IMPROVING THE GLOBAL SUSTAINABILITY OF THE TOTAL RECOVERY WASTE TREATMENT PLANT OF AREZZO

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INTRODUCTION

Waste Framework Directive

The Directive 2008/98/EC on waste introduces the basic concepts and definitions relating to waste management

Landfill Directive

The 1999/31/EC Directive aims at significantly reducing landfilling.

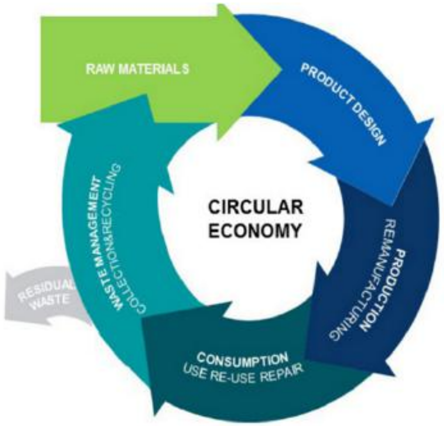
Waste hierarchy

Best use as possible of the material inside the waste able to replace or avoid the consumption of other raw materials

INTRODUCTION

Circular Economy

Closing the Loop – An EU action plan



Sustainable Development Goals

Recovery of resources and reuse are coherent with the implementation of circular economy and sustainable development

INTRODUCTION

Waste-to-energy (WtE) plants

Anaerobic digestion with effective use on land of digestate as recycling operation

Incineration performed at high energy efficiency as a recovery operation (R1) if

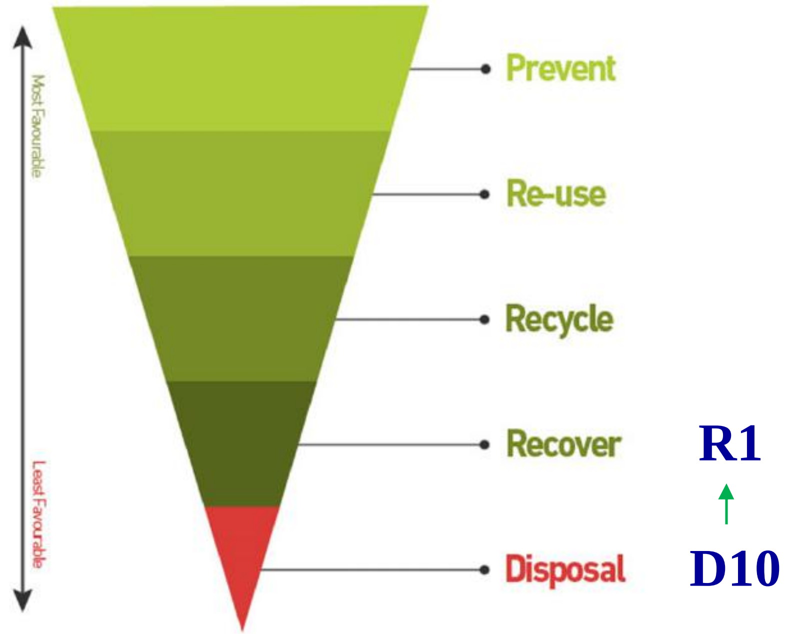
Energy efficiency formula (WFD, 2008)

INTRODUCTION

Waste-to-energy (WtE) plants

Energy efficiency formula (WFD, 2008)

$$E.E. = Kc * \frac{Ep - (Efi + Ei)}{0.97 * (Ew + Ef)} \geq 0.6 - 0.65$$



But…

Goal

- Energy efficiency formula (WFD, 2008) accounts only for direct energetic flows
- The formula doesn't account for other relevant flows of materials
- The formula doesn't account for indirect energy consumptions necessary for the operation of the plant

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Addressing the effective ability of two different scenarios related to an existing integrated waste treatment plant operating in the city of Arezzo (Italy) to replace primary energies

CASE STUDY- Comparison

Base Scenario

Assessment of the primary energies consumed and replaced

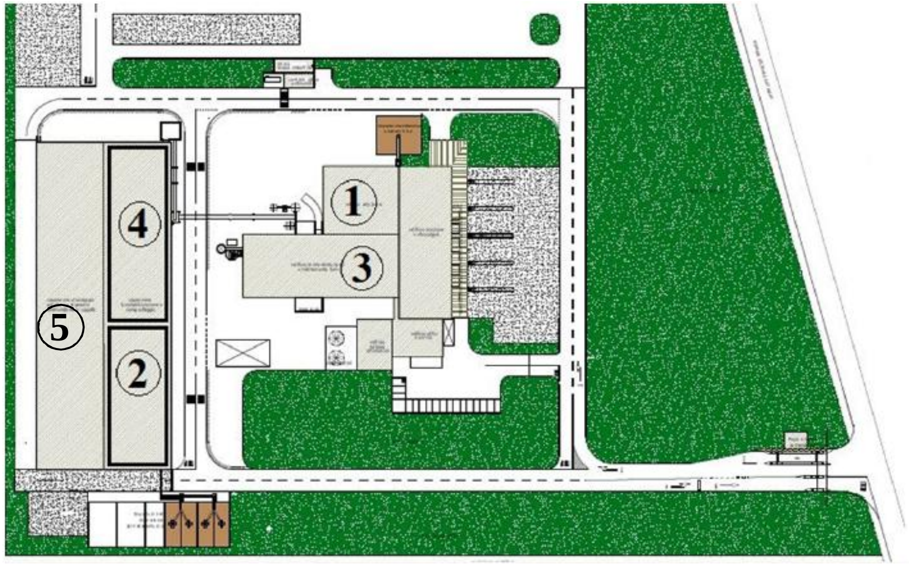
Modified Scenario

SADB plant

CASE STUDY- Comparison

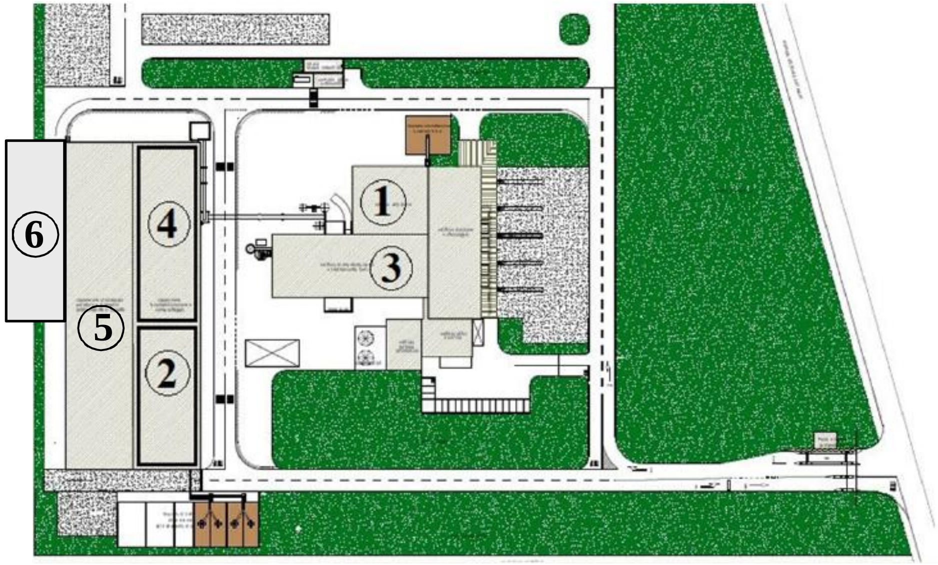
Current state

Integrated treatment plant



Modified state

Integrated treatment plant (implemented)



Legend: MBT plant: 1) Mechanical sorting plant & 2) Bio-stabilization plant - 3) Incineration with energy recovery – 4) Composting plant – 5) Organic fertilizer, trimming and wood chips deposit – 6) Anaerobic Digestion plant for bio-methane production

Methodological approach: CED

The cumulative energy demand (CED) was used for assessing primary energy consumptions and replacements associated with the main materials, energy and fuel inputs and outputs

«represents the direct and indirect energy use of a product or a process throughout the life cycle, including the energy consumed during the extraction, manufacturing and disposal of the raw and auxiliary materials» (VDI, 1997)

↓

CED of waste = 0 by definition

Methodological approach: CED

List of primary energies accounting for the cumulative energy demand (CED) calculation

Energy group	**Subcategory**	**Primary energy included**
Non-renewable	Fossil	Hard coal, lignite, crude oil, natural gas, coal mining off-gas, peat
	Nuclear	Uranium
	Primary forest	Wood and biomass from primary forests
Renewable	Biomass	Wood, food products, biomass from agriculture
	Wind	Wind energy
	Solar	Solar energy (heat and electricity)
	Geothermal	Geothermal energy (100-300m)
	Water	Run-of-river hydro power, reservoir hydro power

Life Cycle Assessment

The LCA was realized following the :

- ISO 14040 (2006), ISO 14044 (2006)
- ILCD (2012)

SimaPro software 8.5.2.0

Scope

Integrated waste treatment plants:

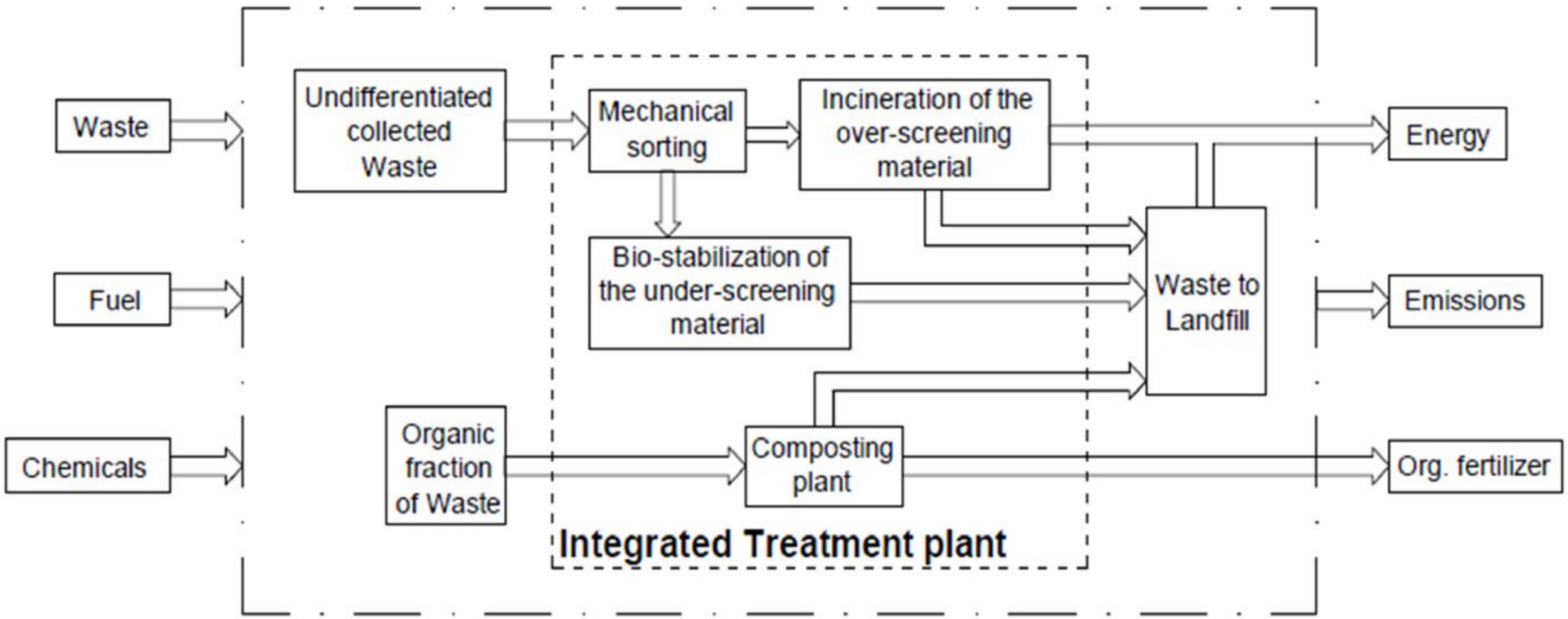
- Mechanical-Biological treatment
- Incineration
- Composting
- Solid Anaerobic Digestion Batch (SADB) plant
- Sanitary Landfill for non-hazardous organic waste

Functional unit (FU): treatment of waste entering the integrated plant aimed to material and energy recovery

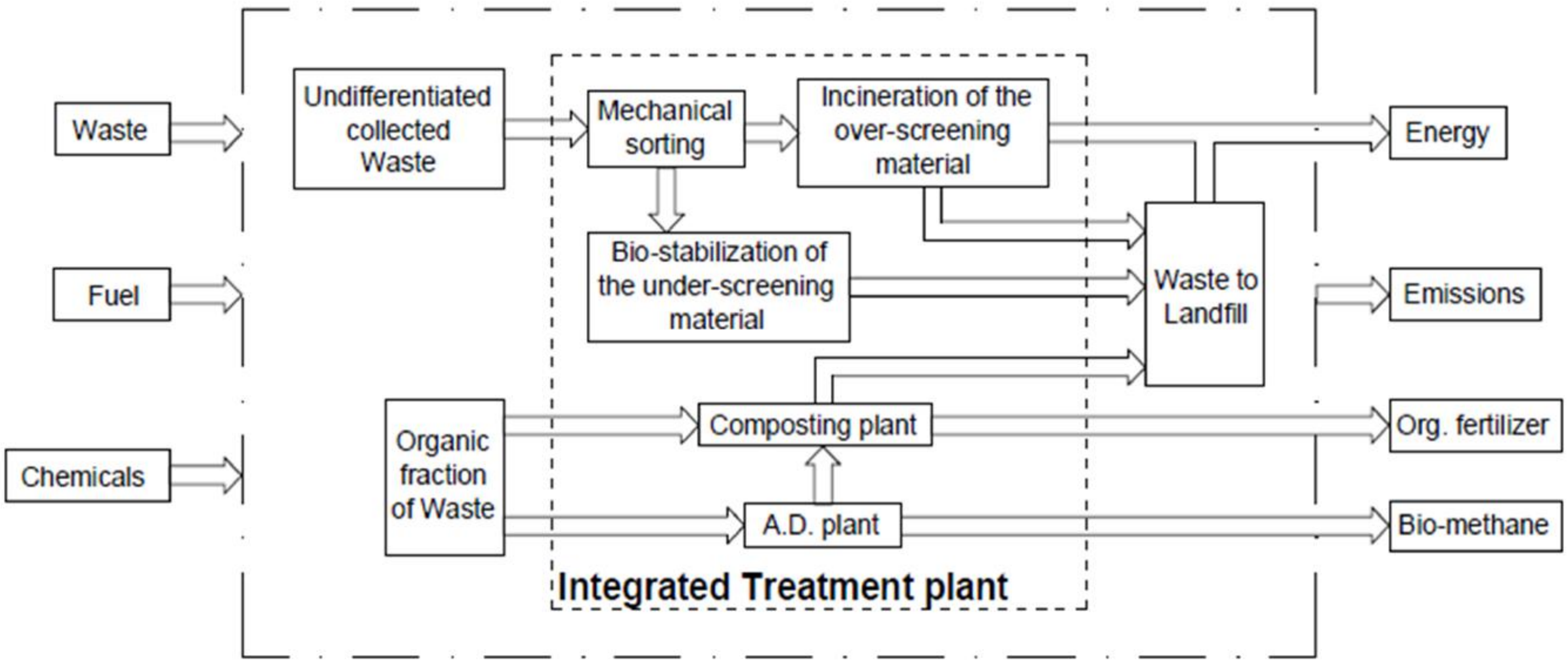
Life Cycle Inventory

- LCI from the Ecoinvent 3.4 (Wernet et al., 2017) database
- AVERAGE MARKET VALUES
- MARGINAL ENERGY: Natural Gas
- BIO-METHANE: Natural gas substitution
- (N, P, K) of OFMSW COMPOST : Substitution of mineral fertilizers
- Disposal on sanitary landfill

System Boundaries
Base Scenario



System Boundaries
Modified Scenario

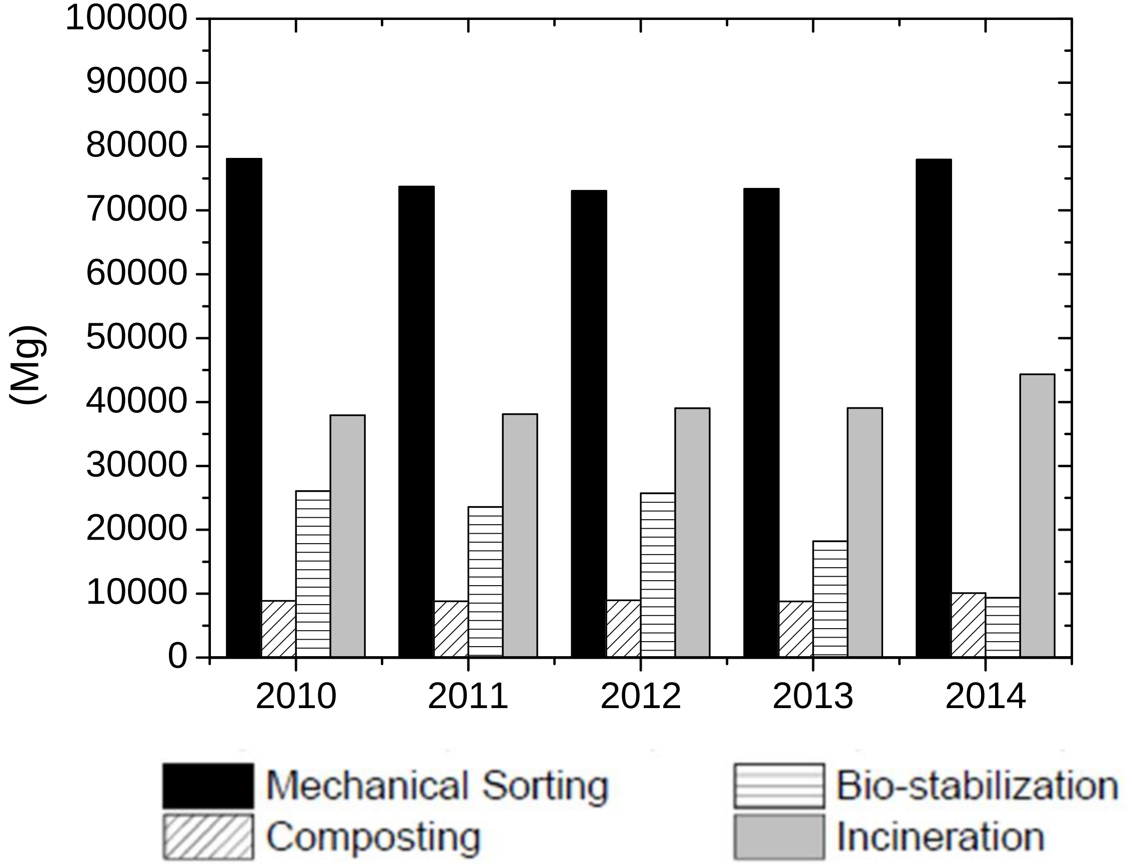


Mass balances (Base Scenario)

Main materials and energy flows for the integrated waste treatment plant from 2010 to 2014

	2010	2011	2012	2013	2014
Incinerated waste (Mg)	37929	38123	39029	39073	44358
Reagents (kg)					
Act. Carbon	18740	18860	14120	16060	24080
Urea	439100	180660	220840	219860	378050
$Ca(OH)_2$	554100	496800	629430	598970	647940
Energy (kWhe)					
Electricity	10058064	10718634	10752468	10528875	10690287
Fuel (kg)					
Diesel	33239	15070	30955	28714	98612

Mass balances (Base Scenario)



Incinerator (Base scenario)

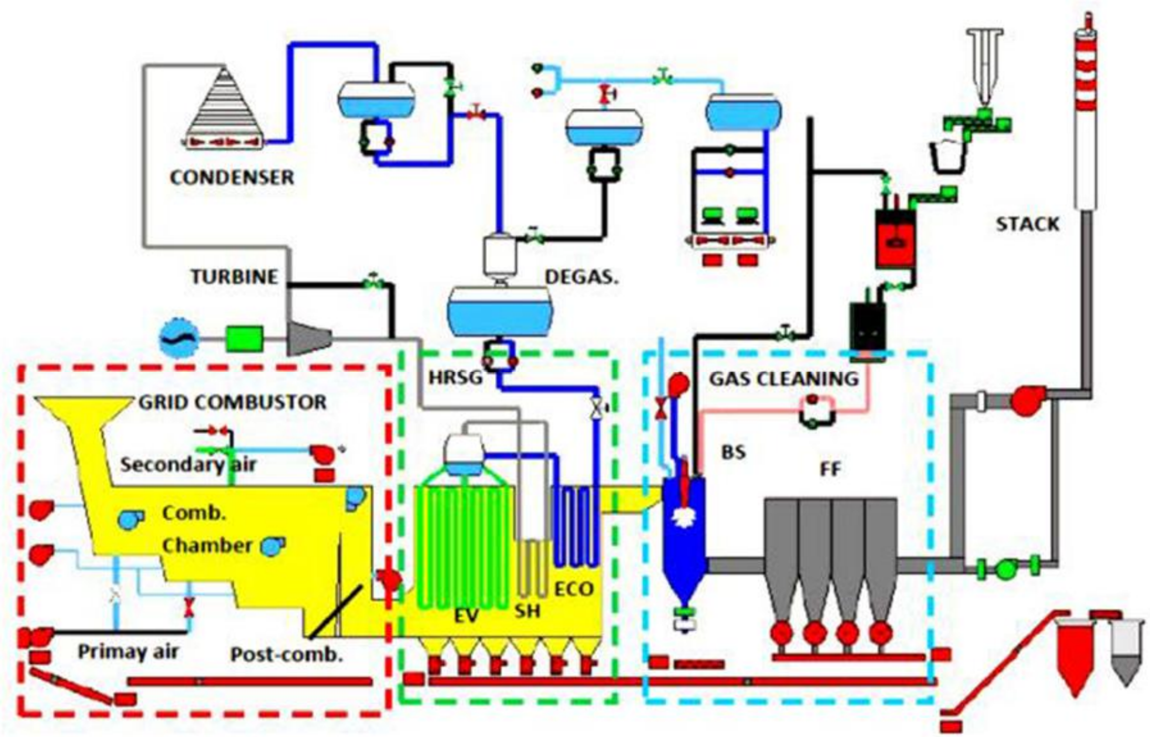
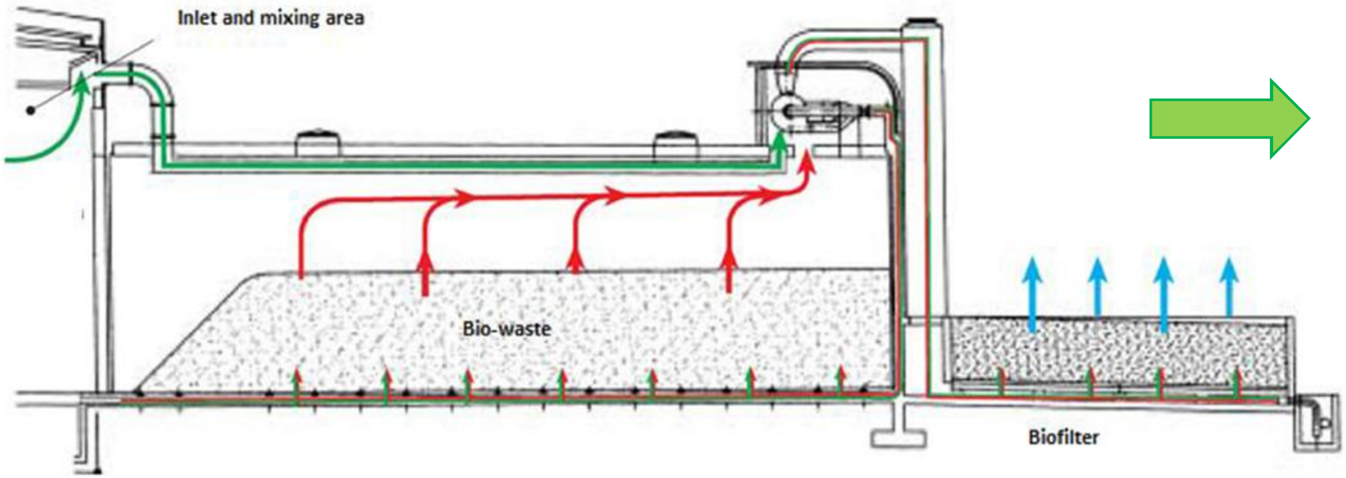


Diagram of the waste-to-energy (WtE) plant and its main components. (HRSG=heat recovery steam generator – EV=evaporator – SH=super heater – ECO=economizer – BS=basic reactor – FF=fabric filters)

- 40,000 Mg/year MSW
- 18,000 MWh gross elec. recovered
- 9,000 Mg/year of slags

Whole energetic needs of the area supplied by the incinerator

Composting (Base scenario)



- heaps of about 300 tonne each one,
- electrical consumption is about 1,000 MW/year.

Average composition of the organic fertilizer from bio-waste

Parameter	Amount	Unit
Urea	17.2*, a	kg /Mg compost
P_2O_5	8.33*, b	kg /Mg compost
K_2O	10.9*, c	kg / Mg compost
TOC	254*, d	kg / Mg compost

Legend: *=average content, k=2 confidential level 95%; a=standard deviation ±0.48; b=standard deviation= ±0.42; c=standard deviation= ±0.90; d= standard variation ±6.2

Anaerobic Digestion (Modified scenario)

- Biowaste processed (AD+ Composting): 58000 tonnes/yr
- SADB: 35000 tonnes biowaste/yr,
- BIOGAS PROD: ~120Nm^3/tonne bio-waste,
- Upgrading system: semipermeable membranes
- Org. fertilizer: 12000tonnes/yr

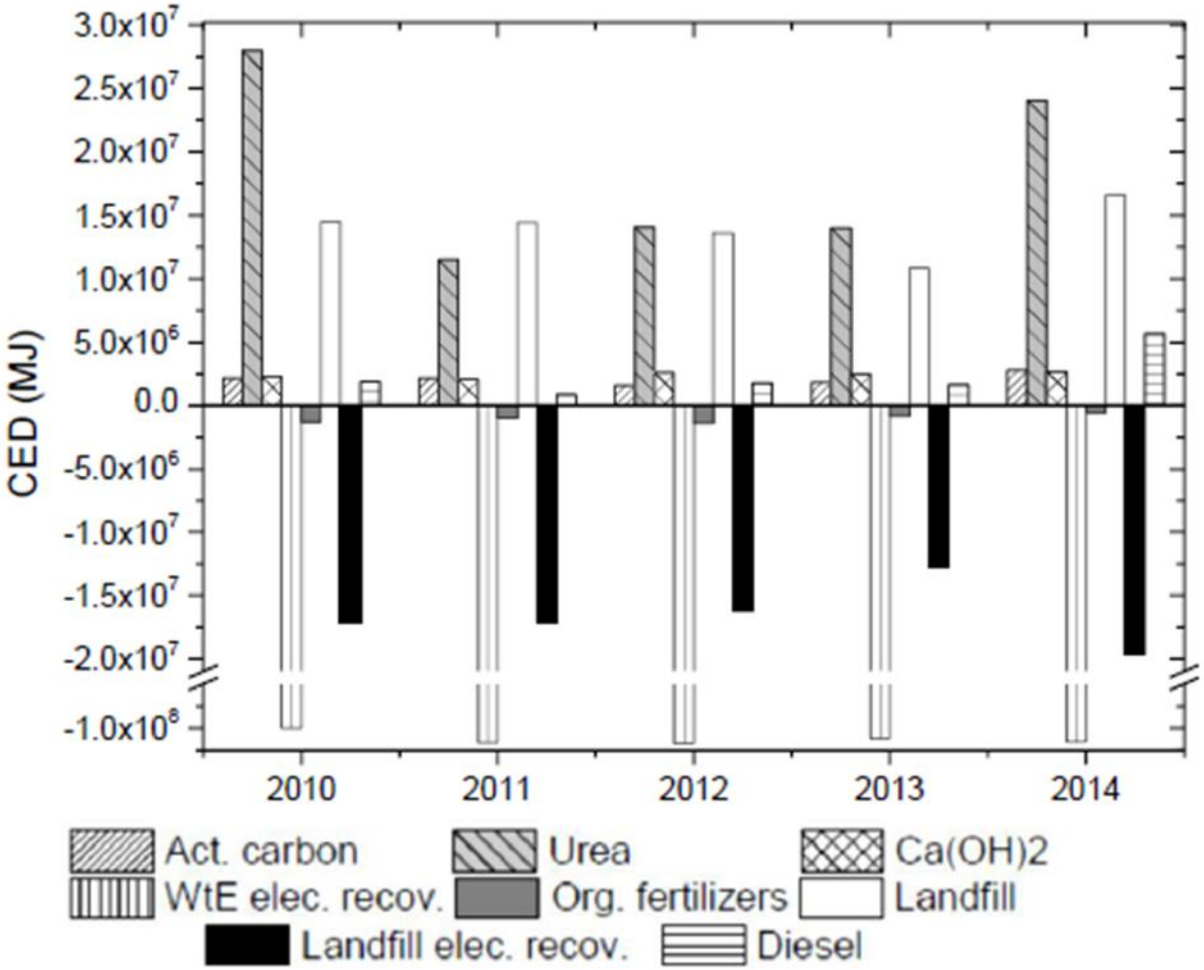
The biomethane generated will be injected in the local grid for the replacement of natural gas

Results: CED

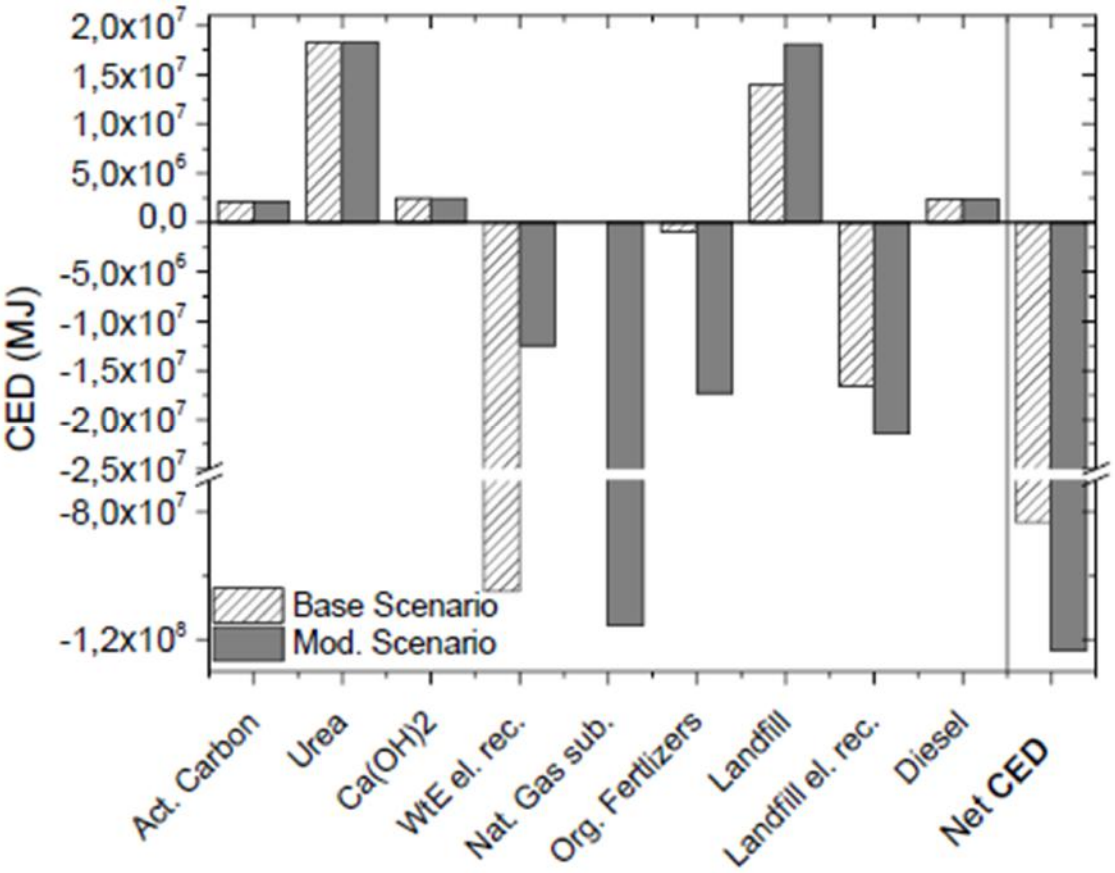
	Primary energy (MJ)						
	Fossil	**Nuclear**	**Primary forest**	**Biomass**	**Renewable**	**Water**	**Total**
Chemicals (1kg)							
Activated Carbon	102.8	8.26	0.00	1.91	0.52	1.32	114.8
$Ca(OH)_2$	3.580	0.34	0.00	0.01	0.00	0.24	4.170
$CO(NH_2)_2$	59.30	2.87	0.00	0.59	0.16	0.70	63.63
*Fertilizer (1kg)**							
N as Urea	57.36	1.72	0.00	0.73	0.09	0.67	60.57
P as P_2O_5	28.86	1.47	0.01	0.56	0.09	0.54	31.54
K as K_2O	7.080	0.34	0.00	0.21	0.02	0.14	7.790
Fuel							
Oil (1kg)	55.78	0.40	0.00	0.07	0.02	0.10	56.37
Nat. gas ($1Nm^3$)	46.51	0.67	0.00	0.04	0.02	0.22	47.46
*Energy (1kWh)**							
Electricity	5.42	3.80	0.00	0.44	0.21	0.68	10.56
Heat	4.10	0.08	0.00	0.01	0.01	0.02	4.210
Slags disposal in landfill							
Landfill	2.191	0.081	6E-5	0.028	0.007	0.061	2.368

Cumulative energy demand (CED) for chemicals, fertilizer, fuel and energy production on the average market in the EU (Wernet et al., 2016)

Results: CED


CED (MJ)
3.0x10^7
2.5x10^7
2.0x10^7
1.5x10^7
1.0x10^7
5.0x10^6
0.0
-5.0x10^6
-1.0x10^7
-1.5x10^7
-2.0x10^7
-1.0x10^8
2010
2011
2012
2013
2014
Act. carbon
Urea
Ca(OH)2
WtE elec. recov.
Org. fertilizers
Landfill
Landfill elec. recov.
Diesel

Results: CED


2,0x10^7
1,5x10^7
1,0x10^7
5,0x10^6
0,0
-5,0x10^6
-1,0x10^7
-1,5x10^7
-2,0x10^7
-2,5x10^7
-8,0x10^7
-1,2x10^8
CED (MJ)
Base Scenario
Mod. Scenario
Act. Carbon
Urea
Ca(OH)2
WtE el. rec.
Nat. Gas sub.
Org. Fertlizers
Landfill
Landfill el. rec.
Diesel
Net CED

Conclusions

- Integrated waste treatment and recovery plants result in a suitable solution for the optimization of energetic and material flows necessary for managing in a sustainable way different waste materials,
- Combining incineration, composting and anaerobic digestion with biogas upgrading leads to noticeable advantages in terms of the amount of primary energies effectively replaced by this kind of integrated facilities,
- An important contribution to primary energies replacement arises also from the production of organic fertilizers from the recovery of the bio-waste,
- In general the approach proposed in this study resulted effective for the assessment of the sustainability of waste treatment facilities.

Thank you

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