CBA Forum meeting on Environment sectors

Case Study: a Waste-to-Energy Facility

Francesco Angelini

JASPERS

Energy and Solid Waste

Brussels, 12 May 2017

Overview of the presentation

- Cost-benefit analysis for a solid waste project – case study on a waste-to-energy facility, part of the new CBA Guide 2014-2020 of the European Commission

I. Project Description
II. Project Objectives
III. Demand Analysis
IV. Option Analysis
V. Costs and Revenue of selected Option
VI. Financial Analysis
VII. Economic Analysis
VIII. Risk Assessment

I - Project Description

- **Existing situation**
  - Region with population of 1.3 million generating 585 ktpa of municipal wastes
  - Low waste segregation rate at source, collected waste is mostly landfilled, risk of not meeting waste related targets, particularly for landfilling of biodegradable waste (BDW)
  - Landfill tax introduced at national level to discourage landfilling

- **Planning context -> not a stand-alone WtE project!**
  - The project is foreseen in the Regional Waste Management Plan together with the following measures:
    - Progressive expansion/scale-up of existing pilot scheme for separate collection and treatment of kitchen and food wastes
    - Progressive introduction of door-to-door collection for paper/cardboard and recyclable packaging materials (in collaboration with Green-dot organisation)
    - Introduction of volume-based charging scheme (Pay-as-You Throw)
  - The Regional WMPs contribute to the objectives of the National WMP, which in turns is aligned with EU waste policy targets

I - Project Description

- **The project**

  Waste-to-energy facility, 200 ktpa (62.5 MWth input)

  - Location: brownfield site, existing industrial park in the city outskirts
  - Waste incineration: single line, grate furnace technology, multistage wet flue-gas cleaning facility
  - Energy recovery: steam boiler, backpressure steam turbine, 40 MWth /13 MWel nominal output; electricity to transmission grid, heat to DH network
  - Project promoter / institutional set-up: Public company 100% owned by Association of Municipalities and Regional Government

II - Project Objectives

- Improve waste management practices in line with current EU and national legislation, and in particular, the EU's waste management hierarchy
  - reduce the amount of total (biodegradable) waste disposed of in landfills
  - recover materials and energy contained in the waste
- Contribution to objectives of Operational Programme (OP):

	OP target 2023	Project (% of target)
Output Indicator		
Capacity for treatment of mixed residual municipal wastes (in kt/a)	200	200 (100%)
Result Indicators		
Annual amount of biodegradable waste diverted from landfill (in kt/a)	300	96 (32%)
Annual amount of energy recovered from waste (in TJ/a)	4,500	1,530 (34%)

III – Demand Analysis

Waste generation:

Parameter	Unit	2013	2015	2017	2020	2030
Population	Inhabitants	1,300,000	1,294,800	1,289,600	1,281,900	1,256,500
Total municipal waste (MW) generation	kg/capita/day	450	464	473	480	480
	tonnes/year	585,000	600,271	609,877	615,375	603,182
Municipal waste (MW) from households and similar waste from commerce	kg/capita/day	383	394	402	410	410
	tonnes/year	497,250	510,230	518,396	525,684	515,268
Other municipal wastes (i.e. bulky waste, street, market and green garden/park waste)	tonnes/year	87,750	90,041	91,482	89,691	87,174

Waste separation and treatment

Parameter	Unit	2013	2015	2017	2020	2030
Total municipal waste (MW) generation	tonnes/year	585,000	600,271	609,877	615,375	603,182
Total materials sent to recycling (paper, plastic, metal, glass)	tonnes/year	70,361	86,739	106,027	165,197	238,590
Total biowaste sent to composting/biogas plants	tonnes/year	51,275	53,634	55,163	79,376	152,963
Total residual mixed waste	tonnes/year	463,364	459,898	448,687	370,802	211,629
Residual mixed waste to waste-to-energy (project)	tonnes/year	-	-	200,000	200,000	200,000

III – Demand Analysis

- System Performance Check: diversion of biodegradable waste from landfill

Parameter	Unit	2013	2015	2017	2020
Total municipal waste (MW) generation	tonnes/year	**585,000**	**600,271**	**609,877**	**615,375**
Biodegradable waste (BDW) content	tonnes/year	335,746	343,490	342,294	333,593
	%	57%	57%	56%	54%
Biodegradable waste (BDW) to recycling (paper/cardboard)	tonnes/year	40,277	48,472	54,172	74,910
Biodegradable waste to composting/biogas plants	tonnes/year	51,275	53,634	55,163	79,376
Maximum BDW allowance to landfill according to targets (BDW landfilled in 1995: 310 kt)	tonnes/year	155,000	155,000	155,000	108,500
Target compliance check without project	tonnes/year	- 89,194	- 86,384	- 77,958	- 70,807
Residual mixed waste to waste-to-energy (project)	tonnes/year	-	-	200,000	200,000
Biodegradable waste (BDW) content	tonnes/year	-	-	103,840	96,713
Target compliance check with project	tonnes/year	- 89,194	- 86,384	25,882	25,906

IV – Option Analysis

- Feasibility Study assessed the following sets of options:
  - Location of the WtE plant => Multi-criteria analysis (MCA)
  - Waste treatment technology => Simplified CBA

- Location of the WtE plant, criteria to be examined:
  - Availability and cost of land
  - Existence of a potential heat off-taker (i.e. DH network, industry)
  - Accessibility to other utility networks (electricity, gas, water, sewage, etc.)
  - Accessibility to road network
  - Distance to closest residential areas
  - Environmental and climate change considerations (impact on air, water, soil, etc.)

IV – Option Analysis

- Waste treatment technology: MBT vs. WtE (same capacity)
  - **Comparison in financial terms (FNPV / LUC), 30 year reference period, 4% FDR**

	Unit	MBT	WtE
FNPV of total cost (investment, O&M, replacements, resid. value)	1000 EUR	- 176,422	- 307,998
FNPV of revenues from sale of recovered materials/energy	1000 EUR	12,015	142,896
FNPV of total net cost, before gate fees	**1000 EUR**	**- 164,407**	**- 165,101**
Financial levelized unit cost (LUC), Total Gross	EUR/t	- 60	- 111
Revenue from sale of recovered materials/energy	EUR/t	4	51
Financial levelized unit cost (LUC), Total Net	**EUR/t**	**56**	**59**

=> similar financial performance of both options, however MBT shows higher risks due to higher uncertainty regarding the off-take conditions for the RDF produced

  - **Comparison in economic terms (ENPV), 30 year reference period, 5% SDR**

	Unit	MBT	WtE
ENPV of total cost (investment, O&M, replacements, resid. value)	1000 EUR	- 147,041	- 270,338
ENPV of total benefits	1000 EUR	171,530	371,633
thereof landfill space saved	1000 EUR	67,516	72,133
thereof materials recovered	1000 EUR	10,579	3,847
thereof energy recovered (heat/electricity)	1000 EUR	-	188,308
thereof avoided GHG emissions (net)	1000 EUR	93,435	107,346
Total ENPV	**1000 EUR**	**24,489**	**101,295**

=> In spite of a higher cost, the WtE option records a higher total ENPV due to better performance in (i) reducing waste deposits in landfills, (ii) recovering materials/energy from waste, (iii) reducing GHG emissions

V – Costs and Revenue

- Investment cost

Project Investment Cost (M EUR)	Total cost	Ineligible cost	Eligible cost
Planning/design fees	5.20	5.20	-
Land purchase	2.00	2.00	-
Building and construction	46.20	-	46.20
Plant and machinery or equipment	92.40	-	92.40
Technical contingencies	6.93	-	6.93
Publicity	0.10	-	0.10
Supervision during construction implementation	5.55	-	5.55
Technical assistance	1.80	-	1.80
Sub-TOTAL	160.18	7.20	152.98
(VAT)	32.04	32.04	-
TOTAL	192.22	39.24	152.98

V – Costs and Revenue

- Operating and maintenance costs (O&M): 43 EUR/t
  - Maintenance/repair (incl. small replacements): 23 EUR/t
  - Staff (incl. overheads for mgt. and admin): 6 EUR/t
  - Consumables (excl. electricity): 5 EUR/t
  - Insurance: 3 EUR/t
  - Transport and disposal of waste outputs: 6 EUR/t

- Asset replacement cost:
  - Major upgrade of technological plant assets required after 15y of operations (70 M EUR) to prolong the plant's economic life

- Decommissioning, dismantling, disposal cost:
  - 6.7 M EUR at the end of the reference period

V – Costs and Revenue

- Revenue:

Revenue item	Annual input/output	Unit price	Remark
Gate-fees for waste	200,000 t	30 - 59 EUR/t	2017: 30 EUR/t (net LUC coverage: 100% LUC O&M + 50% LUC INV) 2025: 43 EUR/t (net LUC coverage: 100% LUC O&M + 70% LUC INV) 2031: 54 EUR/t (net LUC coverage: 100% LUC O&M + 90% LUC INV) 2037: 59 EUR/t (net LUC coverage: 100% LUC O&M + 100% LUC INV) Justified based on analysis of household affordability.
Electricity sold to grid	87,250 MWh	50 EUR/MWh	Estimated long-term average wholesale market price for the country.
Fixed premium for electricity from high efficiency co-generation	106,250 MWh	15 EUR/MWh	Premium granted to waste-to-energy facilities producing electricity in high-efficiency co-generation, which are eligible for support under an existing national scheme. Given that the scheme is due to expire at the latest in 2031, revenues from the premium are computed only in the first 15 years of operations.
Heat sold to DH system	1,147,500 GJ	4.1 EUR/GJ	The heat price corresponds to the total variable cost of heat production saved by the district heating operator in the existing central heat plant.
Metals sold to market	4,000 tonnes	80 EUR/t	Long-term average market price for scrap ferrous metal.

VI – Financial Analysis

- Reference period: 30 years – 4 years of investment phase + 26 years of operations
- Financial discount rate 4%, in real terms (as per Reg. 480/2014) -> cash-flows in constant prices
- Residual value: the useful economic life of the plant considered to end after 26 y of operations; a negative residual value is computed to account for decommissioning and dismantling costs (6.7 M EUR).
- Financial analysis for the project includes the following steps:
  - Return on the investment “FRR(C)” - before EU grant: profitability of the project regardless the way it is funded
  - Determination of level of investment aid in compliance with State Aid rules for Services of General Economic Interest (determination of the “net cost” of the SGEI by means of a “funding-gap” calculation)
  - Profitability of national capital “FRR(K)” – after EU grant and after consideration of financing costs
  - Financial sustainability

VI – Financial Analysis

- Return on the investment “FRR(C)” - before EU grant:

FRR(C)			1	2	3	4	5	6	10	15	20	25	30
			Construction				Operation						
Calculation of the Return on Investment		**NPV 4 %**											
Investment cost (excluding contingencies)	mEUR	-145.0	-7.2	-89.0	-42.6	-14.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0
O&M cost (including replacement cost)	mEUR	-154.3	0.0	0.0	0.0	0.0	-8.6	-8.6	-8.7	-8.7	-72.1	-8.9	-8.9
Revenue	mEUR	266.6	0.0	0.0	0.0	0.0	16.8	16.8	18.1	20.4	0.0	21.2	21.2
Residual value of investments	mEUR	-2.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-6.7
FNPV(C) - before EU grant / Net cash-flow	**mEUR**	**-34.8**	**-7.2**	**-89.0**	**-42.6**	**-14.5**	**8.2**	**8.2**	**9.4**	**11.6**	**-72.1**	**12.3**	**5.6**
FRR(C) - before EU grant		**1.8%**											

- Condition fulfilled for justifying the need for EU support:
  (FNPV(C) < 0 and FRR(C)< FDR)

VI – Financial Analysis

Remarks on determination of the EU grant and Total eligible cost

- The calculation of the "net cost" of the SGEI by means of the "funding gap" method, incorporates besides the cost and revenues of the SGEI activity (i.e. waste treatment) also the net revenues achieved from non-SGEI activities carried out in the plant (i.e. for energy generation), ref. Article 5(5) of SGEI Decision (2012/21/EU)

- The project Total eligible cost is in this case not reduced by the amount of "Discounted Net Revenue" as the MS considers the calculation of the SGEI's "net cost" as "an individual verification of financing needs" done under State aid rules (Article 61(8) of Reg. 1303/2013) -> relevant for comparison with Major Project threshold!

- EU co-financing share of project's "funding-gap" (i.e. the SGEI's "net cost") assumed for this project equal to the Co-financing rate of the "Priority Axis" under which the investment is presented.

VI – Financial Analysis

Calculation of the EU Grant:

EU GRANT			1	2	3	4	5	6	10	15	20	25	30
			Construction				Operation						
Calculation of the Discounted Investment Cost (DIC)		**NPV 4 %**											
Investment cost (excluding contingencies)	mEUR	145.0	7.2	89.0	42.6	14.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0
DIC / Investment cost cash-flow	**mEUR**	**145.0**	**7.2**	**89.0**	**42.6**	**14.5**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**
Calculation of the Discounted Net Revenues (DNR)		**NPV 4 %**											
Waste input	ktpa		0.0	0.0	0.0	0.0	200.0	200.0	200.0	200.0	0.0	200.0	200.0
Gate-fee	EUR/t		0.0	0.0	0.0	0.0	30.0	30.0	36.1	47.4	54.0	59.4	59.4
Revenue from gate-fee	mEUR	123.7	0.0	0.0	0.0	0.0	6.0	6.0	7.2	9.5	0.0	11.9	11.9
Revenue from sale of metals and energy	mEUR	142.9	0.0	0.0	0.0	0.0	10.8	10.8	10.9	10.9	0.0	9.3	9.3
Revenue from sale of heat	mEUR	64.9	0.0	0.0	0.0	0.0	4.7	4.7	4.7	4.7	0.0	4.7	4.7
Revenue from sale of electricity	mEUR	73.6	0.0	0.0	0.0	0.0	5.8	5.8	5.8	5.8	0.0	4.2	4.2
Revenue from sale of metals	mEUR	4.4	0.0	0.0	0.0	0.0	0.3	0.3	0.3	0.3	0.0	0.3	0.3
O&M cost (including replacement cost)	mEUR	-154.3	0.0	0.0	0.0	0.0	-8.6	-8.6	-8.7	-8.7	-72.1	-8.9	-8.9
Fixed O&M cost	mEUR	-91.8	0.0	0.0	0.0	0.0	-6.5	-6.5	-6.5	-6.6	-2.1	-6.7	-6.8
Variable O&M cost	mEUR	-29.3	0.0	0.0	0.0	0.0	-2.1	-2.1	-2.1	-2.1	0.0	-2.1	-2.1
Replacement cost	mEUR	-33.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-70.0	0.0	0.0
Residual value of investments	mEUR	-2.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-6.7
DNR / Net revenue cash-flow	**mEUR**	**110.2**	**0.0**	**0.0**	**0.0**	**0.0**	**8.2**	**8.2**	**9.4**	**11.6**	**-72.1**	**12.3**	**5.6**

ELIGIBLE COST (EC)	mEUR	153.0
FUNDING GAP RATE (FGR = (DIC - DNR) / DIC)		**24.0%**
CO-FINANCING RATE OF PRIORITY AXIS (CF)		80.0%
EU GRANT (= EC x FGR x CF)	mEUR	**29.4**

VI – Financial Analysis

- Financing structure of the initial investment

Financing Sources	M EUR	% share
Eligible investment cost	**153.0**	**95.5%**
EU contribution (grant)	29.4	18.3%
National public contribution (grant)	7.3	4.6%
Loan	80.0	49.9%
Beneficiary contribution (equity)	36.2	22.6%
Ineligible investment cost (excl. VAT)	**7.2**	**4.5%**
Beneficiary contribution (equity)	7.2	4.5%
Total investment cost (excl. VAT)	**160.2**	**100.0 %**

- The loan has a maturity of 18 years (including a grace period of 3 years). An average interest rate of 4 % in real terms is used in the financial analysis to estimate the loan cash-flows.
- In addition to the project investment cost, the promoter will have to finance interest during construction - IDC (4.8 M EUR) and the initial working capital for operations (3.0 M EUR), as well as pre-finance the VAT (32 M EUR), which is recoverable.

VI – Financial Analysis

- Profitability of national capital "FRR(K)" – after EU grant:

FRR(K)

			1	2	3	4	5	6	10	15	20	25	30
			Construction				Operation						
Calculation of the Return on National Capital		**NPV 4 %**											
National public grant	mEUR	-6.9	0.0	-4.5	-2.1	-0.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Shareholder contributions	mEUR	-44.1	-7.2	-22.1	-10.6	-6.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Interest payments	mEUR	-27.6	0.0	0.0	-2.0	-2.9	-3.2	-3.0	-2.3	-1.3	0.0	-0.9	-0.2
Principal repayments	mEUR	-64.5	0.0	0.0	0.0	0.0	-4.0	-4.2	-4.9	-5.9	0.0	-3.4	-4.1
O&M cost (incl. replacement costs funded from project cash-flow)	mEUR	-137.7	0.0	0.0	0.0	0.0	-8.6	-8.6	-8.7	-8.7	-37.1	-8.9	-8.9
Revenue	mEUR	266.6	0.0	0.0	0.0	0.0	16.8	16.8	18.1	20.4	0.0	21.2	21.2
Residual value of investments	mEUR	-2.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-6.7
FNPV(K) - after EU grant / Net cash-flow	**mEUR**	**-16.3**	**-7.2**	**-26.6**	**-14.7**	**-10.2**	**1.0**	**1.0**	**2.2**	**4.4**	**-37.1**	**8.0**	**1.2**

FRR(K) - after EU grant	**1.9%**

- The replacement costs in year 20 of the reference period (year 16 of operations), is financed partially from cash-flow, partially with an additional loan (10 years maturity, 4% interest rate in real terms)
- In this particular case, FRR(K) differs from the promoter's capital – FRR(Kp), which is slightly higher (2.7%) but still below the FDR

VI – Financial Analysis

- Financial sustainability analysis:

FINANCIAL SUSTAINABILITY

		1	2	3	4	5	6	10	15	20	25	30
		Construction				Operation						
Verification of the Financial Sustainability of the Project												
EU grant	mEUR	0.0	17.9	8.6	2.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0
National public grant	mEUR	0.0	4.5	2.1	0.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Shareholder contributions (including WC and IDC)	mEUR	7.2	22.1	12.5	9.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Loan disbursement	mEUR	0.0	48.8	23.3	7.9	0.0	0.0	0.0	0.0	35.0	0.0	0.0
Revenue	mEUR	0.0	0.0	0.0	0.0	16.8	16.8	18.1	20.4	0.0	21.2	21.2
Total cash-inflow	***mEUR***	***7.2***	***93.3***	***46.6***	***21.0***	***16.8***	***16.8***	***18.1***	***20.4***	***35.0***	***21.2***	***21.2***
Investment cost (including contingencies)	mEUR	-7.2	-93.3	-44.6	-15.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
O&M cost (including replacement and dismantling cost)	mEUR	0.0	0.0	0.0	0.0	-8.6	-8.6	-8.7	-8.7	-72.1	-8.9	-15.6
Interest payments	mEUR	0.0	0.0	-2.0	-2.9	-3.2	-3.0	-2.3	-1.3	0.0	-0.9	-0.2
Principal repayments	mEUR	0.0	0.0	0.0	0.0	-4.0	-4.2	-4.9	-5.9	0.0	-3.4	-4.1
Corporate income tax	mEUR	0.0	0.0	0.0	0.0	0.0	0.0	-0.2	-0.7	0.0	-0.6	0.0
Total cash-outflow	***mEUR***	***-7.2***	***-93.3***	***-46.6***	***-18.0***	***-15.8***	***-15.8***	***-16.1***	***-16.7***	***-72.1***	***-13.8***	***-19.9***
Net cash-flow	**mEUR**	**0.0**	**0.0**	**0.0**	**3.0**	**1.0**	**1.0**	**2.0**	**3.7**	**-37.1**	**7.4**	**1.2**
Cumulated net cash-flow	**mEUR**	**0.0**	**0.0**	**0.0**	**3.0**	**4.0**	**5.0**	**12.1**	**26.9**	**6.7**	**42.5**	**72.9**

- Cumulated net cash-flows >0 throughout the entire reference period
- In this particular case, the project cash-flow is the same as the promoter's/operator's cash-flow

VII – Economic Analysis

Methodological approach

- The change in social welfare associated with the investment is valued as the difference between society's maximum willingness-to-pay (WTP) for the change in waste management practice introduced by the project and its opportunity cost.
- The project reduces the amount of waste going to landfill and recovers valuable materials and energy from waste -> WTP for the project can be related to the avoided cost of landfilling and the avoided cost of raw materials and heat and electricity generation from displaced sources
- Incremental GHG emissions from the change in waste management practice and the resulting material/energy recovery from waste are also factored in
- Social discount rate applied: 5%, in line with Reg. 2015/207

VII – Economic Analysis

Economic costs

- The project's investment and O&M cost estimates used in the financial analysis are deemed to adequately reflect social opportunity costs with the exception of labour
  - Land used for the project priced based on local market conditions
  - Procurement of materials, works and engineering services is to follow an open, competitive procedure in line with applicable public procurement rules -> prices reflect equilibrium of "competitive market"
  - Disposal of incineration slag and ashes (hazardous and non-hazardous) by authorized operators in permitted facilities, not subject to landfill tax
  - Unemployment is relatively high in the project region -> wages assumed to be below the opportunity cost of labour (SWCF = 0.6)
- Residual value: same methodology as in the financial analysis (i.e. = plant dismantling, decommissioning, disposal cost)

VII – Economic Analysis

Economic benefits

- Resource cost savings through improved waste management:
  - Saved cost of landfill space (i.e. leading to an extension of landfill lifetime) through diversion of municipal waste to the new WtE plant
  - Avoided cost of production of displaced heat and electricity
  - Avoided cost of metal production from raw materials
- Avoided externalities through the improved waste management:
  - Avoided GHG emissions from improved waste management (avoided CH_4/N_2O emissions from landfills net of fossil CO_2 released by waste incineration)
  - Avoided CO_2 emissions from displaced heat production
  - Avoided CO_2 emissions from displaced electricity production
  - Avoided CO_2 emissions from metal production from raw materials

VII – Economic Analysis

Project externalities left unconsidered (not significant):

- Fossil CO_2 emissions from project implementation (e.g. from fuel and electricity consumption during construction)

- Pollutants released by WtE plant to air, water and soil: minimized through the inclusion of BAT for the treatment of flue gases, incineration ashes and wastewater produced in the plant as well as the safe disposal of ashes (costs internalized by the project)

- Visual or other disammenities (i.e. visual impact, noise, odours) caused by the WtE plant: considered minimal in this case as the project will be implemented in an existing brownfield site located in the outskirts of the town around 2 km away from the closest residential area

  => usually monetized through hedonic price method !!!

VII – Economic Analysis

B1. Resource cost savings through improved waste management

B1a. Economic value of landfill space saved

- Valued at the estimated full cost of landfill space including opportunity cost of land (30 EUR/t), multiplied by the annual amount of waste treated in the WtE plant and diverted from landfill (200,000 tpa)
- Calculation: 30 EUR/t * 200,000 t/year = 6.0 M EUR/year

B1b. Economic value of heat displaced (excl. avoided GHG emissions)

- Valued at the full (long-term marginal) cost of heat production in the displaced facility, i.e. coal-fired heat only boiler (24 EUR/MWh), plus economic penalty for (limited) security of supply of imported coal (5 EUR/MWh, EIB estimate), multiplied by the annual amount of heat production displaced by the WtE plant (1,147,500 GJ = 318,750 MWh)
- Calculation: (24 EUR/MWh + 5 EUR/MWh) * 318,750 MWh/year = 9.3 M EUR/year

VII – Economic Analysis

B1. Resource cost savings through improved waste management

B1c. Economic value of electricity displaced (excl. avoided GHG emissions)

- Valued at the estimated full (long-term marginal) cost of electricity production in the next best alternative plant, i.e. combined cycle gas turbine – CCGT (65 EUR/MWh) plus an economic penalty for (limited) security of supply of gas (10 EUR/MWh, EIB estimate), multiplied by the annual amount of electricity displaced by the WtE plant (84,250 MWh)
- Calculation: (65 EUR/MWh+10 EUR/MWh) * 84,250 MWh/year = 6.4 M EUR/year

B1d. Economic value of ferrous metal recovered

- Valued at the avoided cost of the alternative production from raw materials, proxied by the market price achieved by scrap metal (80 EUR/t), multiplied by the amount of ferrous metal recovered from incineration slag (4,000 t/a)
- Calculation: 80 EUR/t * 4,000 t/year = 0.32 M EUR/year

VII – Economic Analysis

Economic value of GHG emission

- Monetization of externality using a shadow price of CO_2 as estimated by the EIB (values in EUR 2006 prices!)

Scenario	Value in 2010 (Euro/t-CO_2eq)	Annual adders 2011 to 2030
High	40	2
Central	25	1
Low	10	0.5

Source: http://www.eib.org/attachments/thematic/economic_appraisal_of_investment_projects_en.pdf

- CO_2 value adjusted to EUR 2013 prices - price level of the analysis
- Post-2030 annual adders assumed at 2011-2030 level (lower bound recommended by the CBA Guide, though marginal values may actually increase over time)

VII – Economic Analysis

B2. Avoided externalities through improved waste mgt. and material/energy recovery

B2a. Avoided GHG emissions through improved waste management

- Specific GHG emission factor for landfill, estimated for project (2017/2042, first/last year of operations): 0.67 – 0.62 tCO_2eq/t of untreated municipal waste
- Specific GHG emission factor for WtE plant, estimated for project (2017/2042, first/last year of operations): 0.47 - 0.55 tCO_2eq/t of incinerated municipal waste
- Annual amount of waste treated in the WtE plant / diverted from landfill: 200,000 tpa
- Shadow price for CO_2 in constant 2013 prices (2017/2042, first/last year of operations): 36 EUR/t - 63 EUR/t
- Calculation:
  - 2017: (0.67 - 0.47 tCO_2eq/t) * 200,000 t/year * 36 EUR/tCO_2 = 1.5 mEUR/year
  - 2042: (0.62 - 0.55 tCO_2eq/t) * 200,000 t/year * 63 EUR/tCO_2 = 1.1 mEUR/year

VII – Economic Analysis

B2. Avoided externalities through improved waste mgt. and material/energy recovery

B2b. Avoided CO2 emissions from displaced heat production

- Specific GHG emission factor for coal-fired heat boiler (85% gross energy efficiency): 0.416 tCO_2/MWh(th)
- Annual amount of heat production displaced by the WtE plant: 1,147,500 GJ = 318,750 MWh
- Shadow price for CO_2 in constant 2013 prices (2017/2042, first/last year of operations): 36 EUR/t - 63 EUR/t
- Calculation:
  - 2017: 0.416 tCO_2/MWh * 318,750 MWh/year * 36 EUR/tCO_2 = 4.7 mEUR/year
  - 2042: 0.416 tCO_2/MWh * 318,750 MWh/year * 63 EUR/tCO_2 = 8.4 mEUR/year

VII – Economic Analysis

B2. Avoided externalities through improved waste mgt. and material/ energy recovery

B2c. Avoided CO_2 emissions from displaced electricity production

- Specific GHG emission factor for CCGT: 0.36 tCO_2/MWh(el)
- Annual amount of electricity displaced by the WtE plant: 84,250 MWh
- Shadow price for CO_2 in constant 2013 prices (2017/2042, first/last year of operations): 36 EUR/t - 63 EUR/t
- Calculation:
  - 2017: 0.36 tCO_2/MWh * 84,250 MWh/year * 36 EUR/tCO_2 = 1.1 MEUR/year
  - 2042: 0.36 tCO_2/MWh * 84,250 MWh/year * 63 EUR/tCO_2 = 1.9 MEUR/year

VII – Economic Analysis

B2. Avoided externalities through improved waste mgt. and material/energy recovery

B2d. Avoided CO_2 emissions from metal production from raw materials

- Specific GHG emission factor per tonne of ferrous metal recycled: 1.521 tCO_2eq/t
- Annual amount of ferrous metal recovered: 4,000 t
- Shadow price for CO_2 in constant 2013 prices (2017/2042, first/last year of operations): 36 EUR/t - 63 EUR/t
- Calculation:
  - 2017: 1.521 tCO_2/t * 4,000 t * 36 EUR/tCO_2 = 0.2 M EUR/year
  - 2042: 1.521 tCO_2/t * 4,000 t * 63 EUR/tCO_2 = 0.4 M EUR/year

VII – Economic Analysis

ERR

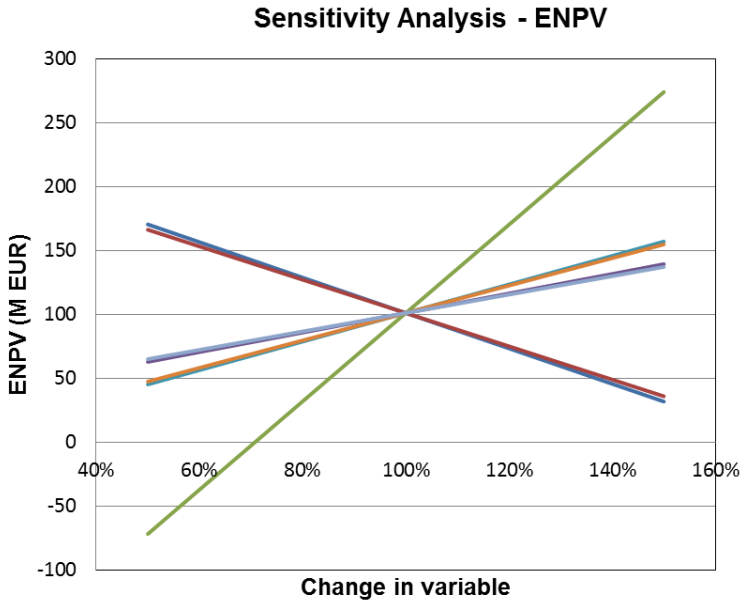
1	2	3	4	5	6	10	15	20	25	30
Construction				Operation						

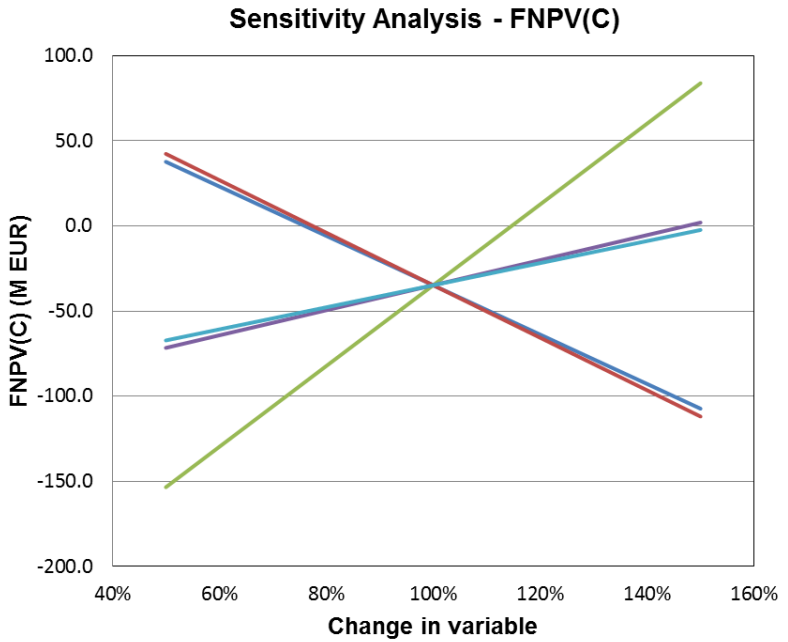
Calculation of the Economic Rate of Return		NPV 5 %										
Investment cost (excluding contingencies)	mEUR	-138.7	-7.2	-84.4	-42.6	-14.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0
O&M cost (including replacement cost)	mEUR	-130.4	0.0	0.0	0.0	0.0	-8.4	-8.4	-8.4	-8.5	-71.8	-8.6	-8.6
Residual value of investments	mEUR	-1.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-5.3
Total economic cost	**mEUR**	**-270.3**	**-7.2**	**-84.4**	**-42.6**	**-14.5**	**-8.4**	**-8.4**	**-8.4**	**-8.5**	**-71.8**	**-8.6**	**-14.0**
B1. Resource cost savings	mEUR	264.3	0.0	0.0	0.0	0.0	22.0	22.0	22.0	22.0	0.0	22.0	22.0
B1a. Economic value of landfill space saved	*mEUR*	72.1	*0.0*	*0.0*	*0.0*	*0.0*	*6.0*	*6.0*	*6.0*	*6.0*	*0.0*	*6.0*	*6.0*
B1b. Economic value of recovered energy in form of heat	*mEUR*	111.8	*0.0*	*0.0*	*0.0*	*0.0*	*9.3*	*9.3*	*9.3*	*9.3*	*0.0*	*9.3*	*9.3*
B1c. Economic value of recovered energy in form of electr.	*mEUR*	76.5	*0.0*	*0.0*	*0.0*	*0.0*	*6.4*	*6.4*	*6.4*	*6.4*	*0.0*	*6.4*	*6.4*
B1d. Economic value of recovered metal	*mEUR*	3.8	*0.0*	*0.0*	*0.0*	*0.0*	*0.3*	*0.3*	*0.3*	*0.3*	*0.0*	*0.3*	*0.3*
B2. Avoided environmental externalities	mEUR	107.3	0.0	0.0	0.0	0.0	7.5	7.6	8.1	8.9	0.0	10.7	11.8
B2a. Avoided GHG emissions through improved waste mgt.	*mEUR*	13.4	*0.0*	*0.0*	*0.0*	*0.0*	*1.5*	*1.4*	*1.2*	*1.0*	*0.0*	*1.0*	*1.1*
B2b. Avoided GHG emissions through heat prod. from waste	*mEUR*	73.9	*0.0*	*0.0*	*0.0*	*0.0*	*4.7*	*4.9*	*5.5*	*6.2*	*0.0*	*7.7*	*8.4*
B2c. Avoided GHG emissions through electr. prod fr. waste.	*mEUR*	16.7	*0.0*	*0.0*	*0.0*	*0.0*	*1.1*	*1.1*	*1.2*	*1.4*	*0.0*	*1.7*	*1.9*
B2d. Avoided GHG emissions through metal recovery fr. waste	*mEUR*	3.4	*0.0*	*0.0*	*0.0*	*0.0*	*0.2*	*0.2*	*0.3*	*0.3*	*0.0*	*0.4*	*0.4*
Total economic benefits (B1+B2)	**mEUR**	**371.6**	**0.0**	**0.0**	**0.0**	**0.0**	**29.5**	**29.6**	**30.1**	**30.9**	**0.0**	**32.7**	**33.7**
ENPV / Net benefits	**mEUR**	**101.3**	**-7.2**	**-84.4**	**-42.6**	**-14.5**	**21.1**	**21.2**	**21.7**	**22.4**	**-71.8**	**24.1**	**19.8**

ERR	**10.6%**
B/C RATIO	**1.37**

VIII – Risk assessment

Sensitivity analysis





VIII – Risk assessment

Critical variables and “switching values”

Variable	FNPV(C) elasticity	Switching value	ENPV elasticity	Switching value
Econ./Fin. Investment cost	4.2%	-24%	-1.4%	73%
Econ./Fin. O&M cost (incl. replacement costs)	4.5%	-22%	-1.3%	77%
Waste input	-6.8%	15%	3.4%	-29%
Gate-fee (WtE)	-3.6%	28%	-	-
Econ./Fin. Heat price	-1.9%	54%	1.1%	-91%
Econ./Fin. Electricity price	-2.1%	47%	0.8%	N.A.
Shadow price of CO_2	-	-	1.1%	-94%
Shadow price of landfill space	-	-	0.7%	N.A.

- The demand is the most critical variable for the socio-economic viability: the ENPV would drop to 0 if the waste input decreased by 29 %.
- For the financial analysis, in addition to the waste input, the most critical variables are the investment and O&M cost and the gate-fee, with “switching values” of -24%, -22% and 28% respectively.

VIII – Risk assessment

Scenario analysis

- A pessimistic scenario is analysed, where investment cost and O&M cost would be 20 % higher than currently budgeted, while all benefit categories would be 10 % lower than in the assumed base-case scenario.
- Under this pessimistic scenario the ENPV would still be positive (3 M EUR), with a 5.2 % ERR.
- Therefore, it can be concluded that the project should remain economically viable also under reasonably adverse conditions.

VIII – Risk assessment

Qualitative risk analysis – the Risk Matrix (1 of 4)

Risk description	Probability (P)	Severity (S)	Risk level (=P*S)	Risk prevention / mitigation measures	Residual risk
Demand & Supply risks					
Available waste flow is much lower than the design capacity of the plant	B	III	Moderate	Demand analysis is carried out based on realistic assumptions on waste generation and separation in the project's catchment area. Demand after separation of recyclables exceeds capacity of the facility throughout the reference period. Municipalities in the catchment area are firmly committed to the project. Function in charge: project beneficiary, partner municipalities	Low
Composition and calorific value of the actual input waste are outside of the range used to design the incineration plant	C	III	Moderate	Reliable tests of waste composition and calorific value were carried out for different seasons. Source segregation is not expected to affect the calorific value of the residual waste significantly as bio-waste and combustible fractions are assumed to be separated in similar quantities. In case of seasonal fluctuations in waste composition, appropriate mixing with waste from different sources is possible. Function in charge: project beneficiary, partner municipalities	Low
Uncertainty with regards to off-take of heat produced in the plant	C	IV	High	Heat off-take agreement signed with local DH provider. Agreement is supported by the Municipality. Function in charge: project beneficiary, partner municipality.	Low

VIII – Risk assessment

Qualitative risk analysis – the Risk Matrix (2 of 4)

Risk description	Probability (P)	Severity (S)	Risk level (=P*S)	Risk prevention / mitigation measures	Residual risk
Financial risks					
Investment cost overrun	C	III	Moderate	Investment cost estimates compare well with costs experienced with similar projects implemented in the EU in the last years. Consultations with plant and equipment manufacturers were carried out to cross-check estimates with current market conditions. Publication of contract notices in the Official Journal of the EU to ensure wider competition. Function in charge: project beneficiary.	Low
Operating cost overrun	C	III	Moderate	Operating cost estimates compare well with costs experienced with similar projects in operations. Consultations with plant and equipment manufacturers carried out to cross-check estimates. Real increases in staff costs have been considered in the operating cost forecasts. Aspects related to disposal of incineration wastes have been duly verified. Function in charge: project beneficiary	Low
Shortfall in revenues from gate fees and sales of materials and energy	B	IV	Moderate	Proposed gate-fees for the WtE have been agreed in advance with the three towns participating in the project. The heat off-take price has been negotiated and agreed in principle with local DH service provider. The agreement includes provisions for regular price adjustments for inflation and for changes in the price of coal or the price paid by the DH operator for CO2 emissions. The off-take price for electricity is a conservative assumption based on current forecasts of demand and supply. Function in charge: project beneficiary.	Low

VIII – Risk assessment

Qualitative risk analysis – the Risk Matrix (3 of 4)

Risk description	Probability (P)	Severity (S)	Risk level (=P*S)	Risk prevention / mitigation measures	Residual risk
Financial risks					
Problems with availability of local co-financing	C	IV	High	National public grants confirmed through commitments of the national government to co-finance the relevant OP Regional Government and involved Municipalities have all provided written commitments to (co-)finance the project, interests during construction and initial working capital Project beneficiary is seeking a loan from the EIB to co-finance the project, for which first negotiations have started Function in charge: Ministry of Finance, Managing authority responsible for the OP, Regional government, municipal governments of the three towns participating in the project, project beneficiary	Low
Delays in project preparation and approval leading to late availability of EU grant co-financing	C	III	Moderate	JASPERS involved in technical assistance early in the project cycle to reduce time for project approval. Function in charge: Managing authority responsible for the OP, project beneficiary.	Low

VIII – Risk assessment

Qualitative risk analysis – the Risk Matrix (4 of 4)

Risk description	Probability (P)	Severity (S)	Risk level (=P*S)	Risk prevention / mitigation measures	Residual risk
Implementation risks					
Delays land purchase	A	II	Low	Land is owned by one the Municipalities promoting the project. Conditions for land purchase have already been agreed in principle. Function in charge: project beneficiary.	Low
Problems with public opposition to the project	D	IV	Very high	The public consultation process required as part of the EIA is well advanced and concerns raised during public hearings do not represent any critical issue for the project. Queries from environmental NGOs have been responded and suggestions partially taken on board. Partner municipalities involved in promoting the project amongst population. Publicity measures aimed at informing the public about the project and its objectives are included in the project. Function in charge: project beneficiary, partner municipalities	Moderate
Delays related to extension of tender procedures	C	III	Moderate	Promoter's procurement division to be supported by specialised technical assistance. Appropriate time contingencies are factored in into the project schedule. Function in charge: project beneficiary.	Low
Operational risks					
Limits for emissions of pollutants to air/water are exceeded	A	II	Low	Installation of proven, best-available technologies for flue gas treatment and wastewater treatment facilities Function in charge: project beneficiary, contractor	Low




Thank you!

f.angelini@eib.org

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JASPERS Networking and Competence Centre

jaspersnetwork@eib.org

www.jaspersnetwork.org