Decision support tool in the waste management field

Cost-comparison tool for different integrated waste management systems

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Abstract

At the request of KFW – the German Development Bank – ICP has developed a cost-simulation tool (based on the Microsoft Excel software) for different integrated waste management systems (including all phases from planning, construction, operation up to closure) in order

- to calculate and compare the dynamic costs of each system chosen
- to provide additional support for decision makers in waste management from beginning on, based on similar frame conditions.

The following three different waste management scenarios are included and can be calculated in the tool:

1. MBT aerobic (mechanical + aerobic biological waste treatment) + landfilling of treated waste
2. MBT anaerobic (mechanical + anaerobic biological waste treatment) + landfilling of treated waste
3. Only landfilling of untreated mixed waste

The calculation has been verified with proven data from a former KFW project in Tunisia with the same scenarios as mentioned above. With the tool it could be successfully and easily demonstrated that for the case study chosen in Tunisia total costs for systems with waste treatment can be comparable or must not be significantly higher than systems without waste treatment (only landfilling).

Keywords

Waste management, total costs, costs of MBT aerobic, costs of MBT anaerobic, costs of sanitary landfilling.

1. Background

In order to show cost-efficiency a major focus is typically on the required investment costs of waste management systems. Investments for waste management systems are following – in the most cases – the lowest price principle not sufficiently taking into account additional relevant cost components (e.g. costs for system planning, operation, maintenance and closure). Experiences worldwide confirm this issue. As it is well known that system investments in waste management for typical operational times between 20 and 30 years represent only a small share of the total system costs a larger focus is required on the major part of the other cost components.

Obviously the total cost calculation of such systems has been carried out, but mostly lacking on an integrative approach.

It became clear that such total cost calculation for a complete waste management system's lifetime (including all phases from planning, construction, operation up to closure and post-treatment), especially of complete integrated systems (regional- or nationwide) mostly are carried out only looking independently on each individual system component, not sufficiently taking into account the dependencies amongst each other.

Based on this background a reliable support tool has been developed –including

- the above mentioned integrative approach
- a calculation model – in this case the dynamic cost model – typically accepted by investors

in order to calculate and compare for a complete project period (from planning up to post-treatment after operation) the development of the dynamic costs as basis for decisions influencing the whole system's lifetime period.

As MBT systems become more popular worldwide especially for developing and emerging countries two important main variants of MBT (with (including biogas) and without energy production) has been chosen for the calculation tool as scenarios to compare it with the simple "only landfilling" one. Aim was and is to provide a decision tool for investors, authorities etc. in order to enable them in the project development's early beginning phase to get a first impression of upcoming total costs for different waste management systems under same frame conditions over a whole project's period lifetime.

2. Structure of cost-comparison tool

This tool allows to calculate and to compare in parallel, the dynamic costs generation for 3 different waste management scenarios.

The tool is based on the calculation method of the DCCC - developed Appraisal Manual for Project designer of the DWA (German Association for Water, Wastewater and Waste) [1] and calculates the dynamic costs of the chosen waste management scenario after input of specific data.

The following three different waste management scenarios are included in the tool:

1. Scenario S1:
   Mechanical-biological waste treatment (with aerobic biological treatment stage) and landfilling of pre-treated residual waste

2. Scenario S2:
   Mechanical-biological waste treatment (with anaerobic biological treatment stage) and landfilling of pre-treated residual waste

3. Scenario S3:
   No pre-treatment, only landfilling of untreated mixed waste

Required specific data as such as

- Waste quantities and composition of waste, existing waste collection system
- Population figures and demographic trends
- Economic basis data (interest rates, inflation , sales tax, cost of general consumables (electricity , water, fuel, etc ...)
- scenario- specific information on investment and operating costs can be individually added, the cost of these scenarios be compared.

The procedure for data filling in the separate data sheets is equal for all scenarios. The steps for the different datasheets to work with are as follows:

1. **Startup** sheet to choose the relevant scenario
2. **Basic Data** sheet to add all the required basic data as m.a.
3. **Investment Cost** sheet to fill in the costs for all investment components (also including specific re-investment periods and estimation of maintenance costs as a percentage of the investment costs)
4. **Operational Cost** sheet with all relevant components (e.g. consumables, staff….)
5. **Realization Phase** sheet with options on the distribution of initial investment costs for max 5 years

All remaining data sheets are resulting from the calculation of the input to the data sheets m.a.:

6. **Total Costs** sheet: Total costs and it's sub-components of the whole project period will be presented here.
7. **Flowchart** sheet: The mass flows are shown in detail for the start of the project.
8. **Flowchart total** sheet: The average mass flows are shown for the entire project period.
9. **Graphs** sheet: Here the relevant project results for each scenario are presented graphically.
10. **Cost Comparison**: For scenarios S1 - S3 the cost comparison for the total, the investment and operating cost is presented here.

2.1. Data Input

2.1.1. Start-up

In the start-up sheet the scenario to work with can be selected. From here you can switch to all different datasheets as mentioned above.

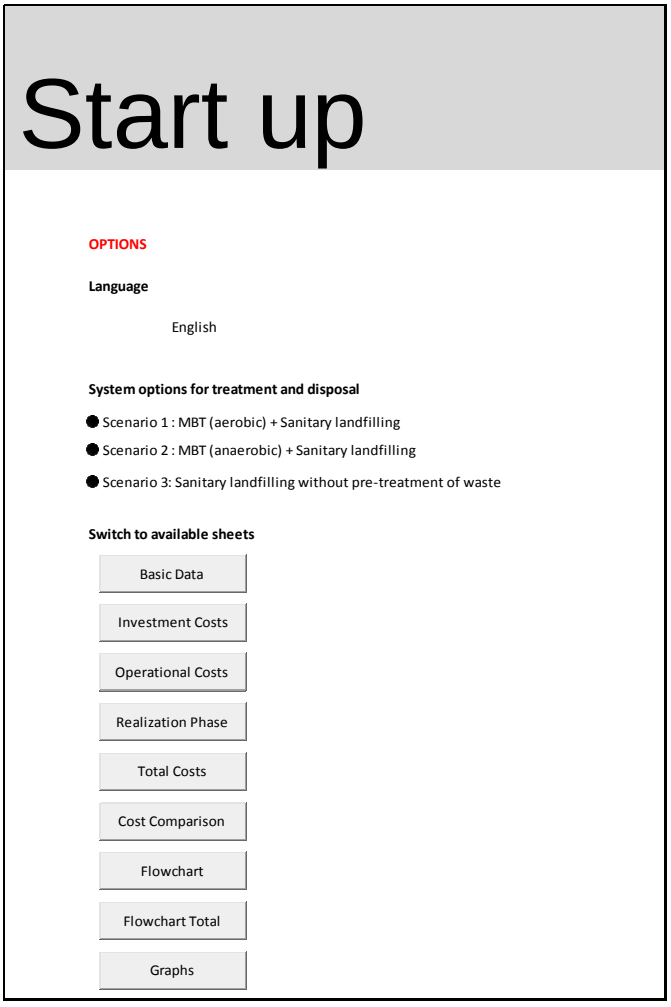

Figure 1: Start-Up

2.1.2. Basic Data

Everything starts with Scenario 1 “Basic Data”. Here all data equal for all 3 scenarios will be added and automatically used for the other scenarios 2 and 3 e.g.: waste amounts, waste composition, number of inhabitants, economic data (income, costs for consumables etc.), afterwards data only relevant for the specific scenarios can be filled in to the relevant basic data sheets 2 and 3.

Required data relevant for all scenarios

The input of following data is required here

1. Project relevant data (name and location of project)
2. Schedule for all project phases
    a. Site selection
    b. Design
    c. Construction
    d. Operation
    e. For landfills closure
3. Climate data

a. Temperature
b. precipitation

4. Waste specific data for all different waste types (e.g. household waste, commercial waste, sewage sludge or other waste)
    a. Quantities
    b. Composition
    c. Water content
    d. Organic matter content
    e. Collection coverage rate

5. Socio-Economic data
    a. Number of inhabitants
    b. Population growth
    c. Income
    d. Inflation rate
    e. Interest rate
    f. Costs for consumables (e.g. fuel, electricity and water)
    g. Selling prices for recyclables

Required data relevant for the specific scenarios 1-3

If the data relevant for all scenarios have been added following specific data relevant for the specific scenario has to be filled in

- S 1: Mechanical + aerobic biological waste treatment + landfilling of treated waste
    - Mechanical treatment:
        - Input amounts for each waste type m.a.
        - Sorting and separation rates for each fraction
    - Aerobic biological treatment:
        - Sorting rate for separation of organic waste
        - Losses through treatment
        - Producible and marketable compost amount (in case of bio-drying: RDF amount)
    - Landfill
        - Dimensions for required treated waste as output from MBT aerobic
        - Leachate amounts estimation based on
            - Precipitation data
            - Water content of input waste
        - No landfill gas extraction foreseen

- S 2: Mechanical + anaerobic biological waste treatment + landfilling of treated waste
    - Mechanical treatment:
        - Input amounts for each waste type m.a.
        - Sorting and separation rates for each fraction
    - Anaerobic biological treatment (biogasification)
        - Sorting rate for separation of organic waste
        - Losses through treatment
        - Expected gas and energy yield
        - Gases methane content
        - In case use of CHP (combined Heat and Power Unit): Degree of efficiency
    - Landfill
        - Dimensions required for treated waste as output from MBT anaerobic
        - Leachate amounts estimation based on
            - Precipitation data
            - Water content of input waste
        - No landfill gas extraction foreseen
- S3: Landfilling of untreated waste
        - Dimensions for untreated waste as output from MBT
        - Leachate amounts estimation based on
            - Precipitation data
            - Water content of input waste

- Landfill gas amounts estimation for extraction collection and treatment

Mechanical Treatment					
				Year	
Input to Mechanical Treatment				2015	
Household Waste				71.489	Mg/a
Commercial Waste				0	Mg/a
Other Waste 1 to MBT				0	Mg/a
Total Input				**71.489**	**Mg/a**
				Year	
Total Output Recycling Materials from Mechanical Treatment	Sorting Quota in % from Input			2015	
Ferrous Metal	35,00%	=		375	Mg/a
Non-Ferrous Metal	30,00%	=		107	Mg/a
Paper	30,00%	=		858	Mg/a
Plastic - PET	35,00%	=		250	Mg/a
Plastic - Other Plastics	35,00%	=		751	Mg/a
Glass	35,00%	=		250	Mg/a
Textiles	35,00%	=		626	Mg/a
Secudary Fuel (RDF)	1,00%	=		57	Mg/a
Wood	35,00%	=		375	Mg/a
Others	35,00%	=		0	Mg/a
Sum of Recycling Materials as Share from Input	**5,11%**	**=**		**3.650**	**Mg/a**

Figure 2: Example for required data for sorting rates in mechanical treatment of MBT aerobic

2.1.3. Investment Costs

In this datasheet all individual investment components for each system segment shall be added

- investment costs
- refinancing period
- costs for repair and maintenance as percentage (%) of investment costs

At maximum 2 investment periods for data input are foreseen.

The costs for the main investment components can be added as total sum or – when specific data available for each sub-component separately. The main cost components are structured as follows

1. Site selection
2. Purchase of site
3. Incidental building costs (e.g. planning, studies, construction supervision etc.)
4. Construction costs for whole infrastructure of MBT and landfill (e.g. roads, buildings, water and energy supply, etc…)
5. Costs for MBT (for Scenario 1 and 2 only)
    a. Construction
    b. Technical equipment
    c. Others
6. Landfill (different for all 3 scenarios)
    a. Construction of 1st cell
    b. Construction of other cells
    c. Closure and post-treatment
    d. Leachate collection and treatment
    e. Gas collection and treatment (only relevant for Scenario 3: only landfilling)

5	Costs of MBT						
	● specific costs	Start	2014				
		End	2014				
	● total costs only						
		Phase 1	Phase 2				
		DNT	DNT				
5.1	Additonal construction costs specific for MBT	3.284.902,00	0,00	0	2,12%	1,00%	
					69.639,92	0,00	
5.1.1	Land	3.284.902,00	0,00				
5.1.2	Cleaning and leveling	0,00	0,00				
5.1.3	Concrete culverts for surface water	0,00	0,00				
5.1.4	Pipes for surface water	0,00	0,00				
5.1.5	Asphalt surfaces	0,00	0,00				
5.1.6	Leachate pool	0,00	0,00				
5.1.7	Building for sorting ,unloading,storing, administration	0,00	0,00				
		Start	2015				
	● specific costs	End	2034				
	● total costs only	Phase 1	Phase 2				
		DNT	DNT				
5.2	Technical equipment for mechanical part of MBT	1.380.836,43	7.726.039,00	0	1,35%	0,40%	
					18.641,29	30.904,16	
5.2.1	*Fix Equipment*	796.675,43	5.913.124,00				
5.2.1.1	Conveyor Belt	796.675,43	5.913.124,00				
5.2.1.2	Magnetic Separator	0,00	0,00				
5.2.1.3	Sieves	0,00	0,00				
5.2.1.4	Belt for manual separation	0,00	0,00				
5.2.1.5	Air classifier	0,00	0,00				
5.2.1.6	Other classifier	0,00	0,00				
5.2.1.7	Pumps	0,00	0,00				
5.2.1.8	Laboratory	0,00	0,00				
5.2.1.9	Other	0,00	0,00				
5.2.2	*Mobile Equipment*	584.161,00	1.812.915,00				
5.2.2.1	Screener	584.161,00	1.812.915,00				
5.2.2.2	Loader	0,00	0,00				
5.2.2.3	Container	0,00	0,00				
5.2.2.4	Tractor with trailer	0,00	0,00				
5.2.2.5	Tank trailer	0,00	0,00				
5.2.2.6	Other	0,00	0,00				
5.3	Technical equipment for biological part of MBT	6.437.059,00	25.667.733,00	0	2,15%	0,21%	
					138.396,77	53.902,24	
					Maintenance and reparation		
		Phase 1	Phase 2		Phase 1	Phase 2	
		DNT	DNT		DNT	DNT	
5.4	Total costs for MBT (5.1-5.3)	11.102.797,43	33.393.772,00		226.677,98	84.806,40	

Figure 3: Example for cost segments to fill in for MBT aerobic

2.1.4. Operational Costs

The datasheet “Operational costs” requires for cost input in the following parts:

- Staff
- Consumption of consumables (fuel, water, electricity)
- Leachate treatment costs
- Landfill gas treatment costs (only relevant for Scenario 3: only landfilling)
- Administrative costs
- Other costs (e.g. insurance etc.)

Block 3: Electricity consumption

● detailed costs

● total costs only

			Electricity per kWh				
	Basic costs consumables		0,21				
	Fix equipment MBT						
		No	**Consumtion kWh**	**Hours/d**	**d/year**	**Cost/KWh**	**Total costs/a**
							DNT
3.1	Conveyor Belt	11	5	7	300	0,21	24.255,00
3.2	Magnetic Separator	2	5	7	300	0,21	4.410,00
3.3	Sieves	4	30	7	300	0,21	52.920,00
3.4	Belt for manual separation	0	500	8	300	0,21	0,00
3.5	Air classifier	0	100	8	300	0,21	0,00
3.6	Other classifier	0	100	8	300	0,21	0,00
3.7	Pumps	0	100	8	300	0,21	0,00
3.8	Laboratory	1	50	4	125	0,21	5.250,00
3.9	Others	2	406	7	300	0,21	358.092,00
	Mobile equipment MBT						
				average tons waste treated/y			DNT
3.10	Screener	1	2	84.400		0,21	35.448,00
3.11	Others	0	100	8	300	0,21	0,00
						Total costs/a	DNT
							480.375,00
	Infrastructure and Landfill						DNT
2.7	General consumption (IT etc.)	1	1	10	300	0,21	630,00
2.8	Lighting	1	5	4	250	0,21	1.050,00
2.9	Landfill gas treatment	0	100	8	300	0,21	0,00
2.10	Leachate pumping	1	10	24	333	0,21	16.800,00
2.11	Leachate treatment	0	100	8	300	0,21	0,00
2.27	Others 1	1	5	8	125	0,21	1.050,00
2.28	Others 2	1	2	24	333	0,21	3.360,00
						Total costs/a	DNT
							22.890,00
						Total costs/a	DNT
							503.265,00

Figure 4: Example for energy consumption costs estimation

2.1.5. Realization Phase

This datasheet allows to individually distribute the total calculated investment costs (see ch. 2.1.3) over a phase of up to 5 years separately for

- Landfill
- MBT

2.2. Evaluation of results

All results of the following datasheets in ch. 2.2 are computed with the input of data mentioned in ch. 2.1.

2.2.1. Total costs

In this data sheet the dynamic prime costs, which represent the average total costs (including all investment and operational cost components) over the whole project's lifetime (planning, construction, operation, post-treatment, closure) are calculated in each scenario for separately for MBT and landfill in relation to

- Input quantity for MBT
- Input quantity for landfill
- Total waste amount

Operation time in years		MBT: 20	Landfill: 20	EUR	Units
Depreciation/ write-down				5%	
Present investment costs MBT- Basis: MBT Input				19,03	Euro/ton
Present investment costs MBT- Basis: Waste total				19,03	Euro/ton
Present investment costs Landfill - Basis: Waste direct to landfill				8,82	Euro/ton
Present investment costs Landfill - Basis: Waste total				7,35	Euro/ton
Present investment costs MBT+Landfill - Basis: Waste total				13,64	Euro/ton
Present operation costs MBT (without revenues) - Basis: MBT Input				6,52	Euro/ton
Present operation costs MBT (without revenues) - Basis: Waste total				6,52	Euro/ton
Present operation costs landfill (without revenues) - Basis: Waste direct to landfill				11,74	Euro/ton
Present operation costs landfill (without revenues) - Basis: Waste total				9,79	Euro/ton
Present operation costs MBT+landfill (without revenues) - Basis: Waste total				16,31	Euro/ton
Present total costs MBT without revenues				21,67	Euro/ton
				22.818.935	Euro
Present total costs landfill without revenues				16,22	Euro/ton
				17.077.004	Euro
Present total costs MBT+Landfill without revenues				37,89	Euro/ton
				39.895.938	Euro
Present total costs MBT+Landfill with revenues				35,46	Euro/ton
				37.332.480	Euro

Figure 5: Example for total cost calculation

2.2.2. Mass balance – flowchart and flowchart total

The datasheet

- **Flowchart** shows the melt streams for the project start time.
- **Flowchart total** shows the melt streams for the average amounts handled for the whole project period.

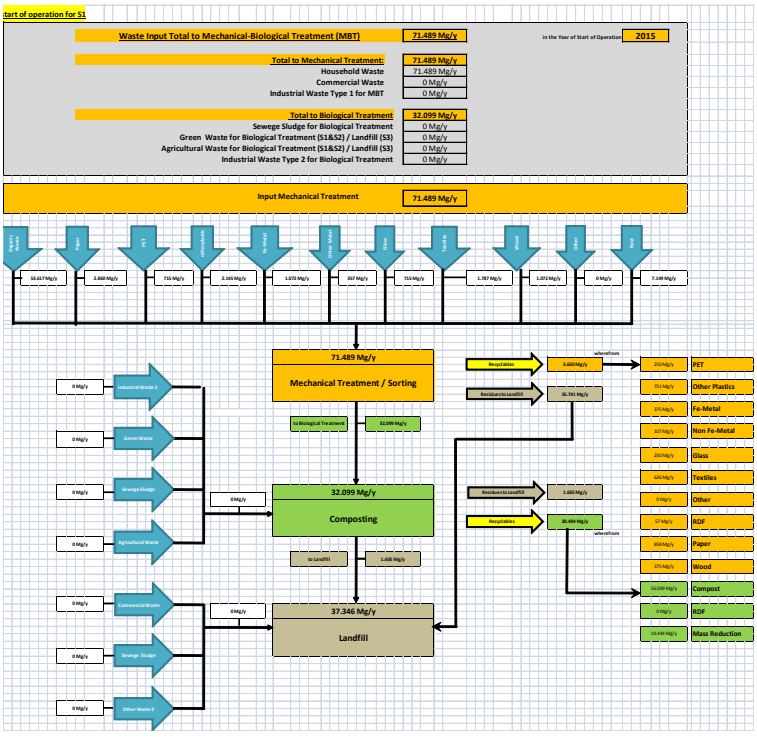

Figure 6: Example for flowchart and melt streams

2.2.3. Graphs

All relevant results and calculation are visualized as graphs for all scenarios such as:

- Population development
- Projection of waste amounts
- Collected and generated waste streams
- Waste composition
- MBT input and output
- Landfill input

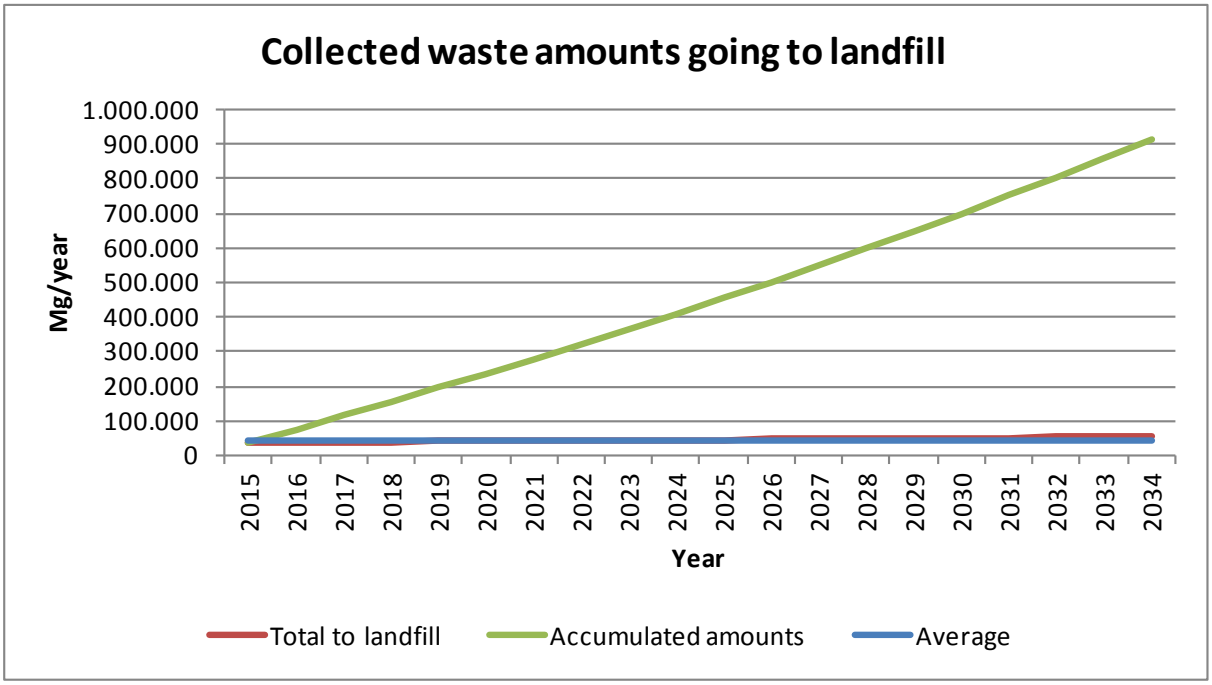

Figure 7: Example for visualized results: Projection of collected wastes amounts going to landfill

2.2.4. Cost comparison between all scenarios

Results of cost calculation of all 3 scenarios will be presented and compared in the datasheet **cost comparison.**

The analysis is presented

- In table form as done in the datasheet for **total costs**
- as graphs showing the comparison of
    - Present Investment Costs
    - Present Operation Costs
    - Present Total Costs total and in Euro/ton

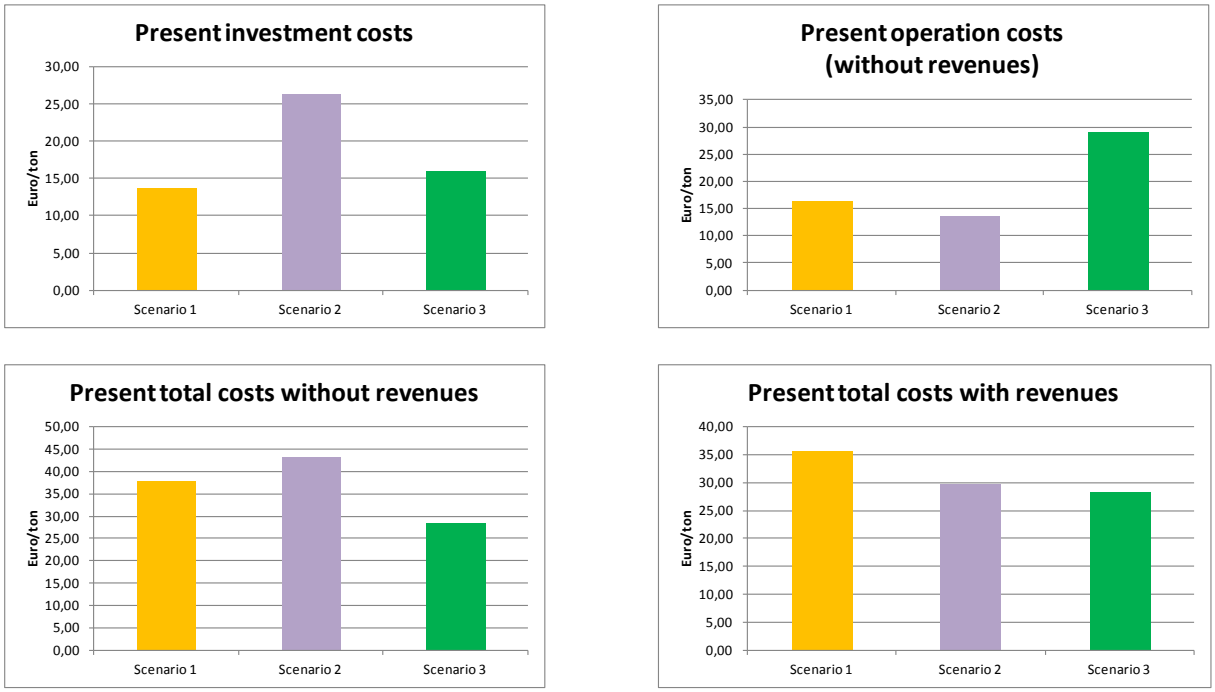

Figure 8: Example for result of total cost comparison for the 3 different waste management scenarios

3. Prove of functionality

In order to prove functionality of the cost calculation tool the calculation process has been checked/verified with data from practice from a former KFW project in Tunisia carried out separately for all the scenarios mentioned.

4. Conclusion and outlook

It could be shown that the cost calculation tool presents sufficiently accurate data in order to enable decision makers in an early project stage to decide for or against a waste management system established for long-term period taking into account not only the investment costs, but also the total costs occurred during the whole project's lifetime.

With the tool it could be successfully and easily demonstrated that for the case study chosen in Tunisia total costs for systems with waste treatment can be comparable or must not be significantly higher than systems without waste treatment (only landfilling).

5. Literature

[1] Dynamic Cost Comparison Calculations for selecting least-cost projects in Water Supply and Wastewater Disposal; DCCC - Appraisal Manual for Project Designers by DWA (German Water Association, December 2011