A Multi-Sectorial Analysis of a Waste to Energy Plant

CUCCHIELLA, F *, D'ADAMO, I., GASTALDI, M.

Department of Industrial and Information Engineering and Economics, University of L'Aquila, Via Giovanni Gronchi 18, Zona Industriale Pile, 67100 L'Aquila,

**Corresponding author, federica.cucchiella@univaq.it*

Abstract

Currently waste management is a critical issue for several countries. Separate collection and recycling activities are growing; Germany, Netherlands, Belgium, Sweden, Austria and Denmark have drastically reduced the use of the landfill while Italy, United Kingdom and Spain give half of their waste to landfill. Real case studies and scientific papers have demonstrated the benefits of the waste to energy (WTE) facilities compared to the traditional incinerators. Typologies of waste suitable for the energy recovery are: unsorted waste, dry fraction from mechanical biological treatment, refuse-derived fuels (RDF) and also some special waste (e.g. medical).

To focus on waste management in Italy, this study uses a multi-sectorial analysis for a region, Abruzzo, reporting a high rate of landfilling. Plant dimensioning, comparison between WTE strategies, centralized or decentralized solution, location of plant are proposed and economic, environmental, financial and social analysis verify the sustainability of the suggested solution.

The outcomes deriving from the present research could be extended in developing countries where ever-increasing amounts of solid waste accompany rapid economic and population growth. Relevant is the municipalities ability to sustainably manage it all and solutions to these problems may be found in the results of the present research.

Keywords: *quantitative analysis, sensitivity analysis, sustainability, waste to energy, multi-sectorial analysis*

1. Introduction

Sustainable waste management (SWM), based on reduction of landfill disposal, is strategic for public health and environmental protection (Shi et al., 2012; Wagner, 2011). The benefits deriving by a proper waste hierarchy application are: greenhouse gases emission prevention, pollutants reduction, energy saves, resources conservation, new jobs creation and development of green technologies (Directive 2008/98/EC (Cucchiella et al., 2014c; European Union, 2008)).

Firms can perform three types of tasks: public service activities that collect waste, processing activities that transform this waste and marketing activities that sell energy and recycled material (Corvellec et al., 2012). Waste management can lead to achieve significant financial benefits and in the case of waste management violations, the firms are subject to substantial fines or civil penalties (Flammer, 2012). The landfill use has to be the last resort for waste management. Really a correct waste management is based on the amount minimization of waste generated, in this way, new waste prevention initiatives are required for waste minimization and new waste reuse initiatives are necessary (Cucchiella et al., 2013b; Cucchiella and D'Adamo, 2013; Kaplan et al., 2009; Mazzanti and Zoboli, 2008).

Materials such as paper, metal, plastic, glass are recycled and recuperated; but also with high levels of recycling, an unsorted fraction of waste will remain (Chen and Christensen, 2010; European Environment Agency, 2008). Waste to Energy (WTE) plant is an attractive technological option in municipal solid waste (MSW), but it is a subject of intense debate (Bezama et al., 2013; Ionescu et al., 2013). WTE plants require efficient controls to avoid emissions of harmful pollutants into the air, land and water. Recent studies define that they do not produce additional health risks for the population living nearby (Ragazzi et al., 2013; Vilavert et al., 2012).

The relevance of WTE is continuously increasing, indeed, converting non-recyclable waste materials into electricity and heat; it is possible to generate a renewable energy source and reduce carbon emissions by offsetting the need for energy from fossil sources and reducing methane generation from landfills (Karlsson-Vinkhuyzen et al., 2012; Lombardi et al., 2013; Tabasová et al., 2012a). In comparison to other renewable energy production sources, the potential energy that could be produced from MSW, presents significant benefits both economic and technical (Xydis and Koroneos, 2012). MSW contains a non-renewable portion that has to be either separated or accepted as part of the fuel (Themelis and Millrath, 2004), only after the material recovery and recycling, wastes in MSW can be treated as renewable.

A correct waste management system requires that several aspects have to be integrated: local governments have to follow sustainable development approach in solving the waste problems, additionally environmental, economic and social impacts of investments in waste sector have to be well integrated (Cucchiella et al., 2014a). There are many factors and influences to consider for define the best solution in real-life applications (Achillas et al., 2013).

The initial phase of our project research had identified for Abruzzo region the optimal solution in a centralized plant by 500 kt. The suggested location was along the coast in central area in order to reduce transportation costs and environmental pollution, in a territory with a high population density (Cucchiella et al., 2012; Cucchiella et al., 2011). In the next step a national waste management plan (NWMP) was proposed, the growing separate collection and the combination of recycling and waste to energy allowed to achieve a sustainable waste management. Several policies of WTE for each region were proposed: with respect to the case of Abruzzo only a policy thrust on WTE enabled to achieve financial sustainability. The selected plant size was by 400 kt (Cucchiella et al., 2013a).

Based on updated data of waste production and management (2010 compared to 2009), on improvements of the used quantitative model and on a policy more oriented to landfill minimization, a new NWMP is been defined (Cucchiella et al., 2014b) and advantages of this plan are highlighted by an analysis of sustainability (Cucchiella et al., 2014a). It was confirmed that the optimal size for Abruzzo is 400 kt.

This paper aims to combine real and scientific expectations (prospects). The first defines the urgency of implementing a WTE plant in the considered region, while the second justifies this choice. To this aim it is proposed a sustainability analysis with a sensitivity analysis based on critical variables such as investment cost, selling price of electricity, heat selling price, interest rate, unit cost of transport, lower heating value, degree of saturation of facility and characteristics of landfill substituted. Furthermore data are updated to 2012.

This paper is organized as follows. Following this introduction, in the next section 2, it is analyzed the critical situation of Abruzzo. Starting from waste facilities sizing (section 3) it is possible to choice the best WTE strategy (section 4). In section 5, the centralized or decentralized solutions and the location of facilities are evaluated. Section 6 is devoted to the analysis of sustainability, in which several indicators are proposed: Economic/Financial Net Present Value, Economic/Financial Rate of Return, Economic/Financial Discounted Payback period, Discounted Aggregate/Net Cost-Benefit, Delay Cost, Waste Valorization, Greenhouse Gas Reduction, Skilled/Unskilled workers. A sensitivity analysis (section 7) is performed to give strength to the obtained results. Finally conclusions complete the paper.

2. Italian current waste situation

Based on ISPRA data (Institute for the Protection and Environmental Research, isprambiente.gov.it) the waste generation in Italy has been reduced from 2011 to 2012 by 4.5% (from 31.4 Mt to 30.0 Mt) and a similar decrease (3.5%) has been observed from 2010 to 2011. This is due to the reduction of household consumption (4.1%) and to the decrease of Gross Domestic Product (2.4%) from 2011 to 2012 (Table 1). Management costs of urban hygiene services are estimated in 157 €/per capita in 2011 (+4.6% than 2010) and are distributed as follows: 42.6% associated to management of mixed waste, 24% for waste collection, 19% to overall costs of the service and cost of capital invested and finally 14.4% for sweeping and washing of streets.

Table 1: Waste generation and separate collection in 2008-2012

	2008	2009	2010	2011	2012
Italy					
Waste generation (Mt)	32.5	32.1	32.5	31.4	30.0
Separate collection (%)	30.6	33.6	35.3	37.7	39.9
Abruzzo					
Waste generation (kt)	699.3	688.7	681.0	661.8	626.4
Separate collection (%)	22.0	24.2	28.5	33.5	37.6

Data on waste treatment show a high variability among Italian regions. Lombardia landfill rate is below 10% and the amount of waste incinerated is equal to the amount of waste recycled. In Piemonte, Trentino, Friuli and Veneto 50% of waste is recycled, on the contrary, more than 70% of waste is landfilled in Liguria, Lazio, Abruzzo, Molise, Puglia, Basilicata and Sicilia. In Abruzzo the separate collection has showed a significant growth (+15.6% from 2008 to 2012) reaching a value comparable to the national one (40%). The national goal of 65% that was to be achieved in 2012 is currently far.

A SWM strategy requires a drastic reduction in the amount of waste (WS) sent to the landfill. The role of WTE is essential and currently in Italy the total waste incinerated are about 5.5 Mt. In 2012 the distribution of incinerated waste is as follows:

- 2.6 Mt unsorted waste;
- 1.9 Mt dry fraction from mechanical biological treatment;
- 0.6 Mt secondary solid fuels;
- 0.4 Mt special waste (e.g. medical).

In the next section the proposed case study is analyzed and is evaluated the facility sizing to realize a WTE plant.

3. Facilities sizing

The choices regarding the size of facilities are based on some assumptions, among which the waste amount that must be treated and the SWM strategy (Cucchiella et al., 2011). Focusing on the Abruzzo case, some waste growth scenarios are defined:

- cWS, which corresponds to the current scenario (626 kt);
- fWS^{avg}, where waste production is equal to the average value observed from 2008 to 2012 (671 kt);
- $fWS^{\Delta 7}$, where it is supposed a waste production of 718 kt with an increase of 7% of scenarios fWS^{avg}. Indeed, the waste amount is directly correlated at two factors: the population of a given area, and its consumption patterns. The global financial crisis seems to have reduced the waste production, but, with the end of the crisis, the waste volumes are destined to grow.

With reference to the objective related to the landfill use, three scenarios have been hypothesised with three different targets equal to a landfill rate of 5%, 10% and 20% (Table 2). The first one is related to an optimal use of landfill treatment with an efficient progress in diverting municipal waste from landfills. The remaining share of wastes, which is not diverted away from landfills, can be recovered with WTE plants. Also for waste incinerated different waste valorisation levels are supposed: $WtoE^{75\%}$, $WtoE^{50\%}$ and $WtoE^{25\%}$ where the contribution of waste incineration is respectively 75%, 50% and 25%

(Table 2). The remaining amount of waste (the total amount less landfilled and incinerated shares) is recycled or composted.

Table 2: Waste disposed in landfills and waste to energy (kt) in Abruzzo

Scenarios	cWS	fWS^{avg}			$fWS^{\Delta 7}$		
Total WS	626	671			718		
Landfill WS (current mix)	495	531			568		
WtoE WS (current mix)	0						
% landfill (target)		5	10	20	5	10	20
e.g. 5% landfill in fWS^{mx}		*531*0,05=27*					
WS in landfill (future mix)		27	53	106	28	57	114
e.g. 5% landfill in fWS^{mx} with $WtoE^{75\%}$		*(531-27)*0,75=378*					
$WtoE^{75\%}$ WS (future mix)		378	358	318	405	383	341
$WtoE^{50\%}$ WS (future mix)		252	239	212	270	256	227
$WtoE^{25\%}$ WS (future mix)		126	119	106	135	128	114

For the correct sizing of energy plants, a multi-criteria analysis is used (Cucchiella et al., 2014b). We assume that the proposed future scenarios have the same weight, while a lower WtoE case has about a double weight with respect to the higher one. Depending on the adopted SWS strategy, the sizes of plant are:

(378*0.57+358*0.29+318*0.14)*0,5+(405*0.57+383*0.29+341*0.14)*0,5 ≈ 400kt; level $WtoE^{75\%}$;

(252*0.57+239*0.29+212*0.14)*0,5+(270*0.57+256*0.29+227*0.14)*0,5 ≈ 250kt; level $WtoE^{50\%}$;

(126*0.57+119*0.29+106*0.14)*0,5+(135*0.57+128*0.29+114*0.14)*0,5 ≈ 150kt; level $WtoE^{25\%}$;

Notice that only same plant capacities are available (from the value of 50kt, all the multiple cases of the base system are considered, up a maximum of 750 kt). A comparison of these strategies, in terms of sustainability, is proposed in the next section.

4. WTE strategy analysis

The best choice among the three strategies of WTE is carried out according to two main reasons: the first has an environmental nature and the second an economic nature.

250kt or 150 kt plant do not even contribute to reduce the half of the waste that are otherwise sent to landfill. In addition, the Abruzzo Region is implementing a recycling policy while the energy recovery is currently unused and then it has a wide margin of action. In fact in according to waste hierarchy and to previous research studies (Cucchiella et al., 2013a; Cucchiella et al., 2014b), we opt for the strategy $WtoE^{75\%}$ in order to minimize waste to landfill and to reduce environmental impact.

Since the GHG reductions, with respect to the landfill disposal, varies on the base of landfill characteristics, in Table 3 an estimation of emissions reduction is proposed based on literature cases (Cucchiella et al., 2014a; De Stefanis et al., 2006; Tabasová et al., 2012b):

- 360 kgCO_2eq/twaste (GHG^{cpt} - collection system that recovers 50% of the biogas produced);
- 650 kgCO_2eq/twaste (GHG^{trd} - is not controlled and is not manifested biogas recovery);
- 500 kgCO_2eq/twaste (GHG^{avg} - average value).

Table 3: Emissions reduction (ktCO_2eq) for plant size

Plant size (kt)	GHG^{trd}	GHG^{avg}	GHG^{cpt}
400	260	200	144
250	162.5	125	90
150	97.5	75	54

The dimensional size of WTE has a relevant role for the Financial Net Present Value (FNPV) results: it is positive only for WTE higher than 350 kt (Cucchiella et al., 2012). However, the sensitivity analysis shows that in the optimistic situation are sufficient small variations in input variables to obtain a positive FNPV from plants starting from 200 kt; on the contrary, in the pessimistic situation, a positive result is achieved only with a 750 kt plant (Cucchiella et al., 2014b).

The basic values of the critical variables in the FNPV calculation are: the lower heating value (LHV) is 10.4 MJ/kg (2,485 kcal/kg), the selling price of electricity (SP_{el}) is 47.29 €/t, the heat selling price (SP_{he}) is 27.02 €/t, the investment cost (I) can range from 376 to 765 €/t and the interest rate (r) is 5%. Table 4 shows the sensitivity analysis of FNPV for the three plant sizes considered in this paper when the critical variables vary as follows:

- interest rate is 3% (r^{++}), 4% (r^{+}), 6% (r^{-}) and 7% (r^{--});
- investment cost, respect to the basic value, is -20% (I^{--}), -10% (I^{-}), 10% (I^{+}), 20% (I^{++});
- selling price of electricity and heat selling price, respect to the basic value, +20% (SP_{el}^{++}, SP_{he}^{++}), +10% (SP_{el}^{+}, SP_{he}^{+}), - 10% (SP_{el}^{-}, SP_{he}^{-}), - 20% (SP_{el}^{--}, SP_{he}^{--});
- lower heating value is 12.6 MJ/kg (LHV^{++}), 10.9 MJ/kg (LHV^{+}) and 9.2 MJ/kg (LHV^{-}).

Table 4: FNPV (M€) sensitivity analysis for plant size

Plant size (kt)	base	r^{-}	r^{--}	I^{-}	I^{--}	SP_{el}^{-}	SP_{el}^{--}	SP_{he}^{-}	SP_{he}^{--}	LHV^{-}	
400	7.7	-9.9	-24.0	-11.2	-30.0	-9.5	-26.6	-2.3	-12.2	-7.1	
250	-11.5	-21.6	-29.8	-24.9	-38.3	-22.2	-32.9	-17.7	-23.9	-13.2	
150	-18.5	-24.0	-28.4	-27.7	36.9	-24.9	-31.3	-22.2	-25.9	-22.3	
		r^{+}	r^{++}	I^{+}	I^{++}	SP_{el}^{+}	SP_{el}^{++}	SP_{he}^{+}	SP_{he}^{++}	LHV^{+}	LHV^{++}
400		29.4	56.6	26.5	45.3	24.8	41.9	17.6	27.5	13.8	21.5
250		1.2	17.0	1.9	15.2	-0.8	9.9	-5.3	0.9	-10.8	-0.8
150		-11.6	-2.8	-9.3	-0.1	-5.3	0.9	-14.8	-11.0	-17.0	-11.6

The 400 kt plant is the best choice. Its profitability is verified in all optimistic scenarios, whereas the results are always negative in the pessimistic scenarios. Only under certain conditions the 250 kt plant can be profitable, for example when investment cost are reduced by 10% or selling price of electricity/heat increases by 20% or interest rate is equal to 4%. While the 150 kt plant can be profitable only with an increase of 20% of selling price of electricity.

The variation of FNPV is greater in larger facilities and interest rate is the variable that determines the deviation more relevant. The next step is to determine the localization of WTE facilities and the evaluation of centralized or decentralized solutions.

5. Centralized or decentralized solution

The localization model displays the waste supply sites as a set of points with the objective to minimize transportation costs. The reference area can be regional or provincial (in Abruzzo there are four provinces: L'Aquila, Teramo, Chieti and Pescara).

The decision to locate one (centralized solution) or more (decentralized solution) WTE plants in a given geographical area is defined by a quantitative approach. However other requirements should be satisfied, such as links to the main arteries of transport and the zoning restrictions (Cucchiella et al., 2011). The analyzed scenarios are:

- scenario S_{1P} with only one plant, represents the centralized solution with a regional area of reference;
- scenario S_{2P}, with two plants, represents the decentralized solution with a regional area of reference;
- scenario S_{4P}, with four plants, represents the centralized solution with a provincial area of reference or decentralized solution with a regional area of reference.

S_{1P} (400 kt capacity) represents the centralized solution, S_{2P} (each plant has a 200 kt capacity) and S_{4P} (each plant has a 100 kt capacity) represent the best solutions in the scenarios that involve the installation of two or four plants, respectively. The plant with a capacity of 100 kt has a strong negative financial performance (Cucchiella et al., 2011) and so the S_{4P} option is not considered in the rest of the paper.

Results, which are provided in Table 5, identify the best choice but do not express the wealth generated by the implementation of a given scenario. In fact FNPV and ENPV (Economic Net Present Value) define a "to be" result over an "as is", while the shipping costs only the "to be" result.

Table 5: The choice between centralized or decentralized solution (M€)

	Financial analysis		Economic analysis	
	Plant FNPV	Shipping Costs	Plant ENPV	Shipping Costs
S_{1P}	7.7	72.8	146.7	80.2
S_{2P}	-30.0	58.3	123.1	65.8

A centralized solution is better than decentralized one: the profitability of the facilities decreases in such a way that does not offset the savings on transport costs; furthermore the starting unit cost of transport (TC) was varied in order to give strength to the obtained results (Table 6) (Cucchiella et al., 2012). The location of facility confirms area of reference identified in previous research (Cucchiella et al., 2011). The sustainability analysis is a necessary step to define the benefits of this choice compared to the landfill.

Table 6: Sensitivity analysis – Unit cost of transport (M€)

	Financial analysis					Economic analysis				
	FNPV	TC^{--}	TC^{-}	TC^{+}	TC^{++}	ENPV	TC^{--}	TC^{-}	TC^{+}	TC^{++}
S_{1P}	7.7	58.7	65.8	80.0	86.9	146.7	66.3	73.2	87.2	94.1
S_{2P}	-30.0	46.4	52.4	64.1	70.0	123.1	53.8	59.9	71.7	77.6

6. The sustainability analysis

Sustainable development requires viable answers following economic, environmental and social criteria (Meyar-Naimi and Vaez-Zadeh, 2012). Plant investments have been evaluated based on several parameters that quantify all the relevant aspects (Table 7).

WTE facilities attract intense debates among political and social groups; phenomenon as Not in my back yard (NIMBY) and Not in my term of office (NIMTO) hinder their realization. An ideal system requires that when a project contributes to making a nation more sustainable it is immediately realized. If this does not happen, it is necessary to quantify the losses linked at a project delay realization and to consider these losses as additional costs (Cucchiella et al., 2014b). For example a 400 kt plant, if it is been realized with a one year delay, produces a loss of 364 k€ (that is equal to 5% of FNPV).

The estimation of financial and economic indexes is been deeply described in a previous work for a 500 kt plant (Cucchiella et al., 2012). Economic indicators (ENPV, ERR, EDPP) have higher value than financial indicators (FNPV, FRR, FDPP) and this is due to two causes: the conversion factors, that act in particular on the investment components reducing cash outflows and the positive value of Social Cost of Carbon, thus representing an incoming flow (is equal to 9 €/twaste). These indicators define the profitability of investment and the same result is obtained from Cost Benefit Analysis ($D(B/C)_A$, $D(B/C)_N$), that is typically used in the evaluation of public projects. Payback period is high because the profitability of facility is calculated on the total cost of the investment, which is concentrated in initial time. In fact, the investment is not spread on the payment period of the loan but on the realization period.

Table 7: Sustainability indicators – 400 kt plant

Indicators	Value
Economic indicators	
Economic Net Present Value (ENPV)	146.7 M€
Economic Rate of Return (ERR)	13.9 %
Economic Discounted Payback period (EDPP)	11.7 y
Discounted Aggregate Cost-Benefit ($D(B/C)_A$)	1.46
Discounted Net Cost-Benefit ($D(B/C)_N$)	2.01
Delay cost 1y	364 k€
Delay cost 2y	712 k€
Delay cost 3y	1,043 k€
Environmental indicators	
Waste Valorization	400 kt
Greenhouse Gas Reduction	200 ktCO_2eq
Financial indicators	
Financial Net Present Value (FNPV)	7.7 M€
Financial Rate of Return (FRR)	5.4 %
Financial Discounted Payback Period (FDPP)	27.6 y
Social indicators	
Skilled workers	16
Unskilled workers	80

From a social point of view, the WTE plant is able to generate new jobs (Cucchiella et al., 2011). In this paper we analyzed the workers employed in the operational phase, but it is also important to deepen the opportunities in the construction phase of such projects. A survey conducted in order to assess social acceptance for the development of a WTE facility in Abruzzo represents a further aim of the future research (Achillas et al., 2011).

The environmental advantage varies on the base of landfill characteristics and the GHG reduction is defined in a range of 144-260 ktCO_2eq (scenario GHG^{avg} is equal to 200 ktCO_2eq). This indicator considers methane emissions that alternatively are released from landfill and CO_2 emissions deriving from energy production from fossil fuel and not by wastes.

The WTE process is an effective method to respond to climate change arising from the global warming effect. The relevance of WTE will continuously increasing, indeed, converting non-recyclable waste materials into electricity and heat, it is possible to generate a renewable energy source and reduce carbon emissions.

New reports by market research firms (ReportsnReports.com and Frost & Sullivan) highlight that the value of the global waste incineration market is increased in last years from $7.9 billion in 2008 to 9.2 billion in 2012. This sector will continue to grow, reaching a value of 16.8 billion in 2022 and among European Countries, Italy is expected to become one of the most attractive markets for energy waste production. In the next section a sensitivity analysis is proposed and so it is evaluated the role of LHV on the economic and financial indicators and the impact of degree of saturation of the plant on FNPV.

7. Sensitivity analysis

The LHV is a critical parameter to define the potential use of MSW as a fuel obtained by energy recovery, in fact it represents the energy actually available to be converted into heat and/or electricity (Brinck et al., 2011). During the last years the composition of MSW is varied, with the decrease of organic waste and the increase of packaging-related waste. Separate collection plays a positive role also for waste sent to WTE plant and influences the main characteristics of the residual waste (e.g. composition, water content, lower calorific value) (Calabrò, 2010). In order to consider the sensitivity of economic and financial indicators with respect to this variable (Table 8), five scenarios with different LHV have been analyzed for the 400 kt plant selected for the Abruzzo region:

- scenario $LHV^{9.2}$ with a LHV equal to 9.2 MJ/kg (2,198 kcal/kg)
- scenario $LHV^{10.9}$ with a LHV equal to 10.9 MJ/kg (2,604 kcal/kg)
- scenario $LHV^{12.6}$ with a LHV equal to 12.6 MJ/kg (3,010 kcal/kg)
- scenario $LHV^{14.2}$ with a LHV equal to 14.2 MJ/kg (3,393 kcal/kg)
- scenario $LHV^{15.9}$ with a LHV equal to 15.9 MJ/kg (3,799 kcal/kg).

Table 8: Performance indicators with different LHV – 400 kt plant (base case $LHV^{10.4}$)

Indicators	Index	$LHV^{10.4}$	$LHV^{9.2}$	$LHV^{12.6}$	$LHV^{14.2}$	$LHV^{15.9}$	$LHV^{15.9}$
Financial indicators							
FNPV	M€	7,7	1.7	9.3	19.7	34.9	47.2
FRR	%	5.4	5.1	5.5	5.9	6.4	6.7
FDPP	years	27.6	28.6	27.4	26.1	24.7	23.8
Economic indicators							
ENPV	M€	146.7	133.8	150.6	171.5	195.5	216.5
ERR	%	13.9	13.9	13.9	14.0	14.3	14.4
EDPP	years	11.7	11.8	11.7	11.7	11.5	11.4
$D(B/C)_A$	index	1.46	1.43	1.46	1.50	1.54	1.57
$D(B/C)_N$	index	2.01	1.96	2.01	2.08	2.17	2.23

The investment is profitable in all scenarios and given that LHV initial value is lower than other values examined, there is an increase of both FNPV and ENPV. In particular this is verified in scenarios $LHV^{14.2}$ and $LHV^{15.9}$, since revenues growth is more proportional than costs. For example FNPV reports a value of 47.2 M€, with an increase (+513%) in scenario $LHV^{15.9}$, +353% in scenario $LHV^{14.2}$, +156% in scenario $LHV^{12.6}$ and +21% in scenario $LHV^{10.9}$ with respect to the scenario base. FDPP presents a variation more significant than EDPP. The first has a range of 4.8 years, the second of 0.4 years. Analogous behaviors are showed by FRR and ERR. Finally, Discounted Aggregate and Net Cost-Benefit Indices are growing and assume the best result in scenario $LHV^{15.9}$ (1.57 and 2.23).

The degree of saturation of a facility influences its financial performance. On the one hand a larger plant has advantages in economies of scale, on the other the under-sizing runs the risk of not exploiting a good share of the waste that would go to landfill - Table 9 (Cucchiella et al., 2012).

Table 9: FNPV (k€) of a 400 kt plant with different LHV in function of degree of saturation

Waste treated (kt)	$LHV^{10.4}$	$LHV^{9.2}$	$LHV^{10.9}$	$LHV^{12.6}$	$LHV^{14.2}$	$LHV^{15.9}$
400.000 (100%)	7,657	1743	9,301	19,667	34,867	47,248
390.000 (97.5%)	2,762	-2,623	4,206	13,718	28,039	39,611
380.000 (95%)	-2,133	-6,989	-889	7,770	21,211	31,974
370.000 (92.5%)	-7,028	-11,355	-5,984	1,821	14,383	24,337
360.000 (90%)	-11,923	-15,720	-11,079	-4,127	7,555	16,700
350.000 (87.5%)	-16,818	-20,086	-16,174	-10,076	727	9,063
340.000 (85%)	-21,713	-24,452	-21,269	-16,024	-6,101	1,426
330.000 (82.5%)	-26,608	-28,818	-26,364	-21,973	-12,929	-6,212
320.000 (80%)	-31,503	-33,184	-31,459	-27,921	-19,757	-13,849

The results confirm a sharp decline in profitability when the plant is not saturated. In particular, the scenario LHV9.2 has a positive FNPV only if the degree of saturation is equal to 100%; whereas in scenario LHV15.9 FNPV is equal to 1,426 k€ also with only 350.000 kt treated. This analysis explains one of the motivation for which many countries have recently begun importing waste from other territories.

8. Conclusions

The reduction of waste sent to landfill is a choice-strategy for green development. In fact landfill use damages the quality of the ecosystems: it not protects public health, increases environmental pollution and not conserves natural resources.

A current paradox is that the WTE facility is contemplated as a technology that can worsen the climate condition, when instead it is a renewable source. According to waste hierarchy recycling is better than energy recovery but the experience of many European countries shows that in sustainable management framework WTE and recycling together could contribute to minimize the tons of waste sent to landfill. The quality and quantity of separate collection influence the best choice, but an economic analysis of these two management strategies requires considering also the need of the territory to have energy and heat from renewable sources or market requirements relating to components recycled.

The primary goal of this paper is to transfer know-how to all readers, because phenomena as Nimby or Nimto accumulate huge economic losses. If a technological system is sustainable and is realized in proximity of waste production, in according to the principle of self-sufficiency territorial (key-element of European energy policy) it is necessary to invest in this project. Not only unsorted waste are suitable for WTE facilities, but also other raw materials and in particular elements with high LHV. On the one hand are necessary very precise instruments that detect these potentially dangerous flows and on the other, the scientific research will provide more environmentally friendly solutions.

In this paper, it is been proposed a real application of the strategy to implementation of WTE plant in a single region. All phases of management project are been described and, actually, there are ongoing studies related to public perceptions of such facilities that generate worries and doubts, same time there is a strong interest of firms to invest in this sector. The results show that WTE plant is sustainable, in fact reduces emissions in comparison to landfill, creates jobs opportunities and produces economic and financial profits.

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