Analysis of Waste Management Policy in Campania (Italy): a System Dynamics approach

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Área Temática: *(indicar el área temática en la que se inscribe el contenido de la comunicación)*

Resumen:

The waste crisis in Campania is a clear example of a complex system since it involves multiple dimensions that affect each other in a dynamic manner and cannot be described from an isolated and static perspective. This paper is focused on the waste crisis in Campania taking into account all the factors involved, including demographic, technological, social, environmental and economic issues. A system dynamics model, developed in Di Nola (2012), is used as a policy laboratory to simulate the behaviour of the waste management system under alternative scenarios and evaluate the effects of each of them. Four different policy scenarios are tested: the Business as Usual (BAU) scenario is compared to the Emergency Waste Plan (EWP) approved by the national government, the Regional Waste Plan (RWP) approved by the regional government and a Recycling Implementation Plan (RIP). The main objective of this policy scenario analysis is to highlight the intended effects of different waste policies as well as their unexpected outcomes. The analysis allows keeping track of the evolution of a hidden flow of waste that has not been treated in the regional infrastructures and that has been alternatively managed, as well as the evolution of the RDF accumulated over the region. The total costs of waste management are also evaluated as well as the CO_2 emissions and their relative damage costs.

Palabras Clave: Waste management policy, municipal solid waste, system dynamics modelling.

Clasificación JEL: Q52, Q58, D78, C61

1. INTRODUCTION

Waste generation has been increasing dramatically in recent years as a result of rapid economic growth in both developed and developing countries, becoming one of the key issues in the environmental agenda.

One of the overall goals of EU waste policy is decoupling resource use and waste generation from the rate of economic growth. The waste hierarchy is the guiding principle to achieve this goal. Source reduction strategies are the first steps of the hierarchy and have been the paramount objective of both EU and national waste policy for many years. They have proven to be the most effective and efficient ways of handling the problem of increasing waste generation in the long run and to play a key role in decoupling waste generation from income. However, only limited progress has been made in transforming this objective into practical action and the targets set in the past have not been satisfactorily met because of their high implementation and compliance costs in the short term. In fact, no specific waste prevention programmes or targets have been included in formal directives so far since EU waste policy has been mainly focused on landfill diversion policies such as recycling, recovery and incineration.

This work is focused on the problem of waste management in southern Italy, taking as case study the waste crisis experienced by the region of Campania over the last two decades. The public perception of the crisis, raised by statements from the press and policy makers, relates to a problem of capacity development that has been impeded by both the local criminality and the community. The former making profits by disposing illegal waste and the latter opposing the capacity development because of the "not in my backyard" (NIMBY) behaviour. However, the academic analysis carried out in the subject provides alternative theories and interpretations (see Di Nola 2012 for a detailed revision of the literature) that emphasise the different aspects of the problem and move the focus from the criminality and community responsibilities to the policymaker failure to define a sustainable exit strategy to the crisis. The picture emerging by collecting the wide literature developed on the topic shows a complex problem that involves multiple dimensions that affect each other in a dynamic manner and cannot be described from an isolated and static perspective.

However, despite the huge amount of research carried out, only little quantitative research has been done and most of it only focuses on single aspects of the problem without providing a comprehensive analysis of the dynamics of the crisis. The complexity of the problem makes it hard to represent it by using standard economic conceptual frameworks and calls for alternative tools of analysis. To bridge this gap, in this work a system dynamic model (Di Nola, 2012) is used as a base to develop a policy laboratory analysis to compare the future evolution of the waste management system in Campania under alternative policy scenarios.

System dynamics is a modeling method that aims to gain insight on complex systems and their evolution over time. It is particularly suited to discover and represent the interactions and feedback mechanisms, which along with stock and flow structures, time delays and nonlinearities, determine the dynamics of complex systems. By specifying the underlying structure and the decision rules among its elements, it enables the description of a given problem behaviour with an endogenous explanation. It is then possible to explore how that behaviour might change by altering those structure and rules. System dynamics has proven to be particularly suited to deal with environmental complex systems, such as agricultural systems (Qu and Barney, 1998; Saysel et al, 2002, Martinez and Esteve, 2004), sustainable development (Moffat and Hanley, 2001; Shi and Gill, 2005; Arquitt and Johnstone, 2008), or environmental policy (Nail et al. 1992; Ulli-Beer et al., 2007; Kunsch and Springael, 2008). More specifically, previous works have shown the effectiveness of system dynamics to deal with waste management problems. Karavezyris et al. (2002) propose an integrated framework to model waste management systems taking the city of Berlin as case of study and Dyson and Chang (2005) used system dynamics modelling to forecast solid waste generation in an urban setting with high economic growth potential based on limited data samples. Mashayekhi (1993) applies this modelling approach to analyse the landfill shortage that occurred in the New York waste system in 1987 and Ulli-Beer (2004) develops a system dynamics model to analyse long-term effects of different local policies in Switzerland over a time span of 30 years.

The paper is structured as follows. Section 2 introduces the waste crisis experienced by Campania over the last two decades. Section 3 presents the key dynamic hypothesis underlying the model and then an overview of the model, the sectors it comprises and the main relations among them is provided. Section 4 describes the policy scenarios explored in the analysis. Finally, section 5 illustrates the results of the policy evaluation and section 6 draws some conclusions.

2. WASTE CRISIS IN CAMPANIA

Campania is located in south-west Italy and it is one of the most populated regions in Italy with almost 6 million people, and the one with the largest population density, 492.22 inhabitants per km^2. The capital is the city of Naples. The regional area covers 13,590 km^2 and comprises five provinces: Naples, Avellino, Benevento, Caserta and Salerno.

Campania has been experiencing an extraordinary waste crisis that officially started in 1994. At that time, landfilling was the only treatment option and the limited legal landfill capacity was reducing dramatically as a result of all the waste generated in the region as well as the illegal waste coming from the rest of the country. Moreover, many illegal landfills have risen all over the region. The decreasing landfill capacity and the failure to develop and implement a regional waste plan[1], led the national government to declare the "state of emergency". A special commissioner was appointed with full power to deal with the waste crisis. Since then, the region has been experiencing several periods of crisis which have revealed all the weaknesses of its waste management system (for a detailed description, see D'Alisa et al., 2010).

In 1997, a first waste plan was approved and integrated in 1998[2]. It agreed the construction of 7 mechanical biological treatment (MBT) plants by 1998 to treat restwaste[3] and produce a dry fraction, refuse derived fuel (RDF), to burn in incinerators

[1] As required by the regional law 10/1993.
[2] Ordinance 2227
[3] By restwaste it is meant the waste resulting after the separation process

and an organic fraction to use in agriculture; 2 incinerators by 2000 to burn the RDF produced by the MBT plants; a target for separate collection of 35% by 2000; finally landfilling was relegated as a last resort. To ensure the new integrated waste management system was in line with European policy, the MBT plants were designed to handle the waste remaining after separation, using a separation rate of 35%. The RDF produced would then be treated outside the region until the incinerator worked to avoid its accumulation during the building process. After numerous changes to the original requirements, the treatment capacity was designed using the whole generation of municipal solid waste and the RDF produced was allowed to be stored inside the region until it could be burnt in the planned incinerators.

The capacity development process lasted longer than expected, its implementation did not produce the expected results and the waste facilities did not work as planned. In the meantime, waste started to accumulate in the streets. From then on, emergency solutions like opening temporary disposal sites, over-filling the already saturated landfill sites or exporting waste to other Italian regions or abroad, became a common management practice to free Campania's streets from waste.

Despite all the legislation approved and the funds allocated both by national and EU institutions, the "state of emergency" has become persistent and remains today. Some of the main issues at stake at the moment are the election of alternative ways of management as well as the types of facilities and its localisation, the strong opposition of the local community, the contamination of lands and the mismanagement of public finances. Furthermore a stock of RDF is disposed over the region waiting to be incinerated or to be alternatively managed. Its accumulation grows as new waste is MBT treated posing serious environmental, social and economic problem.

3. THE MODEL

The system dynamics modelling process has been used to build a model that provides a valid theory of the structure of the waste management problem (Di Nola, 2012). This model is used in this work as base for further policy analysis. Figure 1 describes the key steps of the modelling process followed (Sterman, 2000).

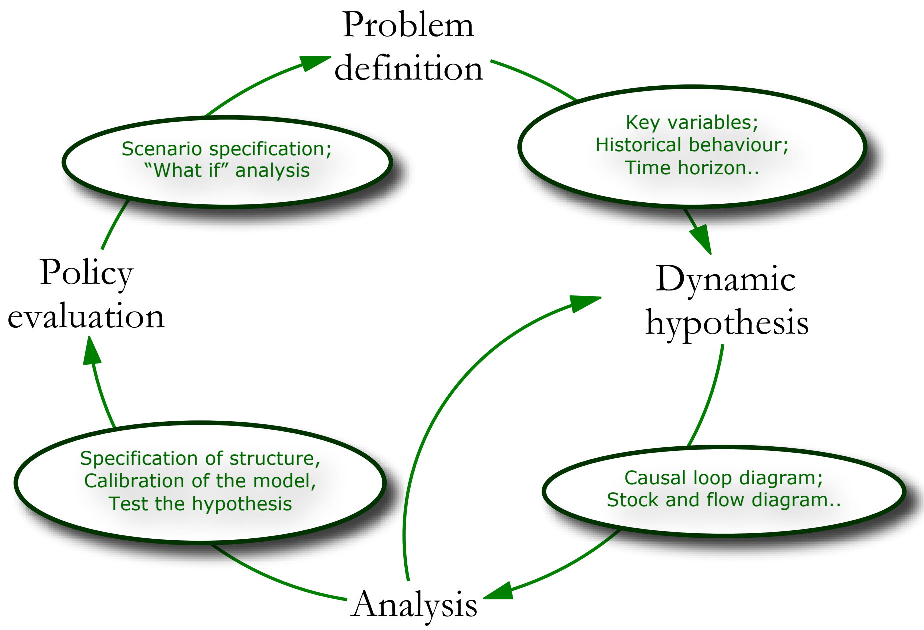

Figure 1 Steps of the modelling process

The first step consists in identifying the problem by clearly defining its purpose and boundaries, in other words, the variables that need to be included and those that can be left out (Richmond 1997; Sterman, 2000). The data collected to build the base model come from official sources as well as different bodies involved in the problem of waste management in Campania: environmental associations (Legambiente), private firms (Impregilo) and other groups of stakeholders involved in the problem of waste in Naples. Regional and provincial waste data have been obtained by the waste reports annually published by the Institute of Environmental Protection and Research (ISPRA[4]) to analyse the generation and management of municipal waste as well as to supervise the territorial planning in Italy. The available data cover the period 1999-2008. Demographic data come from the Italian Institute of Statistics (ISTAT). The analysis of Campania is based on data from the Regional Agency for Environmental Protection (ARPAC) and covers the period 2000-2007.

The problem identified in the base model starts with the concept of integrated waste management as intended by the waste plan approved in 1997. As previously mentioned,

[4] The last waste report available was published in 2009 and contains data up to 2008.

its key objectives were to: (i) encourage separate collection; (ii) treat the restwaste in mechanical biological plants (MBT); (iii) recover energy from it by means of incinerators; (iv) relegate landfilling as a last resort. The main purpose of the base model was to describe the dynamics of the waste system, by taking into account the process of waste generation and separation, the capacity expansion of waste infrastructures, the policy actions and the system of incentives used to finance it as well as the environmental effects of the waste policies implemented.

Once the problem has been defined the next step was formulating a theory explaining the problem identified. This theory is called in system dynamics the dynamic hypothesis; dynamic because it explains the problem behaviour over time in terms of its feedback structure and stock and flows; hypothesis because it is provisional, being the modelling process iterative in itself. The main tools to elicit the dynamic hypothesis are the causal loop diagram (CLD) and the stock and flow diagram (SFD). The former explains the feedback structure of a system, whereas the latter represents the physical structure of the system and tracks the accumulations that move through it. Both the CLD and the SFD are developed and described in detail in Di Nola (2012).

The CLD diagram developed in the base model provides a hypothesis of how the waste crisis occurred and did not resolve over the time horizon considered. According to it, the policy answer to solve the landfill shortage has created feedback loops acting as a vicious circle that has worsened the crisis instead than resolve it. In particular, the system of incentives introduced has pushed incineration higher up in the waste hierarchy while discouraging separate collection. The low separation rate has affected the quality of the restwaste and then the output produced by the MBT plants and their relative operating rate so increasing the infrastructures shortage. The delays involved in the process, related to the construction of major infrastructure projects, have contributed to worsen the crisis. The result has been a flow of waste, here defined as hidden flow, that has not been treated by the regional infrastructures and that may have been either overfilling the capacity already saturated, filling landfills not allowed in the region or it may have been exported outside the region so increasing the total costs of waste management.

Figure 2 depicts a simplified diagram showing the main sectors and feedbacks. The model comprises four main interacting sectors: household sector, waste management sector, environmental sector and government sector.

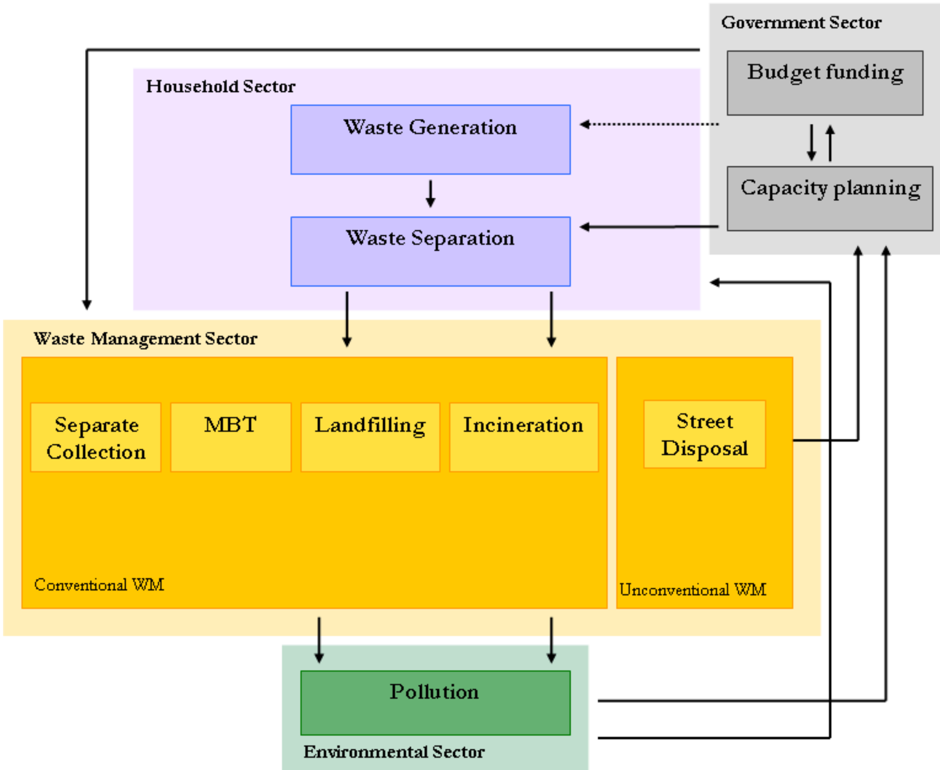

Figure 2 General structure of the model

According to it, the waste generated can be allocated by households in two ways: it can be separated or not. The rate of separation is the final result of both government and households' decisions. As waste is sorted out it can be treated according to different technologies that represent the conventional waste management options: separate collection, MBT, landfilling and incineration. The allocation to one or another option depends on the amounts of waste separated, the infrastructures capacity and their operating rate. When conventional options are not available, waste accumulates in the streets. The street disposal, which has been a common disposal option in Campania over the time period considered, is defined in this model as an unconventional waste management option.

The waste management sector affects both the households and the government sectors. It provides information about the residual capacity of conventional options that is needed to define the waste policy and affects the citizens' environmental behaviour and their willingness to separate. All options, conventional and unconventional, generate externalities, such as environmental and health effects, that further affect the government and the households sectors. Hence the waste policy is continuously adjusted according to the waste management sector and its effects on the environment and citizens.

Once the dynamic hypothesis has been defined, the next step was formulating a simulation model. This means shifting from a conceptual model to a formal model with equations, parameters and initial conditions. The package Vensim[5] has been used in the construction and testing of the model. Several intermediate tests (dimensional-consistency, extreme conditions, etc) and parameter sensitivity tests have been performed to build confidence in the model. The base version of the model compares the simulation results with the data available to test the suitability of the model to reproduce the historical behaviour (see Di Nola 2012). This base model is used in this work as a policy laboratory to evaluate the effects of different waste policy scenarios on the main variables of interest.

4. Policy scenarios

In this section, the policy scenarios considered in this work are synthesised. The first scenario is the business as usual scenario (BAU) that simulates the evolution of the main variables analysed under the current policy conditions, with the assumption that no alternative waste policies are implemented. The second and the third scenarios examine the implementation of two major policies: the emergency waste plan (EWP) approved by the national government; the regional waste plan (RWP) proposed by the regional

[5] Vensim is an icon-based program designed to provide a user-friendly icon-based interface to modelling based on the principles first published by Forrester (1961). Vensim package is a registered trademark of Ventana System, Inc. 60 Jacob Gates Road, Harvard, MA 01451, US (see http://www.vensim.com/software.html).

government. The fourth scenario analyses the effects of a hypothetical recycling implementation plan (RIP).

The main objective of the comparison of the evolution of the main variables of interest under different policy scenarios is to highlight the intended effects of the different waste policies as well as their unexpected outcomes. A synthesis of the main scenarios explored is provided next.

- **Business as usual scenario (BAU)**

The business as usual scenario evaluates the evolution of the main variables of the model without the implementation of new waste treatment and disposal policies in Campania and acts as a benchmark when compared to the other scenarios considered.

In this scenario: the current treatment capacity consists of 7 MBT plants which treat restwaste; the landfill capacity is saturated; incineration is not working; no composting programs exist and the rate of separate collection is less than 20%.

- **Emergency waste plan scenario (EWP)**

The emergency waste plan scenario relates to the decree 90/2008 ruled by the national government containing extraordinary measures to deal with the waste crisis in Campania. It sets a recycling target of 50% by 2010 as well as the construction of three incinerators to cope with the waste generated in the region and a fourth one specifically planned to take only the waste generated in the city of Naples.

The plan also sets some changes in relation to the MBT plants. Since the types of incinerators established by the law are technologically suitable to treat the restwaste, there is no need to separate the dry and wet fraction anymore. Therefore, the MBT plants are set to be converted into plants for the production of high quality compost. Finally, 10 new landfill sites are planned to be opened to meet the infrastructure shortage and guarantee the disposal of the new waste generated as well as of a fraction of waste already accumulated.

The targets established are far from being reached up to this date. Only one incinerator has been built and it started working in 2009. The MBT plants are still used to treat the amount of waste generated and not separated. Most of the landfills indicated in the plan have not been opened. The separate collection rate remains below 20% in 2010. No composting programs have been carried out so far and many waste crisis have followed from then on.

- **Regional waste plan scenario (RWP)**

The regional waste plan scenario refers to the waste management plan proposed by the Campania's regional government (Campania Region, 2011). The plan explores two policy options built on "successful experiences" implemented both in Europe and in Italy, as defined in Mastellone et al. (2009). These options, here called RWP1 and RWP2 are based upon a combination of, respectively: recycling, MBT, incineration and landfilling for the case of RWP1; recycling, incineration and landfilling for the case of RWP2.

Scenario RWP1 has been defined based on the waste management cycle approved by the 1997 waste plan but only hardly implemented so far, as previously discussed. In order to close the waste cycle set out by that plan, it proposes the construction of plants for: the conversion of the RDF produced by the current MBT plants; the treatment of the waste separated which does not enter the normal waste cycle; the anaerobic treatment of the organic fraction collected after separation.

Scenario RWP2 represents a radical change compared to the 1997 plan. It is based on a simplification of the whole waste cycle. It is characterised by the choice to eliminate the MBT process, that is, to treat the waste directly in incinerators after having separated "as much as possible" the organic fraction, able to be treated organically. The assumptions used in the RWP2 are: the fraction of recycling is higher than the current, from 35% up to 65%; the organic fraction is treated through anaerobic digestion or composted; the restwaste is incinerated, without being previously treated; the residuals from recycling are incinerated; the residuals from the anaerobic digestion can be stabilised and used as compost or as cover for land restoration.

- **Recycling implementation plan scenario (RIP)**

In this scenario, a hypothetical recycling implementation policy is considered and its main target is reaching a 65% of separate collection by means of a change in the system of incentives assumed in the model. More specifically, to achieve this target, a change in the model structure is performed towards an increase in the attractiveness of recycling to boost investments in the sector. The rest of infrastructures are maintained as in the BAU scenario.

5. Results

The simulation results allow keeping track of the process of capacity building of the infrastructures planned under the different scenarios considered as well as the relative treatment rates (see Di Nola, 2012). By comparing the total amount of waste generated and the amount effectively treated, a hidden flow of waste emerges which has not been treated neither landfilled due to the lack of waste facilities. This waste flow may have been either overfilling the capacity already saturated, filling landfills not allowed in the region or it may have been exported outside the region. The simulation also allows observing the evolution of the RDF, which is disposed in temporary sites waiting for being incinerated or, in lack of alternative solution, exported.

The evolution of both the hidden flow of waste and the RDF stock under the different scenarios considered is described next. Each scenario is analysed according to two options: option A, which assumes that the incineration capacity burns the new amounts of waste generated; option B, which assumes that the incineration capacity is used to burn the RDF stock.

The simulations under the BAU scenario (see Figure 3 and 4 in the Appendix) confirm that the plant design established by the 1997 plan, approved to cope with the waste crisis, is inadequate to effectively handle the problem both in the short and in the medium term. The system of incentives established, by favouring the expansion of incineration and discouraging separate collection, creates positive feedbacks that are expected to worsen the crisis rather than resolve it. In this scenario, the hidden flow of waste would continue growing and worsening the waste crisis. In the absence of alternative capacity, this flow of waste would be first disposed in the streets and then sent to alternative destinations increasing the total costs of waste management. The problem of the RDF stock is also expected to continue. Even assuming that these piles were incinerated, with no alternative policies implemented, their accumulation would continue, further occupying the limited regional land available. The results also point out the importance to take into account the delays of the system if effective policies are to be achieved. The most important delays are related to the construction of infrastructures and to the adjustment of people's habits to the changes in waste management capacities.

The simulation of the model under the EWP scenario (see Figure 5 and 6 in the Appendix) shows that the crisis is not expected to be resolved either if the policy approved by the national government is implemented. The existing system of incentives would still encourage investments in incineration and penalise separate collection. The halt in MBT plants and the delays involved in building additional incineration capacity would increase the flow of waste that cannot be treated by the regional infrastructures. The lack of adequate landfill capacity would generate further waste crisis, discouraging people to separate as a result. Under this policy scenario, the problem of RDF stock would not be solved in the short term, however a considerable improvement is observable compared to the BAU scenario. Since MBT plants are converted into composing plants they would stop producing RDF. According to the options considered, the stock would then stabilise from 2011 or it would disappear in 2019, if the entire incineration capacity were used to burn it. The simulation of RWP1 scenario (see Figure 7 and 8 in the Appendix) shows that when the policy target is to improve separate collection activities without planning additional incineration capacity, separate collection capacity grows faster than in the rest of options. However, this increase is still lower than expected due to the delays related to the expansion process and to the slow adjustment of people's willingness to separate to the new capacity. The hidden flow of waste generated starts decreasing from 2009 as INC capacity starts operating, then it reduces due to the landfill sites availability. As landfill capacity saturates, this flow starts increasing again then it slowly decreases over the rest of the time horizon, due to the combined effect of higher SC rate and lower MBT rate compared to the BAU scenario. The level of the hidden flow of waste is lower in the RWP1A option. Under this option the incineration capacity is used to treat the new amount of waste generated and then the resulting flow of untreated waste reduces.

The evolution of the stock of RDF under the RWP1 scenario also differs according to the two options considered. Under the RWP1A option, without any alternative policy to get rid of the piles stored, the stock would continue accumulating, with a slightly less steep slope at the end of the period due to the decrease in the MBT rate. If it is assumed that the incinerator burns the RDF (RWP1B), from 2009 the stock would increase at a considerably slower rate until 2027 and then it start decreasing slowly, due to the combined effect of increase in INC activity, reduction in the MBT rate and in the RDF production.

On the other hand, under the RWP2 scenario (see Figure 9 and 10 in the Appendix), the increase in incineration capacity makes separate collection less attractive and the expansion in SC capacity lower than expected. The problem of RDF stock would not be solved but the stock accumulated would be lower than in the rest of scenarios due to the halt in MBT plants and would disappear if its incineration were allowed. The evolution of RDF is inversely related to the hidden flow of waste. In RWP2A this flow to dispose is lower because part of it would be incinerated. However, despite the flow is lower than in BAU, it would not be possible to get rid of it during the period analysed. This means that it should be continuously disposed by overfilling the landfills available or exported outside the region.

The last scenario analysed, the RIP scenario (see Figure 11 and 12 in the Appendix), explores how the system behaviour evolves by performing a change in the structure and rules underlying the model. More specifically, the system of incentives is changed and an incentive to encourage recycling activities is established. Under this assumption, feedback effects are generated driving the system towards the desired level of separation considerably faster than in the rest of scenarios. Incentivising separate collection affects people's willingness to separate in a positive manner reinforcing the behaviour. This would reduce the amount of restwaste that is treated by MBT plants and improve its quality. The quality of the outputs would also improve making it suitable for different uses so reducing even further the hidden waste that needs to be disposed. This would further affect people willingness to separate in an iterative cycle: as the crisis reduces people are encouraged to change their habits and separate more. The level of hidden flow of waste to dispose also changes according to the two options. In RIPA, since the waste generated is burnt directly without any previous treatment, the hidden flow of waste decreases considerably. The increase in SC rate would also reduce the amount of restwaste generated so there would be less restwaste to dispose. Furthermore, the good quality SOF produced would not account as waste to dispose but would be destined to alternative uses. From 2011, the available landfill capacity would be sufficient to dispose the amount of untreated waste. The hidden flow to dispose would go to zero and there would be no need to overfill the landfill sites available or to export anything outside. In RIPB, the incinerator is used to burn the RDF. This means that the hidden flow of untreated waste would only reduce as the landfill capacity becomes available, after that it would increase again and finally stabilise at less than 1 million tons.

The RDF stock continues to increase in the option RIPA, as RDF is produced by MBT plants. The rate is slightly lower as the MBT waste starts reducing, but in 2030 there would be about 17 million tons stored over the regional land. In RIPB, if incineration capacity was available to burn these piles, the stock would peak in 2014 at 6 million tons, stabilising for some years after that before it starts reducing. The combined effect of higher SC waste and lower MBT rate would also decrease the production of RDF).

The different waste policy scenarios are also compared in terms of their effects on total waste management costs and CO_2 emissions. The total management costs comprise the costs of handling waste according to the infrastructures existing in the region[6], the costs of storing RDF along the region and finally the costs of managing the hidden flow of waste that is not treated in the region due to the limited capacity available. This waste flow may go to overfill the capacity already saturated, may fill landfills not allowed in the region or it may be exported outside the region.

Table 1 Waste management costs (Million euro) Scenarios comparison Option A

Scenario	LF	INC	MBT	SC	RDF	Export	Total

[6] LF= Landfilling; INC= Incineration; MBT=Mechanical Biological Treatment; SC=Separate Collection

BAU							
Overfilling	1,000	1,140	753	115	2,900		5,900
Export		1,140	753	115	2,900	3,500-7,500	8,400-12,400
EWPA							
Overfilling	804	2,200	32	134	2,970		6,100
Export	158	2,200	32	134	2,970	2,150-4,600	7,900-10,000
RWP1A							
Overfilling	596.54	1,140	695.94	246.78	5,900		8,600
Export	45.6	1,140	695.94	246.78	5,900	1,836-3,948	9,864-11,976
RWP2A							
Overfilling	852.54	1,620	0	246.78	2,965		5,684
Export	158.7	1,620	0	246.78	2,965	2,300-6,000	7,290-10,990
RIPA							
Overfilling	172.63	1,140	624.81	378.11	5,598		7,913
Export	158.7	1,140	624.81	378.11	5,598	46.51-100	7,946-7,999

The results in Table 1 highlight that the RWP2 option is the least expensive, if all the hidden flow of waste is over-landfilled. However, under this scenario, this flow of waste would not be entirely absorbed and the RDF stock would continue growing, which means that periods of crisis would occur in the future if no alternative waste policy is implemented. The RIP scenario is more expensive and it does not resolve the problem of RDF but it allows get rid of the hidden flow of waste. However, it is the least expensive if assumed that all hidden flow of waste is exported. Under this scenario, this flow would go to zero reducing dramatically the total management costs compared to the other options. It would also allow a considerable reduction of CO_2 emissions and related damage costs (see Table 2).

Table 2 CO_2 emissions and damage costs Scenarios comparison Option A

Scenario	LF	Over-LF	INC	Total
BAU				
Mtons/CO_2eq	0.5	12.5	9	22
Million euro	38	710	200	948
EWPA				
Mtons/CO_2eq	1.7	8.98	18.19	28.87
Million euro	106.11	522.50	372.05	1,000
RWP1A				
Mtons/CO_2eq	0.9	8.1	9.5	18.5
Million euro	57.85	481.92	200.34	740.11
RWP2A				
Mtons/CO_2eq	1.7	5.4	13.38	20.48
Million euro	106.11	302.09	276.66	684.86
RIPA				
Mtons/CO_2eq	1.77	2.62	9.54	13.93
Million euro	103.73	172.89	200.34	476.96

Table 3 highlights that the RWP2 option is the least expensive if all the hidden flow of waste is over-landfilled. The EWP2 option also allows reducing total waste management costs. Under these two scenarios, it would be possible to get rid of the RDF stock, which would dramatically reduce total costs. However, there would be still a hidden flow of waste that cannot be treated by regional infrastructures and that would be disposed in the streets, waiting for an alternative treatment option. That is, the problem of RDF would be solved over time but future waste crises would possibly occur until 2030 if no alternative policy is implemented. The RIP scenario is the least expensive compared to the rest, assuming that the hidden flow of waste is exported. Under this scenario, the flow of waste would reduce dramatically and so would the total waste management costs. The RDF stock would slightly reduce compared to the rest of

scenarios but it would not disappear over the time span analysed. The levels of pollution would be lower, as well as the relative damage costs (Table 4).

Table 3 Waste management costs (Million euro) Scenarios comparison Option B

Scenario	LF	INC	MBT	SC	RDF	Export	Total
BAU							
Overfilling	1,000	1,140	753	115	2,900		5,900
Export		1,140	753	115	2,900	3,500-7,500	8,400-12,400
EWPB							
Overfilling	956	2,200	32	134	591		3,900
Export	158	2,200	32	134	591	2,700-5,700	5,800-8,800
RWP1B							
Overfilling	938.54	1,140	695.94	246.78	2,767		5,788
Export	45.6	1,140	695.94	246.78	2,767	2,976-6,400	7,871-11,295
RWP2B							
Overfilling	1,004	1,620	0	246.78	588.76		3,460
Export	158.7	1,620	0	246.78	588.76	2,800-6,000	5,414-8,614
RIPB							
Overfilling	503.13	1,140	624.81	378.11	2,463		5,109
Export	158.7	1,140	624.81	378.11	2,463	1,167-2,511	5,931-7,272

Table 4 CO_2 emissions and damage costs Scenarios comparison Option B

Scenario	LF	Over-LF	INC	Total
BAU				
Mtons/CO_2eq	0.5	12.5	9	22
Million euro	38	710	200	948

EWPB				
Mtons/CO_2eq	1.7	10.36	18.19	30.25
Million euro	106.11	602.59	372.05	1,080
RWP1B				
Mtons/CO_2eq	0.9	11.19	9.5	21.59
Million euro	57.85	643.20	200.34	901.39
RWP2B				
Mtons/CO_2eq	1.7	6.8	13.38	21.88
Million euro	106.11	382.01	276.66	764.68
RIPB				
Mtons/CO_2eq	1.72	5.67	9.54	16.93
Million euro	106.11	331.9	200.34	638.35

The comparison of these results provides a tool for policy makers to evaluate the effectiveness of different policy scenarios in achieving the target established under different criteria, i.e. economic, social and environmental. In this respect, this analysis points out that none of the waste policies analysed is capable of addressing all aspects of the waste crisis in Campania. Some of them enable a reduction of environmental and social impacts of the crisis, some others a reduction of the economic impacts.

Regarding the recycling scenario (RIP), the results obtained show that compared to the rest, it allows a considerable reduction in both harmful environmental impacts, represented by the hidden flow of waste to dispose, and the social impacts related to future waste crisis that would possibly occur. It also allows reducing the waste management costs but would not be effective in solving the RDF problem. The integration of this scenario with strategies to reduce the RDF stock would then enable policy makers to achieve more effective solutions to the crisis.

6. CONCLUSIONS

The problem of waste management has become one of the key issues in the environmental agenda and the research in the field has witnessed considerable development in recent years. A wide range of models has been carried out to address different aspects such as: the drivers of waste generation; the localisation of waste management facilities; the choice of waste treatment technologies; their environmental impacts; the economic mechanisms of waste management; the transportation of waste; complex planning. However, most part of this body of research has focused on single aspects of the problem without analysing their interactions to provide an integrated and comprehensive understanding of the problem.

This work is focused on the problem of waste management in southern Italy, taking as case study the waste crisis that occurred in the region of Campania over the last two decades. A system dynamics model developed in Di Nola (2012) to describe the dynamics of the crisis is used as base to examine evolution of the waste crisis under different policy options. The main objective of this scenario analysis is to highlight the intended effects of different waste policies as well as their unexpected outcomes. The analysis allows keeping track of the evolution of a hidden flow of waste that has not been treated in the regional infrastructures and that has been alternatively managed, as well as the evolution of the RDF accumulated over the region. The total costs of waste management are also evaluated as well as the CO_2 emissions and their relative damage costs. The scenarios explored are: the business as usual scenario (BAU) that simulates the model behaviour under the current policy conditions; the emergency waste plan (EWP) approved by the national government; the regional waste plan (RWP) proposed by the regional government and a hypothetical recycling implementation plan (RIP).

The simulation results show that the scenario analysis developed is a useful tool for policy makers to evaluate the effectiveness of different waste policy scenarios in achieving the target established under different criteria, i.e. economic, social and environmental.

In this respect, the analysis points out that none of the waste policies analysed is capable of addressing all aspects of the waste crisis in Campania. Some of them enable a reduction of environmental and social impacts of the crisis, some others a reduction of the economic impacts. Most importantly, some policies may generate unintended effects that would eventually worsen the crisis rather than resolve it.

More specifically, policies aimed to increase both the incineration capacity and the separation target would eventually fail if the system of incentives is not changed and separate collection is not encouraged. Focusing only on incentivising the construction of major infrastructure projects may generate feedback effects that would impede the achievement of separate collection targets.

The failure to resolve the problem of the RDF accumulated in the region is a further unintended effect of these policies. The low increase in separation rate affects the quality of the restwaste to treat in MBT plants and, as a result, the quality of the output produced. The low quality of RDF makes it unsuitable to be burnt or exported so that it continues accumulating if no alternative solution is taken. The policy scenario analysis has proven that the problem of RDF might be worsened if some of those policies were implemented. The stock would continue accumulating, occupying the limited regional land and loading the total costs of management dramatically.

The last scenario analysed, the RIP scenario, explores how the system behaviour evolves by performing a change in the structure and rules underlying the model. The simulation of this scenario highlights that policies aimed to encourage recycling create balancing feedbacks that reduce the flow of waste to treat and then the hidden flow that needs to be disposed. The problem of RDF would not be solved in the medium term but the high quality piles produced could be burnt or exported without the need of special changes in the regulation.

The quantification of the environmental and economic impacts of exporting the stock or treating it inside the region would provide useful insights to policy makers in the search of an effective strategy to address this problem. Depending on the different emissions produced, burning low quality RDF or export it would have different environmental impacts. The damage costs would also be different, as well as the management costs of both options. However, because of unavailability of data, this has been left beyond the scope of this work but will be considered as further research.

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APPENDIX

Figure 3 Hidden waste flow BAU

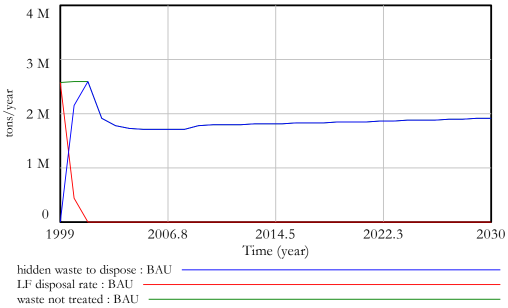

Figure 4 RDF stock - BAU

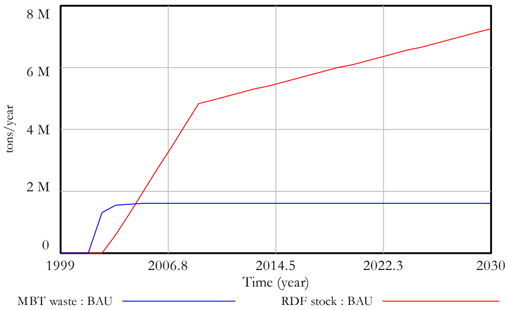

Figure 5 Hidden waste flow – EWP

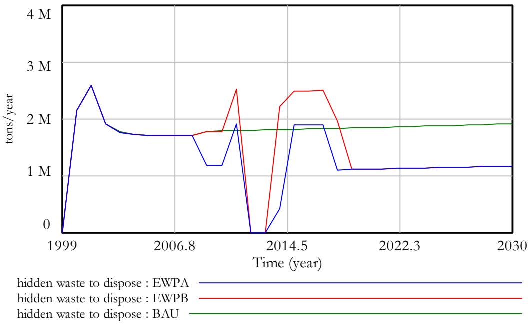

Figure 6 RDF stock - EWP

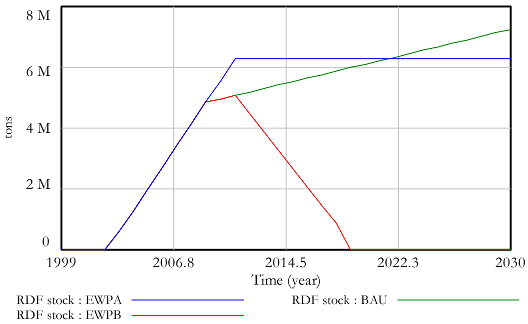

Figure 7 Hidden waste flow – RWP1

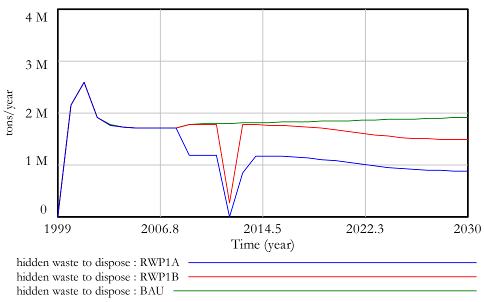

Figure 8 RDF stock - RWP1

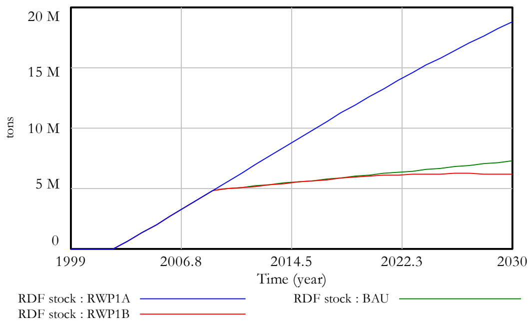

Figure 9 Hidden waste flow - RWP2

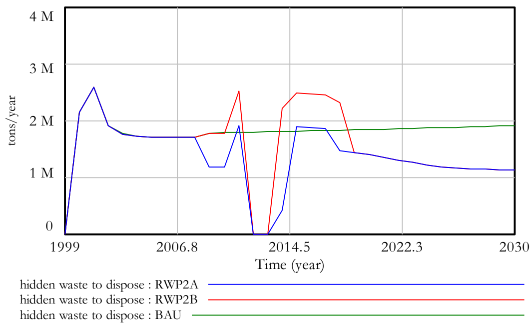

Figure 10 RDF stock - RWP2

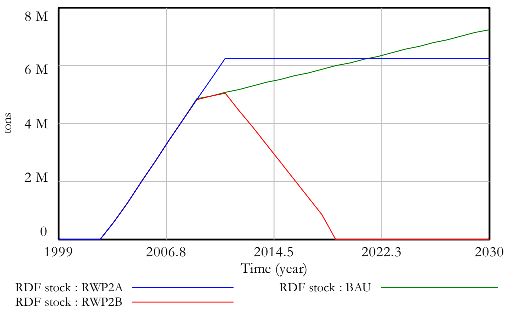

Figure 11 Hidden waste flow RIP

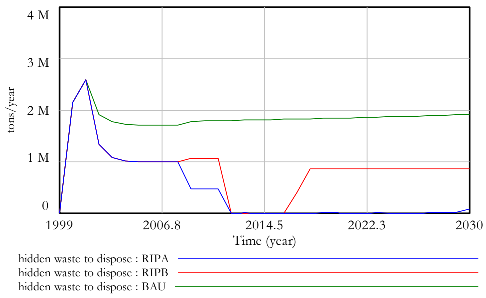

Figure 12 RDF stock - RIP