Conversion of municipal solid waste into biomass fuel, by means of the MARSS concept. An integrated sustainability assessment.

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Abstract

Growing concerns about the increasing resource demand by society and the poor way society has been dealing with waste and natural resources call for increased attention to waste management in developed and developing societies. Landfilling and incineration, the most common practices for waste management worldwide, are not seen to be an acceptable solution in many countries with consumer resistance causing conflicts with decision makers who have the responsibility to try to find an economic workable solution for that location and culture. This paper addresses the urgent search for a viable solution based on technological innovation and cross-cultural stakeholders participatory strategies.

The proposed innovation in waste management arises from the EU LIFE Plus program MARSS, dealing with a modular MBT plant to extract useful waste fractions still available in the municipal solid waste after pre-sorting. A 10 tonnes per hour waste stream will be processed to produce a high quality biogenic refused recovered biomass fuel concentrated on the fraction <40mm. The project (www.marss.rwth-aachen.de) covers the technical production of RRBF, combustion and certification of the material and monitoring actions in different EU countries.

A preliminary LCA and socio-economic survey was carried out in in the city of Naples (Italy, project partner) to assess the environmental costs of energy management as well as the stakeholders opinions and attitude about present waste management strategies and technologies.

The project is not simply about the development and testing of a new technology, but also embraces integrated monitoring and impact assessment, combining the fields of innovative process engineering, environmental Life Cycle Analyses (LCA), multi-criteria socio-economic analyses, stakeholders participatory strategies in different EU countries.

Keywords: Biomass fuel, advanced municipal solid waste, integrated assessments, sustainability science

Introduction

Waste continues to be a significant problem in the 21st century, but the problem is not new. People create waste and people have to deal with it over time and have to make sometimes very conflicting decisions. Waste is not simply what we throw away but is rather a *complete narrative* about society's values, people's behavior and changing cultural conventions and the patterns of modern living. Waste in one location is not the same as in another and it constantly changes over time and with different ways of dealing with it. It is also about resources, development, environmentalism, personal identity, human behavior, finance, global market supply and demands and much more.

The motivation for the research also acknowledges that many strategic decision-making for dealing with municipal solid waste management is a real problem for many municipalities in the European Union. Only a few countries can be said to have a "grip" on waste in terms of reaching the targets set by different pieces of European legislation, but even these more advanced countries (such as Germany) also acknowledge that some decisions made in the past were not really sustainable or ecologically friendly, and maybe would have not been taken in exactly the same form today. Other countries are trying to benefit from lessons learnt, both good and bad, however are finding that it is *not easy or possible to simply transfer one basket of technologies or strategies per se* to other countries due to

differences in local problems, lack of funds, political preferences and population perceptions at the local and regional levels.

Project description and Technology

The Material Advanced Sustainable Systems (MARSS) project was successful in receiving funding from the European Commission and officially started in September 2012 and will end December 2015. The technical aim of the project is to demonstrate and assess the production of a renewable biomass solid fuel from mixed municipal solid waste (MMSW). A consortium of 5 partners (3 universities, 1 public authority and 1 SME) has joined together to design, build, monitor and analyse results from this innovative plant as well as carrying out integrated assessments supported by a multi-country stakeholder analysis. *This project is partly funded by the Life plus Programme coming under the Environment Theme of the 7th Framework Programme for Research and Technological Development.* The input material for the MARSS demo plant comes from an adjacent mechanical biological treatment plant (MBT) housed in the same purpose-built building in Mertesdorf, Germany. The MBT plant is owned by RegEnt GmbH and has been in operation since 2007, using the Herhof bio-drying technology, to process some 225,000 tonnes of residual mixed municipal solid waste produced by 532,000 inhabitants each year from households in the city of Trier and surrounding regions. In this process, the MMSW is stabilized through aerobic biological treatment steps to produce high calorific refused derived fuels (RDFs).

A side stream of about 10 tonnes per hour is taken from the main MBT plant and will be processed in the separate MARSS processing line to produce a quality biogenic solid dry fuel identified as a Refuse Recovered Biomass Fuel (RRBF) for energy production in biomass Combined Heat and Power plants. Research prior to building the plant showed that the MMSW is taken 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 so that the final concentrated organic fraction can meet the quality for combustion in biomass plants and therefore be used as a refined renewable biomass fuel (RRBF) with less than 5% contaminants. Further analyses will be carried out in the project to obtain accurate information about the right calibration of the system steps to enrich the organic fraction of biogenic origin and its use as a suitable biomass fuel with a final marketable quality for biomass power plants for the local decentralised production of heat and power. *The preliminary results of the testing campaign carried out by I.A.R. RWTH Aachen University in 2014 indicate that the majority of the biodegradable fraction is concentrated in the <40 mm fraction.* By additional further steps, it is possible e.g. to increase the heating value of the group size 4-11.5 mm fraction up to 13.800 kJ/kg. *(Giani et al, 2014 MARSS results).* The produced fuel would then be tested in a combustion research institute (UMSICHT – Fraunhofer Institute) as well as in chosen biomass heat and power plants in order to ascertain and reach required levels of quality and performance.

In addition to the technical demonstration in Germany, environmental as well as socio-economic impacts of the process will be assessed in an in depth study of Naples and Barcelona. Wide multi-cultural stakeholder involvement and consultation is also an important part of the broad assessment activities in the project. Therefore, considering the scope and ambition, such a project demands an carefully designed integrated approach towards the sustainability assessment of the production of a biomass fuel from mixed municipal solid waste based on the MARSS demonstration concept within the different chosen countries of Italy, the UK, Greece, Spain and the Czech Republic.

Inter-disciplinary approach: a mosaic effect

Three multi-disciplinary university research groups are using very different tools in their work however a combined novel methodology to integrate the different approaches and tools for different stages of the analyses has been made which is shown in Figure 1. This multi-faceted approach is can be compared to building up a mosaic where many different pieces are used, but the end effect is to provide a more complete picture. This paper should be seen as an introduction to this novel approach taken in the MARSS project and more as a discussion platform to add to the body of research in the combined fields.

The MARSS technology is seen as a EU-wide solution especially for those countries that do not comply with the Landfill directive at the moment, and is intended as an additional technology to add to a basket of sustainable municipal waste management waste technologies for replication and adoption in other European countries. In addition, the monitoring and cross-cultural stakeholder consultancy actions are specifically designed to provide deeper understanding about how to monitor and integrate this kind of technology into 5 selected very different countries with very different cultures and waste management histories.

It clearly therefore also demands integrated analyses that recognise the interconnections between multiple spatial/temporal scales and different cultures. “Studying sustainability entails facing a severe epistemological challenge: how to properly perceive and represent a process of becoming which is taking place across different scales, and therefore requires the simultaneous adoption of different dimensions and scales of analysis” (Giampietro et al, 2003 & 2009).

This paper acknowledges this demand, and deals with the management of municipal solid waste in the broadest

sense, acknowledging the need to evaluate the pros and cons of the different alternatives through a number of different approaches and disciplines, different time scales and criteria that embrace different dimensions of sustainability.

The aim is to understand what the key "sticking" points are when transferring a new technology to different cultures within the EU and to gain deeper insights into the similarities and differences between the different points of views of local stakeholders in those different cultures. In some Member States more than 80% of waste is recycled, however at the same time, based on the same legislation, many Member States still landfill over 75% of their municipal waste with low recycling rates (EU COM 2011) The technologies used are often the same but how can we account for the extreme differences in levels of uptake of what are considered to be more environmental friendly activities such as waste prevention, recycling and recovery eventually leading to a more sustainable solid waste management future? We need to gain a greater understanding of regional complexities in environmental, economic, psychological, social, cultural and political contexts in which the waste strategy will be inserted.

Over the last decades, there has been a developing awareness of the need to better understand what is required to *support good decision making*, and that the design of sustainable waste management systems is *much more than a technical issue*. Problems often arise in countries which conclude long-term waste contracts (such as in Greece with 35 years contracts being normal), so bad or misinformed decisions within municipal government can have long-term impacts at regional or even national levels. Simplified approaches, which do not take the social, political, and cultural contexts into account, are of little use to the decision-makers (Vigileos 2002). Little account was taken before of the wider public social acceptance of waste management decisions and recent reviews have advocated the "development of models that involve a wide range of relevant stakeholders in the decision making process" (Morrisey and Brown 2004) traditionally taken by those responsible for local and regional waste management and are often based on financial constraints rather than public concerns. However this is changing with the experience in some countries of public resistance to decisions made leading to calls for new ways of stakeholder consultancy with full public participation at all stages of the participatory process, and with a widening of decision support tools based on multi-criteria assessment principles. (Petts 2004).

The current trend is certainly towards the greater inclusion of different competences coming from economics, social sciences, human psychology and even anthropology, and research is going beyond traditional simple waste management models and assessment tools. This paper is part of this trend.

Several studies have already taken a similar broad-based approach and have combined different combinations of tools and multi criteria methods and a one description among many is provided by Shmelev et al (2006), however as their analysis shows, each one has their limitations and cannot be used because "they have not elaborated all the complex of factors influencing waste management processes at the regional level".

There is a growing call for more *integrated assessments of real world applications* (Higgs 2006) in order to provide objective assessments especially in the area where the decision-making process is primarily participative and involves possibly contentious decision making and when dealing with a wide range of different groups of stakeholders. This was highlighted also by Norese (2006) that it is more advantageous to carry out an early multi-criteria analysis with environmental impact assessments before any decisions are taken to site a new technology (with reference to waste incinerator and a waste disposal plant in Northern Italy) as it takes a considerable amount of time and effort not only to identify and set up the multi tool criteria for the integrated analysis, but also to understand the political and social dimensions especially in areas where there is some contention about the choice and operation of waste management technology.

This paper gives a broad overview of the multi-faceted approach taken within the analyses work carried out in the frame of the MARSS project and some results from the first phase will be presented. Further results from work done by all the teams will be presented in later publications when the research work is concluded and at end of project.

Motivation for chosen approach and assessment programme

Evidence and *concern about the human influence on climate* change is mounting (IPCC-AR5). Concerns are growing across the board and in many diverse sectors of society about the *increasing resource demand* by society and the poor way in which society has been dealing with waste and natural resources. It is clear that the times of what seemed to be abundant and cheap natural resources is coming to an end with the growing needs of a ever increasing global population combined with concerns about the security of supply of many essential materials and products. At the same time, there is a rise in interest in understanding different stakeholder groups in the sustainable management of natural resources and the environment linked with civil society's concerns about environmental impacts compounded by concerns of the continuing and growing practise of landfilling. The *increasing use of media and social networks* certainly play a role in rallying the normal citizen to take part in local resistance initiatives which in turn leads to greater public awareness in waste issues. In line with the growing number public-voiced concerns and demands for more transparency and greater access to environmental information, the EU Directive 2003/4/EC deals with these issues and provides guidance on the dissemination of environmental information to the public and Directive 2003/35/EC endorses

public participation and allows a direct expression of concerns relating to decisions affecting the environment within their local community (EU 2003). However timing is essential in this consultancy process in that it is too late when simply involving the public in the decision for the siting itself of the new proposed technology and not before in the discussions about the overall suitability of the proposed waste management strategy and approach for that local region (Rowe and Frewer 2000).

All research carried out in the area of waste has to take account of the legislative background in Europe which forms an important background to understanding new developments. What has been called the *"dynamic policy arena*" (Shmelev et al 2006) is known to be one of the most significant drivers to waste management strategy development and change. One specific aim in European legislation, as a response to some of these concerns about climate change, was to try to reduce landfilling of biodegradable municipal waste and laid out in the EU Landfill Directive 1999/31/EC (26 April 1999). This Directive was followed up by additional commitments to the adoption of different strategies to reduce landfilling of biodegradable fractions by member states as set out in Article 5(2)[1] in stages with the largest reduction to take place by 2006, followed by two further reductions by 2009 and 2016. All member states were asked to submit their national strategies and there were clearly significant differences in the detail of the responses and measures chosen. It is also well known that there are also significant differences in success rates between the different member states in reaching these agreed targets set for 2006 and 2009. This implies that any research looking into possible problems and solutions at an EU wide level must adopt a multi-country approach to be able to understand the mechanisms and appropriateness of possible solutions to deal with biodegradable waste in different countries and cultures.

Germany already fulfils the Landfill Directive and has a particular history in waste management. In the early 1990's, it was chosen to solve the problems of MSW treatment mainly via expensive high-tech incineration. At that time, CO_2 emissions from plastic combustion were not under direct scrutiny and climate change was not considered as an urgent issue as it is today. In comparison to Germany, most European countries have only just started (or even not yet) to decide on and set up their waste management systems and are looking for ways to comply with the Landfill Directive as fast as possible due to the acceptance of European legislation. Incineration is also not seen to be an acceptable solution in many countries, such as Italy, with consumer resistance causing conflicts with decision makers who have the responsibility to try to find an economic workable solution for that location and culture. Italy is an example of one such country where there is high resistance to the use of incineration technologies and also where there are still considerable problems and debates on the subject of MSW and landfilling. The choice of waste management solution is often made based on short-term visions, political agendas, lack of integrated knowledge and financial constraints; potential long-term impacts on the environment or society are of secondary concern. The expectations of the EU have simply not been met, with 2011 statistics showing that despite the legislation on landfilling and ambitious targets set for recycling, the EU continued to burn and bury between 60 to 100% of municipal solid waste (EEB, 2014).

Waste is normally seen as a problem to deal with in the fastest and cheapest way rather than a resource. However this too is now slowly changing in line with implementation of waste legislation (at different rates in different countries) as well as improved technological developments to provide more effective and robust processing systems to recover secondary raw materials. MARSS is one example of this.

Countries which are at a less advanced stage in municipal waste management and rely mostly on landfill still have the option to adopt more sustainable and environmentally friendly treatment options for MSW as they are only just starting down the path towards an integrated waste management system. There is no possibility of "one size fits all" solutions or using single approaches to solve complex societal problems.

It was due to this, that the MARSS project took a very different approach to normal demonstration projects, where the focus is normally on demonstration of the process and technology which is then in turn replicated and transferred using a "cut and paste" approach to other countries without taking cultural differences or the local situation into account. This paper acknowledges this need, and deals with the management of municipal solid waste in the broadest sense, acknowledging the need to evaluate the pros and cons of the different alternatives through a number of different approaches, different disciplines, different time scales and criteria that embrace different dimensions of sustainability.

Methodology

[1] *The strategies should include measures to achieve the targets set out in Article 5(2) by means of in particular recycling, composting, biogas production or materials/energy recovery.*
Article 5(2) requires the reduction of biodegradable municipal waste going to landfills to
– 75% by 16 July 2006
– 50% by 16 July 2009 and
– 35% by 16 July 2016
calculated on the basis of the total amount of biodegradable municipal produced in 1995 or the latest year before 1995 for which standardised Eurostat data is available.

The MARSS project has been divided into clear working packages (or Actions as they are called in the Life Plus Programme) and each team has clear tasks and goals set out in the working programme. The MARSS project is not simply about the development and testing of a new processing technology, but also embraces a much wider concept of novel integrated monitoring and impact assessment working in inter-disciplinary teams combining the fields of innovative process engineering, environmental Life Cycle Assessment (LCA), combined with specific multi-criteria analyses (MCA) tools to understand socio-economic impacts; in addition the project embraces the addition of a multi-cultural harmonised stakeholder consultancy programme to assess the differences, preferences and scope of stakeholder concerns. The first phase of the stakeholder consultancy has been concluded and some results are summarised. Adjustments to the integrated approach and teamwork will be carried out on the basis of critical assessments and analysis of intermediate results. Monitoring activities and results will be constantly discussed with a set of already identified stakeholders, in order to achieve an appropriate balance of technical, social and economic perspectives.

An in-depth study is being made on the city and region of Naples and comparing it to the city of Barcelona using a multi-criteria approach (based on a novel combination of MuSIASEM[2] and LCA) supported by different phases of stakeholder consultancy and local interviews. The partners are still developing a common approach to data determination and collection within the two case studies to enable effective comparison of results through the different methodologies. The LCA work is the responsibility of the team at University of Parthenope with support from RWTH University of Aachen. The life cycle analysis assessment will provide information about the range and quantities of emissions and impacts form the actual MARSS technical process whereas different regional scenarios of Naples and Barcelona will be compared using multi-criteria assessment methodologies (Munda and Romo, 2001). The reason for this is that LCA provides information on all emissions from a given technological process however it does not make geographical comparisons nor can it deal with time dimensions. When used on its own, LCA cannot adequately provide qualitative conclusions about what is more "sustainable or the "best "solution to the waste management problem in a regional area where a number of solutions could be viable depending on the set of priorities and conflicts of that particular region. The choice in the end has to be made between multi-dimensional scenarios and this is beyond the scope of normal LCA analyses. In this case of comparing different scenarios, multi-criteria assessment could be applied. (Munda and Romo 2001) The multi-criteria methodology chosen has been developed in-house by the group of Societal Metabolism Studies of the Institute of Environmental Science and Technology. Universitat Autonoma de Barcelona, Spain (ICTA-AUB). ICTA-AUB team is responsible for developing a methodological approach to interface the quantitative analysis of biophysical flows with the socio-economic analyses however this work will not be reported on in this paper as it has only just started.

This collaborative programme of integrated sustainability assessment combining LCA, multi-criteria analytical methodologies, and cross-cultural stakeholder consultancy incorporating knowledge generated by psychology and social sciences has been agreed and work is underway between the teams. Due to the complexity of the task of generating further understanding of sustainability assessment using the MARSS project as the main framework, we use a combination of *five non-equivalent methodologies/approaches*:

(i) *Life Cycle Analysis*

Life Cycle Analysis focuses on the flows of matter, environmental impacts, energy, costs and other services associated with the currently applied waste management in order to evaluate the environmental performance of the baseline scenario and to know if the proposed MARSS demo plant can be considered as a viable waste management alternative and what kind of emissions/impacts it could have at local level.

(ii) *Multi-criteria complex analysis*

"The multi-scale integrated analysis of societal and ecosystem metabolism (MuSIASEM) approach employed makes it possible to perform a check on the feasibility and desirability of patterns of metabolism of socio- economic systems by providing a characterization at different levels and scales of: (a) the performance of socio-economic activities (for households, enterprises, economic sectors, national economies, world economy) and (b) ecological constraints (micro, meso, macro) by looking at the interference that the metabolism of matter and energy flows controlled by human activity induces on the expected pattern of metabolism of matter and energy flows associated with the self-organization of natural ecosystems" (Giampietro et al 2009). Societal/urban Metabolism focusing on the flows of matter, energy and other services associated with the choices society makes in waste management. This multi-scale integrated analysis of the metabolic pattern of societal systems can then be interfaced with the analysis of the metabolic pattern of ecosystems looking at the exchanges of energy and material flows. In this way, it becomes possible to study potential constraints inside the society (technical feasibility and social acceptability) and outside the society in relation to the compatibility with the natural environment.

(iii) *Multi-cultural Stakeholder consultancy*

[2] © 2009 Societalmetabolism.org

The importance of stakeholder consultancy is becoming more and more appreciated and even required in many decision making process. Often detailed cost-benefit analyses are made on the choice and siting of a waste management technology only to find that local opposition requires a different final decision. As Petts (2003) put it so clearly, 'if the public could be involved more directly in the identification of relevant criteria, in understanding the site-selection process and in applying multi-criteria assessment methods to site identification they would be able to contribute to consideration of the trade-offs that have to be made'. Stakeholder consultancy actions are also taking place in parallel in the UK, Greece and the Czech Republic to compare and understand the different cultural and political constraints in different EU countries looking at the MARSS project and its applicability and transfer modalities to different countries however this will not be reported in this paper.

(iv) *Psychological and cross-cultural approaches*

Behaviour change models have been developed from the behavioural psychology and social sciences, and to a smaller extent from anthropology. All three disciplines try to understand how individuals affect, and are affected by, their culture and environment. The growth of research in looking at how psychology and social science competences can contribute to decision-making processes and stake-holder consultancy issues indicate the growing importance of these fields in multi-criteria analyses and the broad area of waste management.

(v) Technological approach

This approach deals with the design, construction and optimization of the MARSS process plant into the integrated assessment programme. This means that there is close cooperation between the engineers working on the modular design of the demonstration plant as well as monitoring the operational results. The data collected about performance and operation are fed into the LCA analysis as well as into the stakeholder consultancy actions.

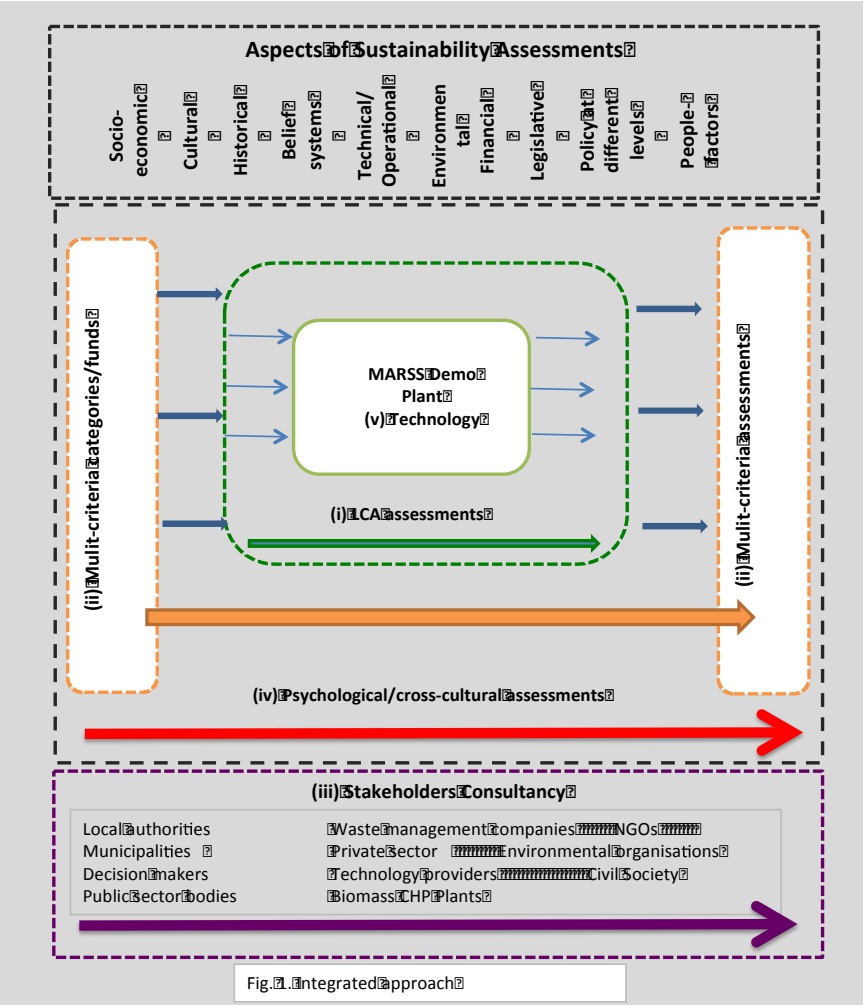

Figure 1. The main elements and interactions of MARSS approach.

So in addition to the knowledge generated by learning how to combine different methodologies and generating a protocol of integrated assessments from the comparison of the different integrated assessments generated in different case studies, we can learn about the different priorities given or needed in different cities and different societies. The

"assessment of the degree of '*integrated sustainability'* needs an analysis that uses a range of criteria, both quantitative and qualitative indicators, as well as a mechanism to weigh these different indicators against each other (Klundert et al July 1999). A short overview is given of the research disciplines used in the multi-criteria approach below.

Description of methodologies

(i) LCA

In business, applying a sustainable management strategy has often meant a strategy of reducing environmental impacts that is confined within the factory gates. These strategies have not considered consequences on upstream supply chains, product use and end-of-life. Government actions focused primarily on the needs and problems of the country or region, without considering knock-on impacts or benefits that would occur in other geographies. In both cases, if there is insufficient attention to the full life cycle (production/supply/use/end-of-life), overall environmental degradation and unwise resource use may result. Additional potential consequences are damaged image and impaired financial performance for the parties involved. Life Cycle Thinking (LCT) is a conceptual approach that seeks to identify improvements and to lower the impacts of goods or services (products) at all stages of associated life cycles, from raw material extraction and conversion, product manufacture, through distribution, use and end-of-life treatment. The concept of Life Cycle Thinking helps to avoid the situation of resolving one problem while creating another. LCT avoids the so-called "*shifting of burdens*", e.g., from one stage in the life cycle to another, from one region to another, from one generation to the next or finally amongst different types of impacts.

A Life Cycle Assessment (LCA) is a tool to assess each and every impact associated with all the stages of a process from "cradle to grave" or better from "cradle to cradle", including recycling and reclamation of degraded landscape and environmental resources. Life Cycle Assessment (LCA) is a structured, comprehensive and internationally standardized method (ISO 14040, 14044: 2006). It quantifies all relevant emissions and resources consumed, their related environmental and health impacts, and resource depletion issues that are associated with any good or service (the term 'service' includes for example waste management systems) delivered by a process ("products"). The use of Life Cycle Assessment methodology (LCA) following the ISO standards, for evaluating alternative waste management strategies is becoming a commonly utilised tool for addressing the decision makers (Finnveden, 1999).

(ii) Multi-scale integrated analysis

Multiple Criteria Analysis (MCA) is actually a part of normal daily activity carried out by everyone having to make a decision or choice depending on a set of personally chosen criteria with a specific target in mind bound by constraints around that choice. These informal analyses are normally based on intuition or a set of personal chosen priorities such as financial limits, personal preferences and cultural values. *Multiple-criteria decision-making* (MCDM) and *multiple-criteria decision analysis* (MCDA) take this informal activity into formal active areas of research to try to understand and support decisions that have to be taken in complex situations with seemingly competing priorities, different scales and different input criteria. In these cases, there are no perfect obvious choices or solutions for the presented problems. In addition, how do we determine or define the "best" solution especially when there are multiple criteria at the basis of the assessment procedure?

The scaling of the MARSS demonstration plant and the capacity indicates that it is aimed to be a regional solution where at least 150,000 to 300,000 people are living. Of course, as it is built on a modular design, it could be downsized or even scaled up depending on the local needs and total waste produced. At the pre-decision phase, the actual path of how MARSS process could fit into the final development of the locally adopted waste management system and the impacts are not known and therefore this uncertainty already represents a situation of choice between multi-dimensional scenarios in different physical locations. Traditional life cycle analyses as a stand-alone tool does not easily deal with risk or uncertainty and therefore it seems clear that additional multi-criteria assessment tools need to be brought into the analyses. Literature searches have shown that many other researchers support the use of more than one multi-criteria method or the use of hybrid approaches in environmental management applications, for example Kangas & Kangas 2005. As Janssen said *'MCA is used to bring forward the differences among alternatives' (Janssen 2001).*

MuSIASEM approach, derived from Complex Systems Theory (multi-purpose grammars, impredicative loop analysis, Sudoku effects), makes it possible to generate "quantitative representations of the viability and desirability of the metabolic pattern of modern societies using simultaneously technical, economic, demographic, social and ecological variables defined on different hierarchical levels and scales".[3] It is therefore possible to characterize and describe different levels and scales of the performance of (a) diverse sets of socio-economic activities (from households, enterprises, economic sectors, national economies and the global economy) and (b) different scales of ecological constraints (micro, meso, macro) by looking at the interference of human activity impacting on natural ecosystems

[3] http://eco2bcn.es/eco/people_senior_researchers.html

(Giampietro et al. 2014). MuSIASEM is a recent and still evolving approach (developed by Giampietro and Mayumi as of 1997) that tries to deal with providing a better understanding of complex systems by taking into account different factors and non-equivalent dimensions such as economic, social, cultural, technical, environmental and political domains in an integrated analysis of what seems to be incompatible domains. It allows a representation of the performance of a system taking into account different factors and attributes, by relating and describing different (but working in parallel) non-equivalent domains (i.e., formulations of the same problem from different perspectives). This issue has been long discussed and difficulties arise when trying to solve such problems when dealing with sustainability and complex systems (Giampietro et al. 2012). In conclusion the MuSIASEM approach makes it possible to deal with "the complexity implied by the available heterogeneous types of information, because these sources of data are irreducible and incommensurable in their nature." (Giampietro et al 2009

(iii) Stakeholder consultancy

Stakeholder analysis is a process of systematically gathering and analyzing qualitative information to determine whose interests should be taken into account when developing and implementing a policy or program. The first question to answer is: who is a stakeholder? In the consultancy process, stakeholders are identified as the actors (persons or organizations) who have a vested interest in the promotion of a policy, a program or an action. These stakeholders or "interested parties" can usually be grouped into the following categories: international, public, national political, commercial/private, nongovernmental organization (NGO)/civil society, labor, and users/ consumers. In general, it is important to properly map the stakeholders closer to the organization or to the administrative or political parties that operate in an area, and then, after a primary list of stakeholders, it is important to analyze their characteristics, (such as information about their point of view about the organizations, or the administrative parties; interests related to the policy, position for or against the policy that administrative will make; potential alliances with other stakeholders, and ability to affect the policy or the organization or process, through their power and leadership).
Knowing who the key actors are, their knowledge, interests, positions, alliances, and importance related to the policy or plan allows policy makers and managers to interact more effectively with key stakeholders and increase support for a given policy or program. By carrying out this analysis before implementing a policy or program, policy makers and managers can detect and act to prevent potential misunderstandings and/or opposition to the implementation of the policy or program. A policy or program will more likely succeed if a stakeholder analysis, along with other key tools, is used to guide its implementation. Stakeholder analysis yields useful and accurate information on stakeholders and their needs or interests. This information can be used to provide input into other analyses; to develop action plans to increase support for a reform policy; or to guide a participatory, consensus-building process. To increase support or build consensus for reform, policy makers and managers must take additional steps following the stakeholder analysis. The information generated by the stakeholder analysis is also useful to develop and implement strategic communication, advocacy, and negotiation plans and to create the transparent dialogue that it is necessary for some project, especially project that might have non-negligible impact on environment and health of stakeholders.
Essentially the stakeholder's analysis involves four steps:

- Identifying the key stakeholders from the large array of groups and individuals that could potentially affect or be affected by the proposed intervention.
- Assessing stakeholders' interests and the potential impact of the project on these interests.
- Assessing the influence and importance of the identified stakeholders.
- Outlining a stakeholder participatory strategy (a plan to involve the stakeholders in different stages of the project preparation and implementation process).

All in all, a project or proposal might be technically feasible and environmentally sound, but might not be accepted by stakeholders for a set of reasons that have nothing to do with technicalities or environmental constraints. Stakeholders might have a system of beliefs and values (aesthetic, economic, social, etc) that conflict with technical reasons. If this is the case, this conflict has to be discussed and carefully addressed.

After the creation of a preliminary stakeholders' list, a first consultancy phase is being carried out by using a survey methodology (e.g. distributing questionnaires to the stakeholders)[4], this methodology has been used for MARSS project, as show later. The stakeholder analysis is a methodology used to facilitate institutional and policy reform processes by accounting for and often incorporating the needs of those who have a 'stake' or an interest in the reforms under consideration. Stakeholder Analysis was born from the business sciences, it has evolved into a field that now incorporates economics, political science, game and decision theory, and environmental sciences. Actually the models of Stakeholder Analysis apply a variety of tools on both qualitative and quantitative data to understand stakeholders, their positions, influence with other groups, and their interest in a particular reform.

(iv) Psychological and cross-cultural approaches

[4] This methodology has been successfully used in another stakeholder's consultancy, in the years 2012-2013 in Agri Valley, Italy, for risk assessment of hydrocarbon extraction, for communication purpose, and for monitoring of the social and economic impacts of these activities.

Psychological: One of the clear initial results of the stakeholder interaction has been to show up some clear psychological issues such as the issue of trust – trust in the group carrying out the consultancy procedures and lack of trust in the municipal authorities who are responsible for making the final decisions about solid waste management in the Naples region. This strongly implies that the inclusion of competence and analytical tools found in behavioural psychology is essential if we are to really understand the underlying mechanisms and drivers of behaviour as well as to understand how to actually approach the consultancy and decision making process.

With the increasing broadening of the involvement and type of stakeholders in waste management decision making processes, it is clear that the interactions and personal agendas of people within the different groups have to be taken into account. The more interactive and complex the decision making process becomes, the more we need new types of analytical procedures drawing on a broad range of knowledge from different disciplines. In fact, one could say that stakeholder interaction can be a success or a failure simply because the wrong approach and tools were used in the consultancy procedures. Information and how it is presented can have a direct effect on how it is understood and received. It is also important to know what questions to ask, including a careful choice of which words/language will be used before asking the questions, as the format of the question will already affect the answer.

Bearing this in mind, it makes sense that researchers then draw on competences and insights provided by behavioural, psychological and social sciences. This is an enormous and flourishing area of research and it is not the aim of this paper to go into any great detail about the different theories, which could be relevant to extend multi-criteria analysis by using the one or other combination of competence found within this area. However, a short summary of some theories that are being considered in the set up of the consultancy programme would be useful. Moreover some of these theories can provide insights as to how to interpret and assess received stakeholder reactions from the surveys.

The largest area of research so far has been focused on the individual as being the centre and starting point of how that person interacts with society and the surrounding environment (internal to external). Most work comes from psychology (particularly social psychology), and sociology. Behaviour is seen to be the outcome of the sum of external influences on that individual and how that individual decides to think and act in response to these influences. Other theories concentrate on the relationships between individual behaviour and how that interacts with the social, political and physical environments. Others explore the effects of society, environment and technologies on the individual (external to internal). Only a few will be mentioned here.

One of the main theories that focus on the link between beliefs and behaviour of an individual, *The Theory of planned Behaviour says* that human behaviour is based on three considerations: " beliefs about the likely consequences of the behavior (behavioral beliefs), beliefs about the normative expectations of others (normative beliefs), and beliefs about the presence of factors that may facilitate or impede performance of the behavior (control beliefs). Another area of interest of work being carried out in the stakeholder consultancy in MARSS also has to do with the provision of accurate information in the form of a project description about the new technology and potential impacts if applied in Italy, and how this is received and perceived by the stakeholders. Current research interests of Aizen Icek are actually addressing this issue. As he says "Accurate information is considered necessary for effective action, yet empirical evidence provides little support for a relation between knowledge and behavior". A deeper understanding of this are will be followed up in the on-going research.

The Health Belief Model (HBM) (Hochbaum, 1958; Rosenstock 1966; Becker, 1974; Sharma and Romas, 2012) centres on individual fears about threats to that person and the level of costs/benefits to that person from different courses of action. So if the person sees little personal benefit, they are unlikely to adopt new ways of behaving however if the personal costs are high, then there is more motivation to carrying out. These cues to action can come from internal or external influences. Although designed and developed in the healthcare context, the HBM has been applied to the analysis of other types of behaviour, such as recycling (Lindsay and Strathman 1997), and is most suited to explaining or predicting patterns of behaviour. There are of course criticisms about using this model per se without consideration of other social or economic or determinants of behaviour (Jackson 2005: 133). Every model can be criticized for serious shortcomings or an "incomplete" analysis however there is a strong intuitive element when considering the use of individual models as part of a multi-criteria analysis. Each reader can identify with the one or other aspect portrayed in the models and theories and it is clear that individuals themselves play a significant role in deciding what they want or do not want to do or what they want to accept in waste management.

Social interaction within stakeholder groups and communities also acts as a carrier of information and belief systems. *Social practice theory (SPT)* approach is not a focus per se on the individual but rather on social practice and is increasingly being applied to the analysis of human behaviour; examples of studies include energy use, consumption patterns and habits. The main point is that the individual´s behaviour is impacted by external material influences (Reckwitz 2002). In particular SPT identifies the fact that it is very difficult to break away from "business as usual" practices especially during the process of introducing a new technology or during a technological transition (Smith 2007). This is one relevant aspect in the MARSS project where traditional practices are to be substituted by new

technological advances.

Cross-cultural: In addition, an attempt is being made within the assessment programme to try to understand the role, differences and effect of human beliefs/behaviour and how this is connected and formed by the different ways of dealing with solid waste within the five countries assessments. One of the interesting aspects of the MARSS project has been the deliberate inclusion of a multi-cultural assessment within the activity structure of stakeholder consultancy and inclusion in the integrated sustainability assessment. The multi-cultural assessment being carried out is based on the field of cross-cultural psychology, which is the study of differences and similarities in human behavoiur in different cultures and how and why this individual behavior is influenced by cultural contexts. One of the goals is to try to determine the cause and effect relationship between culture and behavior (Vijver et al 2008). Some of the questions we asked when setting up the multi criteria approach used in the MARSS project were:

- How strong is the influence of culture on behavior and attitudes to solid waste managements and to the possible introduction of the MARSS technology?
- Can we identify these cultural specific variables, and can this lead to a deeper understanding of differences and uniformities found within the multi-cultural stakeholder assessment programme?
- How should this knowledge impact on the methodology and approach used in the stakeholder consultancy programme?
- Can we predict behavior of different stakeholder groups who speak different languages, and are governed by different social and political systems?

Another interesting aspect is the fact that we have a multi-cultural team looking at a cross-cultural assessment using the same project base. Previous criticisms of such studies were that they were "culture-bound" in that Group A coming from culture A was studying Group B coming from Culture B so that we have to ask how much the culture of the observer is influencing the interpretation of the results of the assessment made of the observed. Campbell also pointed out that there were serious problems of making a comparison between 2 different cultures, as there are too many factors with too many possible interpretations including a basic lack of equivalence. This paradox of equivalence was already pointed out some time ago by Lee Sechrest (1972) There is also the issue of translation into different languages when issuing the stakeholder questionnaire to multi countries. These issues will be considered in the setting up of the research questionnaires however it is almost impossible to completely eradicate all paradoxes.

(v) Technological approach of MARSS plant

A demo plant has been built on a modular design, with the main aim of using the biogenic fraction to produce a biomass fuel and in so doing, to design a processing plant that can demonstrate reduced emissions of harmful emissions in comparison with landfill and/or incineration technologies. The demo MARSS plant has a planned capacity input of 10t/h (4000t/a) of biologically dried MMSW taken as a bypass stream from the main MBT plant output material. First sampling indicates a 45% mass recovered RRBF output from the raw MSW. That implies a result of about 5 t/h of biomass fuel from the MARRS plant. Sampling tests also indicate a recovery rate of about 200kg/h (0.2t/h) (ferrous metals at 140kg/h, NF Metals recovery at 60kg/h). Batteries recovered are estimated to be about 5% of the recovered ferrous metal scrap fraction.

GHG emission savings at country level: Nearly 100 % of the organic content of MSW is avoided from being land filled giving CO_2 emission savings at the Demo Plant Level estimated at 10.000 t CO_2eq[5]. Electricity produced from the RRBF potentially saves another 0,3 t CO_2 emissions by replacing electricity, which is generated from the typical energy mix. Recovery and recycling of metals, which account for 1,5 % of the MSW only, can further reduce the GHG emissions by 38 kg CO2eq / t MSW. Regarding some European countries' conditions, the GHG saving potential can even be much higher due to higher organic and metals content in MSW and higher electricity emission factors.

The process performance is being regularly monitored in order to understand how to improve the quality of RRBF being produced and what optimisation actions need to be carried out on the modular plant. Data and results are being provided to the environmental and socio-economic impacts teams for their monitoring and assessment actions.

Results & Discussions

[5] GHG emission avoided from MSW landfills are determined using the "Tool to determine methane emissions avoided from disposal of waste at a solid waste disposal site" approved by the U. N. Framework Convention on Climate Change (UNFCCC).

This paper presents a combination between biophysical and sociological dimensions at different scales and was performed as a first step in the assessment and research programme focused on the region of Naples. Since the mid-90s, the southern Italian city of Naples and surrounding provinces have struggled with waste management policies. Naples Municipality shows the highest waste generation in 2011 among Campania Municipalities due the high population density and large tourist flows. Environmental issues of the current waste management system have received great attention because the disposal emergency has not been totally resolved yet. At the same time, the implementation of new landfills was opposed by the local population resulting in strong social conflicts with the decision makers. Political and scientific analyses of the waste crisis indicate the emergency situation in and around Naples was created by inappropriate waste management policy and practice.

Discussion of the LCA results: As a first step of a wider study, we carried out a preliminary assessment of the currently applied waste management strategy (baseline scenario), using the city of Naples as a representative case study, with the aim of providing an overview of the present state of the art and identifying possibilities, barriers and treatment issues. Naples is located in the Campania Region, Southern Italy. It is the capital of the region Campania and the third-largest municipality in Italy, after Rome and Milan. As of 2011, around 960,000 people live within the city's administrative limits. The production of 5.16E+08 kg is subdivided into the following (Table 1): 4.22E+08 kg of unsorted mixed collection sent to treatment and disposal (hereinafter referred as restwaste), 7.62E+07 kg of separate collection sent to recycling or organic treatment; 1.88E+07 kg (representing less that 4% of total waste generation) of 'others' including batteries, clothes, bulky waste is not included in the analysis due to the lack of reliable data.

Table 1. Waste composition in Naples in 2011. Source: ASIA, 2012

Waste fraction	Unit	Amount	%
Paper&Cardboard	kg/yr	3.15E+07	6.09%
Glass	kg/yr	1.08E+07	2.08%
Plastic	kg/yr	9.54E+06	1.84%
Steel	kg/yr	1.52E+06	0.29%
Aluminium	kg/yr	3.81E+04	0.01%
Organic	kg/yr	2.29E+07	4.42%
Restwaste	kg/yr	4.22E+08	81.62%
Other	kg/yr	1.88E+07	3.64%
Total	kg/yr	5.17E+08	100.00%

The aim of this study is to assess the current waste management practices and their associated environmental impacts in Naples using a life-cycle perspective. The functional unit of the study is the collected, transported and treated urban waste produced in Naples for one year (2011). The life cycle starts once a material or product becomes a waste, i.e. its owner discards it in the waste collection bins. The system of the study starts with collection of MSW from residential areas and includes waste transport, waste treatment alternatives (recycling, composting and incineration) and landfilling of waste. The system was limited at the landfilling of residual materials after treatment processes. At this aim, an attributional LCA was performed in order to illustrate the environmental impacts of the analyzed process. Life cycle analyses of the secondary materials obtained from the recycling and composting processes were not considered. All the data collected regarding the collection and transport phases are modeled on real data provided by ASIA (company in charge of waste collection in Naples) whereas data concerning the disposal of restwaste are provided by Arpac (Environmental Regional Authority in Campania Region). The background data for life cycle inventory was gathered from actual applications in the database Ecoinvent 2.2. The database of the software was adjusted to the conditions in Italy.

The first goal of this preliminary analysis was to obtain a static 'snapshot' of the current situation in order to investigate the environmental impacts associated to a given system today (Business As Usual). Life Cycle Impact Assessment (LCIA) results were aggregated to a selection of environmental impact categories which are considered the most relevant and for which data are more reliable, because the effects are well known and the quantification fairly straight forward: Abiotic Depletion Potential (ADP, in kg Sb eq), Acidification Potential (AP, in kg SO_2 eq), Eutrophication Potential (EP, in kg PO_4^{3-} eq), Global Warming Potential (GWP, in kg CO_2 eq), Human Toxicity Potential (HTP, in kg 1,4-DB eq) and Photochemical Oxidation Potential (POP, in kg C_2H_4).

According to the preliminary results, shown in Figure 2, the disposal of waste in Naples Municipality translates into about 280 millions kilograms of CO_2 equivalents in terms of Global Warming Potential (Table 2) which is, in

normalized values (Figure 2), the most impacted category among the environmental priorities here considered. This mainly occurs due to the disposal in landfill of large amount of waste, converted into methane and carbon dioxide. Another large contribution comes from incineration due to the emission of nitrogen oxides.

Table 2. Characterized values for BAU

Impact category	Reference unit	Result
ADP	kg antimony-eq	3.49E+05
AP	kg SO_2-eq	3.08E+05
EP	kg PO_4-eq	4.22E+04
GWP 100	kg CO_2-eq	2.82E+08
HTP	kg 1,4-DCB-eq	3.41E+07
POP	kg ethylene-eq	5.69E+04

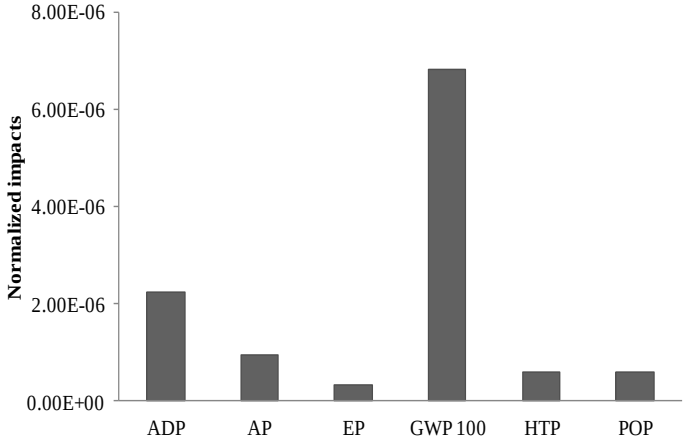

Figure 2. Normalized impacts BAU scenario current waste management in Naples.

The first survey in Naples shows that the critical nature of the situation that has led to the crisis in Naples may be attributed, besides social factors, to the following factors:

1. separate collection is not widespread and makes up for a too small proportion of overall waste production;

2. lack of local biological treatment plants. This forces the municipalities that achieve high percentages of separate collection of the organic fraction to export it to other regions at high cost;

3. separate collection fractions are not 100% recyclable. Thus, when such fractions are recycled, a non-negligible quantity of residues is produced, which must be diverted to landfill. In some cases, this amount reaches up to 50% of the separately collected fraction.

4. the considerations above indicate that storage sites and landfills are required with a capacity of more than 85% of the amount produced daily. This causes that landfilling is the process with the highest environmental impacts

Analyzing current urban waste management and looking for innovative recovery processes present both unique problems and opportunities to fill the sustainability gap and plan future resource recovery strategies. However, although this work provides a first understanding of the technical issues being faced, it does not fully reflect the political, institutional and management dynamics influencing waste management operations. In fact, waste management involves a wide range of stakeholders from the political to the street level, each with their own professional backgrounds and priorities. It is important for the strategic planning initiative to be as inclusive as possible, involving all those likely to be involved in securing real improvements to waste management practices. A stakeholders consultancy involving all key stakeholders provides a valuable opportunity for open discussion and debate of all aspects of waste management, define key issues and establish the strategic planning framework. Participation of key stakeholders during the strategic

planning provides a major opportunity to link the strategic plan firmly to reality and mobilize stakeholder involvement. LCA must be considered as a tool for transparent debate and aware waste management policy, that involves all the stakeholders on the basis of a scientific knowledge of waste flows, waste technologies and waste management impacts.

Discussion of the Stakeholders consultancy results: For MARSS Project, and in particular for the stakeholder consultancy in Naples, Italy, we have identified and analysed a selected stakeholders set in Naples, and Campania Region, out of a preliminary list of stakeholders broken down into 10 categories[6]. Within these 10 groups we identified about 300 stakeholders who were sent a questionnaire by email, introduced by a clear explanation of the MARSS project's goal and scope and the reasons underlying the stakeholders consultancy. A questionnaire and further information about MARSS plant were also attached. The questionnaire was designed to address three key areas: general information about the stakeholder identity, stakeholder knowledge and perspective about Waste management, and stakeholders feeling about the MARSS plant. General information about stakeholders (gender, education, province of residence, age and job's position) was requested in order to establish a profile of those who responded. In the General Area of the survey we tried to understand how waste management, collection and recycling are organized in the local area (province) of the stakeholders, how stakeholders are informed about the way to separate and collect waste, and what are their level of satisfaction about waste management and their perspectives about waste emergency in Naples and in Campania Region in the past years. In the Technical Area there was a first technical explanation about the MARSS plant and how it works; then, 50 questions (39 open and 11 closed) were listed. Some questions were repeated under different points of view and it may seem that there was some redundancy, but this was a purposeful decision because it is one strategy to catch the real point of view of the stakeholders involved into the survey and to better understand their feeling about these matters. Here some figure that shows the preliminary results of this first survey for Stakeholder Consultancy in Naples.

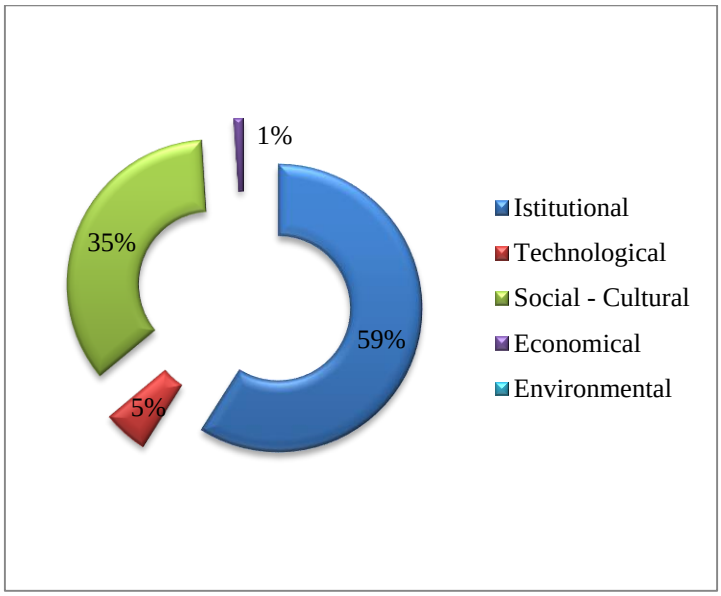

Figure 1 - What do you believe is the main reason for the current emergency in Naples and Campania Region?

[6] National Ministry, Local Authorities, Local Waste Management Authority, Local Waste Management Authority, Emergency Commissioner, Companies in charge of collection and recycling urban waste, Professional Associations, Environmental Associations and social groups, Local Actors, Academic Research institutions, Mass media.

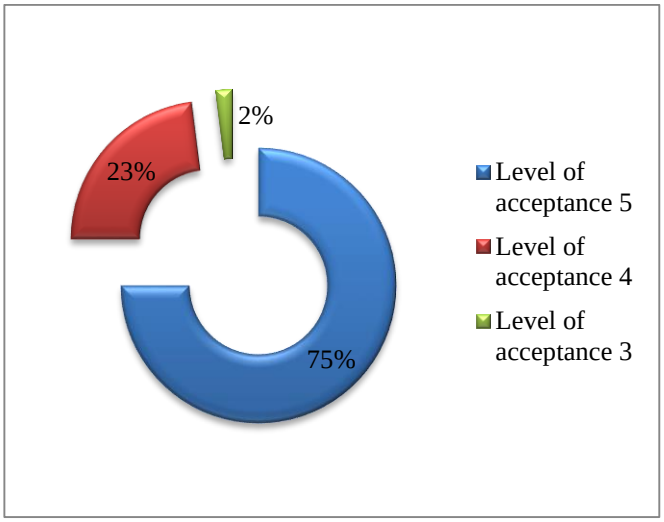

Figure 2- How do you estimate your level of acceptance of the MARSS technology? (1 the lowest, 5 the highest acceptance)

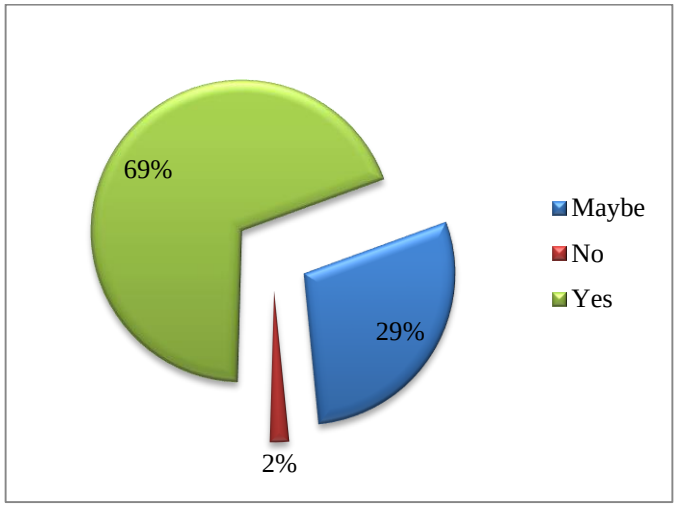

Figure 3 – How likely is the MARSS technology able to definitely solve the problem of waste management and emergency in Naples and in Campania Region?

The largest fraction of respondents is from the Province of Naples, while smaller fractions are from province of Salerno, Caserta, Benevento and Avellino. The stakeholders involved are from 27 to 63 years old; the largest group from 30 to 40 years; then from 40 to 50, and smaller fractions over 50 and below 30 years old. According to the respondents, administrative and governmental Institutions are mainly responsible for the bad waste management in the Campania Region, followed by social and cultural factors. Nobody thinks the cause can be attributed to economic or environmental reasons. To make the issue even clearer, a question about the specific cause that provoked waste emergency in Naples and in Campania Region in the last years was also raised. A large number of stakeholders marked two answers, in particular institutional default and technological inappropriateness, while just few people think citizens' default can be considered a reason of waste emergency. When the stakeholders were asked to identify the factors that do not help find a resolution to waste emergency in Naples, technological problems were indicated as a very important aspect, soon after the institutional ones. The main risks perceived by the larger fraction of respondents are those related to negative impacts on environment and human health, while social and economic risks are given much smaller importance. The largest fraction of stakeholders who responded to the survey thinks that the situation in Naples and in Campania Region is not stable, and that there will probably be a new emergency in the near future. In general, the negative impacts of the waste emergency are related to the environment and social sphere, the majority of respondents reckon that the past emergency had a bad impact not only on the reputation of the city, that might lose tourists and foreign investments, but also made the pollution level of the city and of the entire province of Naples much worse (with a score on the perceived level of each impact, calculated from 1 to 5, being 1 the less negative impact and 5 the most negative impact).

From these preliminary results it is possible to say that all the interviewed stakeholders are not satisfied of the waste management in Naples and in Campania Region, with a level of satisfaction around 1 and 2 (considering the range is from 1 to 5, being 1 the lowest level of satisfaction and 5 the highest level of satisfaction), and they think it is urgent and mandatory to change the entire management system. According to the third set of questions of the questionnaire that mainly refers to the MARSS technology and the preliminary results show very interesting aspects. The majority of respondents seem to know the technologies that are used for waste collection and disposal in Naples and in Campania Region. The main tree groups[7] of stakeholders, among the 10 groups involved in this preliminary survey, are well informed and they care about waste management, even if not directly working on it. After all the questions about the possible risks and the level of experience of each plant, we asked if respondents would be favorable or adverse to the MARSS plant. The largest amount of the stakeholders responded in a favorable way (97% favorable; only 3% against). Their level of acceptance (indicated by a grade 1 to 5, being 1 the lowest level of acceptance and 5 the highest) is most often 5 and never below 4 (Figure 2, where the total is not 100% because respondents against are not included). Furthermore, the 97% of people that are pro MARSS consider that this solution will likely resolve the waste management in Naples (69% replied "yes", 29% "maybe", and 2% are not convinced at all) (Figure 3).

The first analyses of responses collected indicate that the respondents trust the potentially good performance of the proposed new technology because they assess the Consortium (and the questioner) as being very reliable and not being driven by economic interests or corruption. However, this is only the first stage consultation. The information (language and content) needs to be improved in the subsequent stages of consultation; local and global scales of emissions need to be clearly explained; comparative advantages over other methods discussed; calculations of costs and benefits in economic and environmental terms clearly presented, and finally management and time scales addressed. This would mean that the choices made and opinions given would be more reliable and the result of a better managed participatory process. This is the next step in the stakeholder consultancy programme, namely the formulation of new questionnaires in light of the results already made as well as taking into account work already done in the area of what is seen to be more effective communication with stakeholder groups.

Conclusions

The launch of new technologies such as a new waste treatment plant will be a major challenge on several levels such as new business models and possible changes of consumer's habits. To demonstrate the performance of management alternatives in the decision-making process, authorities, communities, industry and waste management companies should consider environmental aspects in addition to the evaluation of technical and economic aspects. The results of the integrated life cycle assessment (LCA) are crucial as they will be used as part of the needed decision support for governmental policies, for production and operation improvements and finally to disclose environmental data to specific stakeholders around the world. It is clear that only a multidisciplinary approach could open a successful way in this work. The future purpose of this research is to better understand how LCA-based environmental performance information might be effectively communicated in an advertising setting, the impact of such messages on individuals' attitudes and behavioral intentions, and the mediating roles of informational complexity and credibility.

Results seem to indicate that there are significant psychological elements behind the opinions and responses received from the different stakeholder groups indicating that the multi-disciplinary approach is required to obtain deeper understanding as well as to inform the research team about the content and manner of the second phase of the stakeholder consultancy programme. In fact, stakeholders coming from civil society attribute a large fraction of the responsibility for waste emergency in the Region to the Institutions; that they are very concerned about the environmental and health consequences of bad waste management; that there are non-negligible expectations on appropriateness of technology; that they believe to have sufficient knowledge about the different available technologies; that their perception of reliance on waste combustion and landfilling is very small; that they would welcome a MARSS-like technology as described in the questionnaire. We may point out that, based on the detailed questionnaires received in the first phase, the expectations on MARSS technology seem very optimistic and attribute to the MARSS technology (or to technology as such) a power to solve problems that is unlikely to be attributable to one solution only. More likely, waste management problem requires integrated solutions. Further and more detailed questionnaires need to be designed to go beyond generic expectations and identify other specific solutions and stakeholders' willingness to be involved or contribute.

This combination of the multiple tools and methods being employed in the MARSS integrated sustainability assessments should be able to provide new perspectives regarding the inter-linkages between the different sustainability dimensions. The comparison of the data interactions across the steps are already indicating new information about (i) possible underlying causes that exist in the different studies at different scales and locations and (ii) factors underlying the trade-offs and their impacts that may be the result of the multi-dimensional and multi-scale interplay of the different processes and elements within the different country studies and (iii) cultural and political factors behind the perceived

[7] Local administrative authorities, academic research institutions and local actors.

differences as well as providing some interesting insights into the cross-cultural comparison studies. Useful waste management assessments require analyses that can embrace and cope with complex interactions, significant uncertainty and with even contestation of the fundamental nature of sustainability. These challenges are recognised and have been addressed by many researchers. As the statistician so simply stated "Essentially all models are wrong but some are useful"(Box 1987). What is less often recognised is that regardless of sophistication, the outcomes of tool choice and use will often be contested, particularly if decisions adversely affect the interests of particular stakeholder groups (McCown 2005). However the continuous development of multi criteria assessments based on real case studies with all the associated complexities and paradoxes will eventually lead to new knowledge and understandings.

"Adequate processes are required if the outcomes as such are to be considered credible by stakeholders used to exercising high degrees of autonomy and judgement based agency" (McCown, Hochman, & Carberry 2005). A significant research challenge therefore remains; to develop and test the effectiveness of processes that successfully embed sophisticated decision support tools within the decision-making processes of planners and policy makers. Often, difficult decisions must be made resulting in conflicts with the community, so conflict avoidance based on understanding the points of views of civil society leading to better management is also becoming a central issue in local government.

With the increasing broadening of the involvement and type of stakeholders in waste management decision making processes, and within the background of a multi-cultural pan-European background, it is clear that the interactions and interests of the different groups have to be taken into account. The more interactive and complex the decision making process becomes, the more we need new types of analytical procedures drawing on a broad range of knowledge from different disciplines. In fact, one could say that stakeholder interaction can be a success or a failure simply because the wrong approach and tools were used in the consultancy procedures. Bearing this in mind, it makes sense that researchers then draw on competences and insights provided by behavioural, psychological and social sciences.

As Schnitzer and Ulgiati (2007) wrote about sustainability: "It develops more and more like a discussion about a mosaic. Some speak of the image they expect to be seen at the end, others speak of the tesserae they have to shape or the cement that fills the gaps between. Some tesserae might not fit into the final mosaic; many more are still missing and have to be developed with the goals and constrains in mind".

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References

Achterkamp M., Vos J., 2007. *Critically identifying stakeholders*. Systems Research and Behavioral Science: 3 – 14

Ajzen, I., December 1991. *"The theory of planned behavior"*. Organizational Behavior and Human Decision Processes **50** (2): 179–211. doi:10.1016/0749-5978(91)90020-T

ASIA, 2012. Unpublished data

Barton, J.R., Issaias, I. and Stentiford, E. I., 2008. *Carbon – making the right choice for waste management in developing countries.* Waste Management, 28 (4): 690-698

John W. Berry et al., 2002. *Cross-cultural psychology: Research and Implications* (2nd edition). Cambridge universal Press

Bevitori P., 2004. *La comunicazione dei rischi ambientali e per la salute*. Milano, Franco Angeli.

Bourne L., Walker D.H.T., 2005. *Visualising and mapping stakeholder influence*. Management Decision, 2005: 649 – 660.

Box, G. E. P., Draper, N. R., 1987. *Empirical model building and response surfaces*. New York, NY: Wiley.

Clarkson, M. B. E., 1991. *Defining, evaluating, and managing corporate social performance: A stakeholder management model*. In J. E. Post (Ed.), Research in corporate social performance and policy: 331-358. Greenwich, CT: JAI Press.

Ecoinvent, 2010. The Ecoinvent Center, a Competence Centre of the Swiss Federal Institute of Technology Zürich (ETH Zurich) and Lausanne (EPF Lausanne), the Paul Scherrer Institute (PSI), the Swiss Federal Laboratories for Materials Testing and Research (Empa), and the Swiss Federal Research Station Agroscope Reckenholz-Tänikon (ART). Switzerland. http://www.ecoinvent.org

Esty D. C., Winston S., 2006. *Green to Gold – How smart companies use environmental strategy to innovate, create value and build competitive advantage*. John Wiley &Sons, Inc., Hoboken, New Jersey.

EU – COM (2011) Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee, and the Committee of the Regions, *"Roadmap to a Resource Efficient Europe"*. http://ec.europa.eu/environment/resource_efficiency/pdf/com2011_571

European Environmental Bureau (EEB), 2014. *Advancing Resource Efficiency in Europe. Indicators and waste policy scenarios to deliver a resource efficient and sustainable Europe.* http://www.eeb.org/EEB

European Commission, Roadmap to a Resource Efficient Europe {SEC(2011) 1068 final}

Finnveden, G., 1999. *Methodological aspects of life cycle assessment of integrated solid waste management systems.* Journal of Cleaner Production. Resources, Conservation and Recycling 26: 173-187

Giampietro M., 2003. *Multi-scale integrated analysis of agro-ecosystems.* Boca Raton, FL: CRC Press

Giampietro, M., Mayumi, K. and Sorman A.H. 2012 *The Metabolic Pattern of Society: Where Economists Fall Short*. Routledge, 408 pp.

Giampietro, M., Aspinall R. Ramos-Martin J. and Bukkens, S. 2014 *Resource Accounting for Sustainability: the nexus between Energy, Food, Water and Land use*. Routledge, 250 pp.

Giampietro, M., Mayumi, K., Ramos-Martin, J. (2009): *"Multi-scale integrated analysis of societal and ecosystem metabolism (MuSIASEM): Theoretical concepts and basic rationale"*, Energy, Vol. 34 (3): 313-322 http://dx.doi.org/10.1016/j.energy.2008.07.020 © 2009 Societalmetabolism.org

Gibson K., 2012. *Stakeholders and Sustainability. An Evolving Theory*, Springer Science + Business Media B.V: 15 – 25

Higgs, G., 2006. *Integrating multi-criteria techniques with geographical information systems in waste facility location to enhance public participation.* Waste Management Research 2006, 24: 105

ISO (International Organization for Standardization) 14040, 2006. Environmental management - Life cycle assessment – Principles and framework. Brussels: International Standard Organization

ISO (International Organization for Standardization) 14044, 2006. Environmental management - Life cycle assessment - Requirements and guidelines. Brussels: International Standard Organization

Jackson, T., 2005. *Motivating Sustainable Consumption: a review of evidence on consumer behaviour and behavioural change.* Sustainable Development Research Network

Janssen, R., 2001. *On the use of Multi-criteria analysis in environmental impact assessment in The Netherlands.* Journal of Multi-criteria Decision Analysis, 10: 101–109

Keyes, C. L. M., 1998. *Social well-being. Social Psychology*, Quarterly, 61:121-140.

Kivits R.A., 2011. *Three component stakeholder analysis*. International Journal of Multiple Research Approaches: 318 – 333

Lindsay, J.J., Strathman, A., 1997. *Predictors of recycling behaviour: an application of a modified health belief model.* Journal of Applied Social Psychology, 27:1799-1823

Lofstedt R. E., 2006. *How can we make food risk communication better: where are we and where are we going?* Journal of Risk Research 9

Lonner, W. J., 1980. *The search for psychological universals.* In H. C. Triandis & W. W. Lambert, (Eds.), *Handbook of cross-cultural psychology* (Vol. 1) Boston, Allyn and Bacon:143-204

Masi D., 2010. *Go green, il nuovo trend della comunicazione*, Fausto Lupetti Editore

McCown R. L., 2005. *New Thinking About Farmer Decision Makers.* The Farmer's Decision: Balancing Economic Successful Agriculture Production with Environmental Quality. J.L. Hatfield (ed.) Soil and Water Conservation Society, Ankeny, Iowa, USA: 11-44

Mitchell R.K., Bradley R.A., Donna J. W., 1994. *Toward a Theory of Stakeholder Identification and Salience: Defining the Principle of Who and What Really Counts*. The Academy of Management Review, Vol. 22, (4): 853-886

Morrissey, A.J., Browne, J., 2004. *Waste management models and their application to sustainable waste management.* Waste Management, 24: 297–308

Munda, G., Romo, M., 2001. *Combining life cycle assessment and multicriteria evaluation: comparing waste managment options in Spain.* Splash, C., McNally, S., EdwardElgar, W., (Eds), Managing Pollution and Environmental Toxicology

Norese, M.F., 2006. *ELECTRE III as a support for participatory decision-making on the localisation of waste treatment plants.* Land Use Policy, 23: 76–85.

Petts, J., Homan, J. & Pollard, S., 2003. *Participatory Risk Assessment: Involving Lay Audiences in Environmental Decisions on Risk.* R&D Technical Report E2-043/TR/01. Environment Agency, Bristol: 281

Petts, J., 2004. *Barriers to participation and deliberation in risk decisions: evidence from waste management.* Journal of Risk Research, **7**: 115–133

Rawlins B., 2006. *Prioritizing stakeholders for public relations.* The Institute for Public Relations: 1- 14

Rwckwitz, A., 2002. *Toward a theory of social practices: a development in culturalist theorizing.* European Journal of Social Theory 5: 243-263

Rowe, G., Frewer, L.J., 2000. *Public participation methods: a framework for evaluation.* Science, Technology & Human Values, 25: 3–29.

Sechrest, L. et al, 1972. *Problems of translation in cross-cultural psychology.* Journal of Cross-cultrual Psychologyy, Vol. 3 (1): 41-56

Schnitzer, H., Ulgiati, S., 2006. *Less bad is not good enough: approaching zero emissions techniques and systems.* Editorial of Journal of Cleaner Production, 182: 1-5.

Shmelev, S. E., Powell J.R., 2006. *Ecological-economic modelling for strategic regional waste management systems.* Ecological Economics 59: 119

Smith, A., 2007. *Translating Sustainabilities between Green Niches and Socio- Technical Regimes.* Technology Analysis & Strategic Management, 19: 427-450.

Varvasovskzy Z., Brugha R., 2000. *A stakeholder analysis*. Oxford University Press, 2000: 338 – 345

Vigileos, G., 2002. *Analysis of Institutional Structures for Sustainable Solid Waste Management for the South West of England*. (PhD thesis) University of Gloucestershire, UK

Vijver, F.J.R. et al, 2008. *Multilevel analysis of individuals and cultures.* New York: Lawrence Erlbaum

Walker D.H.T., Bourne L.M., Shelley A., 2008. *Influence, stakeholder mapping and visualization*. Construction Management and Economics: 645 – 658

Walley P., 2013. *Stakeholder management: the sociodynamic approach*. Stakeholder Management 2013: 485 – 504