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A Waste to Energy (WtE) strategic analysis in Italy

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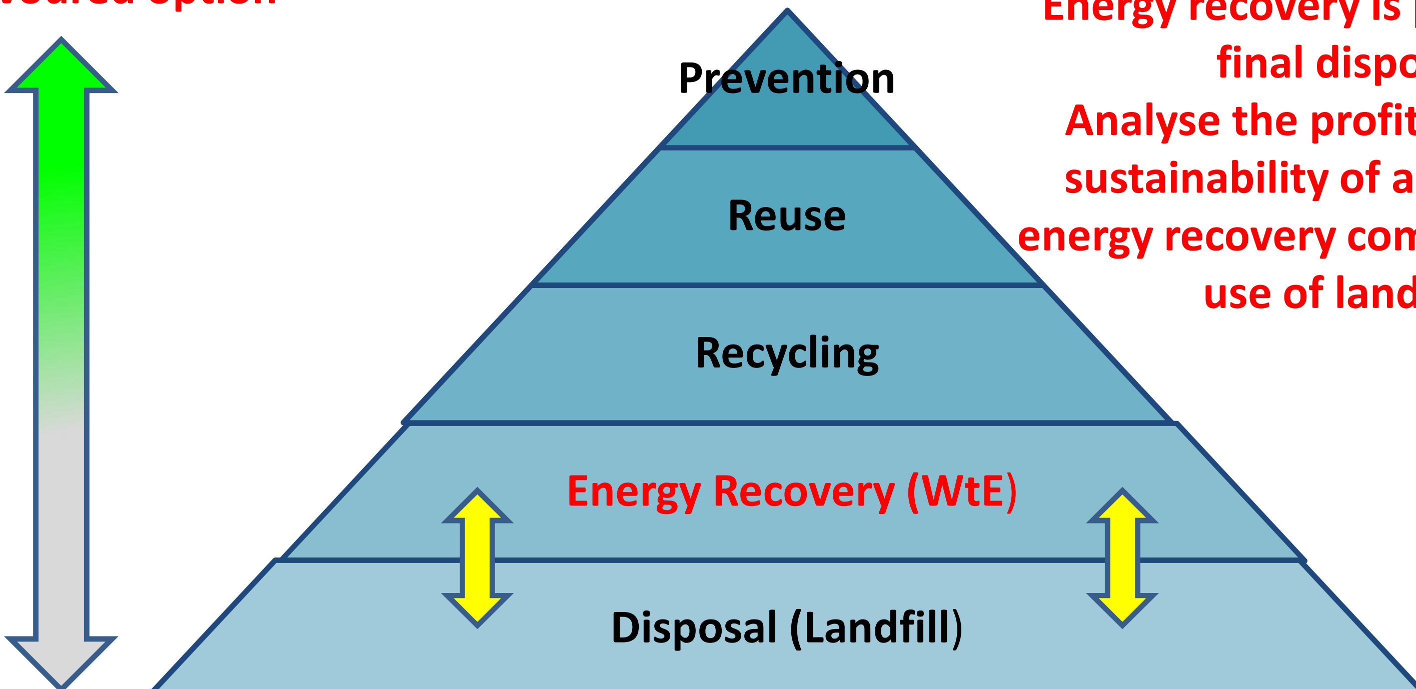
Hierarchy of waste management

Proper waste management is one that aims to minimize the amount of materials to bring to final disposal. In order to achieve this goal it is necessary first to minimize their production and maximize the recovery of other materials found there. The use of disposal is possible only when all the preceding phases are been dispatched.

Most favoured option



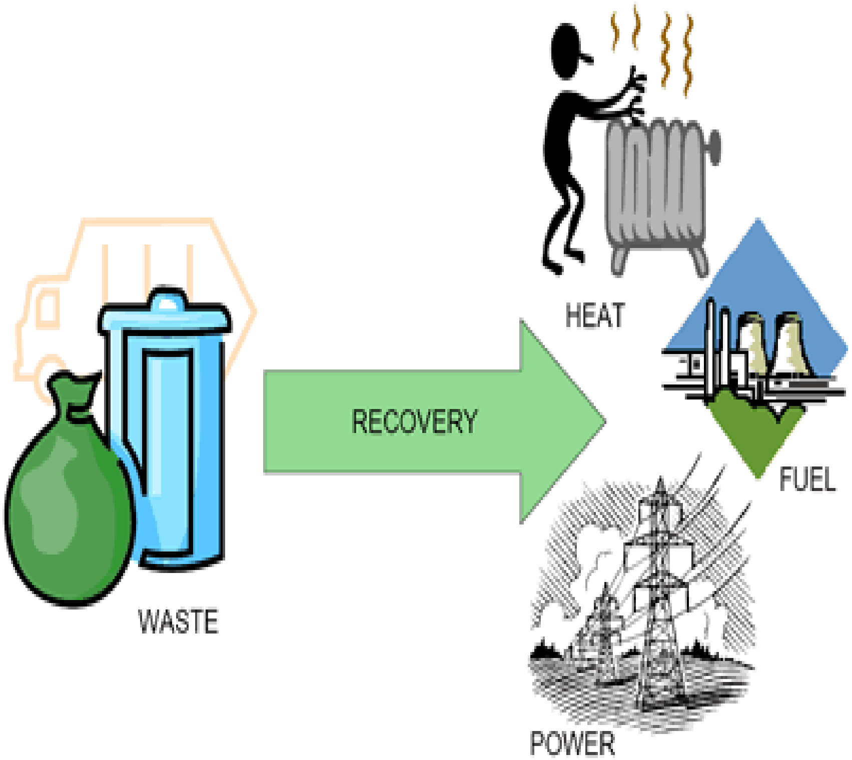
Least favoured option

Energy recovery is preferred to final disposal

Analyse the profitability and sustainability of a plant with energy recovery compared to the use of landfills

The WtE relevance is continuously increasing

Waste to energy (WtE) is the process of generating energy from the incineration of waste



Converting non-recyclable waste materials into electricity and heat it is possible to generate a renewable energy source and reduce carbon emissions

The potential energy that could be produced from waste presents significant benefits both economic and technical

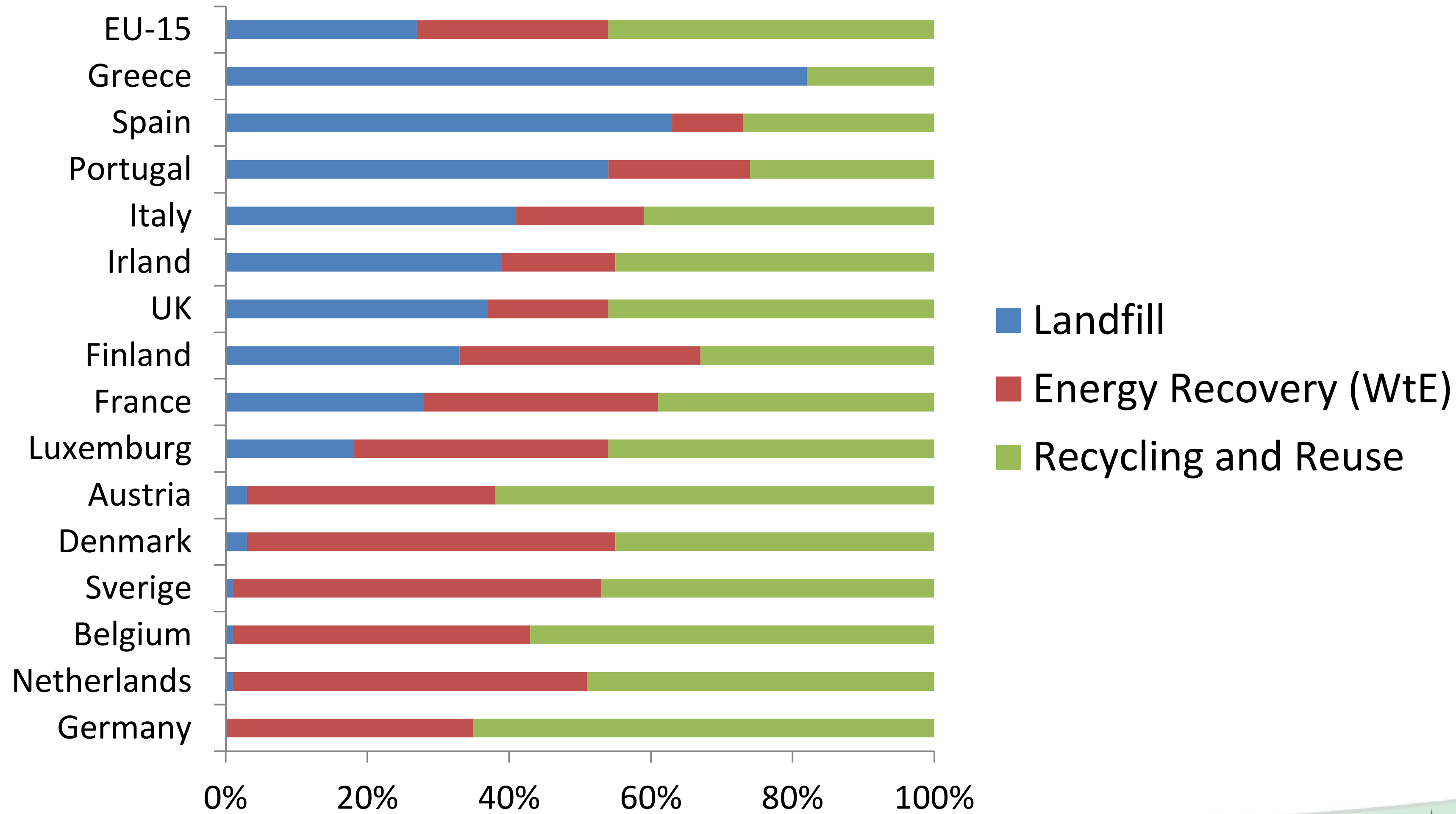
Aims of the paper

- Propose a WtE strategy in Abruzzo
- Evaluate the sustainability of the proposed WtE strategy
- Propose a sensitivity analysis of the results based on critical
- … economic
- … financial
- … social
- end environmental variables

Presentation steps

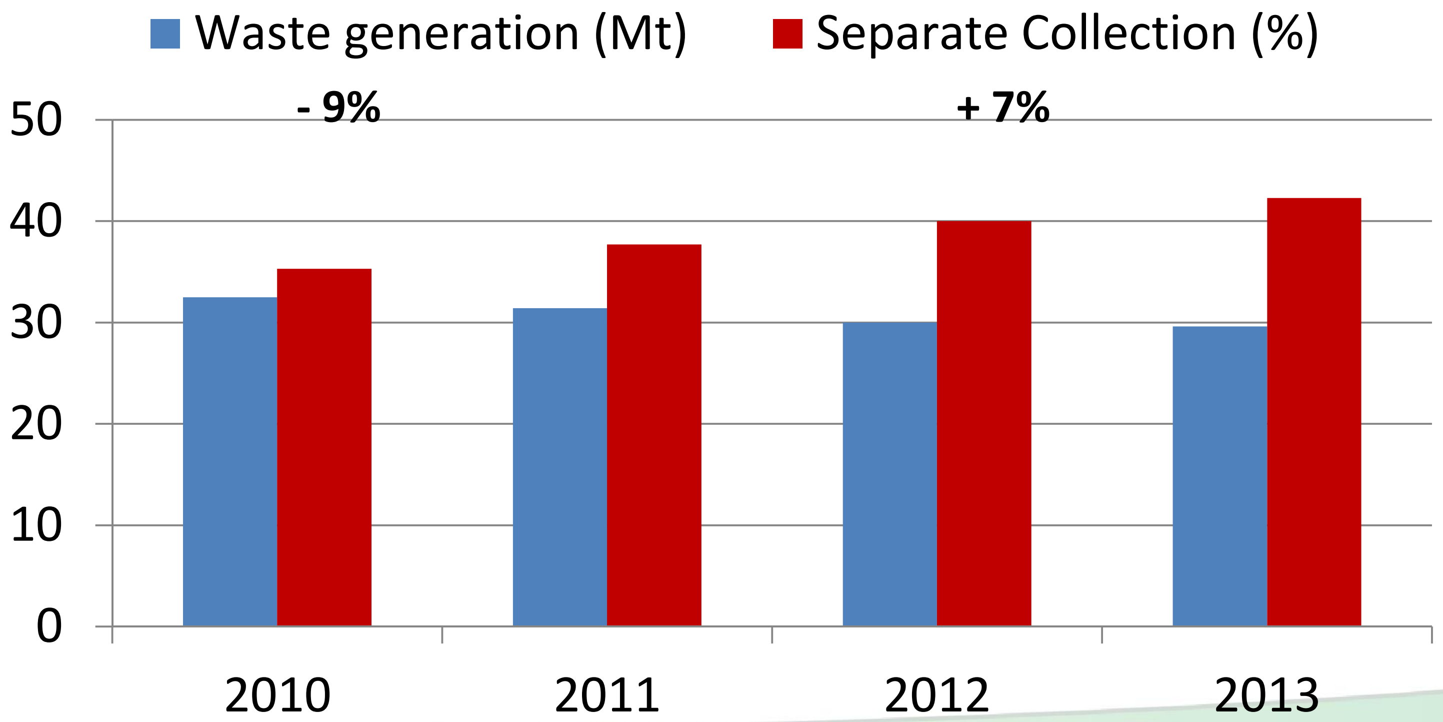
- Analysis of the reference area: Abruzzo
- WtE strategy definition
- Plant capacity
- Plant location: centralized or decentralized solutions
- Sustainability analysis
- Sensitivity analysis

Waste Treatment in Europe, 2013



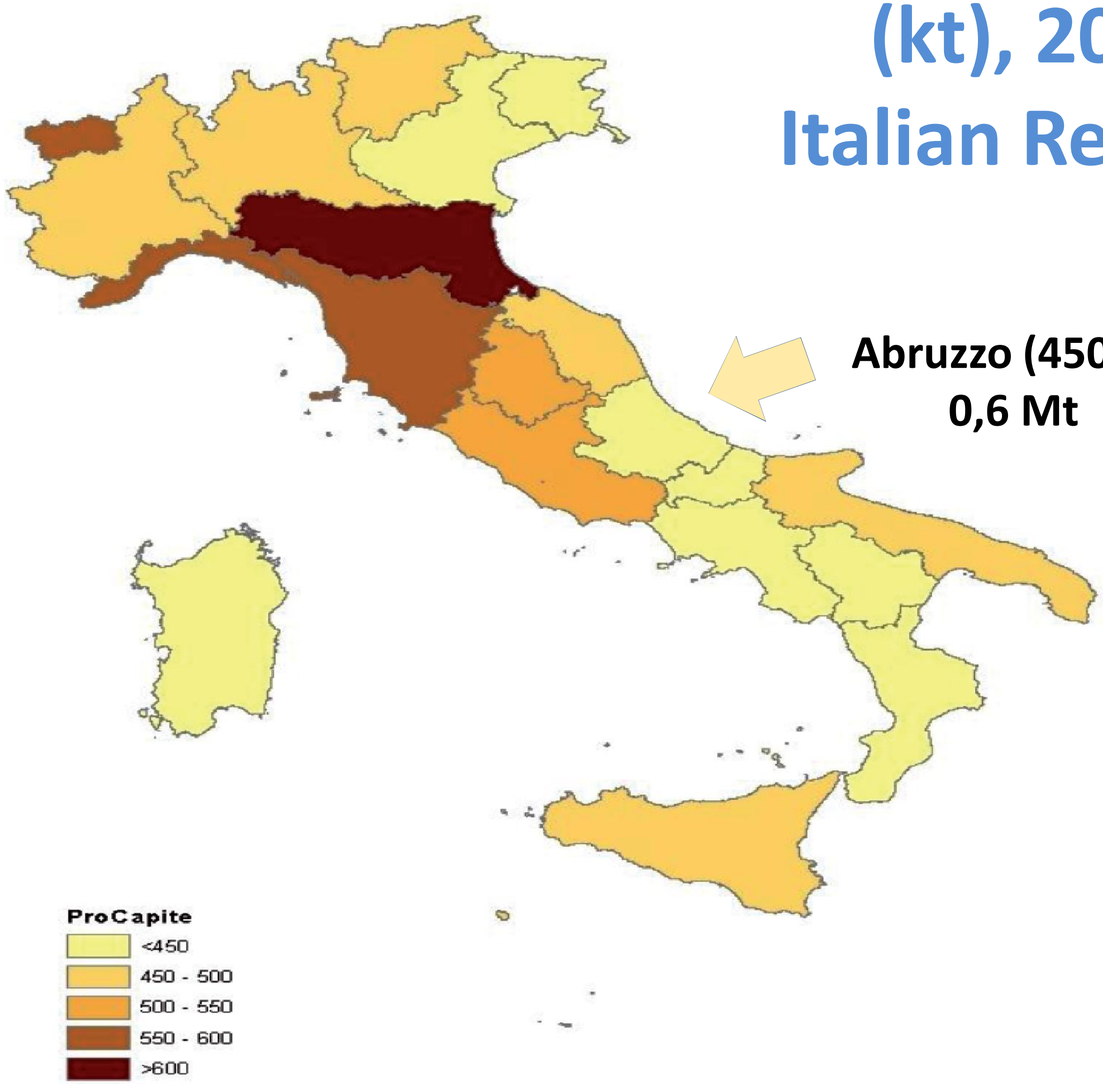
Italy reports a landfill rate of 41%, a higher value of 14% compared to the average of 15 European Countries.

Waste generation and separate collection in Italy 2008-2013



Total waste generated (kt), 2013
Italian Regions

Italy (528 kt)
29,6 Mt

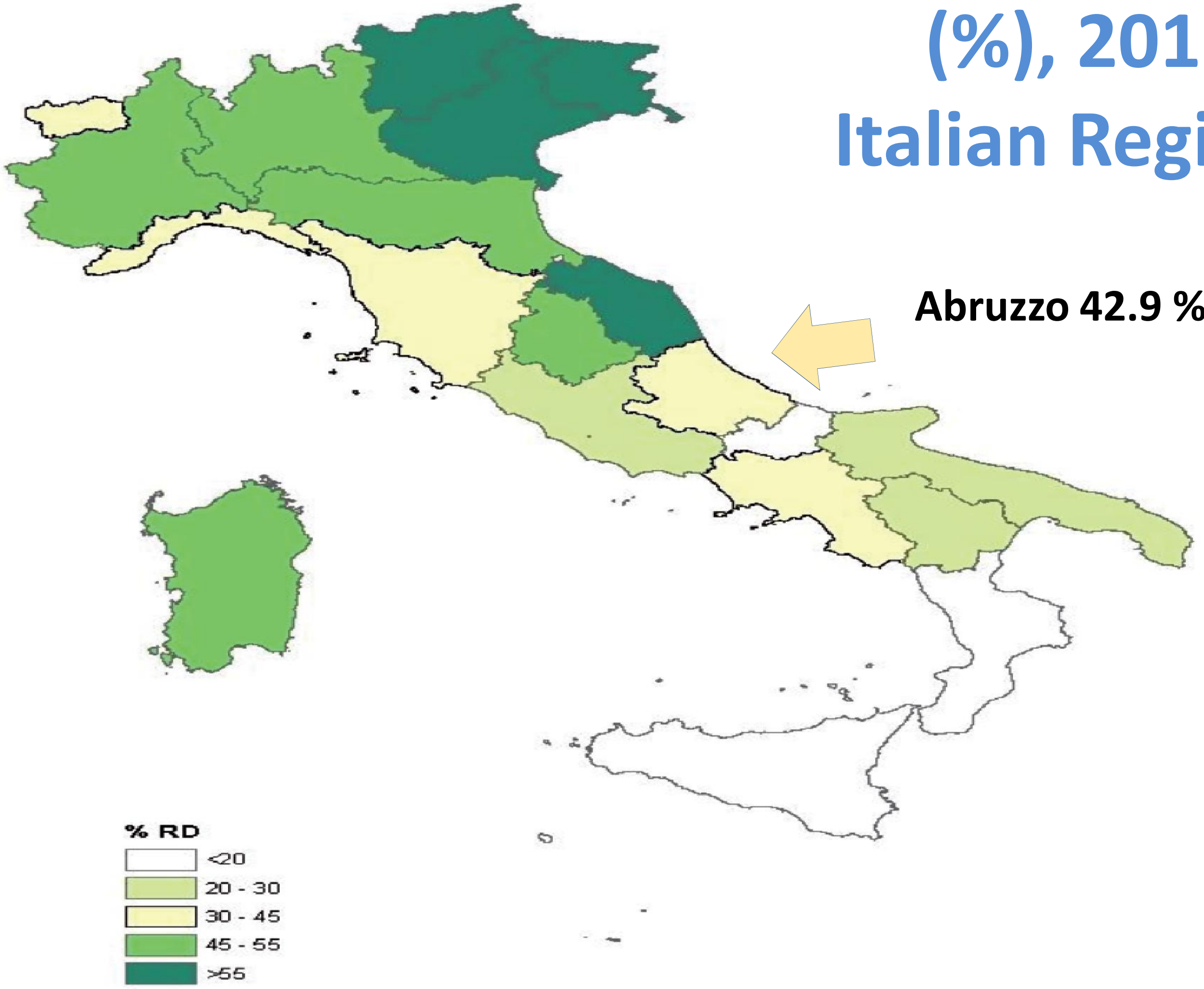


Abruzzo (450 kt)
0,6 Mt

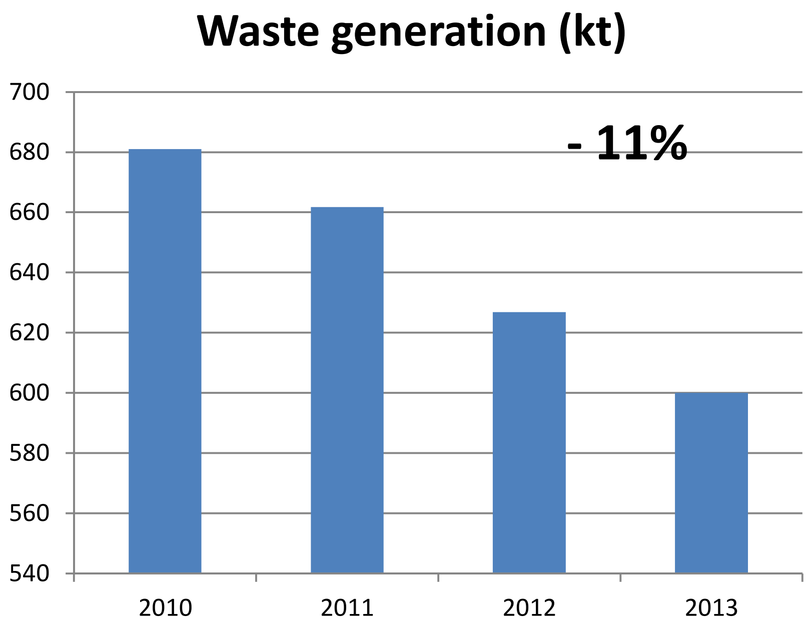
Separate collection (%), 2013 Italian Regions

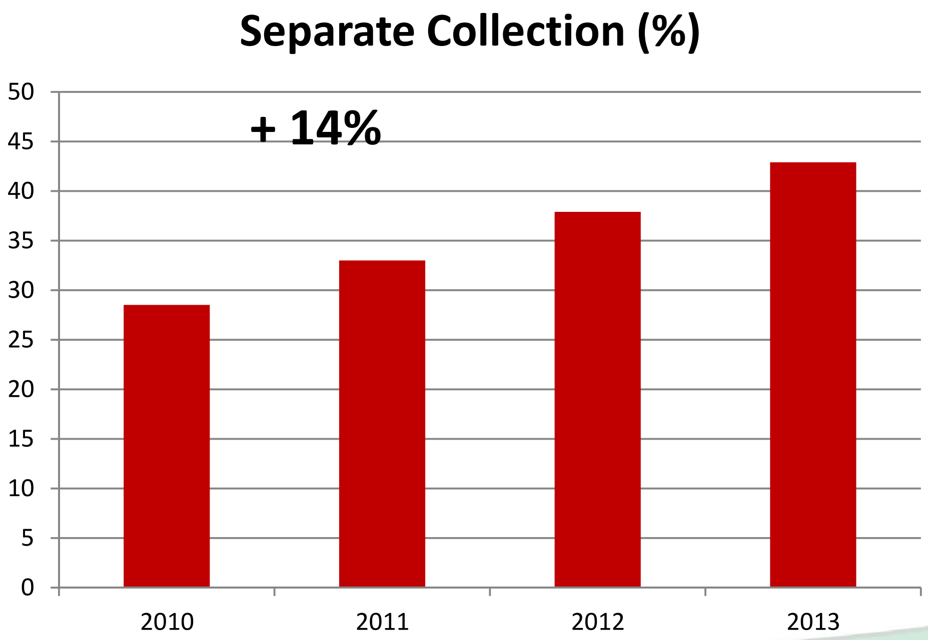
Italy 42.3 %

Abruzzo 42.9 %

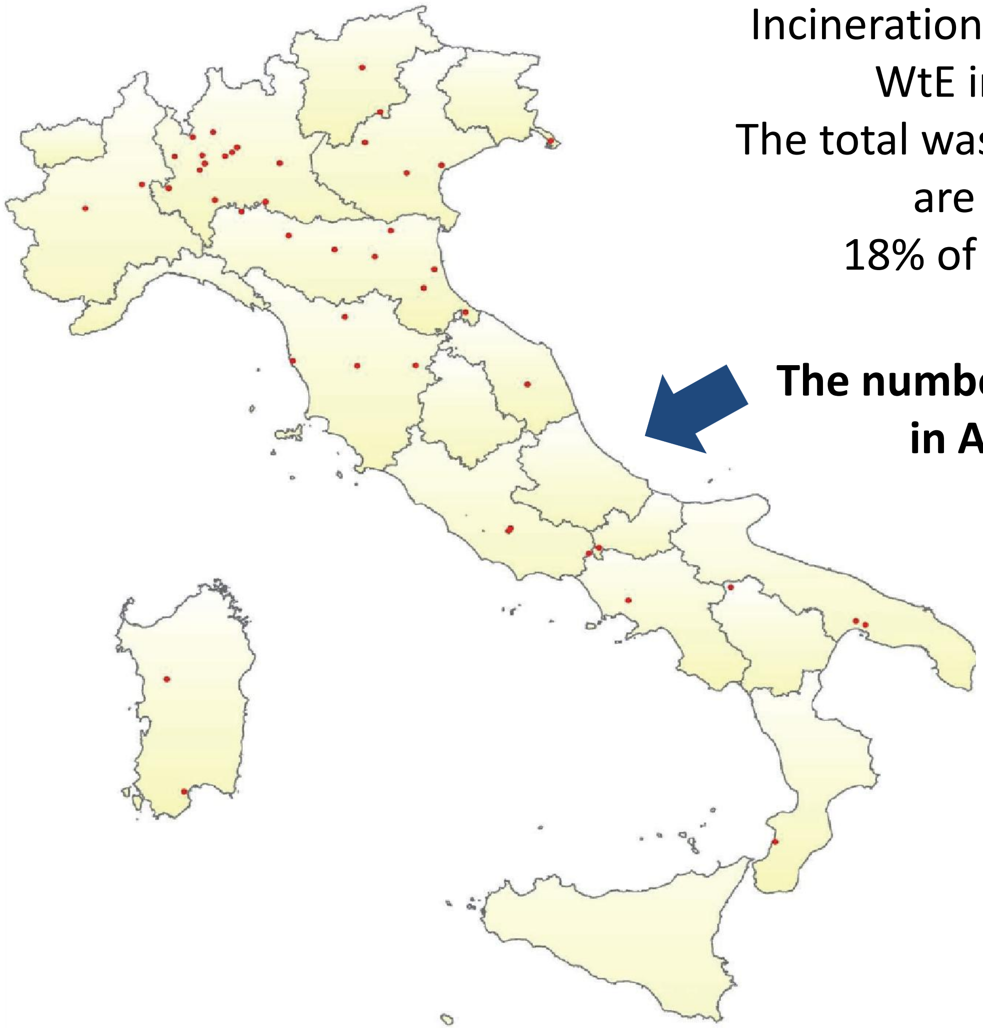


Waste generation and separate collection in Abruzzo 2008-2013





WtE Incinerators in Italy, 2013

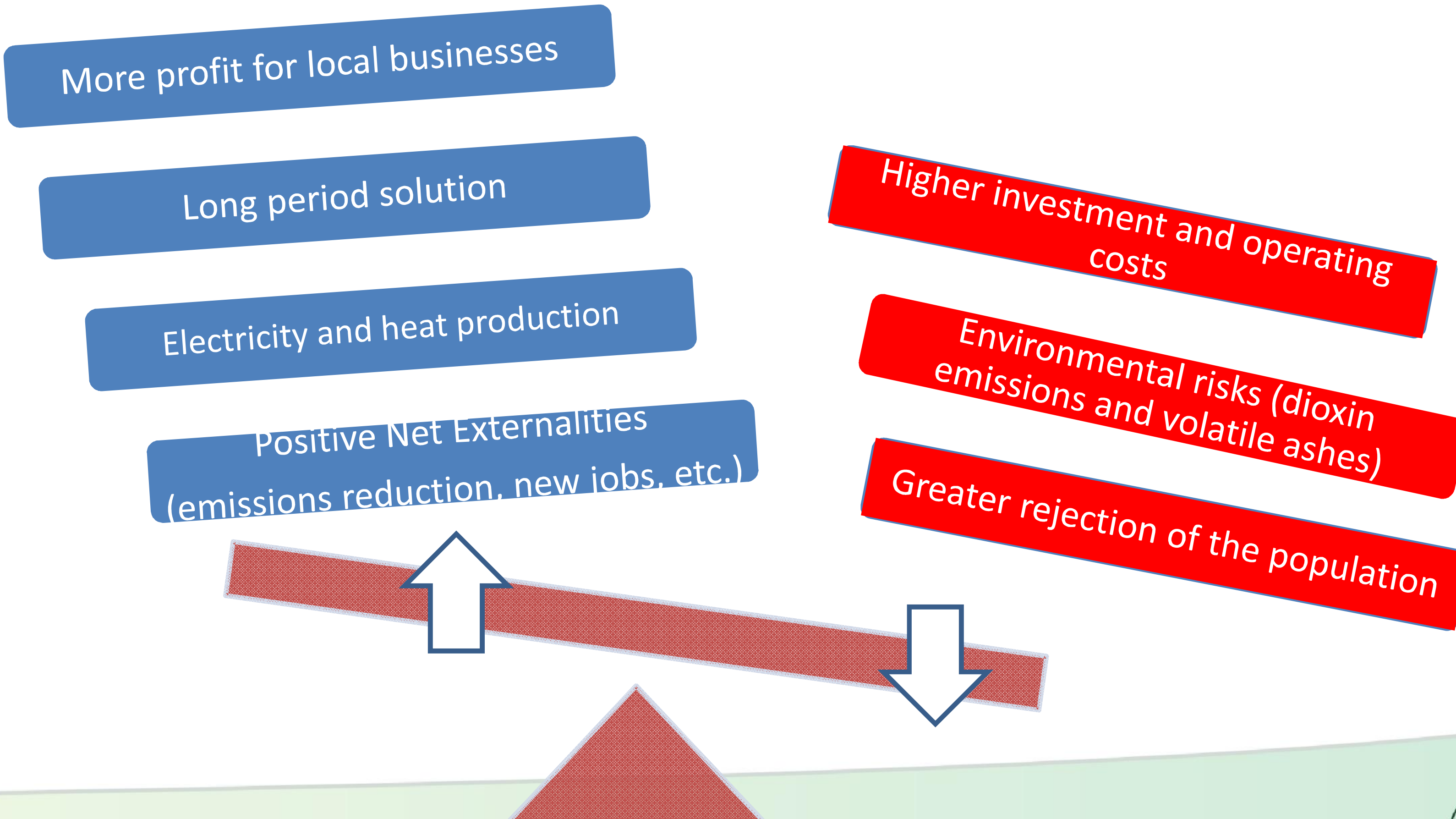


Incineration is the most common WtE implementation
The total waste incinerated in Italy are about 5.5 Mt
18% of waste generated

The number of incinerators in Abruzzo is 0

It is proposed a case study for evaluating the facility sizing to realize a WtE incinerator plant in Abruzzo.

Feasibility of an incinerator with energy recovering compared to a landfill



Parameters

Territorial area of expertise

It can exploit economies of scale, if there are no legislative or ideological constraints.

Quantities of waste to valorise

It is a function of the territorial area of reference and environmental policy adopted by the Local authority.

Nature of the waste

Urban 95% ; Other 5%

Lower calorific value of waste

The average value recorded in plants with energy recovery in Italy equal to 10,4 MJ/kg.

Nature of the output produced by the plant

Percentual electricity 50% ; Percentual heat 50%

Time

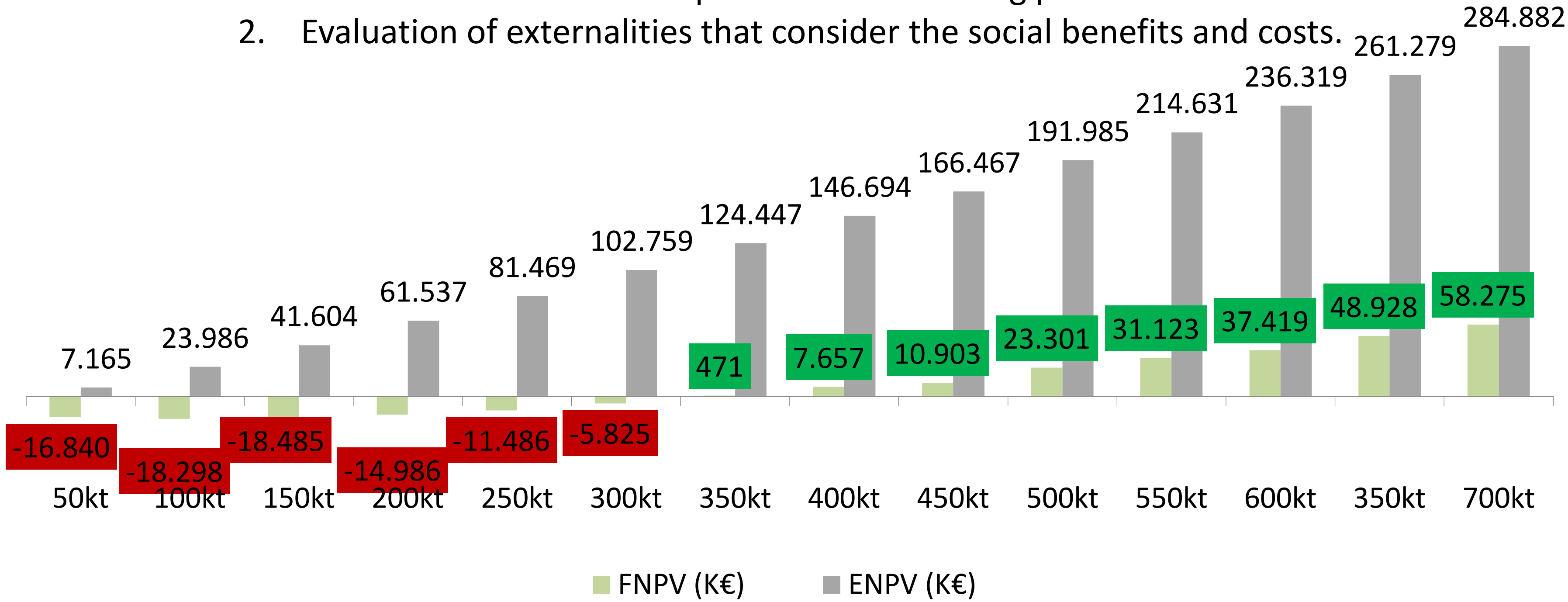
Life of project 30 y ; Investment realization 3,5 y

Cost opportunity of capital

Financial discount rate 5% ; Social discount rate 5%

Financial NPV – Economic NPV (cash flow)

1. Transformation of market prices into accounting prices.
2. Evaluation of externalities that consider the social benefits and costs.



The analysis of the results obtained in the 14 business plans shows:

- FNPV is negative for systems with treatment capacity of less than 350 kt of waste;
- ENPV is always positive.

WtE Strategic Analysis

Plant Size

Plant Location

Economic and Financial Sustainability

Plant Size – Multicriteria Analysis

For Abruzzo case, some waste growth scenarios are defined related to 2012 data:

- A current scenario (626 kt), incinerator absent
- Scenario F1 - waste production is equal to the average from 2008 to 2012 (671 kt)
- Scenario F2 - waste production is supposed growing with and increase of 7% respect to scenario F1; the global financial crisis seems to have reduced the waste production, but, with the end of crisis and the stability of estimated population, the waste volumes are destined to grow

Plant size – Multicriteria Analysis

- The best choice has to be selected taking in to account environmental reasons (emission reduction calculated in KgCO2eq/twaste).

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

Plant size – Multicriteria Analysis

Scenarios	F1			F2		
% landfill	5%	10%	20%	5%	10%	20%
Waste disposed in landfills	27	53	106	28	57	114
Waste to incinerate High WV 75%	378	358	318	405	383	341
Waste to incinerate Medium WV 50%	252	239	212	270	256	227
Waste to incinerate Low WV 25%	126	119	106	135	128	114

Planned capacity

400 kt

250 kt

150 kt

Negative FNPV

Plant size - Sensitivity analysis

Basic values of the critical variables for FNPV are:

- lower heating value (LHV) = 10.4 MJ/kg (2,485 kcal/kg)
- selling price of electricity (SP_{el}) = 47.29 €/t
- heat selling price (SP_{he}) = 27.02 €/t
- investment cost (I) from 376 to 765 €/t
- interest rate (r) = 5%.

FNPV (M€) sensitivity analysis - Different plant sizes

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

Plant size (kt)	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 best solution is a plant of 400 kt

Plant Location
Centralized or decentralized solution?

The decision to locate one (centralized solution) or more (decentralized solution) WtE plants in a given geographical area. Three case studies:

- S_1 (400 kt capacity) is the centralized solution
- S_2 (each plant has a 200 kt capacity) involves the installation of two plants (decentralized solution)
- S_3 (each plant has a 100 kt capacity) involves the installation of four plants (decentralized solution)

Plant Location

Solution centralised

Number of plants: 1 – Case S_1

The plant has a capacity of 400 kt

Negative FNPV

Solution decentralised

Number of plants: 2 – Case S_2

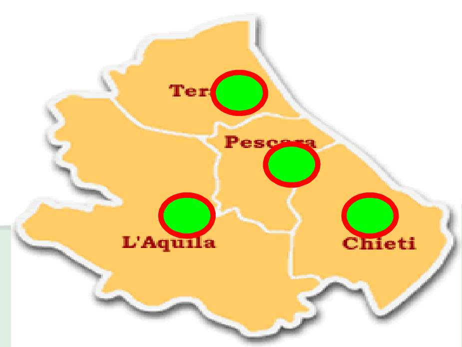
Each plant has a capacity of 200kt

Strong Negative FNPV

Solution decentralised

Number of plants: 4 – Case S_3

Each plant has a capacity of 100kt



Centralised or decentralised solution?

FINANCIAL ANALYSIS (M€)		
Case Study	FNPV	Shipping Cost
S_1	7.7	72.8
S_2	-29.8	58.3

Higher transportation costs are compensated by lower investments and operating costs

ECONOMIC ANALYSIS (M€)		
Case Study	ENPV	Shipping Cost
S_1	146.7	80.2
S_2	123.1	65.8

Centralised solution (400 kt)

Centralised or decentralised solution?

FINANCIAL ANALYSIS (M€)						
Case Study	FNPV	SC $R_i = 0.10$	SC $R_i = 0.11$	SC Base $R_i = 0.12$	SC $R_i = 0.13$	SC $R_i = 0.14$
S_1	7.7	58.7	65.8	**72.8**	80.0	86.9
S_2	-29.8	46.4	52.4	**58.3**	64.1	70.0

ECONOMIC ANALYSIS (M€)						
Case Study	ENPV	SC $R_i = 0.10$	SC $R_i = 0.11$	SC Base $R_i = 0.12$	SC $R_i = 0.13$	SC $R_i = 0.14$
S_1	146.7	66.3	73.2	**80.2**	87.2	94.1
S_2	123.1	53.8	59.9	**65.8**	71.7	77.6

Centralised solution (400 kt)

Are plants with energy recovery financially and economically convenient?

Case study: Plant with a capacity of 400 kt

Discounted Aggregate Cost-Benefit 1,46

Discounted Net Cost-Benefit 2,01

Financial Rate fo Return 5,4%

Economic Rate of Return 13,9%

Financial Discounted Payback Period 7,6 y

Economic Discounted Payback Period 11,7 y

Financial Net Present Value 7.7 M€

Economic Net Present Value 146.7 M€

Skilled workers 16

Unskilled workers 80

A plant for energy recovery produces economic, financial and social benefits

Are plants with energy recovery environmentally convenient?

Case study: Plant with a capacity of 400 kt

Waste Valorization 400 kt

Greenhouse Gas Reduction 202 kt CO_2 eq

⇨ **A plant for energy recovery produces environmental benefits**

Sensitivity analysis (plant of 400kt)

Variable ± 1%	FNPV Sensitivity	ENPV Sensitivity
Municipal Waste price	3,07%	0,40%
Other Waste price	0,19%	0,02%
Electricity price	6,32%	1,05%
Heat price	5,12%	0,50%
Labour skilled cost	0,50%	0,05%
Labour non skilled cost	1,02%	0,09%
Gas input price	0,13%	0,03%
Electricity input price	0,50%	0,06%
Water input price	0,01%	0,00%
Materials	0,28%	0,04%
Intermediate service&goods	1,04%	0,10%
Elimination of ash and slag waste	2,07%	0,19%
Investment	9,07%	0,69%
Replacement cost	1,21%	0,10%
Remediation&decontamination costs	0,30%	0,02%
Residual value - long life parts	0,04%	0,01%
Residual value - short life parts	0,02%	0,00%
Externalities net	-	0,39%
Inflation rate	2,41%	0,40%
Labour cost growth rate	0,10%	0,01%
Gas input price growth rate	0,04%	0,01%
Water consumed growth rate	0,00%	0,00%
Electricity input price growth rate	0,07%	0,01%
Waste treatment price growth rate	0,27%	0,02%
Produced electricity price growth rate	0,76%	0,08%
Produced heat price growth rate	0,41%	0,05%

> 5%

	Electricity Price			Heat Price			Investment			Externalities net		
	Δ%	x*	(Δx/x)	Δ%	x*	(Δx/x)	Δ%	x*	(Δx/x)	Δ	x*	(Δx/x)
Pessimistic scenario												
FNPV	-5%	4.1	-46%	-5%	5.5	-27%	5%	4.0	-48%	-	-	-
	-10%	0.6	-92%	-10%	3.6	-53%	10%	0.4	-95%	-	-	-
	-15%	-2.9	-138%	-15%	1.5	-80%	15%	-3.2	-142%	-	-	-
ENPV	-5%	138.8	-5%	-5%	142.1	-3%	5%	141.4	-4%	8€/t	142.2	-3%
	-10%	131.0	-11%	-10%	137.5	-6%	10%	136.1	-7%	7€/t	137.8	-6%
	-15%	123.2	-16%	-15%	133.0	-9%	15%	130.7	-11%	6€/t	133.3	-9%
Optimistic scenario												
FNPV	5%	11.1	46%	5%	9.7	28%	-5%	11.2	47%	-	-	-
	10%	14.6	92%	10%	11.6	53%	-10%	14.8	95%	-	-	-
	15%	18.1	138%	15%	13.7	80%	-15%	18.5	143%	-	-	-
ENPV	5%	154.0	5%	5%	151.1	3%	-5%	152.6	4%	10€/t	151.1	3%
	10%	162.0	11%	10%	155.5	6%	-10%	157.0	7%	11€/t	155.5	6%
	15%	170.2	16%	15%	159.9	9%	-15%	162.8	11%	12€/t	159.9	9%
Switching values												
FNPV	-10.5%	0		-15%	0		10%	0		-	-	

$\Delta\%_y$ = variation percentage of the variable y (electricity price=47,29 €/t; heat price=27,02 €/t; investment esteemed=410 €/t)

x^*_i = value of the indicator (FNPV or ENPV) in the sub-scenario i, data in M€

$(\Delta x/x)_i$ = variation percentage of the indicator in the sub-scenario i in comparison to its value in basic-scenario (FNPV=23 M€; ENPV=192 M€)

Δ = variation of the variable "externalities net" (=9 €/t)

Sensitivity analysis – Plant of 400kt

Interest rate

Financial/social discount rate	FNPV (M€)	ENPV (M€)
7%	-5.7	92.4
6%	0.3	116.9
5% (base)	**7.7**	**146.7**
4%	16.9	183.1
3%	28.3	227.8

Do nothing costs (M€)		
1 year	2 years	3 years
0.3	0.7	1.0

Performance indicators with different LHV – 400 kt
LHV (Lower Heating Value)

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

LHV represents the amount of energy released by combusting

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

Conclusions

- It is been proposed a real application of the strategy to implementation of WtE plant in a single region.
- 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.

Thank you for the attention