the discussion ask for the importance of the role of technology) - we need technology, especially modular technology for dealing with the "humid" (organic fraction) – there are units processing 50,000 tonnes/year that can be used to adjust properly the required capacity.

2.1.3 Strategy C – we need a strong discontinuity and use the crisis as an opportunity to build a better system of governance because technology alone will not solve the problem (during the discussion ask for the importance of the role of technology)
SKIPPED

2.2 Criteria and Indicators of performance
Can you suggest criteria of performance (and relative indicators) in relation to:

2.2.1 The quality of the service for the citizens
Cost
2.2.2 The effect on the health of people and of the environment
The indicators that already used at the moment
2.2.3 Socio-economic effect of changes in the Waste Management System
Jobs
2.2.4 Economic performance of the WMS (performance for whom?) SKIPPED

B. Quantitative representation of the UWM (preparation of the DELPHI)
(only if the interviewed has technical expertise)

2.3 Direct questions about the proposed characterization

2.3.1 How "useful" are the products of the WMS?
a. Who buy and what is the "value" and "revenue" of the recovered fractions:
(i) Metals; (ii) Plastics; (iii) Glass; (iv) Paper – who gets the money?
The interviewed has provided a very detailed and useful explanation of the functioning of the different platforms of recycling especially in relation to the interface between the output coming from ASIA and the second step of other operators involved in this sub-sector.
b.What is the "value" of other outflows and what are attributes determining their value? (v) Biogas; (vi) Compost; (vii) Fuels
NOT SURE so at the end he preferred to SKIP this question;

c. What is the demand (local and/or external) for these outflows? SKIPPED

2.3.2 How "problematic" are the outflows of the WMS?
SKIPPED for shortage of time, outside the expertise of the interviewed
a. What are the emissions that are more problematic?
b. The issue of leachates
c. Specific problems with heavy metals?
d. Other?

2.3.3 Quality check on quantitative assessment of the WMS of Naples

a. Checking the proposed scheme based on the characterization of functional units and structural units (at two different scales) OK

b. Checks on the data: quantity of flows, composition, costs
Some information has been written directly on the figure (but only related to the step of waste collection).

c. how obsolete is this representation we use, that is referring to the year 2012?
It is still OK

2.4 Questions about future collaboration with the person interviewed

2.4.1 Check contact information (update and expand if needed) - DONE

2.4.2 Can we schedule a second interview in the week 19-23 October?
You will be able to have a look at the results of our characterization using NAIADE and participate in a DELPHI about simulations and scenarios. - OK

2.4.3 Can we contact you, via e-mail in the case we need "specific information" referring to your expertise? YES

2.5 Specific Technical Questions (if there is enough time)
Questions about the door-to-door collection, the cost of dumpster, clarification about transfer platforms (for both undifferentiated collection and separate collection)

3. Feed-back and Final Comments

3.1 Your suggestions to improve the analysis

3.1 General comments about the goals of our work
Interesting

3.2 other aspects/factors to be considered in the analysis missing in the proposed approach The impact of the behavior of citizens on the cost of collection

3.3 Direct feed-backs on the proposed approach of accounting
None

3.2 You have the last word: what is your bottom line?

Messages you want to be send through the report about a key point to be considered to improve the situation in Naples - To improve the performance of the collection it is necessary to have more control on the behavior of citizens – we need more "fines" to delinquent citizens!

Interview #4

Interviewed: Activists
Institution: Cittadini Campani per un piano alternativo dei Rifiuti
Address: Via Cavallerizza, 15 → interview at Bar della Stazione Centrale
Date: Sept. 16th, 2015 - 18,00 a.m. – 18,50 a.m.

A. General discussion of issues (information for NAIADE)

1. Checking the basic story-telling

1.1 The specificity of Naples

1.1.1 What are the factors that make UWM in Naples "special" and that generated the past crisis?
The crisis was generated by a growing awareness of the bad management of the UWM that led to a popular movement that was effective in fighting against the political establishment.

1.1.2 Ranking motivations for action (assessing urgency from 1 to 10):
a. The economic costs are not sustainable; 3
b. Threats to human health and the environment; 6

c. Damage to the image of the city (negative impacts on tourism, agriculture): 8
d. Damage to social cohesion, de-legitimization of institutions: 10
e. other? NO

1.2 Governance/actors

1.2.1 Total Disaster – bad organization, incompetent or even worse corrupt incumbents

1.2.2 too many (sic)

1.3 Economic View: the big picture (test the existing capability of analysis)

1.3.1 Approximate profile of economic flows (total and relative importance) over the different functional sectors;
Indicated in % over the figure

1.3.2 Who pays and who gets the money for doing what A lot of money goes to transport, because transporting was the main activity of the organized crime.
1.3.3 Would you be able to estimate for the different functional sectors: (i) fixed and circulating money expenditures; (ii) JOBS; (iii) what remains in Naples and what goes out SKIPPED

1.3.4 What are the functional sectors that are really bad in terms of cost/effectiveness?
Lack of composting capacity

2. Perceptions about strategies changes to be adopted

2.1 Pros and Cons of the following strategies

2.1.1 Strategy A – revolutions do not work and can generate more damage than improvements, we need just to patch and improve the existing system
Against this strategy, we need changes as soon as possible.

2.1.2 Strategy B – getting out from Business As Usual requires technological innovations capable of eliminating bottlenecks (during the discussion ask for the importance of the role of technology) - we do not need new futuristic plants, but we need a wiser combination of existing technologies within an effective institutional regulation.

2.1.3 Strategy C – we need a strong discontinuity and use the crisis as an opportunity to build a better system of governance because technology alone will not solve the problem (during the discussion ask for the importance of the role of technology)
There is a risk in the continuous change of institutional settings that "everything changes" but with a permanent revolution "everything remains the same". What has to be changed is the way the UWM functions.

2.2 Criteria and Indicators of performance

Can you suggest criteria of performance (and relative indicators) in relation to:

2.2.1 The quality of the service for the citizens
Better way of defining the cost (*Pay as you throw*), Transparency of information about the indicators and the monitoring, the ability of generating trust about the data!
2.2.2 The effect on the health of people and of the environment
Epidemiological studies on disease associated with negative effects of UWM, air quality, water quality, effective monitoring in space and time
2.2.3 Socio-economic effect of changes in the Waste Management System
Jobs, impact on tourism, generation of cooperatives
2.2.4 Economic performance of the WMS (performance for whom?) SKIPPED

B. Quantitative representation of the UWM (preparation of the DELPHI)

(this section has been SKIPPED – group of activists with not technical expertise)

2.4 Questions about future collaboration with the person interviewed

2.4.1 Check contact information (update and expand if needed) - DONE

2.4.2 Can we schedule a second interview in the week 19-23 October?
You will be able to have a look at the results of our characterization using NAIADE and participate in a DELPHI about simulations and scenarios. - OK

2.4.3 Can we contact you, via e-mail in the case we need "specific information" referring to your expertise? YES

3. Feed-back and Final Comments

3.1 Your suggestions to improve the analysis

3.1 General comments about the goals of our work
Very good it is necessary to integrate technical information with other type of information and involve the civil society in the discussion of policies.

3.2 other aspects/factors to be considered in the analysis missing in the proposed approach - NONE

3.3 Direct feed-backs on the proposed approach of accounting
Focusing more on the necessity of reducing the role that transportation plays in the actual UWM. So far the past choices had the goal to maximize the transportation and this is distorting the performance of the whole system.

3.2 You have the last word: what is your bottom line?

Messages you want to be send through the report about a key point to be considered to improve the situation in Naples - It is necessary also to address what is going on BEFORE the waste is generate. One has to reduce the amount of waste generated in the first place.

Interview #5

Interviewed: Capo Gabinetto
Institution: Cittá Metropolitana (ex-Provincia)
Address: Piazza Matteotti, 1 – 80133 Napoli
Date: Sept. 17th, 2015 - 9,30 a.m. – 10,15 a.m.

A. General discussion of issues (information for NAIADE)

1. Checking the basic story-telling

1.1 The specificity of Naples

1.1.1 What are the factors that make UWM in Naples "special" and that generated the past crisis?
The normative within which the UWM was developed was not appropriate for the city of Naples. The Italian Government applied norms to a urban entity (Naples) having a much higher population density and therefore this generated a syndrome of "mission impossible". That is, 3 million people at a certain point were forced to accumulate their wastes without the option to move this material elsewhere. On the top of this the management of the crisis was very very bad, it made things worse.

1.1.2 Ranking motivations for action (assessing urgency from 1 to 10):
a. The economic costs are not sustainable; 6
b. Threats to human health and the environment; 9
c. Damage to the image of the city (negative impacts on tourism, agriculture): 9
d. Damage to social cohesion, de-legitimization of institutions: 8
e. other? NO

1.2 Governance/actors

1.2.1 The Region can generate laws, a problem is that the governance has been so far very top-down

1.2.2 There is a tendency to integration in the waste cycles in which the municipalities (comuni) are in charge of the collection and the province (now they are becoming "aree metropolitan" are in charge for the disposal.

1.3 Economic View: the big picture (test the existing capability of analysis)
SKIPPED - NO HAVING THE REQUIRED INFORMATION
1.3.1 Approximate profile of economic flows (total and relative importance) over the different functional sectors;
1.3.2 Who pays and who gets the money for doing what
1.3.3 Would you be able to estimate for the different functional sectors: (i) fixed and circulating money expenditures; (ii) JOBS; (iii) what remains in Naples and what goes out
1.3.4 What are the functional sectors that are really bad in terms of cost/effectiveness?

2. Perceptions about strategies changes to be adopted

2.1 Pros and Cons of the following strategies

2.1.1 Strategy A – revolutions do not work and can generate more damage than improvements, we need just to patch and improve the existing system
- he doesn't agree - A revolution and discontinuity with the past is needed

2.1.2 Strategy B – getting out from Business As Usual requires technological innovations capable of eliminating bottlenecks (during the discussion ask for the importance of the role of technology) - technology is needed to have a more effective separate collection

2.1.3 Strategy C – we need a strong discontinuity and use the crisis as an opportunity to build a better system of governance because technology alone will not solve the problem (during the discussion ask for the importance of the role of technology) – the crisis has shown that a better organization and better coordination are needed

2.2 Criteria and Indicators of performance
Can you suggest criteria of performance (and relative indicators) in relation to:

2.2.1 The quality of the service for the citizens
Reduction of Cost
2.2.2 The effect on the health of people and of the environment
The existing ones
2.2.3 Socio-economic effect of changes in the Waste Management System
Jobs
2.2.4 Economic performance of the WMS (performance for whom?) SKIPPED

B. Quantitative representation of the UWM (preparation of the DELPHI)

2.3 Direct questions about the proposed characterization
(SKIPPED the interviewed does not have a technical expertise on UWM structure)
2.3.1 How "useful" are the products of the WMS?
2.3.2 How "problematic" are the outflows of the WMS?

2.3.3 Quality check on quantitative assessment of the WMS of Naples

2.4 Questions about future collaboration with the person interviewed

2.4.1 Check contact information (update and expand if needed) - DONE

2.4.2 Can we schedule a second interview in the week 19-23 October?
You will be able to have a look at the results of our characterization using NAIADE and participate in a DELPHI about simulations and scenarios. - OK

2.4.3 Can we contact you, via e-mail in the case we need "specific information" referring to your expertise? YES

3. Feed-back and Final Comments

3.1 Your suggestions to improve the analysis

3.1 General comments about the goals of our work
It may be very useful

3.2 other aspects/factors to be considered in the analysis missing in the proposed approach NONE

3.3 Direct feed-backs on the proposed approach of accounting - NONE

3.2 You have the last word: what is your bottom line?

Messages you want to be send through the report about a key point to be considered to improve the situation in Naples - The most important objectives:

- Generating a more Effective Normative
- Avoid the insurgence of "ECOMAFIA"
- Prevent other cases of lack of coordination
- Reduce the negative effect of red tape

Interview #6

Interviewed: Vice Sindaco, Assessore all' Ambiente
Institution: Comune di Napoli –
Address: Palazzo S. Giacomo, Piazza Municipio – 80133 Napoli
Date: Sept. 17th, 2015 - 13,00 a.m. – 14,30 a.m.

A. General discussion of issues (information for NAIADE)

1. Checking the basic story-telling

1.1 The specificity of Naples

1.1.1 What are the factors that make UWM in Naples "special" and that generated the past crisis?
The interviewed answered this question with a reconstruction of the events that led to the crisis starting from 1960. The explanation has been incredibly informative and lasted more than 45 minutes. What is remarkable about his reconstruction is that the majority of the facts he described have been experienced by him directly. In fact he was first the responsible of "Lega Ambiente", that is the leading organization fighting against the bad policies implemented in the past, then it became President of ASIA (in charge for the MSWMS of the city) during the period of the crisis, and finally he became "Assessore all'Ambiente" (the person in charge in the municipality for the waste management) from inside the institutions. A lot of the information given in this long description of the story and the situation has been used also for checking the quality of the representation (what generally is asked in Section B of this interview).
Very briefly, his accounting confirm several of the points made by other interviewed. Everything started with a bad normative not appropriate for the situation of Naples and a national policy that damaged the possibility of Naples and more in general Campania to develop an effective MSWMS. The crisis made it possible for power lobbies (from the North) to make money – taking advantage of the suspension of all the rules and laws because of the "emergency" situation declared by the government. In this phase the local organized criminality was essential to help powerful lobbies in getting public money for handling the emergence. This has generated a situation in which local municipalities (ousted for almost 20 years) did not developed any expertise in this field, and a series of decisions have been made that did not help the building of infrastructure and technical capacity in the area.

Due to the incredible level of expertise and competence it was difficult to have the interviewed stick to the questions. We received a lot of information (he could answer almost any type of question) but it was really difficult to keep the interview organized according to the protocol. To specific questions he always replied by enlarging the issue to a more general framing of the issue.

1.2 Governance/actors

1.2.1 The story he told us shows clearly that the governance of the UWM in the past and during the crisis was a disaster. As a matter of fact, the "special commissioner" that centralized all the power for almost 20 years generated a major worsening of the situation and a collapse in the efficacy of the governance.

1.2.2 Now there is an attempt of the Municipality to improve the participation of the civil society in the process of decision making. What is important is to avoid another collapse in the precarious equilibrium that is working right now.

1.3 Economic View: the big picture (test the existing capability of analysis)

1.3.1 Approximate profile of economic flows (total and relative importance) over the different functional sectors; This has been the only interviewed that was able to provide an overall assessment of the monetary flows around the MSWMS – he suggested 500/550 Million € per year (a value that is consistent with what we estimates with our accounting system)
1.3.2 Who pays and who gets the money for doing what
It is possible to get this information but it requires some specific study

1.3.3 Would you be able to estimate for the different functional sectors: (i) fixed and circulating money expenditures; (ii) JOBS; (iii) what remains in Naples and what goes out Again this is information that can be gathered but it requires time.

1.3.4 What are the functional sectors that are really bad in terms of cost/effectiveness?
It is difficult to answer this question because the problem is generated by a mix of: (i) shortage of economic resources (how to finance the new plant of composting required for handling the humid?) – plants of 50,000 tons mixed (aerobic and anaerobic); (ii) normative obstacles – the Italian central government is not helping the development of composting in Campania; (iii) resistance of local people (NIMBY) to accept composting plants in individual locations. So it is easy to individuate the sector with problems, but it is difficult to individuate an defective policy.

2. Perceptions about strategies changes to be adopted

2.1 Pros and Cons of the following strategies
SKIPPED
2.2 Criteria and Indicators of performance
SKIPPED

B. Quantitative representation of the UWM (preparation of the DELPHI)

2.3 Direct questions about the proposed characterization
Due to the length of the interview (that lasted at the end 1 hour and half!) we decided to skip specific questions that could have been answered by other and to work on the big picture of the MSWMS

2.3.1 How "useful" are the products of the WMS?

SKIPPED

2.3.2 How "problematic" are the outflows of the WMS?

SKIPPED

2.3.3 Quality check on quantitative assessment of the WMS of Naples

a. Checking the proposed scheme based on the characterization of functional units and structural units (at two different scales) After looking at various slides presenting the approach, he was very happy with it, and suggested (he called in front of us) to the Director of ASIA (Paolo Stancanelli) to check with us (in the interview to be made in the afternoon) the possibility of using our proposed model to start the collaboration between the experts of the Regione, Provincia and Comune. This would be very good for us because it would help the DELPHI exercise.

b. Checks on the data: quantity of flows, composition, costs
It provided his assessments of quantities and costs of different flows.

c. how obsolete is this representation we use, that is referring to the year 2012?
Minor changes took place but the general scheme is still valid

2.4 Questions about future collaboration with the person interviewed

2.4.1 Check contact information (update and expand if needed) - DONE

2.4.2 Can we schedule a second interview in the week 19-23 October?
You will be able to have a look at the results of our characterization using NAIADE and participate in a DELPHI about simulations and scenarios. - OK

2.4.3 Can we contact you, via e-mail in the case we need "specific information" referring to your expertise? YES

2.5 Specific Technical Questions (if there is enough time)
NO TIME

3. Feed-back and Final Comments

3.1 Your suggestions to improve the analysis

3.1 General comments about the goals of our work
Very good.

3.2 other aspects/factors to be considered in the analysis missing in the proposed approach This can only be answered when the model is applied to a practical case.

3.3 Direct feed-backs on the proposed approach of accounting
NONE

3.2 You have the last word: what is your bottom line?

Messages you want to be send through the report about a key point to be considered to improve the situation in Naples - NONE (too late)

Interview #7

Interviewed: Coordinatore Nazionale (activist)
Institution: Let's do it
Address: bar Piazza Municipio
Date: Sept. 17th, 2015 - 15,00 a.m. – 15,40 a.m.

A. General discussion of issues (information for NAIADE)

1. Checking the basic story-telling

1.1 The specificity of Naples

1.1.1 What are the factors that make UWM in Naples "special" and that generated the past crisis?
The problem has been generated by bad management generated by national and local institutions. Moreover, the citizens do not care enough for the environment.

1.1.2 Ranking motivations for action (assessing urgency from 1 to 10):
a. The economic costs are not sustainable; 6
b. Threats to human health and the environment; 10
c. Damage to the image of the city (negative impacts on tourism, agriculture): 8
d. Damage to social cohesion, de-legitimization of institutions: 9
e. other? NO

1.2 Governance/actors

1.2.1 The integration across vertical levels has been a disaster.

1.2.2 It is important to integrate analysis and policies referring to different issues, waste management has important effects of tourism, agro-food industry, the health of the people (terra dei fuochi). The actual system is not capable to coordinate the policies across levels and issues.

1.3 Economic View: the big picture (test the existing capability of analysis)
SKIPPED – the interviewed does not have the expertise to answer these questions

1.3.1 Approximate profile of economic flows (total and relative importance) over the different functional sectors;
1.3.2 Who pays and who gets the money for doing what?

1.3.3 Would you be able to estimate for the different functional sectors: (i) fixed and circulating money expenditures; (ii) JOBS; (iii) what remains in Naples and what goes out
1.3.4 What are the functional sectors that are really bad in terms of cost/effectiveness?

2. Perceptions about strategies changes to be adopted

2.1 Pros and Cons of the following strategies

2.1.1 Strategy A – revolutions do not work and can generate more damage than improvements, we need just to patch and improve the existing system
We need a radical change in culture and behavior, not only in the citizens, but also in the politicians and entrepreneurs

2.1.2 Strategy B – getting out from Business As Usual requires technological innovations capable of eliminating bottlenecks (during the discussion ask for the importance of the role of technology) - we need better technology but not to burn more

2.1.3 Strategy C – we need a strong discontinuity and use the crisis as an opportunity to build a better system of governance because technology alone will not solve the problem (during the discussion ask for the importance of the role of technology)
Same observation as before – we need better politicians and better entrepreneurs

2.2 Criteria and Indicators of performance
Can you suggest criteria of performance (and relative indicators) in relation to:

2.2.1 The quality of the service for the citizens
City cleanliness, fraction of waste sorting
2.2.2 The effect on the health of people and of the environment
Epidemiological studies looking for "hot spots" where it is possible to identify "smoking guns", bio-indicators (e.g. heavy metal in fish, problems in sheep)
2.2.3 Socio-economic effect of changes in the Waste Management System
Jobs, but not only in the MSWMS but also in sectors that may be affected (tourism)
2.2.4 Economic performance of the WMS (performance for whom?) SKIPPED

B. Quantitative representation of the UWM (preparation of the DELPHI)

(only if the interviewed has technical expertise) – SKIPPED NO EXPERTISE

2.3 Direct questions about the proposed characterization
2.3.1 How "useful" are the products of the WMS?

2.3.2 How "problematic" are the outflows of the WMS?
The interviewed made a remark about the fact that the data provided by ARPAC are not credible. The general public simply does not trust the data (lack of maintenance of the equipment recording pollution, especially before elections, bad positioning of monitoring spots, measurements only once a year not following through the different periods/events of the year. The lack of transparency in the

choice of protocols and equipments indicates a serious lack of quality in the work of ARPAC.

2.3.3 Quality check on quantitative assessment of the WMS of Naples
SKIPPED

2.4 Questions about future collaboration with the person interviewed

2.4.1 Check contact information (update and expand if needed) - DONE

2.4.2 Can we schedule a second interview in the week 19-23 October?
You will be able to have a look at the results of our characterization using NAIADE and participate in a DELPHI about simulations and scenarios. - OK

2.4.3 Can we contact you, via e-mail in the case we need "specific information" referring to your expertise? YES

3. Feed-back and Final Comments

3.1 Your suggestions to improve the analysis

3.1 General comments about the goals of our work
OK but it is important in this type of exercises to involve the civil society. The analysis cannot be done only by experts. For example, there are volunteers (environmental sentinels) that are helping to monitor illegal dumping, and the involvement of the civil society could dramatically improve the quality of the monitoring and the education of the citizens.

3.2 other aspects/factors to be considered in the analysis missing in the proposed approach - NONE

3.3 Direct feed-backs on the proposed approach of accounting
NONE

3.2 You have the last word: what is your bottom line?

Messages you want to be send through the report about a key point to be considered to improve the situation in Naples - NONE

Interview #8

Interviewed: Direttore Operativo
Institution: Azienda Servizi Igiene Ambientale Napoli
Address: via Ponte Francesi 37/d – 80100 Napoli
Date: Sept. 17th, 2015 - 16,30 – 17,45 a.m.

A. General discussion of issues (information for NAIADE)

1. Checking the basic story-telling

1.1 The specificity of Naples

1.1.1 What are the factors that make UWM in Naples "special" and that generated the past crisis?
Political factors, bad regulations, bad management, excess of bureaucracy generated a situation that could only end up in a collapse. Then the handling of the situation in terms of "exceptional action" for a very long period of time in which the central power ousted local authority in the handling of the issue of WM implied a serious underdevelopment of the WMS and the required expertise in the municipalities of the Campania region. This situation lasted until recent years.

1.1.2 Ranking motivations for action (assessing urgency from 1 to 10):
a. The economic costs are not sustainable; 9
b. Threats to human health and the environment; 4
c. Damage to the image of the city (negative impacts on tourism, agriculture): 4
d. Damage to social cohesion, de-legitimization of institutions: 5
e. other? The existing plants are not capable of handling the flow of wastes.

1.2 Governance/actors

1.2.1 The situation has been very messy in the past, especially when we had the "special commissioner", but now the situation is getting better.

1.2.2 The Region, Area Metropolitana and the Municipality are working to establish a coordination over the different jurisdictions.

1.3 Economic View: the big picture (test the existing capability of analysis)

1.3.1 Approximate profile of economic flows (total and relative importance) over the different functional sectors; the interviewed knows several important data, but cannot provide an assessment of the big picture or the relative size of different functional elements.
1.3.2 Who pays and who gets the money for doing what It is possible to obtain these data, but it requires time
1.3.3 Would you be able to estimate for the different functional sectors: (i) fixed and circulating money expenditures; (ii) JOBS; (iii) what remains in Naples and what goes out It is possible to obtain these data, but it requires time

1.3.4 What are the functional sectors that are really bad in terms of cost/effectiveness?
Lack of composting capacity

2. Perceptions about strategies changes to be adopted

2.1 Pros and Cons of the following strategies

2.1.1 Strategy A – revolutions do not work and can generate more damage than improvements, we need just to patch and improve the existing system
The system is now stabilized and it is important that remains functioning, but many things have to be fixed and adjusted

2.1.2 Strategy B – getting out from Business As Usual requires technological innovations capable of eliminating bottlenecks (during the discussion ask for the importance of the role of technology) - we need more investments in technology for sure, but it would be possible to use also existing technology

2.1.3 Strategy C – we need a strong discontinuity and use the crisis as an opportunity to build a better system of governance because technology alone will not solve the problem (during the discussion ask for the importance of the role of technology)
SKIPPED

2.2 Criteria and Indicators of performance
Due to time constraints, this question was skipped in order to take advantage of the expertise of the interviewed for other questions
Can you suggest criteria of performance (and relative indicators) in relation to:

2.2.1 The quality of the service for the citizens SKIPPED
2.2.2 The effect on the health of people and of the environment SKIPPED
2.2.3 Socio-economic effect of changes in the Waste Management System SKIPPED
2.2.4 Economic performance of the WMS (performance for whom?) SKIPPED

B. Quantitative representation of the UWM (preparation of the DELPHI)

2.3 Direct questions about the proposed characterization

2.3.1 How "useful" are the products of the WMS?

a. Who buy and what is the "value" and "revenue" of the recovered fractions: (i) Metals; (ii) Plastics; (iii) Glass; (iv) Paper – who gets the money?
Some data have been obtained

b.What is the "value" of other outflows and what are attributes determining their value? (v) Biogas; (vi) Compost; (vii) Fuels
SKIPPED;

2.3.2 How "problematic" are the outflows of the WMS?
SKIPPED for shortage of time, outside the expertise of the interviewed

2.3.3 Quality check on quantitative assessment of the WMS of Naples

a. Checking the proposed scheme based on the characterization of functional units and structural units (at two different scales) OK
The approach has been discussed in detail. It has been judged very promising and the interviewed has expressed his commitment in helping its implementation.

b. Checks on the data: quantity of flows, composition, costs
In his opinion it is possible to obtain all the required information and he will collaborate in fetching and transmitting the data that we require, in order to be able to do a DELPHI in October with the other experts of different institutions.

c. how obsolete is this representation we use, that is referring to the year 2012?
Minor changes took place but the general scheme is still valid

2.4 Questions about future collaboration with the person interviewed

2.4.1 Check contact information (update and expand if needed) - DONE

2.4.2 Can we schedule a second interview in the week 19-23 October?
You will be able to have a look at the results of our characterization using NAIADE and participate in a DELPHI about simulations and scenarios. - OK

2.4.3 Can we contact you, via e-mail in the case we need "specific information" referring to your expertise? YES

3. Feed-back and Final Comments

3.1 Your suggestions to improve the analysis

3.1 General comments about the goals of our work
Very Positive

3.2 other aspects/factors to be considered in the analysis missing in the proposed approach It depends on how the tool is used.

3.3 Direct feed-backs on the proposed approach of accounting
Strong commitment in helping the study.

3.2 You have the last word: what is your bottom line?

Messages you want to be send through the report about a key point to be considered to improve the situation in Naples - The fear is that now that the crisis is over the concern for urban waste management will fade away. The separate collection will not be pushed and the citizens will lose their commitment.

Interview #9

Interviewed: Operations Manager and Technical Manager
Institution: ARPACampania (Regional Agency Protection of the Environment)
Address: via Vicinale Santa Maria del Pianto – 80100 Napoli
Date: Sept. 18th, 2015 - 10,00 a.m. – 11,00 a.m.

A. General discussion of issues (information for NAIADE)

1. Checking the basic story-telling

1.1 The specificity of Naples

1.1.1 What are the factors that make UWM in Naples "special" and that generated the past crisis?
Shortcomings in the infrastructures (lack of proper dumping places, composting plants);
Insufficient separate collection, insufficient contribution from the final users, Insufficient investments in treatment plants. Lack of know-how at the municipal level.

1.1.2 Ranking motivations for action (assessing urgency from 1 to 10):
a. The economic costs are not sustainable; 9/10
b. Threats to human health and the environment; 9/10
c. Damage to the image of the city (negative impacts on tourism, agriculture): 10/10
d. Damage to social cohesion, de-legitimization of institutions: 7/8
e. other? NO

1.2 Governance/actors

1.2.1 The different institutions cannot make informed decisions because they do not have data about the situation and what the other know and do.

1.2.2 There are many institutions but they lack coordination (catasto rifiuti, osservatorio rifiuti, ufficio flussi, 5 osservatori provinciali, lega ambiente, ANCI) ma i dati sono non compatibili e non integrabili.
It would be important to integrate the generation of normative "top-down" with normative "bottom-up".

1.3 Economic View: the big picture (test the existing capability of analysis)
SKIPPED they say they cannot provide such an assessment
1.3.1 Approximate profile of economic flows (total and relative importance) over the different functional sectors; SKIPPED
1.3.2 Who pays and who gets the money for doing what SKIPPED
1.3.3 Would you be able to estimate for the different functional sectors: (i) fixed and circulating money expenditures; (ii) JOBS; (iii) what remains in Naples and what goes out SKIPPED

1.3.4 What are the functional sectors that are really bad in terms of cost/effectiveness?
SKIPPED

2. Perceptions about strategies changes to be adopted

2.1 Pros and Cons of the following strategies

2.1.1 Strategy A – revolutions do not work and can generate more damage than improvements, we need just to patch and improve the existing system
Things are changing anyhow

2.1.2 Strategy B – getting out from Business As Usual requires technological innovations capable of eliminating bottlenecks (during the discussion ask for the importance of the role of technology) - what is needed is "enough" technology to do what is needed

2.1.3 Strategy C – we need a strong discontinuity and use the crisis as an opportunity to build a better system of governance because technology alone will not solve the problem (during the discussion ask for the importance of the role of technology)
SKIPPED

2.2 Criteria and Indicators of performance
Can you suggest criteria of performance (and relative indicators) in relation to:

2.2.1 The quality of the service for the citizens
Cost
2.2.2 The effect on the health of people and of the environment
Environmental indicators are available on line they include all the indicators required by law and used for this goal. In relation to the emission, it is important to consider not only the emissions of the incinerator but also the emissions of all the trucks that are transporting around wastes.
In relation to health it is difficult to establish a easy-to-prove correlation between the performance of waste management and human health. It is easy to identify "special glaring cases". There is a study from (Istituto Superiore di Sanitá) – Studio SENTIERI – looking at tumors and illegal disposal of wastes (terra dei fuochi), but in that case other types of wastes (toxic, industrial) can be responsible for the problem.
The use of bio-indicators could be an interesting (sheep, fishes, other animals) direction.

2.2.3 Socio-economic effect of changes in the Waste Management System Jobs
2.2.4 Economic performance of the WMS (performance for whom?) SKIPPED

B. Quantitative representation of the UWM (preparation of the DELPHI)

2.3 Direct questions about the proposed characterization

2.3.1 How "useful" are the products of the WMS?

a. Who buy and what is the "value" and "revenue" of the recovered fractions:
(i) Metals; (ii) Plastics; (iii) Glass; (iv) Paper – who gets the money?
According to Alberto Grosso the value of the fractions recycled is much larger (more than 35M€) than the value estimated in our analysis (15M€). This difference is probably due to a different method of representation of the network of flows: our analysis refers to quantities of flows coming out from the MSWMS (urban waste), whereas the larger assessment include all the flows coming from other type of wastes (recycled material from industry).

b.What is the "value" of other outflows and what are attributes determining their value? (v) Biogas; (vi) Compost; (vii) Fuels
* Biogas is competitive only because there are incentives, not very promising as main source of revenues;
* Compost – it really depends on the quality of the final product, also in this case there are not big expectations about becoming an important source of revenue
* Digestate – this is a form stabilized waste with no economic value. It can be an input for the composting process, or it has to be processed and disposed into a landfill;
* Fuel – there are very few fluidized beds in Italy (Pietrasanta, in the Province of Lucca) so a local demand is not there. It can be used in cement plant, but it is not sure that it will be an economic hit (CDR with tires has problems). 17 MJ/kg is plenty for incinerators

2.3.2 How "problematic" are the outflows of the WMS?
SKIPPED they do not see systemic problems with these outflows (different than in other geographic situations) when considering urban waste management. The problem of illegal dumping of toxic wastes should not muddle the discussion of a proper management of MSWMS.
a. What are the emissions that are more problematic?
b. The issue of leachates
c. Specific problems with heavy metal?
d. Other?

2.3.3 Quality check on quantitative assessment of the WMS of Naples

a. Checking the proposed scheme based on the characterization of functional units and structural units (at two different scales) The approach seems interesting but they would like to see an application with numbers, in order to be able to give a more robust judgment.

b. Checks on the data: quantity of flows, composition, costs
Some of the required information has been written directly on the figure (but not much)

c. how obsolete is this representation we use, that is referring to the year 2012?
Minor changes took place but the general scheme is still valid

2.4 Questions about future collaboration with the person interviewed

2.4.1 Check contact information (update and expand if needed) - DONE

2.4.2 Can we schedule a second interview in the week 19-23 October?
You will be able to have a look at the results of our characterization using NAIADE and participate in a DELPHI about simulations and scenarios. - OK

2.4.3 Can we contact you, via e-mail in the case we need "specific information" referring to your expertise? YES

3. Feed-back and Final Comments

3.1 Your suggestions to improve the analysis

3.1 General comments about the goals of our work
So far so good, but let's see the application

3.2 other aspects/factors to be considered in the analysis missing in the proposed approach NONE

3.3 Direct feed-backs on the proposed approach of accounting
Alberto Grasso provided a very useful feed-back: when characterizing the technical coefficients of nodes, consider different "typologies" – e.g. the same plant of treatment can have outputs with a different composition of fractions, depending on the characteristics of the input (e.g. in different seasons the fraction of organic can change) so that one can imagine in the future in a more elaborated version, to utilize a taxonomy of different typologies to characterize the flows at lower level (technical coefficients and composition of flows).

3.2 You have the last word: what is your bottom line?

Messages you want to be send through the report about a key point to be considered to improve the situation in Naples - The main problem with the management of MSWMS in the Campania region is the fragmentation of the political/sociological fabric. Each small town and each small administration represents a different universe – feudalism.

Interview #10

Interviewed: Technician
Institution: Regione Campania – Pianificazione Gestione Rifiuti
Address: via Bracco 15/1 – 80133 Napoli
Date: Sept. 18th, 2015 - 12.00 – 12,45

A. General discussion of issues (information for NAIADE)

1. Checking the basic story-telling

1.1 The specificity of Naples

1.1.1 What are the factors that make UWM in Naples "special" and that generated the past crisis?
Bad planning, for example they were loading MBT (in Italian STIR) without having incinerators (this is how they got all the "ecoballe"). So the plants got flooded by the organic fraction (because of lack of separate collection). But then also for the separate collection there is no capacity for composting. The final result has been a maximization of transportation and saturation of the dumping sites.

1.1.2 Ranking motivations for action (assessing urgency from 1 to 10):
a. The economic costs are not sustainable; 3
b. Threats to human health and the environment; 3 (only outside the center)
c. Damage to the image of the city (negative impacts on tourism, agriculture): 5
d. Damage to social cohesion, de-legitimization of institutions: 3
all these refer to the past
e. other? WHAT IS IMPORTANT IS TO AVOID THAT THE NEW EQUILIBRIUM COLLAPSE!!!

1.2 Governance/actors

1.2.1 Vertical integration is a problem

1.2.2 Too fragmented (old consorzi di bacino). A test will be decision of re-definition of the ATO (the definition of the area in which the flow of waste has to be produced and disposed). Now the ATOs are too small and not logically defined within Campania.

1.3 Economic View: the big picture (test the existing capability of analysis)
This is the only other interviewed that guessed the overall amount of economic flow that can be associated to the operation of the MSWMS. Also in this case, the assessment given (600 M€) is close to the one we obtain with our model. Clearly this assessment depends on what is included in the assessment (e.g. the flows and activities included in the boundaries of the MSWMS and whether we include the overhead of the administration for spending the money.

1.3.1 Approximate profile of economic flows (total and relative importance) over the different functional sectors; NO
1.3.2 Who pays and who gets the money for doing what SKIPPED
1.3.3 Would you be able to estimate for the different functional sectors: (i) fixed and circulating money expenditures; (ii) JOBS; (iii) what remains in Naples and what goes out SKIPPED
1.3.4 What are the functional sectors that are really bad in terms of cost/effectiveness?
SKIPPED

2. Perceptions about strategies changes to be adopted

2.1 Pros and Cons of the following strategies

2.1.1 Strategy A – revolutions do not work and can generate more damage than improvements, we need just to patch and improve the existing system
It depends on the phase we are analyzing. Now it is important not to disturb the new equilibrium that is slowly emerging. For example exporting to The Netherlands is not good but it buys time to the system to develop more plant capacity and avoid the flooding of the plants (that reduce the efficacy of the operations)

2.1.2 Strategy B – getting out from Business As Usual requires technological innovations capable of eliminating bottlenecks (during the discussion ask for the importance of the role of technology) - the requirement of technology is certainly there but it depends on the choices done in the WM plan.

2.1.3 Strategy C – we need a strong discontinuity and use the crisis as an opportunity to build a better system of governance because technology alone will not solve the problem (during the discussion ask for the importance of the role of technology) A new system is under construction

2.2 Criteria and Indicators of performance
Can you suggest criteria of performance (and relative indicators) in relation to:
2.2.1 The quality of the service for the citizens
Costs, efficiency of the services, timing of the services
2.2.2 The effect on the health of people and of the environment
The conventional set of indicators
2.2.3 Socio-economic effect of changes in the Waste Management System
Jobs, effects on the tourism and other sector
2.2.4 Economic performance of the WMS (performance for whom?) SKIPPED

B. Quantitative representation of the UWM (preparation of the DELPHI)

(only if the interviewed has technical expertise)

2.3 Direct questions about the proposed characterization

2.3.1 How "useful" are the products of the WMS?

a. Who buy and what is the "value" and "revenue" of the recovered fractions: (i) Metals; (ii) Plastics; (iii) Glass; (iv) Paper – who gets the money?
The interviewed clarified the difference between the different assessments of the value of the recyclable fractions. The assessment of about 9 M€/year (given by ASIA) refers only to the materials sold by ASIA to the other economic agents involved in the recycling. The assessment of 15 M/€ (obtained by multiplying the final price to the quantities) includes also the value added generated by the private operators buying the material from ASIA. The value of over 35 M€/year (given by ARPAC) refers to the whole flow of recyclable fractions and it includes also industrial wastes.

b.What is the "value" of other outflows and what are attributes determining their value? (v) Biogas; (vi) Compost; (vii) Fuels
* Biogas – its economic viability depends essentially on the availability of subsidies;
* Compost – cannot be considered a source of income;
* Digestate – it is a stabilized waste no economic meaning;
* fuel – it really depends on the normative – whether it is categorized as a CSS (in the Italian normative "Combustibile Solido Secondario" previously called CDR) – that can only be used in a waste processing plant (CER code – 191210) or it is categorized "CSS-combustibile" (CSS-fuel) that then is considered to be a regular product. But then it can only be used in cement plant or power stations.

2.3.2 How "problematic" are the outflows of the WMS?
SKIPPED for shortage of time
a. What are the emissions that are more problematic?
b. The issue of leachates
c. Specific problems with heavy metal?
d. Other?

2.3.3 Quality check on quantitative assessment of the WMS of Naples

a. Checking the proposed scheme based on the characterization of functional units and structural units (at two different scales) The approach is interesting

b. Checks on the data: quantity of flows, composition, costs
Some of the required information has been written directly on the figure (but not much)

c. how obsolete is this representation we use, that is referring to the year 2012?
Minor changes took place but the general scheme is still valid

2.4 Questions about future collaboration with the person interviewed

2.4.1 Check contact information (update and expand if needed) - DONE

2.4.2 Can we schedule a second interview in the week 19-23 October?
You will be able to have a look at the results of our characterization using NAIADE and participate in a DELPHI about simulations and scenarios. - OK

2.4.3 Can we contact you, via e-mail in the case we need "specific information" referring to your expertise? YES

2.5 Specific Technical Questions (if there is enough time)
NO TIME

3. Feed-back and Final Comments

3.1 Your suggestions to improve the analysis

3.1 General comments about the goals of our work
It is interesting and he is willing to contribute to the future discussions

3.2 other aspects/factors to be considered in the analysis missing in the proposed approach Check the normative aspects (that can limit what can be done)

3.3 Direct feed-backs on the proposed approach of accounting
NONE

3.2 You have the last word: what is your bottom line?

Messages you want to be send through the report about a key point to be considered to improve the situation in Naples - NONE

Interview #11

Interviewed: Activis
Institution: Rete Commons (Presidio contro l'inceneritore di Acerra)
Address: Interview done at the University Parthenope - Napoli
Date: Sept. 18th, 2015 - 14,45 – 15,30

A. General discussion of issues (information for NAIADE)

1. Checking the basic story-telling

1.1 The specificity of Naples

1.1.1 What are the factors that make UWM in Naples "special" and that generated the past crisis?
Political choices made by the central government in a vision in which the north of Italy had the role of driver of economic growth and the south the role of disposing the wastes.
The mismanagement has later on generated a strong awareness in the population suffering the consequences of the bad management.

1.1.2 Ranking motivations for action (assessing urgency from 1 to 10):
a. The economic costs are not sustainable; 7

b. Threats to human health and the environment; 10
c. Damage to the image of the city (negative impacts on tourism, agriculture): 7
d. Damage to social cohesion, de-legitimization of institutions: 9
e. other? NO

1.2 Governance/actors

1.2.1 It is proved that the governance never worked so far

1.2.2 The involvement of the civil society in the process of decision making is only apparent. There is no empowerment and the participatory processes are more a form of public relation and anger diffusion, rather than a serious attempt to listen to the civil society.

1.3 Economic View: the big picture (test the existing capability of analysis)
SKIPPED – no expertise in relation to this field
1.3.1 Approximate profile of economic flows (total and relative importance) over the different functional sectors;
1.3.2 Who pays and who gets the money for doing what
1.3.3 Would you be able to estimate for the different functional sectors: (i) fixed and circulating money expenditures; (ii) JOBS; (iii) what remains in Naples and what goes out
1.3.4 What are the functional sectors that are really bad in terms of cost/effectiveness?

2. Perceptions about strategies changes to be adopted

2.1 Pros and Cons of the following strategies

2.1.1 Strategy A – revolutions do not work and can generate more damage than improvements, we need just to patch and improve the existing system
At times you need revolutions, when we behaved nobody has considered our requests…

2.1.2 Strategy B – getting out from Business As Usual requires technological innovations capable of eliminating bottlenecks (during the discussion ask for the importance of the role of technology) - we do not need silver bullets, but appropriate technologies doing useful processes

2.1.3 Strategy C – we need a strong discontinuity and use the crisis as an opportunity to build a better system of governance because technology alone will not solve the problem (during the discussion ask for the importance of the role of technology)
- we need a different method of decision making

2.2 Criteria and Indicators of performance
Can you suggest criteria of performance (and relative indicators) in relation to:

2.2.1 The quality of the service for the citizens
Fraction of separate collection, gradients in service between the city and the periphery

2.2.2 The effect on the health of people and of the environment
Epidemiological studies (especially tumors), transparency in the monitoring (data ARPAC cannot be trusted),
2.2.3 Socio-economic effect of changes in the Waste Management System
Jobs, costs
2.2.4 Economic performance of the WMS (performance for whom?) SKIPPED

B. Quantitative representation of the UWM (preparation of the DELPHI) SKIPPED – interviewed did not have technical expertise

2.3 Direct questions about the proposed characterization
2.3.1 How "useful" are the products of the WMS?
2.3.2 How "problematic" are the outflows of the WMS?
2.3.3 Quality check on quantitative assessment of the WMS of Naples

2.4 Questions about future collaboration with the person interviewed

2.4.1 Check contact information (update and expand if needed) - DONE

2.4.2 Can we schedule a second interview in the week 19-23 October?
You will be able to have a look at the results of our characterization using NAIADE and participate in a DELPHI about simulations and scenarios. - OK

2.4.3 Can we contact you, via e-mail in the case we need "specific information" referring to your expertise? YES

3. Feed-back and Final Comments

3.1 Your suggestions to improve the analysis

3.1 General comments about the goals of our work
Happy, whatever increase the chance of the civil society to participate in the process of decision making is good.

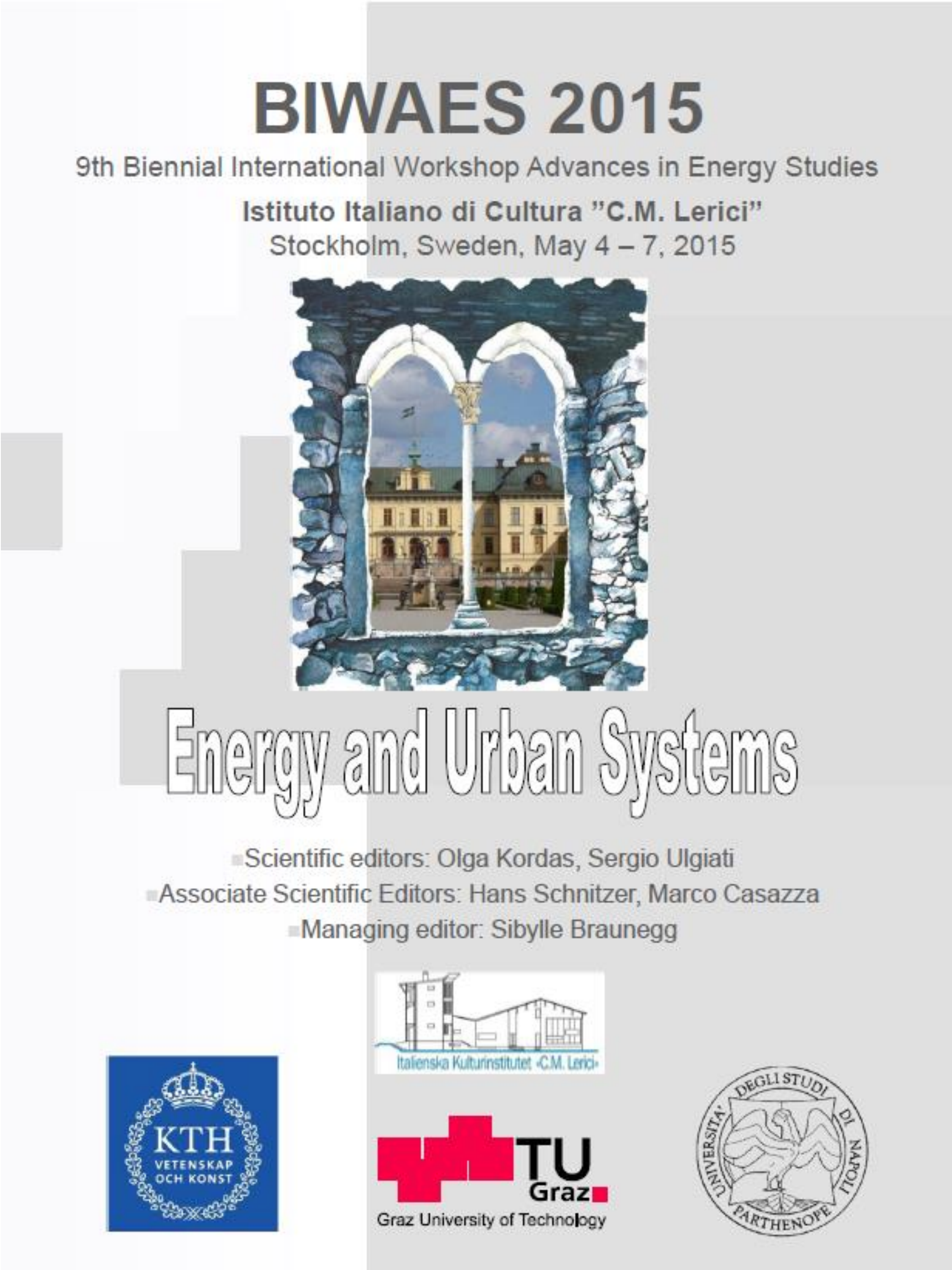
3.2 other aspects/factors to be considered in the analysis missing in the proposed approach It is important to check in practice whether things written on paper are then functioning in reality – e.g. "municipalitá" (ex-circoscrizioni) – the smallest institutional setting in the organization – do not have any power and they have only a symbolic role in the functioning of the civil society.

3.3 Direct feed-backs on the proposed approach of accounting
NONE

3.2 You have the last word: what is your bottom line?

Messages you want to be send through the report about a key point to be considered to improve the situation in Naples - The only relevant ingredient for achieving success in this situation is TRUST. In turn this requires: transparency and empowerment of the civil society that must be able to control what is going on.

Annex 3 - 1st Scientific publication



Participatory Integrated Assessment of Urban Waste Management Systems

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Abstract
An Urban Waste Management System (UWMS) modulates the interaction between the metabolic processes of a city, which generate a given mix of wastes, and the metabolic processes of its embedding ecosystems, which determine a given sink capacity. Framing the analysis of UWMS within this rationale of the metabolism of a 'socio-ecological system' allows us to study three criteria of performance: (i) feasibility in relation to external constraints (environmental impact at the local and global scale) and the prevailing law and regulations; (ii) viability in relation to internal constraints (economic costs and technical coefficients); (iii) desirability in relation to expectations and normative values of the social actors involved. A proper characterization of the performance of a UWMS in relation to these criteria requires us to define and assess four aspects: (i) the input from the society (city), that is, the quantity and quality of the flows of waste for processing; (ii) the characteristics of the embedding ecosystems that provide sink capacity; (iii) the mix of inputs required for the operation of the different stages of the process, such as technology, labour, energy, water and materials flows; (iv) the level of openness of the system, that is, the inflows and outflows of urban wastes for processing in the different stages of its operation and the final output to be disposed of into the environment. In this paper we illustrate a conceptual framework to integrate this quantitative information characterizing the performance of an UWMS based on MuSIASEM (Multi-Scale Integrated Analysis of Societal and Ecosystem Metabolism), an accounting method based on the flow-fund model developed by Georgescu-Roegen in the field of bioeconomics.

1. Introduction

We present here a general conceptual framework (grammar) for the analysis of the performance of Urban Waste Management Systems (UWMS), based on the Multi-scale Integrated Analysis of Societal and Ecosystem Metabolism (MuSIASEM). Like any meta-model, it can be tailored to specific cases and situations as need arises. The construction of the conceptual framework involves two steps: (i) selection of a set of relevant semantic categories and definition of expected relations among these categories; and (ii) formalization of the semantic framework into a quantitative characterization.

2. Defining a conceptual semantic framework for the analysis of UWMS

MuSIASEM integrates two non-equivalent views of the system under analysis, in this case the urban waste management system, the outside view and the inside view (Giampietro et al 2012; 2013; 2014):

(A) The outside view focuses on the interaction of the UWMS (seen as a black box) with its context. In this view we consider: (i) the source of waste flow to be processed; (ii) the sink capacity of ecological funds; and (iii) the inflows/outflows of waste during the various steps of the waste management process that determine the final quantity and quality of wastes, particles and pollutants released into the local environment or exported elsewhere. The outside view provides relevant information on the environmental impact of the UWMS and the consequences for human health.

(B) The inside view focuses on the functions and the structures of the parts that make up the UWMS, such as processes and technologies used for collecting, processing and disposing waste, and that together determine the 'capacity of managing waste' of the system as a whole. This view provides relevant information on the performance of the UWMS in relation to criteria such as economic costs, employment, and local development. For the internal view we thus need a functional definition of the UWMS (what functions are expressed) and a structural definition (what technologies are used; how are the functions carried out). An overview of the generic semantic framework, including the external and internal view of the UWMS, is shown in Fig. 1.

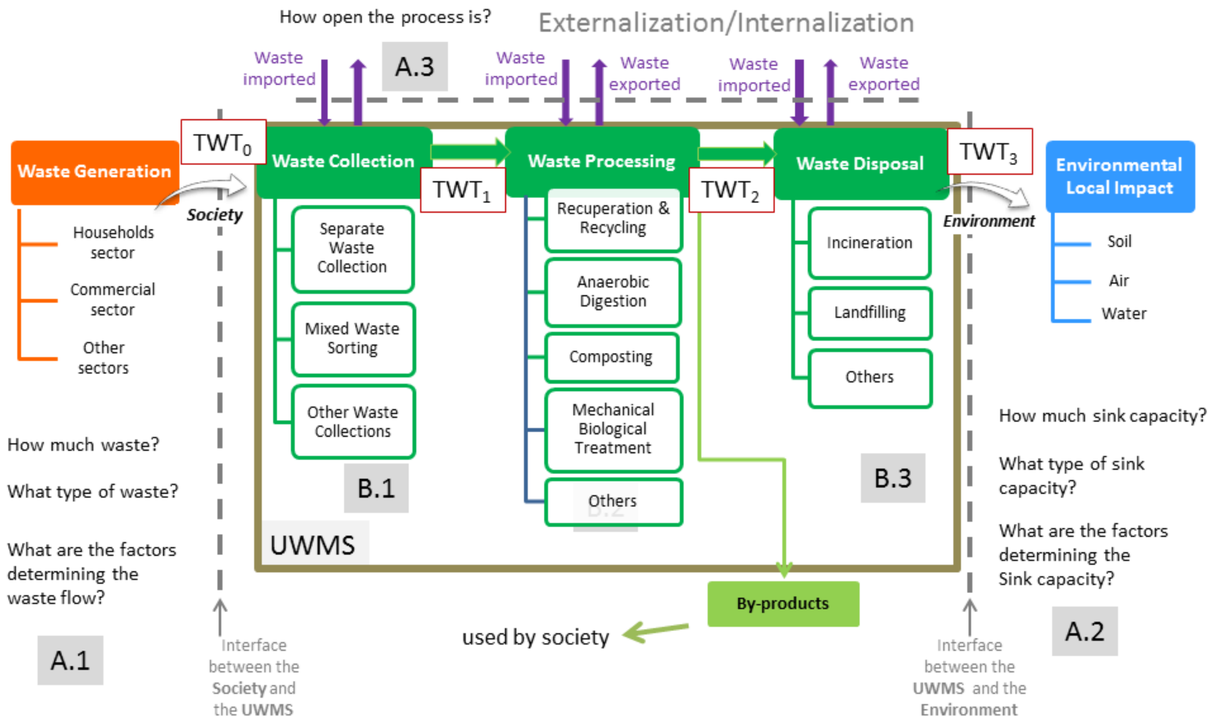

Fig. 1 *Conceptual semantic framework to characterize UWSM metabolism (UWSM = urban waste management system; A = outside view; B= inside view; TWT = total waste throughput)*

This pre-analytical, conceptual framing facilitates the definition of the technological option space of the UWMS (that is, the set of functions or tasks to be realised by the set of technologies) and also makes it easier, later on, to develop a multi-criteria assessment of alternatives and scenarios. Ideally, the semantic representation given in Fig. 1 should match with the perceptions of the social actors of what a UWSM is and what it does. Given the semantic skeleton of Figure 1, we thus need to operationalize and quantify the following concepts in our analysis:

A. In the outside view:
A.1 Waste generation by society (the input to the UWMS in terms of quantity and quality);
A.2 Environmental impact matrix (contextualization of the impact of the outputs of the UWMS in relation to relevant ecological funds);
A.3 Level of openness of the system as determined by the inflows and outflows of wastes and by-products from the various internal components of the system, including the final effluents (solid, liquid and gaseous) resulting from the overall function of waste disposal (all flows that are crossing the boundary of the UWMS);

B. In the inside view:
B.1 Waste collection (determining the interface: context/UWMS);

B.2 Waste processing (the network of processes taking place inside the black box);
B.3 Waste disposal (determining the interface: UWMS/environment);

This conceptual semantic framework can be further refined with additional, case-specific information about the different functional tasks within the UWMS and the technologies used to perform these tasks (inside view), as well as with context-specific aspects. For example, when focusing on solid urban waste management we may add the following processes to the conceptual semantic framework (see Fig. 1):

B.1 Waste Collection – Solid urban waste may be collected in different ways (as door-to-door, street containers, underground containers) separately, sorted afterwards, and/or other specific dedicated waste collection centres may be in place. The characterization of this step can be obtained by identifying: (i) the set of processes; and (ii) their relative importance.

B.2 Waste Processing – Also here, a mix of diverse technologies is usually in place. For example, separate waste collection of recyclables and biowaste, collection of mixed waste, complemented by waste collection centres. Selected solid municipal waste may be sent to recuperation and recycling material centres where different inorganic fractions of the separated municipal waste are extracted. Organic waste may be sent for anaerobic digestion or composting. As mixed municipal solid waste is concerned, it may be sent to mechanical and biological treatment plants or directly to landfills. The solutions adopted in this phase are affected by those adopted in the previous one (waste collection) and will affect those of the next phase (by influencing the level of reduction of the volume in quantity and quality). In the waste-processing phase it is essential to identify the fraction of waste that has been recycled or transformed in mechanical biological plants.

B.3 Waste Disposal – Any waste management system has a specific percentage of waste going to landfill/incineration. However, other solutions such as material or temporary storage may be employed. The percentage of TWT (Total Waste Throughput) disposed of into the environment is key to defining typologies of UWMS.

The advantages of constructing a semantic framework for the UWMS are manyfold and include:

(1) Facilitation of participatory problem structuring – A semantic definition of the UWMS is helpful to identify and compare the different perceptions and narratives of social actors involved;
(2) Awareness of potential environmental problems – The semantic framework elucidates key aspects of the interaction of the USWM with its context, such as: (i) quantity and quality of waste to process (in terms of pace per hour and density per hectare); (ii) the characteristics of the ecological context (in terms of critical thresholds of environmental loading); (iii) the level of openness of the system (in terms of externalization/internalization of waste flows during the various operations of the waste management system);

(3) Insight into the functioning of the UWMS – The semantic framework establishes a relation between the overall performance of the UWMS and the technical characteristics of the specific processes taking place within the system. The hierarchical organization of the different processes and corresponding functional compartments, that together express the overall function of the UWMS, can be tracked in quantitative terms by adopting an appropriate set of accounting categories.

3. Formalization of the semantic framework into a quantitative characterization

The second step involves a translation of the semantic definition into a set of formal categories associated with quantitative variables. In relation to the external view we have:

A.1 Waste generation by society. Depending on the society under analysis, waste generated by the household-, commercial-, industrial, or other sectors may have different properties (e.g. impurities, contamination). Hence, first of all, we must define a set of relevant attributes and corresponding values to identify flows of municipal waste. We focus here on municipal solid waste and use three indicators to quantify its generation (D'Alisa et al. 2010): (1) the Solid Waste Metabolic Rate per person (SWMR), an intensive variable measuring the amount of solid waste (in kg) generated per person per day; (2) the Total Solid Waste Throughput per year (TSWT), an extensive variable measuring the total amount of solid waste (in kg) generated in a year in a given community (over its total population); and (3) the Solid Waste Metabolic Density (SWMD) the flow of solid waste (in kg) generated by a given socio-ecological system per unit of area. These three indicators are crucial to compare the flow of solid waste produced and to be handled (characteristics of the society) to the sink capacity of the context (characteristics of the embedding environment). Indeed, TSWT and SWMD are indicators of 'environmental loading' and are related to SWMR as follows: TSWT = SWMR x population x 365; SWMD = SWMR x population density x 365.

A.2 Environmental Impact Matrix. This matrix relates the effluents generated by the UWMS to the ecological funds in its surrounding areas. It is generated by considering the ecological processes that provide sink capacity (the capacity of absorbing wastes without the insurgence of environmental problems) and/or ecological funds vulnerable to damage by the final effluents. The conceptual framework should be helpful to individuate, for each of the three types of effluents (gaseous/particles, liquid and solid) produced, the ecological funds that are (i) required to absorb effluents or provide inputs (e.g. water) to the UWMS; and/or (ii) jeopardized by the effluents. This type of analysis, when dealing with local impacts, can only be carried out in spatial terms and requires the use of GIS and interdisciplinary expertise (e.g., geology, ecology, hydrology, soil science).

A.3 Inflows and outflows of wastes, by-products, and final effluents for the various internal compartments of the UWMS. This is the most delicate aspect of the analysis. Indeed, due to lack of transparency, it is often difficult to describe the degree of openness of an UWMS. At times unwanted or unplanned flows of waste are (illegally) appearing or disappearing from a given process. In other cases, problematic fractions are exported to other UWMS, thus boosting the efficiency of the given system through 'externalization' of the problem. It is important to have an idea of the extent to which a given UWMS depends on other UWMS for complementing its functions and tasks. The degree of externalization (or internalization) can be detected by carefully looking at the mix of flows (inputs and outputs) passing the 'borders' of the different functional compartments. For example, in Fig. 1 the value of TWT_0 may be different from TWT_1 (when assessing the weight of solid wastes on dry basis, not considering changes in water content), and that of TWT_1 may be different from TWT_2, etc. Only after having identified the actual functions carried out in the various internal processes of an UWMS and after having assessed the degree of externalization or internalization of the flow to be processed to/from other plants, can we generate relevant comparisons among UWMS.

As regards the internal view, the semantic definitions have to be translated into a quantitative representation that can track the characteristics of elements across hierarchical levels: (i) the characteristics of the individual technical processes (local scale); and (ii) the relative importance of the different technical processes within each functional compartment (meso scale); and (iii) the relative importance of the different functional compartments within the UWMS (scale of the whole system). The MuSIASEM accounting scheme allows us to characterize technical processes in terms of a vector of 'end uses'. Indeed, any technical process requires *a set of inputs* including: (i) human labour, technology, infrastructures, and land (fund elements); and (ii) electricity, fuels, water, and other material inputs that appear or disappear over the duration of the analysis (flow elements). See Georgescu-Roegen (1971) for the distinction between funds and flows. In this way, the expected metabolic characteristics of a given activity (technical process) can be described by a specific profile of fund and flow elements –the vector of end uses– required to express the given task. The concept of 'end uses' was originally developed in the field of energy analysis (Giampietro et al. 2013; 2014) and goes beyond the conventional idea of efficiency or productivity focused on one input and one output at the time (e.g., labour productivity, energy efficiency). The idea of the vector of end uses flags the obvious fact that in order to express a given function we do not simply need an input of energy or water or an amount of hours of labour but the right combination of these inputs in the right quantity at the right time. Thus, we map the characteristics of a technological process ***j*** (TPj) onto a vector of end uses describing the quantities of fund and flow elements required per unit of output:

$TP_j = x_1, x_2, \ldots, x_i, \ldots x_n$

An overview of this approach is illustrated in Fig. 2.

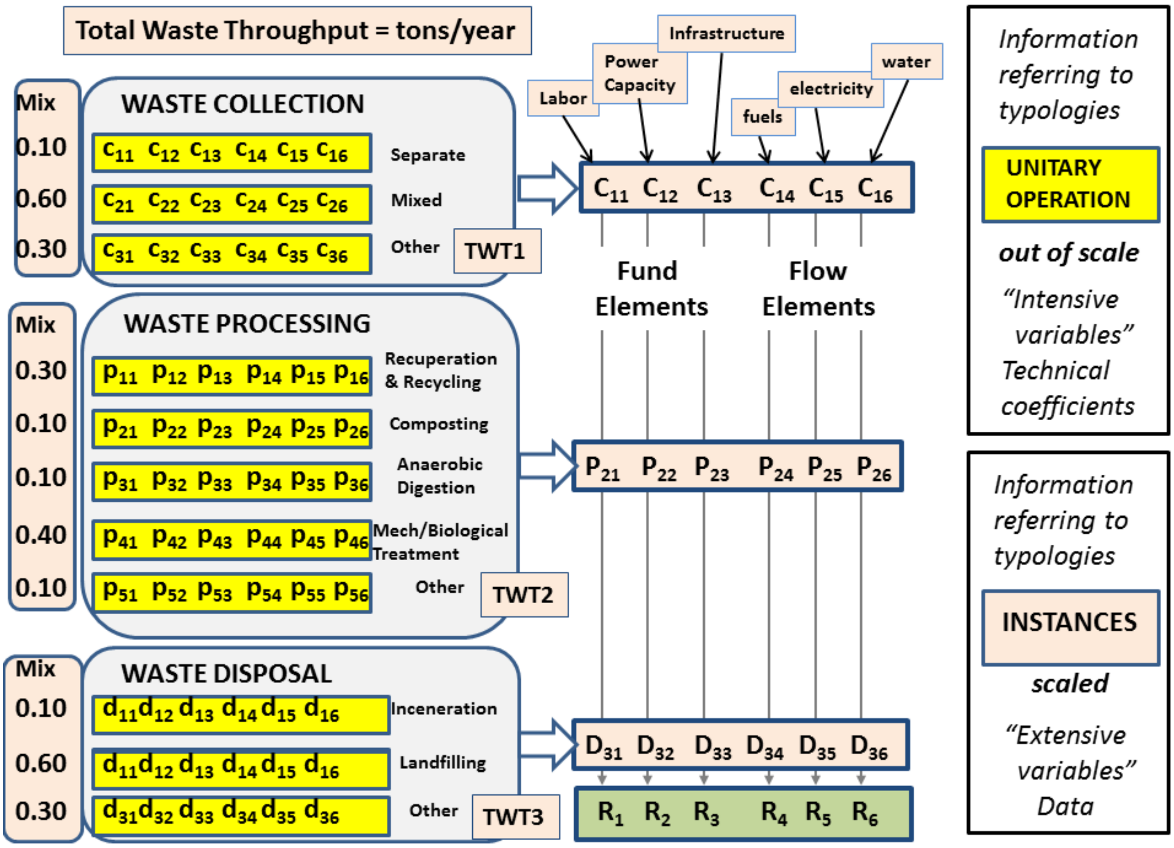

Fig. 2 – *Formal categories integrating information referring to types (technical coefficients of unitary operations) and information referring to instances (extensive variables describing the size of fund and flow elements at the level of the whole functional compartment)*

It shows the organization of quantitative data according to the internal view of the different functional compartments of the UWMS (as illustrated in Fig. 1). For example, for "separate waste collection" (a specific process taking place within a specific compartment) we define an end-use vector made up of 6 (intensive) variables: three fund elements (x_1 - hours of labour per ton/year; x_2 - kW of power capacity (size) of machines using fuels per ton/year; x_3 - kW of power capacity (size) of machines using electricity per ton/year) and three flow elements (x_4 - MJ of fuels per ton; x_5 - kWh of electricity per ton; x_6 - m^3 of water per ton of TWT processed).

Obviously, the selection of relevant variables for inclusion in the analysis depends on the nature and the goal of the study. However, in general, the formalization of the semantic representation is based on an integration of different types of data (extensive variables and intensive variables):

(1) Fund elements that give information about the size of the system. These elements are supposed to remain "the same" over the duration of the representation of the whole process. They represent the set of attributes used by the analyst to define *what the system is made of*. In general, the fund elements considered include:

- The hours of human work required in the process (linked to the presence of workers);
- The kW of power capacity of the machinery (either using electricity or fuels) required in the process;

- The infrastructure in the area required by the process (not shown in Fig. 2).

(2) Flow/fund ratios that give information on the characteristics of the processes performing specific tasks. Flow elements are both inputs and outputs that appear or disappear through the duration of the representation of the whole process. Flow/fund ratios are expected relations between fund and flow elements in relation to the throughput processes, that is, technical coefficient calculated on unitary operations. The profile of flow/fund ratios indicates *how the system does what it does*.
In relation to this point it is important to make a distinction between:

(1) technical coefficients (output/input ratios, flow/flow ratios) characterizing the technical performance of a process in relation to specific inputs. For example:

- kWh of electricity required in the process → kWh/ton of waste processed;
- MJ of fuels required in the process → MJ/ton of waste processed;
- m^3 of water required in the process → m^3/ton of waste processed;
- tonnes of technical inputs required in the process (not shown in Fig. 2). → ton of input/ton of waste processed

(2) flow/fund ratio defining the relation between the size (quantity of a given fund element) and the pace of a flow (quantity of the flow element per unit of fund). For example:
 * Hours of labor → hours/ton of waste processed
 * kW of power capacity electric → $kW_{electric}$/ton of waste processed
 * kW of power capacity thermal → $kW_{thermal}$/ton of waste processed

Whereas the technical coefficients (flow/flow ratios) are essential to study the characteristics of technological processes in terms of unitary operations (out of scale), the information about flow/fund ratios, makes it possible to scale-up the information about the performance of technical processes, moving to the meso-scale. Therefore, the set of relations illustrated in Fig. 2 makes it possible to integrate two types of information referring to:
(i) structural types (technologies assessed in terms of unitary operations) – i.e. intensive variables describing technical coefficients (technological performance described using flow/flow ratios) and flow/fund ratios – the vector of “end uses”;
(ii) instances of functional compartments – i.e. the characteristics of a specific functional compartment defined by extensive variables describing the overall use of fund and flow elements in the functional unit described in the grammar. The characteristics of a functional compartment do not depend only on the technical characteristics of the technologies used there, but also on the mix of technologies and the relative importance of the utilization of the different technologies included in the mix. Therefore, when using extensive variables to describe the size of fund and flow elements at the level of functional compartments we are describing “special instances”, in the sense that the values of these numbers depend on the special combination of: (a) the mix of technical processes carried out within each one of the functional compartments; (b) the relative importance of these processes; and (c) the technical coefficients reflecting the characteristics of the technologies used in these processes (the

characteristics of the types of technology assessed on unitary operations by the vector of “end-uses”).
The combination of technical coefficients (flow/flow ratios) and flow/fund ratios provided in the vector of “end-uses” makes it possible to interface these two non-equivalent forms of information.

Wrapping up, the organization of accounting categories illustrated in Fig. 2 includes three sets of accounting categories on the left side:
(i) a set of extensive variable referring to the size of the flow of waste to be processed – the assessment is expressed in tons/year of TWT. As illustrated in Fig. 1, depending on the level of openness of the UWMS the quantity of TWT_i can change when moving though the different functional compartments;
(ii) a set of intensive variables defining horizontal vectors of “end uses” (with 6 elements) describing both flow/fund ratios and technical coefficients (flow/flow ratios) of the different technologies used in the functional compartments to carry out specific Technical Processes, for example:
$TP_{jcollection} = c_{j1}, c_{j2}, c_{j3}, c_{j4}, c_{j5}, c_{j6}$; $TP_{jprocessing} = p_{j1}, p_{j2}, p_{j3}, p_{j4}, p_{j5}, p_{j6}$;
(iii) a set of fractions defining vertical vectors $[y_i]$ describing the profile of allocation of the throughput (TWT_i) over the mix of different processes included in the same functional compartment. In the example given in Fig. 2 there are three vertical vectors (one made of 5 elements – describing the profile of fractions of TWT handled by the mix of technologies adopted in waste processing – two vertical vectors made of 3 elements – describing the fractions of TWT handled by the mix of technologies adopted in the other two functional compartments). In each one of the three vertical vectors the fractions have to get closure on TWT: $\Sigma y_i = 1$
The two sets of accounting categories on the right side are:
(i) a set of six extensive variables defining three horizontal vectors describing the amounts of fund and flow elements used in each one of the three functional compartments FC_j:

$FC_{1(collection)} = C_{11},C_{12},C_{13},C_{14},C_{15},C_{16}$; $FC_{3(disposal)} = D_{31},D_{32},D_{33},D_{34},D_{35},D_{36}$;

(ii) a set of six extensive variables defining a horizontal vector describing the total requirement of fund and flow elements to operate the whole UWMS:

$UWMS = R_1, R_2, R_3, R_4, R_5, R_6$;

The organization of the categories of accounting illustrated in the scheme of Fig. 2 establishes a set of relations in the dataset making possible to combine: (i) information referring to technical coefficients (structural types described by intensive variables – flow/fund ratios and flow/flow ratios - describing the performance of unitary operations); and (ii) information referring to the specific circumstances of operation of the functional compartments: mix of technical processes and the relative quantity of TWT processed in each one of the processes included in the mix. For example, when considering the first of the three vectors on the right, the vector of “end uses” of collection determining the value of six cells:

$FC_{collection} = C_{11}, C_{12}, C_{13}, C_{14}, C_{15}, C_{16}$.

Each one of the six elements of this vector can be calculated combining the information provided by the categories of accounting illustrated on the left side of the figure. That is, information referring to: (1) types (c_{ij}); (2) fractions (y_i); and (3) extensive variable defining how much waste is processed (TWT_i) in each compartment. Then the element C_{1i} of this vector can be calculated as follows:

$C_{11} = (y_1 * c_{11} * TWT_1) + (y_2 * c_{21} * TWT_1) + (y_3 * c_{31} * TWT_1)$
. . .
$C_{1i} = (y_1 * c_{1i} * TWT_1) + (y_2 * c_{2i} * TWT_1) + (y_3 * c_{3i} * TWT_1)$
. . .
$C_{16} = (y_1 * c_{16} * TWT_1) + (y_2 * c_{26} * TWT_1) + (y_3 * c_{36} * TWT_1)$

This operation can be repeated for each one of the three horizontal vectors:

$FC_{processing} = P_{21}, P_{22}, P_{23}, P_{24}, P_{25}, P_{26}$
$FC_{disposal} = D_{31}, D_{32}, D_{33}, W_{34}, D_{35}, D_{36}$.

Finally, we can combine the three vectors describing the "end uses" of fund and flow elements in each one of the three functional compartments (collection, processing and disposal) to form an "end uses matrix" referring to a higher hierarchical level of organization: the requirement of funds and flow elements described at the level of the whole "Urban Solid Waste Management System".

Collection	C_{11},	C_{12},	C_{13},	C_{14},	C_{15},	C_{16}
Processing	P_{21},	P_{22},	P_{23},	P_{24},	P_{25},	P_{26}
Disposal	D_{31},	D_{32},	D_{33},	D_{34},	D_{35},	D_{36}
UWMS	R_1,	R_2,	R_3,	R_4,	R_5,	R_6

Having generated this end use matrix, by summing the values included in each of the columns we can generate a vector describing the overall requirement of each one of the fund and flow elements considered in the accounting for the entire UWMS.

In this way, the accounting scheme illustrated in Fig. 2 makes it possible to bridge information referring to different levels of analysis (local and meso scale) and different external referents – typologies of technologies and specific instances of functional compartments, when adopting the internal view. Then this information can be integrated with data referring to the outside view: (i) the input of waste produced by society; (ii) the sink capacity required from the environment; and (iii) the level of openness of the UWMS; with data referring to the inside view: (iv) the matrices and vectors of extensive and intensive variables describing the functioning of the functional compartments of the UWMS; and (v) the vector of extensive variables describing the requirement of inputs of the UWMS as a whole.

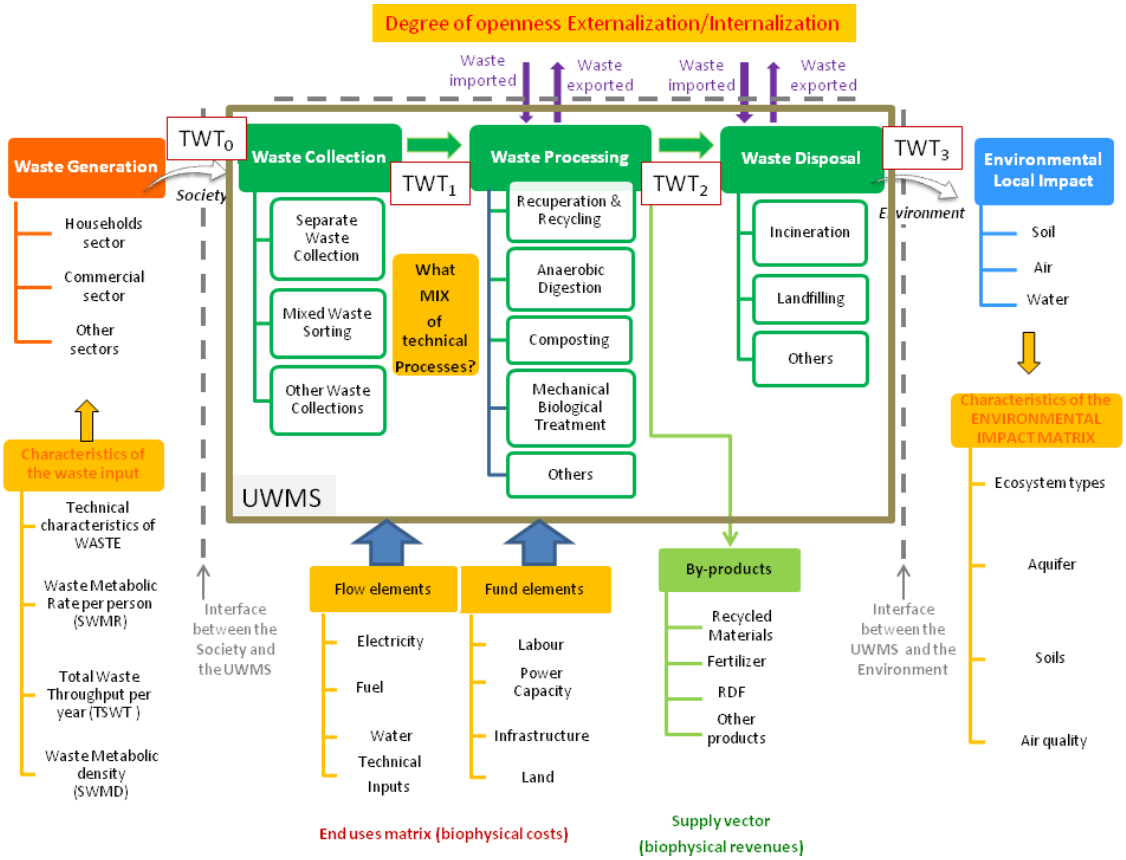

Fig. 3 – *Formal categories associated to the grammar needed to characterize the performance of UWMS metabolism – adopting both the outside and inside view - defining an integrated set of indicators.*

4. Conclusion

The scheme of multi-scale integrated accounting illustrated in this paper, based on the flow-fund model of metabolic analysis proposed by Goergescu-Roegen, can be used to combine different typologies of information: (i) internal and external view, as illustrated in Fig. 1, and (ii) information about "types" - bottom-up data referring to technical coefficients – and "special instances" – top-down data referring to statistical data, as illustrated in Fig 2.

The integration of the different data is illustrated in Fig. 3:
In relation to the outside view it identifies: (i) the characteristics defining the waste input coming from the society (on the left side); (ii) the characteristics defining the Environmental Impact Matrix used to check the sink capacity of the ecosystems embedding the UWMS (on the right side); (iii) the characteristics defining the degree of openness of the UWMS determining changes in the volume of TWT_i going through the different functional compartments (on the top).
In relation to the inside view (in the middle of the figure) we can identify the requirement of investments of fund and flow elements inside the UWMS determining the biophysical and economic costs (please note that in this figure we are listing among the production factors more than 6 typologies among the required fund and flow elements) and the overall supply of economic valuable by-products determining the revenues.

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Annex 4 – 2nd Scientific publication

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A holistic framework for the integrated assessment of urban waste management systems

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ABSTRACT

We report on the development of a holistic framework to organize and integrate quantitative information characterizing the performance of Urban Waste Management Systems (UWMS) across dimensions and scales. The framework builds on the theory of metabolic networks and the Multi-Scale Integrated Analysis of Societal and Ecosystem Metabolism (MuSIASEM) accounting method. We perceive the UWMS as an organ of a socio-ecological system that modulates the interaction between the metabolic processes of the urban area and those of the embedding ecosystems providing inputs and local sink capacity. Building on these premises, we can define: (i) the flow of wastes produced by the urban system in quantity and quality; (ii) the mix of inputs required for the operation of the different stages of the waste management process, such as technology, labor, energy, water and material flows; (iii) the degree of openness of the system, that is, the imports and exports of urban waste flows in the different stages of its operation; (iv) the final outputs released into the local environment. The proposed framework can accommodate various indicators referring to the socio-economic performance of the UWMS (viability and desirability) and those related to environmental impact/stress (feasibility). Theoretical considerations are illustrated with preliminary data from a case study on the Metropolitan Area of Naples, Italy.

1. Introduction

In 2014, 54 per cent of the world population was reported to live in urban areas and, according to UN projections, this percentage could reach 66 per cent by 2050 (UN, 2014). This phenomenon of massive urbanization is expected to exacerbate problems of inefficient municipal solid waste management already experienced in major cities world-wide (e.g., Bhuiyan, 2010; D'Alisa et al., 2010; Guerrero et al., 2013; Santibañez-Aguilar et al., 2013). In fact, the choice of a specific urban waste management system directly affects the metabolic pattern of a city and, as a consequence, the surrounding environment and the quality of life of its urban dwellers. Not surprisingly then urban waste management has become a crucial issue in the agenda of local and national governments both in developed and developing countries. Concomitantly, scientific research on the performance of urban waste management systems (UWMS) has seen an upsurge and various models and indicators have been proposed to support decision-making in municipal solid waste management (see, for example, Chang et al., 2011; Contreras et al., 2008; Hung et al., 2007; Kijak and Moy, 2004; Rigamonti et al., 2016; Thorneloe et al., 2007; Zaman, 2014). This has resulted in a scattered body of widely different types of qualitative and quantitative methods, individual and composite indicators, and more or less deterministic models. Morrissey and Browne (2004) reviewed the merits and shortcomings of the principal models for municipal waste management decision-making and come to the conclusion that none of the models proposed examines environmental, economic and social aspects at the same time. In line with their criticism, Marshall and Farahbakhsh (2013) plead for a complex systems approach, but do not make any attempt to quantification.

Indeed, an integrated quantitative assessment of UWMS performance presents a major epistemological challenge as it involves the simultaneous consideration of several dimensions (ecological, economic, technical, socio-cultural and political) and scales of analysis (spatial: household, urban zone, municipal, regional, national, and global; temporal: short-term versus long-term concerns). Moreover, the information generated by the assessment has to be relevant and useful for different stakeholders having legitimate but contrasting points of view about the performance of UWMS. Therefore, to develop a decision support system, we must

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Annex 5 – Curriculum vitae

Curriculum Vitae (09/2016)

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Nationality: Italian (Naples)

ACCADEMIC EDUCATION

1999 – 2006 **Master of Science in Environmental and Territory Engineering**
"University of Naples "Federico II" • Naples, Italy

- Thesis Title: "Project design of small biogas production facilities from anaerobic digestion of the organic fraction of Municipal Solid Waste in the Campania Region".
- Academic award "110/110 Cum Laude"

ACCADEMIC EXPERIENCE

11/2013 – to present *Barcelona, Spain* **UAB - Universitat Autònoma de Barcelona**	**PhD student in Environmental Sciences and Technology** Institute of Environmental Science and Technology (ICTA) PhD Thesis Title: "A Holistic Framework for the Integrated Assessment of Urban Waste Management Systems applied to the case study of the Metropolitan Area of Barcelona". PHD program funded by the European LIFE+ Project MARSS – Material Advanced Recovery Sustainable Systems (contract LIFE11 ENV/DE/343) aiming at evaluating the performance of an innovative technology for processing and recycling municipal solid waste.
04/2015 - 07/2015 *Rio de Janeiro, Brazil* **UFRJ - Universidade Federal do Rio de Janeiro**	**Marie-Curie fellow** COPPE Research fieldwork on the application of the Multi-Scale Integrated Analysis of Societal and Ecosystem Metabolism (MuSIASEM) to waste patterns for urban communities under conditions of social, economic and environmental vulnerability. Case studies of two favelas in Rio de Janeiro. Research secondment funded by the European Project: NETEP European-Brazilian Network on Energy Planning.

02/2013 - 07/2013 *Barcelona, Spain* **UPC - Universitat Politècnica de Catalunya BarcelonaTech**	**Researcher** Instituto de Técnicas Energéticas (INTE) Investigation on transparent electrodynamic shield application to mitigate the solar panel power output reduction due to dust accumulation in remote areas.

PROFESSIONAL EXPERIENCE

12/2010 to present **SQ Consult B.V.** *Barcelona, Spain* *Utrecht, The Netherlands*	**Renewable Energy Independent Consultant and Bioenergy Expert** • *Project Coordinator:* Coordination of national and international renewable energy projects. • *Research Analyst:* Data gathering, analysis, treatment and organization of information. Evaluation of results/conclusions. Legislation and literature review. • *Technical content developer:* Preparation of technical reports and working papers. Presentation of project findings in workshops and conferences. Biogas expert. • *Self-employment & Entrepreneurship* • *Acquisition and sales:* Tendering process coordination and preparation of proposals, grant requests and expressions of interest. Identification of new business opportunities in the international renewable energy markets with particular attention in Spain, Italy and Latin America. • *Project management:* Management of biogas production projects.
09/2009 - 12/2010 **Factor CO2 Ideas** *Barcelona, Spain*	**Renewable Energy and Climate Change Consultant and Bioenergy Expert** • *Project coordinator:* Coordination and development of technical content in renewable energy projects. • *Research Analyst:* Carbon footprint assessment. Evaluation of social-economic and I+D+i impact of wind parks projects. Biogas feasibility studies. • *Acquisition and sales:* Acquisition of new clients and projects in renewable energy market in Spain. • *Project management:* Management of carbon budget projects. • *Technical content developer:* Preparation of technical reports and working papers on bioenergy issues.
06/2007 - 08/2009 **Ecofys International** *Roma, Italy* *Barcelona, Spain* *Cologne, Germany* *Utrecht, The Netherlands*	**Bioenergy Consultant** • *Project coordinator:* Coordination of international bioenergy projects and teams. • *Research Analyst:* Data gathering, analysis and treatment and organization of information for bioenergy strategic studies. • *Support to acquisition and sales:* Coordination in tendering and proposal development process framed within multilateral development banks (World Bank, Inter American Development Bank, Asian Development Bank, Africa Development Bank). Support in acquisition of new projects and clients.
02/2007 - 05/2007 **Ies consulting**	**Bioenergy Junior Consultant** • *Project coordinator and research analyst:* project coordination and research of technical content of projects related to use of residues

S.r.l. *Roma, Italy*	and waste as alternative fuel within cement production sector.
06/2006 - 01/2007 **Faber S.r.l.** *Naples, Italy*	**Bioenergy Junior Consultant** • *Project coordinator and research analyst:* project coordination and development of design and permitting procedure for biogas CHP plants. (These projects were approved and financed on regional funding "POR CAMPANIA 2000-2006" from the Campania Region).

LANGUAGE SKILLS

- ***Italian*** Mother tongue
- ***English*** Fluent – working language during 8 years in academia and international professional area
  (Proficiency English certifications: IELTS and ESOL Level C1)
- ***Spanish*** Fluent - Daily use during 8 years of residence in Spain
- ***Catalan*** Basic - Participation in different conferences and courses

KEY SKILLS AND COMPETENCIES

- ***Organizational and coordination skills*** (Experience in international projects and multidisciplinary team coordination).
- ***Ability to work in a team*** (Strong inter- personal skills, ability to build relationships with the staff in a multicultural environment)
- ***Capacity for learning new topics*** (Practise in engaging continuous learning and adjusting the application of knowledge)
- ***Effective communication skills*** both written and verbal (Communication skills gained through the experience of report writing and speaking at workshops)
- ***Results orientation*** (Focus on completing and achieving efficient, timely, quality results by directing efforts on expected outcomes).
- ***Flexibility/adaptability*** (Ability to work under tight deadlines and to develop various projects simultaneously).

COMPUTER SKILLS

- Advanced knowledge of business software such as:
  Specific programs: AutoCAD, Sketch up and, Solarge, SIMAPRO
  Microsoft Office – Word, Excel, PowerPoint, Outlook, Access and PDF's
- Experienced with communication tools such as 2.0 websites, Yammer, LinkedIn, and Twitter

ACCADEMIC PUBLICATIONS

- Chifari, R. and Giampietro, M. (2015). "*Participatory integrated assessment of urban waste management systems"* that has been published in the book of proceedings: O. Kordas and S. Ulgati (Eds.), Proceedings of the 9th Biennial International Workshop Advances in Energy Studies, Energy and Urban Systems, Stockholm, Sweden, 4-7 May 2015. Verlag der Technischen Universität Graz, Graz, Austria, pp. 115-125. http://lamp.tugraz.at/~karl/verlagspdf/BIWAES_2015_os.pdf
- Chifari, R., Lo Piano S., Bukkens, S.G.F. and Giampietro, M. (2015) *"A Holistic Framework for the Integrated Assessment of Urban Waste Management Systems".* In press in the journal Ecological Indicators.

RECENT CONFERENCES AND WORKSHOPS

2015	• Speaker at UPC Terrassa presenting "Participatory integrated assessment of the performance of municipal solid waste management: Comparing the experience of Naples and Barcelona" (September 2014 -Terrassa) • Speaker at COPPE/UFRJ presenting "Understanding urban solid waste metabolism and role of local institutions: the case of two "favelas" in Rio de Janeiro" (July 2015 – Rio de Janeiro, Brazil) • Speaker at 15th International Waste Management and landfill Symposium presenting the oral presentation: "Integrated Assessment of Urban Solid Waste management Systems: a quantitative characterization of the situation in Naples" given by Rosaria Chifari (UAB) (October 2015 - Sardinia, Italy
2013	• "VIII Barcelona Global Energy Challenges Conference - energy challenges, opportunities and strategies already in action by those organizations who are leading this change" (June 2013 – IREC • Barcelona, Spain) • Speaker at INTE presenting "Electrodynamic Dust Screen (EDS) Application: Dust Mitigation Technology for solar panels in remote areas" (May 2013 - Barcelona, Spain)
2012	• "RenewableUK: The UK's premier renewable energy event" (October 2012 – Glasgow, UK) • "Roadmap to a Sustainable Bioenergy Supply Chain" (November 2012 – Amsterdam, The Netherlands) • "2012 European Advanced Biofuels Congress" (December 2012 – Brussels, Belgium) • Speaker at "Biogas plant opportunities for the Dairy industry in Gipuzkoa" (April 2012 - Gipuzkoa, Spain)

OTHER QUALIFICATIONS

2012	"The business formula" entrepreneurship and sales course. Seeseuno - CINC • Barcelona, Spain
2010	ECOFARM Course "Innovation for sustainable farmer sector". ADAP • Barcelona, Spain
2010	WISE (Waste In Social Environment) Course on "Human – producer of waste and decision-maker for recycling systems" Marie Curie Actions • Madrid, Spain
2009	Project Management Skills Course. Ecofys International • Utrecht, The Netherlands.
2007	Qualification to the Profession of Engineer in National Engineer Chart of the Province of Naples. National Engineer Chart of the Province of Naples • Naples, Italy.

SELECTED PROJECTs and assignments

Waste& Biowaste	• LIFE+ MARSS project: development of a tool-kit for the integrated assessment of municipal waste management systems that encompasses the environmental, institutional, socioeconomic, biophysical and socio-cultural dimensions of waste management. Client: European Commission. 2013-2015; • Survey on use of Refuse Derived Fuels for the cement production industry in 10 European countries (additional analysis of regulatory framework and

	financing schemes regarding energy use of biomass). Client: Cemex. 2008; • Manure Biodigestion technologies analysis in Aragón. Client: Aragón Government. 2010; • Resource evaluation for solid biomass for energetic use to identify the market dynamics in the European Union and the rest of the world. 2008; • Italian vegetable used oil market analysis; Client: Ferrero. 2008; • Use of residues and waste within "waste to energy" industries (such as cement production). Client: Holcim.2007; • Design and permitting scheme of plants for the production of biogas CHP plants in some Municipalities of Campania Region. Client: Campania Region.2007
Renewable Energy	• Investigation on transparent electrodynamic shield application to mitigate the solar panel power output reduction due to dust accumulation in remote areas. Client: UPC - Universitat Politècnica de Catalunya. BarcelonaTech, 2013; • Implementation of a new energy infrastructure for a small village based on Renewables. Client: Diputación de Gipuzkoa. 2010 – 2011; • Local strategy energy plan for a self-sustained energy system for the Municipality of Sitges. Client: Municipality of Sitges. 2010; • Full conceptual design of a "Renewable Energy Sustainable Demonstration Farm" in Dominican Republic. Client: Inter-American Development Bank. 2009-2010; • Evaluation of Wind Park proposals for the region of Cantabria, Spain. Client: GENERCAN. Socio-economical- impact. 2009; • Installation Guideline for Large Scale Solar Thermal Systems - 2 Case Studies). Client: Confidential, 2009.
Bioenergy	• Study on Biogas plant opportunities for the Dairy industry in Gipuzkoa. Client: URKOME Rural Development Association in Basque Country. 2011; • Detailed sustainable lignocellulosic biomass market study to identify its dynamics in 5 European countries. Client: Abengoa Bioenergy. 2008; • Technical and economic analysis of logistics and markets adaptation for biofuels in Spain. 2009-2010; • Evaluation of the emissions derived from biofuels supply chain through SIMAPRO software. Life cycle analysis for the characterization of no-GHG emission within specific biofuels supplies chain and related fossil fuels. 2008; • Study on biofuels (biodiesel, bioethanol, biogas) potential of the Province of Turin and assessment of the environmental and economic outcomes. Client: Province of Turin. 2007-2008; • Market analysis regarding potential and available solid biomass streams for "district heating". Client: SHV. 2007;
Policy Assessments	• Advice on transposition of RED for biofuels sustainability criteria in Spain. National Energy Commission (CNE). 2012; • Advice on sustainability policies for biofuels trading. Client: ED&F MAN, 2011 • Renewable Energy and Energy Efficiency political framework and financial support schemes in Spain. Client: Mars.2009 • Project on analysis of taxation schemes (fuels and energy) on European

	level. 2009; • Analysis of the regulatory framework and subsidize schemes for the promotion of renewable energy projects in Spain and Italy. 2008;
Climate Change	• Evaluation of carbon footprint of GSMA Mobile World Congress 2011. Client: GSMA 2010; • Developing carbon budget and domestic offset projects for Spain. Client: Friend of the earth Spain. 2009-2010;