Analysis of Current Situation in Municipal Waste Management and Implementation of Decision Support Software in Astana, Kazakhstan

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SUMMARY: The city of Astana, capital of Kazakhstan with population of 804,474 generates approximately 1.39 kg/inh./day of municipal solid waste while collection rate is higher than 72% (MSW). An MBT plant of planned capacity of 600-800 tn/day and a new landfill cell of about 2 million tones are in place. Preliminary studies showed that the MSW composition is as follows: food and garden waste 29.5%, plastics 18.5%, paper 13%, glass 14.5%, textiles 9.5%, metals 0.9% and others 14.1%. About 23-34 tons of recyclables (paper, metal, glass, PET bottles, HDPE film, HDPE plastic, etc.) is separated in the existing MBT daily. In 2014 it is planned to implement separate waste collection in places of waste accumulation and a waste separation at source system. The purpose of the study is to assess the current situation of municipal solid waste in Astana and implement a Decision Support Software tool developed by the research team in order to analyse data, compare alternative waste management scenarios and propose a holistic approach in solid waste management planning. The latest available data on waste generation, composition and existing infrastructure were used in order to identify the baseline situation. This is the first research of this type conducted in Kazakhstan.

1. INTRODUCTION

The quantity of municipal solid waste (MSW) in developing countries has been consistently rising over the years and its composition is similar but varies from country to country depending on the average standard of living, climate and cultural, industrial, infrastructural and legal factors (Khajuria et al., 2010). MSW disposal in most developing countries around the world poses major environmental problems. Several environmental and public health problems arise from insufficient collection and disposal systems. With only some exceptions, waste management in Kazakhstan is in the very first steps and municipal solid waste is disposed in open dumps and a small portion in engineered landfills (Orazbayev et al., 2013). Outside of the big cities, typically only about one quarter of the population has access to MSW collection services and 97% of MSW is taken to uncontrolled dumps and substandard authorized landfills without processing or recycling (Concept, 2013). Technology and infrastructure do not meet current standards due to a lack of economic incentives and although some standards/requirements are in place, enforcement is weak due to insufficient state control. Moreover, there has been little incentive for local authorities and business in the waste disposal sector to increase added value recovery through recycling, composting, or energy recovery from urban waste, with recycled volumes reported to be less than 5% of total MSW volumes (Concept, 2013). Thus, is evident that Kazakhstan needs to build a new integrated waste management system, taking into account reforms in the institutional and legal framework. To face the future problems a sufficient waste management system should be developed and Decision Support Tools is one of the available means to achieve this goal.

A waste management plan has to be developed according to the needs of the respective region where it will be applied. However, there are some common elements that do not depend on the region. Such elements include the characteristics of the waste treatment technologies that will be integrated into the management system (Chen et al., 2011; Ghinea et al., 2012). Competent authorities and stakeholders have to be able to identify how those technologies can be applied within technical and financially feasible terms always respecting and satisfying the legislative restrictions and prerequisites. In addition, they have to examine them as standalone units in order to comprehend their environmental impacts, advantages and disadvantages. In that context the Decision Support Software (DSS) tool, developed by members of the research team in collaboration with partners from Europe, is applied in Astana, capital city of Kazakhstan in order to examine and compare the application of different waste treatment options (Chang et al., 2012; Pires et al., 2011; Panagiotidou, 2012).

The DSS tool for waste management is a computer integrated tool, aiming at supporting the decision maker throughout the various steps of waste management planning and allows a thorough understanding of the complex interplay between the numerous factors involved in integrated waste management (Panagiotidou et al., 2012). It is true that most existing tools developed for assessing waste management practices are incorporating large number variables and result in complex solutions, inadequate for practical use (Bani et al., 2009). On the other hand, DSS tool is a user-friendly software equipped with multiple functions (Panagiotidou et al., 2012):

- an automated process tool, identifying and suggesting the most suitable technologies within an integrated waste management framework, and guiding the decision-maker towards formulating appropriate scenarios for waste management planning
- an analytical tool, evaluating available waste management options through Material Flow Analysis, providing a multidisciplinary comparison (Environmental, Economic, Social, Legislative and Technical) between different waste management technologies

- a decision support system, assisting the appropriate authorities to comparatively assess and evaluate the alternative waste management scenarios, based on a predefined set of quantitative and qualitative criteria

As any decision support tool, DSS provides solutions that can be considered neither optimal nor absolute, as the solution includes the perceptions of decision-makers. PROMETHEE multi-criteria decision making method and MATLAB graphical user interface environment were used. After developing the Graphical User Interface (GUI), a standalone distributable application (exe) for Windows Operational System is created, using MATLAB Compiler, allowing executions on computers with no MATLAB installed. As far as the application of PROMETHEE method in the present case study, it seems that its major advantage towards other multicriteria methods lies in its simplicity and very clear information that is easily obtained and understood by both decision-makers and analysts.

2. ASSESSMENT OF THE CURRENT SITUATION OF MUNICIPAL WASTE MANAGEMENT IN ASTANA

2.1 Municipal Waste quantity, composition and treatment facilities

Astana is the capital city of the Republic of Kazakhstan with a population of approximately 804,474 (Department of Statistics of Astana city, 2013). Waste management problems in Astana can be well understood in the light of rapid urbanization in many cities along Kazakhstan. As the economic situation improves, with Astana constituting approximately 8.5% of the total GDP of US$ 151.67 billion in 2011 the concerns for waste management rises since a stronger economy often leads to an increased waste production due to a higher purchasing capacity. According to the latest projections, production of municipal solid waste in the period 2011-2025 in urban areas is likely to grow by more than 50% along with growth in prosperity (Concept, 2013). This means that the annual waste growth rate is expected at a level of 3.33%, higher that other developing countries in Asia, as Malaysia with a rate of 2% (Moh and Manaf, 2014).

According to the latest data (2013) about 1,118 tn of MSW are generated per day in the city and the collection capacity is approximately 600-800 tn (Ministry of Regional Development, 2012). According to these data, waste generation rates are 507 kg/inh./year or 1.39 kg/inh/day, while waste collection rates are 365 kg/inh/year or 1 kg/inh/day (72%). According to historical statistical data (Table 1), the MSW generation is between 1.14-1.39 kg/inh./day, without any clear growth or decline trend (Department of statistics of Astana city, 2013). Similar values are found in other cities in developing countries, as for example 1.62 kg/inh/day in Kuala Lumpur (Malaysia, 2009), 1.01 kg/inh/day in Kuwait city (Kuwait, 2009-2013), 1.26 kg/inh/day in Bahrain (2005), 1.3 kg/inh/day in Qatar (2005), 1.11 kg/inh/day in Shanghai, 1.08 kg/inh/day in Chongqing, 1.51 kg/inh/day in Lhasa, 1.17 kg/inh/day in Hangzhou and 1.33 kg/inh/day in Hong Kong (China, 2006-2009) (Alhumoud, 2005; Al-Jarallah and Aleisa, 2014; Zhang et al., 2010; Saeed et al., 2009).

Table 1. Waste generation in Astana in 2006-2012

Year	**Waste generation (tn/year)**	**Population**	**Waste generation (kg/inh./day)**
2006	247,697	550,400	1.23
2007	362,477	574,400	1.73
2008	410,891	602,500	1.87
2009	370,502	605,300	1.68
2010	295,243	649,100	1.25
2011	290,022	697,200	1.14
2012	376,566	742,900	1.39

In 2012 experimental studies on waste generation in Astana were performed (Ministry of Regional Development, 2012). Based on the results the Astana city governor's office established new norm on the waste generation:

- 2.16 m^3/person/year for people living in apartment houses
- 2.33 m^3/person/year for people living in private houses.

The experimental measurements were performed by calculating the volume and weight of waste using special containers and waste collection cars. The data on mass and volume of waste was recorded daily and the data were used to determine the average weekly, monthly and seasonal norms. The density of the waste is 157 kg/m^3 (Ministry of Regional Development, 2012). Based on these data the waste generation is 353 kg/inh./year or 0.968 kg/inh./day.

As is evident, a fluctuation is observed in Table 1 on waste generation and a difference between the statistical data (based on waste collected) and actual data (normative, based on waste generated, experimentally measured). This discrepancy was investigated by the Ministry of Regional Development and it was revealed that actual values are higher than statistics values by 45% in 2011 (Ministry of Regional Development, 2012). These observations were explained by several factors as lack of weighing equipment for landfill of municipal solid waste that is causing inaccurate data and low collection rates by organized systems, which lead to a waste disposal at illegal dumps and does not allow for consideration of waste generated (Ministry of Regional Development, 2012). However, the trend in Astana is the opposite, i.e. actual data are lower than statistical data. Furthermore, the collection rate in Astana is high enough, estimated between 72-90%. A possible explanation is that population figure is underestimated and thus collection rates (kg/inh) appear higher. The booming construction activity in the city brings in an increasing number of commuting workers who generate waste but are not officially registered as citizens of Astana. Furthermore, statistics data are based on MSW which possibly contains large amount of construction and other commercial waste while the norms are based on purely household solid waste. The differences between MSW and household waste could be considerable, as for example 1.04 and 0.88 kg/inh/day in Korea (Zhang et al., 2010). Thus, the value of 1.39 kg/inh/day is used in the DSS tool.

The composition of domestic waste in Astana is presented in Table 2. MSW composition varies depending on weather conditions and season. In the fall amount of food waste increases markedly that is associated with the use of a population of more fruits and vegetables, but in the summer and spring the number of small dropouts (street debris) grows. The composition of MSW also has changed significantly over the time. So, the proportion of plastic materials and paper has increased recently, whereas coal and slag has almost disappeared (after the transition to centralized heating).

Table 2. MSW composition for major Kazakhstan and Chinese cities and other developing countries (Ministry of Regional Development, 2012; Al-Jarallah and Aleisa, 2014; Zhang et al., 2010; Saeed et al., 2009)

MSW composition (% wt)	**Astana (2012)**	**Almaty (2006)**	**Middle income countries**	**Hong Kong (2009)**	**Shanhai (2009)**	**Hangzhou (2009)**	**Kuala Lampur (2009)**	**Turkey (2006)**	**UAE (2013)**
Food wastes	28.0	23.0	20-65 (organic)	44.0 (organic)	66.7 (organic)	57.0	57.0	54.2 (organic)	39.0 (organic)
Landscaping wastes	1.5	2.0	-	-	-	-	-	-	-
Paper and cardboard	13.0	28.0	8-30	26.0	4.5	15.0	17.0	12.3	25.0
Plastic	18.5	14.0	2-6	18.0	20.0	3.0	15.0	13.2	19.0
Glass	14.5	9.0	1-10	3.0	2.7	8.0	1.0	6.3	4.0
Metals	0.9	2.0	1-5	2.0	0.3	3.0	2.0	3.0	3.0
Textile	9.5	1.0	2-10	3.0	1.8	2.0	1.0	-	-
Others	14.1	21.0	-	4.0	4.0	12.0	7.0	11.0	10.0

In order to calculate the prognosis of packing waste generated for Astana the proportion and composition of packaging waste in household waste is required. According to available data, in European countries, an average of about 35% of MSW is packaging waste (with great variations between countries) while 60% of the quantity of packaging waste is coming from population and 40% from industry, commerce and institutions. Data on packaging waste are presented in Table 3 (Ambarus et al., 2012; Akcay Han et al., 2010; Burnley et al., 2007; Magrinho and Semiao, 2008).

Table 3. The percentage of material type of packaging waste in mixed municipal or household (*) waste.

	Romania* (2006)	**Turkey Istanbul (2007)**	**Wales (2007)**	**Wales* (2007)**	**Portugal Lisboa (2008)**	**Average**
Paper/cardboard	3.2	13.0	5.1	6.1	7.1	8.4
Glass	3.0	4.7	5.3	6.7	5.5	5.2
Metal	1.3	1.4	2.0	3.0	1.3	1.6
Plastic	7.1	12.5	4.5	4.4	8.8	8.6
Composite	-	3	-	-	-	-
Wood	-	-	-	-	0.4	-
Total (% in mixed waste)	**14.6**	**34.6**	**16.9**	**20.2**	**23.1**	**23.8**

As expected the composition of packaging waste differs by region and in absence of local data the average of MSW is used in DSS tool. Based on the preceding analysis, the data for the Composition panel of DSS are as in Table 4.

Table 4. Input data regarding waste composition for Astana

Type	Composition (%)
Organics	28.0
Garden	1.5
Paper/cardboard (packaging)	8.4
Paper/cardboard (other)	4.6
Wood (packaging)	0.0
Wood (other)	0.0
Glass (packaging)	5.2
Glass (other)	9.3
Metal (packaging)	0.9
Metal (other)	0
Plastic (packaging)	8.6
Plastic (other)	9.9
Other	23.6

The waste that is collected is processed in the MBT plant or is directed to the landfil. The waste processing complex LLP «Altyn-TET» started its operation in the end of 2012 (Ministry of Regional Development, 2012). The projected capacity of the complex is 250-300 thousand tons/year i.e. 685-822 tons per day. The complex was projected to recover 20% of incoming waste, so the remaining 80% of waste is briquetted (compacted) and disposed to the landfill. The facility accepts mixed (not separated) solid waste and proceeds to separate out the recyclable materials. The recyclables are separated, and the remainder is compacted and disposed to the landfill. The compaction of the remaining waste allows decreasing the area required for the landfill.

In March 2013 the waste acceptance capacity of the plant was about 300- 380 tn/day. About 10-15% of the incoming waste is recycled (paper, plastic glass and metal), 40-55% is organic waste and 30-40% is considered residual and is briquetted and directed to the landfill. The recycling rate is much lower than the potential of the waste (46.9%), while organic waste is also lower than the statistics figure as presented in Table 1 (29.5%). According to the MBT plant operator, the explanation for low recycling rate is the low market demand and the potential of recycling is indeed higher. Based on the data provided by the MBT plant operator, the selling prices for separated recyclables are: PET 25-70 KZT/kg (0.10-0.28 €/kg), HDPE and LDPE 10-40 KZT /kg (0.04-0.16 €/kg), aluminum 50-130 KZT /kg (0.20-0.52 €/kg) and ferrous metals 10-30 KZT /kg (0.04-0.12 €/kg). According to governmental sources, the recyclables prices are: paper 3 KZT/kg (0.012 €/kg), metals 27 KZT/kg (0.108 €/kg), glass 5 KZT/kg (0.02 €/kg) and plastics 150 KZT/kg (0.6 €/kg). Additionally, current electricity export rate in the Republic of Kazakhstan is around 51 €/MWh for cogeneration systems (Astanaenergosbyt, 2014).

According to the current panning (early 2014), the waste acceptance capacity of the plant will be increased to 600-800 tn/day. Furthermore, treatment of separated recyclable materials will be made in the same facility. The feasibility of implementation of the biogas plant (anaerobic digestion) for organic waste treatment to the currently operating facility is under consideration. The implementation of the biogas plant will allow to increase the percentage of waste recovery to 50% and generate power.

It also is important to mention that the plan is to implement separation at source (at home) system in Astana starting in 2014.

Based on the analysis above, the data in Table 5 are used in the DSS tool.

Table 5. DSS input data

Parameter	Value
Waste generation per capita (kg/inh/day)	1.39
Annual waste generation growth (%)	3.33
Equivalent population	742,900
Population reference year	2012
Planning period (years)	20
Plastics price (€/tn)	236
Ferrous metals price (€/tn)	89
Aluminum (€/tn)	360
Glass (€/tn)	20
Paper (€/tn)	12
Electricity (€/kWh)	51
MBT capacity (early 2014, tn/y)	124,100

Finally, concerning final disposal, the operation of the old landfill started in 1972, whilst the newest landfill (first cell) started in 2006 and finished in 2012. On March, 2013 about 11 million tons of municipal solid waste was accumulated on the old landfill (Ministry of Regional Development, 2012). Currently the design specifications and calculations are performed for reclamation of the old landfill territory, which is expected to start in 2014 .The new landfill is built using modern technologies, including collection and utilization of generated methane system, rain water collection and wastewater treatment and drainage systems. The area of the new landfill is 50.4ha and it will consist of 4 cells. Currently the first cell with area 300*400 m and height 14 m is used. The projected capacity of first cell is 2 million tons of MSW with the projected life of 6 years. On March 2013 about 1.6 million tons of municipal solid waste was accumulated on the first cell of new landfill (Ministry of Regional Development, 2012). The construction of the second cell of new landfill is planned to be finished in 2014.

3.2 Kazakh legislative framework

Current policies that guide the management of solid waste in Kazakhstan include:

- Environmental Code of the Republic of Kazakhstan (with alterations and amendments as of 17.07.2009)
- Order of the Ministry of Health of the Republic of Kazakhstan № 555 dated 28.07.2010 on the approval of sanitary rules "Sanitary facilities requirements for domestic purposes"
- Resolution of the Government of the Republic of Kazakhstan dated March 6, 2012 № 291. On approval of the Sanitary Rules "Sanitary requirements for the collection, use, application, processing, transportation, storage and disposal of production and consumption waste".
- Sanitary rules of solid waste landfills organization and maintenance N 3.01.016.97 * 9 (Logged Sanitary requirements for the content of sites for solid waste approved by Order of the Acting Minister of Health of the Republic of Kazakhstan dated March 24, 2005 № 137).

- SN RK 1.04-15-2002. "Landfills for municipal solid waste".
- Program of Modernization of municipal solid waste management for the years 2013-2050.

The basis for the "Program of Modernization of municipal solid waste management for the years 2013-2050" are:

- Concept of transition of Kazakhstan to a green economy, approved by the President of the Republic of Kazakhstan dated May 30, 2013 № 577.
- P. 72 of Action Plan of the Government of Republic of Kazakhstan to implement the "Concept of transition of Kazakhstan to a green economy, approved by the President of the Republic of Kazakhstan" dated August 6, 2013 № 750.

This program aims to increase efficiency, reliability, environmental and social acceptability of MSW collection, transportation, processing and disposal services. According to the "Concept for transition of the Republic of Kazakhstan to Green Economy", to overcome the MSW challenge, the following measures should be implemented (Concept, 2013):

1. Perform detailed audit of all large MSW landfills and define rehabilitation measures.
2. Develop a state MSW recycling and disposal program covering the following aspects:
   - Set the target for MSW recycling of up to 40% by 2030 and 50% by 2050; and storage of residual MSW volumes at environmentally friendly and sanitary landfills with their share to increase to 100% by 2050 so that all landfills in the country comply with the most up-to-date environmental and sanitary requirements;
   - Introduce a household waste separation program for consumers;
   - Define a tariff calculation methodology which will cover operational costs and investments with a certain rate of return taking into account profit generated from recycled materials;
   - Implement the principles of a manufacturer's extended liability to cover a part of the costs of collection and disposal of packaging, electronic and electric equipment, transport vehicles, batteries, furniture and other used goods;
   - Develop a mechanism to attract investments, e.g., through public-private partnerships in big cities and at the level of municipalities in small populated centers, using budget resources to develop industry;
   - Enter into contracts for household waste management on a tender basis with a broad coverage of the territory;
   - Define public support measures for socially vulnerable groups when setting tariffs for MSW collection and disposal.
3. Update MSW recycling and storage standards using new technologies, such as anaerobics, composting and biogas.
4. Create a regulatory and legal framework to control MSW collection, transportation and storage until 2015.
5. Improve collection, processing and presentation of statistical information to monitor achievements of target indicators in MSW management.

As is evident, government's policy is in principle in line with European Union policies although, as expected, the targets timeline is much different (see paragraph below in paragraph 3.1). Taking into account that MSW legislation is undeveloped the targets set in DSS tool are derived from the European Union legislation, which is a solid and successful regulatory framework and can be a pilot for legislation development in Kazakhstan. Concerning the only quantified target for MSW recycling of up to 40% by 2030, it refers to national level, where the MSW management is underdeveloped, with about 25% MSW collection rate outside of the big cities and 97% of MSW taken to uncontrolled dumps and substandard authorized landfills without processing or recycling. In contrast, in Astana, which is the study area for the present research, is a city with well-developed MSW collection system achieving more than 90% collection rate and existing treatment facilities that recycle and recover more than 20% of incoming MSW. Thus, EU targets for 2020, as are presented below in paragraph 3.1, could be considered as feasible.

3. DECISION SUPPORT SOFTWARE METHODOLOGY

3.1 Structure and targets

The DSS tool is divided into different sections which correspond to the steps followed during the development of a waste management plan. The structure of the tool is presented in the following flow diagram (Figure 1).

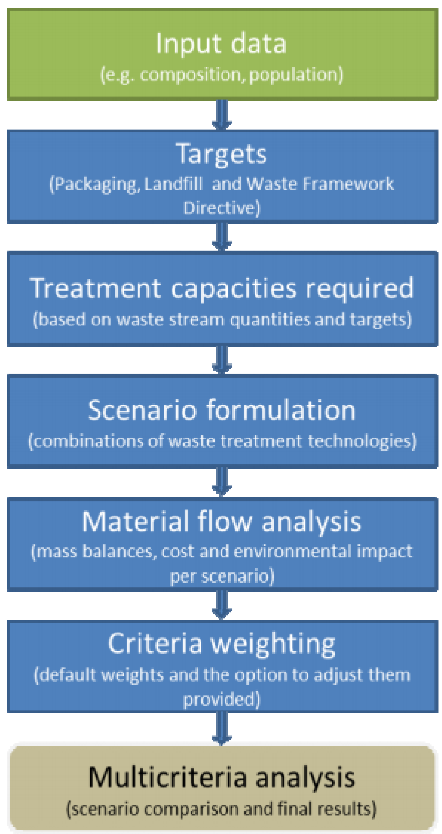


Figure 1. Structure of the DSS Tool

The definition of waste generation, waste composition and capacity of existing waste management facilities constitute the baseline of the DSS tool. In case that there is a lack of available data, suggested average values for the chosen country are provided. The DSS tool using the certain data inserted by the user displays analytical results for the achievement of targets and obligations derived from legislative/policy targets.

Recycling targets and obligations in DSS tool derived from existing European Union waste legislative framework and future policy priorities in solid waste management. The baseline for waste management planning through the DSS tool consists of the directives briefly described below.

Landfill Directive 1999/31/EC enforces the setup of a national strategy for the implementation of the reduction of biodegradable waste (BMW) going to landfills in a specific interval of time, by means of recycling, composting, biogas production or materials/energy recovery. The extended targets refer to years 2010-2013-2020 and in 2020, BMW going to landfills must be reduced to 35% of the total amount of BMW produced in 1995 for which standardized Eurostat data are available. DSS tool targets are based on this planning and the calculation of particular amounts of waste is based on the amounts of MSW and BMW produced in 1995 according to the projection of waste generation performed by the DSS tool with starting year 1995 until the last year of planning period.

Packaging Directive refers to 94/62/EC directive and focuses on the promotion of the use of packaging system, which can be reused without endangering the environment. Necessary measures must be taken, in order the packaging waste recycled by 2008 to be between 55% and 80% by weight (the target set in the DSS tool is minimum 60%). In order for the aforementioned restrictions to be fulfilled until the deadlines set (2008/2011), the following values were set for recycling via diversion for packaging waste:

- Paper and Cardboard -Packaging (%) must be more than 60%
- Glass-Packaging (%) must be more than 60%
- Metal-Packaging (%) must be more than 50%
- Plastics-Packaging (%) must be more than 22.5%
- Wood-Packaging (%) must be more than 15%

Waste Framework Directive refers to 2008/98/EC and encourages countries to take the necessary measures designed to achieve by 2020, the preparing for reuse and recycling of waste materials, such as at least paper, metal, plastic and glass from households and possibly from other origins as far as these waste streams are similar to waste from households, shall be increased to a minimum of overall 50% by weight.

3.2 Scenarios formulation

DSS tool includes three main waste streams for waste management planning with corresponding waste treatment facilities (Table 6).

Table 6. Description of technologies (Panagiotidou et al., 2012)

Technology Index	Technology Description	Biowaste	Packaging waste	Residual waste
Tech.1	Composting	✓		
Tech.2	Anaerobic digestionD	✓		
Tech.3	Material Recovery Facility (MRF)		✓	
Tech.4	Aerobic Mechanical and Biological Treatment (MBT)-Composting-Recyclables			✓
Tech.5	Aerobic Mechanical and Biological Treatment (MBT)-Composting-RDF			✓
Tech.6	Anaerobic Mechanical and Biological Treatment (MBT)-AD-Recyclables			✓
Tech.7	Anaerobic Mechanical and Biological Treatment (MBT)-AD-RDF			✓
Tech.8	Biodrying			✓
Tech.9	Incineration			✓

Based on the available best practices and EU legislation targets the methodology for the formulation of the scenarios is the following:

1. Obligatory separation at source and recovery of materials in a material recovery facility (plastic, paper, glass, metal)
2. Obligatory separation at source of biowaste and treatment in a biological treatment facility (composting or anaerobic digestion)

3. Treatment of the residual waste in one or combination of two of the following options (% capacity of each option is defined by the user):
   - MBT-composting-recyclables
   - MBT-composting-RDF
   - MBT-anaerobic digestion-recyclables
   - MBT-anaerobic digestion-RDF
   - Biological drying (production of SRF)
   - Incineration
4. Landfilling or incineration (waste-to-energy) of the residues/RDF/SRF

First two steps are obligatory while several possible scenarios can be formulated by combining the rest of options. Six main scenarios can be developed which are the basis for the alternative management scenario that are integrated in the DSS tool. Additional scenarios can be developed by combining certain elements of the main scenarios.

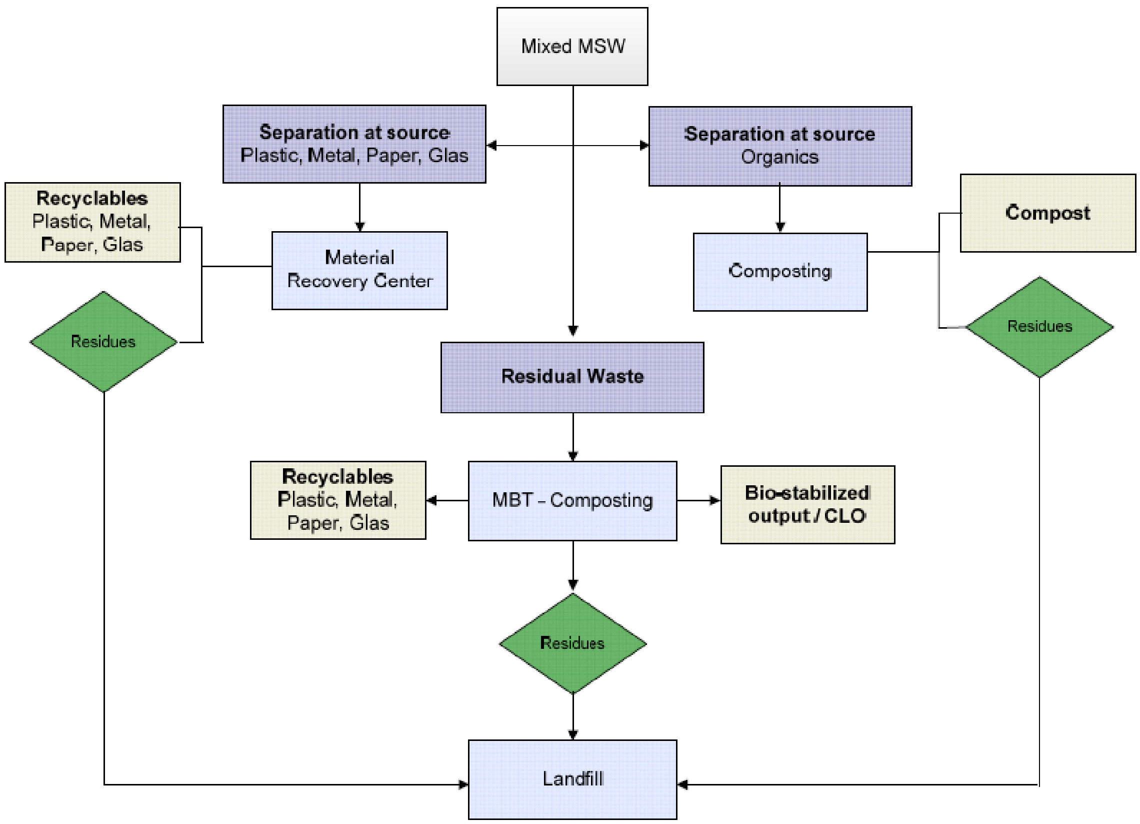


Figure 2. Example of an alternative scenario

The scenarios can comprise of different technologies for the treatment of the waste and based on economic and technical restrictions, the DSS tool allows or rejects the selection of particular technologies or combination of technologies for formulation of alternative scenarios (viability check based on required facility capacity). The key parameters that should be taken into account, are the amounts of total waste, biowaste, packaging and residual waste to be treated at the year 2020, according to the prediction for waste generation. Finally, after the definition of viable scenarios a Material Flow Analysis (MFA) per scenario is performed. The outputs of the MFA, such as environmental impact, costs, energy and mass balance, can be visualized by numeric results in tables for all formulated scenarios or by flow diagram for each scenario.

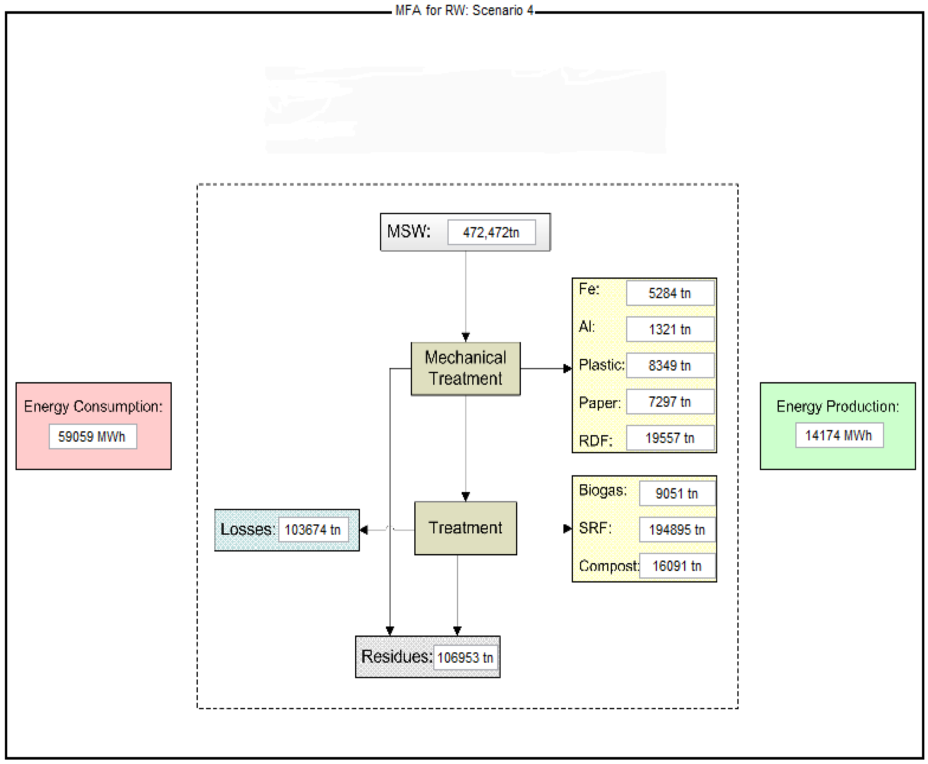


Figure 3. Example of MFA flow diagram (see: Scenario 4 below)

For the purpose of comparative assessment of alternative scenarios Economical, Environmental, Technical, Social and Legislative criteria have been developed (Panagiotidou et al., 2012). The tool evaluates the formulated scenarios based on a set number of 28 quantitative and qualitative criteria. The user is able to modify the rates of each criterion in order to depict the local needs and priorities regarding waste management. The established set of criteria can be separated to quantitative and qualitative criteria, according to the type of measurement scale used to express the performance of alternatives. It is important to notice that, for the particular study, each criterion is expressed in its own units taking into account that the evaluation of alternatives for each criterion which represents the qualitative information is based on evaluation scale (Hokkanen and Salminen, 1997).

The DSS tool provides default evaluations per technology for each qualitative criterion, which rely on the studies concerning waste management status in south-east European countries but the user can modify these evaluations by changing the rating/evaluation (0-100) per waste treatment technology. More particularly, the rating method requires the user to evaluate criteria on the basis of a predetermined scale (0-100) with 0 point to represent “very low” performance, whereas 100 point “very high” performance (Panagiotidou et al., 2012). In the present study the default ratings form the BALWASTE project were adopted (Alevridou et al. 2011).

After the criteria have been identified and scored, the next step is their weighting. The method of weight assignment is indirect, meaning that it is performed by means of questionnaires distributed to the competent waste management authorities and other stakeholders involved, in order to achieve a classification of the evaluation criteria. The user is provided with the ability to modify default weights or use different weights to each criterion. Once the user determines the value (1-100) for a criterion, the DSS tool calculates the corresponding weight in percentage (%) based on normalization of the weights for all the criteria so that the sum of weights always remains 100%. After consultation with the local authorities and waste management experts the proposed weights for all the criteria are presented in Figure 5.

Environmental Criteria	Rating (1-100)	Weights (%)
Greenhouse Gas Emissions (tn CO2 eq...	60	4.84
Emissions to air (tn SO2 eq./tn)	60	4.84
Conventional Fuel Savings (toe/tn)	10	0.81
Wastewater Generation (1-100 min)	10	0.81
Water Consumption (m3/tn)	20	1.61
Production of Non-hazardous waste-R...	60	4.84
Production of Hazardous Residues (% ...	40	3.23
Noise Pollution (1-100 min)	10	0.81

☐ Default values

Technical Criteria	Rating (1-100)	Weights (%)
Existing Experience-Reliability (1-100 m...	50	4.03
Adaptability to Local Conditions (1-100 ...	50	4.03
Flexibility (1-100)	60	4.84
Energy Consumption (kwh/tn)	50	4.03
Energy Production (kwh/tn)	50	4.03
Secondary Products (% input)	60	4.84
Correlation with Recycling Activities (1...	60	4.84

☐ Default values

Economical Criteria	Rating (1-100)	Weights (%)
Capital Expenditure (euro/tn)	70	5.65
Operation&Maintenance Cost (euro/tn)	70	5.65
Revenues from Products (euro/tn)	80	6.45
Land Requirement (m2/tn)	10	0.81
Market Prospect of Products (1-100 ma...	70	5.65
External Costs&Benefits (euro/tn)	20	1.61

☐ Default values

Social Criteria	Rating (1-100)	Weights (%)
Social Acceptance (1-100 max)	50	4.03
Visual Impact (1-100 min)	10	0.81
Risk Perception (1-100 min)	40	3.23
Employment Quality (1-100 min)	30	2.42
Creation of New jobs (1-100 max)	30	2.42

☐ Default values

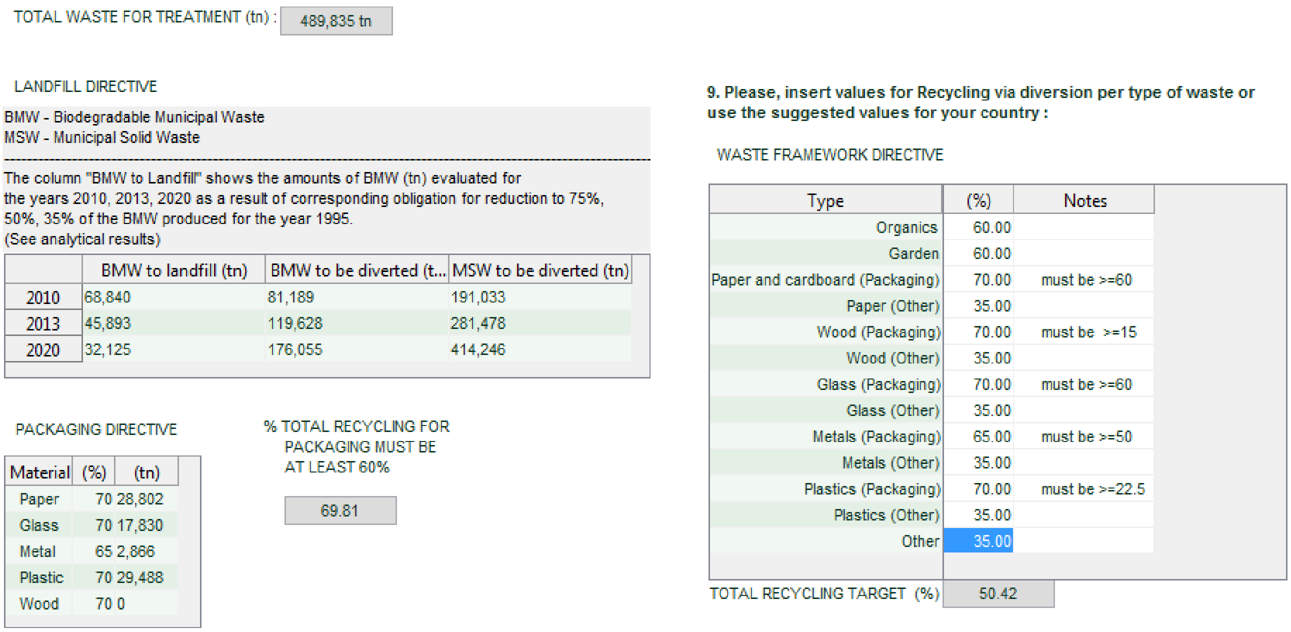
Legislative Criteria	Rating (1-100)	Weights (%)
Harmonization with the Priorities of the ...	100	8.06
Contribution to the Landfill Directive Tar...	10	0.81

☐ Default values

Figure 5. Criteria weights for the implementation of the DSS Tool

4. RESULTS AND DISCUSSION

In the Figures 6 and 7, the required recycling rates for recyclables, total recyclables rate, total recycling rates and capacities for the additional facilities needed in order to reach the targets for the year 2020 set are presented.


TOTAL WASTE FOR TREATMENT (tn) : 489,835 tn

LANDFILL DIRECTIVE

BMW - Biodegradable Municipal Waste
MSW - Municipal Solid Waste

The column "BMW to Landfill" shows the amounts of BMW (tn) evaluated for the years 2010, 2013, 2020 as a result of corresponding obligation for reduction to 75%, 50%, 35% of the BMW produced for the year 1995.
(See analytical results)

	BMW to landfill (tn)	BMW to be diverted (t...	MSW to be diverted (tn)
2010	68,840	81,189	191,033
2013	45,893	119,628	281,478
2020	32,125	176,055	414,246

PACKAGING DIRECTIVE

Material	(%)	(tn)
Paper	70	28,802
Glass	70	17,830
Metal	65	2,866
Plastic	70	29,488
Wood	70	0

% TOTAL RECYCLING FOR PACKAGING MUST BE AT LEAST 60%

69.81

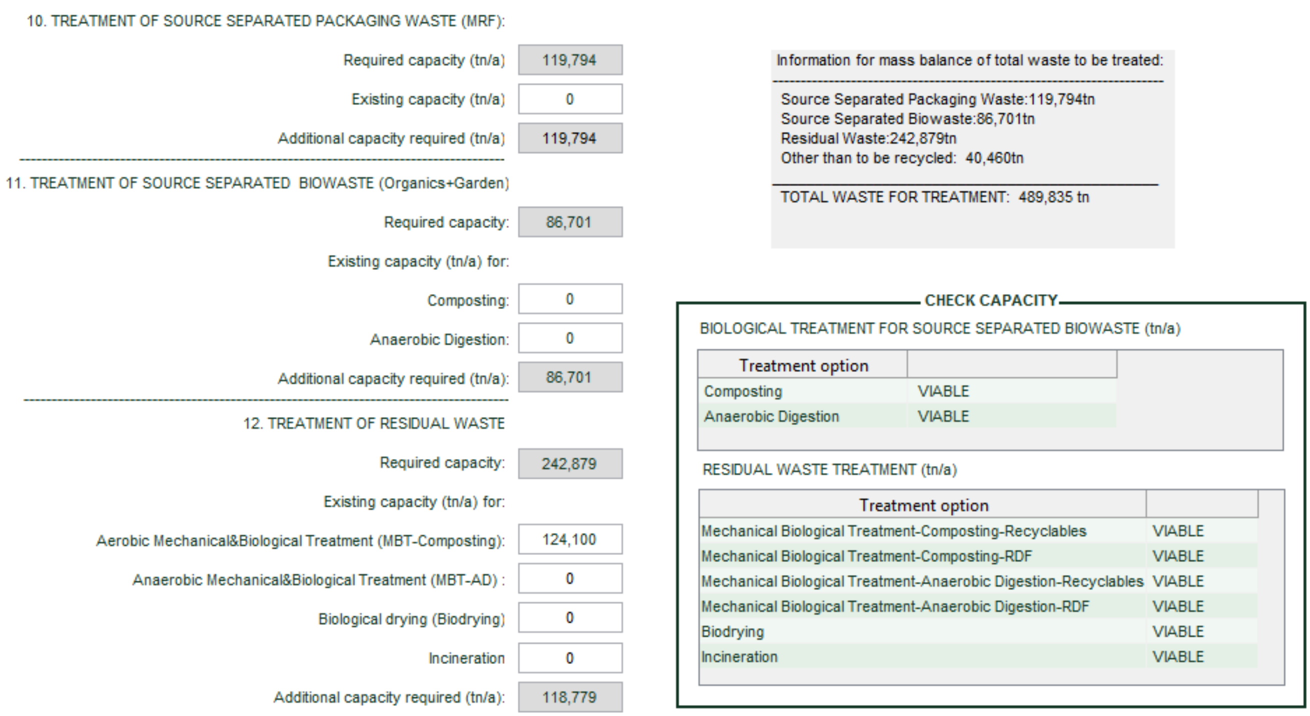
9. Please, insert values for Recycling via diversion per type of waste or use the suggested values for your country :

WASTE FRAMEWORK DIRECTIVE

Type	(%)	Notes
Organics	60.00	
Garden	60.00	
Paper and cardboard (Packaging)	70.00	must be >=60
Paper (Other)	35.00	
Wood (Packaging)	70.00	must be >=15
Wood (Other)	35.00	
Glass (Packaging)	70.00	must be >=60
Glass (Other)	35.00	
Metals (Packaging)	65.00	must be >=50
Metals (Other)	35.00	
Plastics (Packaging)	70.00	must be >=22.5
Plastics (Other)	35.00	
Other	35.00	

TOTAL RECYCLING TARGET (%) 50.42

Figure 6. Targets and required recycling rates


10. TREATMENT OF SOURCE SEPARATED PACKAGING WASTE (MRF):

Required capacity (tn/a)	119,794
Existing capacity (tn/a)	0
Additional capacity required (tn/a)	119,794

11. TREATMENT OF SOURCE SEPARATED BIOWASTE (Organics+Garden)

Required capacity:	86,701
Existing capacity (tn/a) for:	
Composting:	0
Anaerobic Digestion:	0
Additional capacity required (tn/a):	86,701

12. TREATMENT OF RESIDUAL WASTE

Required capacity:	242,879
Existing capacity (tn/a) for:	
Aerobic Mechanical&Biological Treatment (MBT-Composting):	124,100
Anaerobic Mechanical&Biological Treatment (MBT-AD) :	0
Biological drying (Biodrying)	0
Incineration	0
Additional capacity required (tn/a):	118,779

Information for mass balance of total waste to be treated:

Source Separated Packaging Waste:119,794tn
Source Separated Biowaste:86,701tn
Residual Waste:242,879tn
Other than to be recycled: 40,460tn

TOTAL WASTE FOR TREATMENT: 489,835 tn

CHECK CAPACITY

BIOLOGICAL TREATMENT FOR SOURCE SEPARATED BIOWASTE (tn/a)

Treatment option	
Composting	VIABLE
Anaerobic Digestion	VIABLE

RESIDUAL WASTE TREATMENT (tn/a)

Treatment option	
Mechanical Biological Treatment-Composting-Recyclables	VIABLE
Mechanical Biological Treatment-Composting-RDF	VIABLE
Mechanical Biological Treatment-Anaerobic Digestion-Recyclables	VIABLE
Mechanical Biological Treatment-Anaerobic Digestion-RDF	VIABLE
Biodrying	VIABLE
Incineration	VIABLE

Figure 7. Existing and required facilities capacities

After the basic data are defined for the case study of Astana, formulation of alternative scenarios can be performed (Figure 1). Obviously, based on the current planning, Scenario 1 is MBT-AD-Recyclables (100%) and landfilling of the residual waste. MBT capacity is considered to be 124,100 tn/y, i.e. the average before expansion (early 2014 capacity). Taking into account the governmental policy for separation at source, it can be assumed that this base scenario will be soon accompanied by MRF and composting or anaerobic digestion facilities for treatment of the separated recyclables and biowaste, respectively.

BIOWASTE	PACKAGING WASTE	RESIDUAL WASTE:	Other waste (tn)
Capacity (tn):	Capacity (tn):	Capacity (tn):	
86,701	119,794	118,779	40,460

	Biowaste	Packaging w...	Technology for Facility1	% for Faciltity1	Technology for facility2	% for Facility2	RDF/SRF treatment
1	Composting	MRF	MBT-AD-Recyclables	100.00		0.00	Landfilling
2	AD	MRF	MBT-AD-Recyclables	100.00		0.00	Landfilling
3	Composting	MRF	MBT-AD-Recyclables	100.00		0.00	Waste to Energy
4	AD	MRF	MBT-AD-Recyclables	100.00		0.00	Waste to Energy
5	Composting	MRF	MBT-AD-Recyclables	50.00	MBT-Composting-Recyclat	50.00	Landfilling
6	Composting	MRF	MBT-AD-Recyclables	50.00	MBT-Composting-Recyclat	50.00	Waste to Energy
7	AD	MRF	MBT-AD-Recyclables	50.00	MBT-Composting-Recyclat	50.00	Waste to Energy

Figure 8. Screenshot of the DSS tool – Alternative scenarios formulation.

The scenarios that were examined during the application of the tool in Astana are presented below.

➢ Scenario 1
- Composting for bio-waste
- MRF for packaging waste
- Mechanical biological treatment-anaerobic digestion with recyclables recovery for residual waste
- Landfilling for RDF/SRF

➢ Scenario 2
➢ Anaerobic digestion for bio-waste
➢ MRF for packaging waste
➢ Mechanical biological treatment-anaerobic digestion with recyclables recovery for residual waste
➢ Landfilling for RDF/SRF

➢ Scenario 3
- Composting for bio-waste
- MRF for packaging waste
- Mechanical biological treatment-anaerobic digestion with recyclables recovery for residual waste
- Waste-to-Energy for RDF/SRF

➢ Scenario 4
- Anaerobic digestion for bio-waste
- MRF for packaging waste

- Mechanical biological treatment-anaerobic digestion with recyclables recovery for residual waste
- Waste-to-Energy for RDF/SRF

➢ Scenario 5
- Composting for bio-waste
- MRF for packaging waste
- Mechanical biological treatment-anaerobic digestion with recyclables for 50% of the residual waste
- Mechanical biological treatment-composting with recyclables recovery for 50% of the residual waste
- Landfilling for RDF/SRF

➢ Scenario 6
- Composting for bio-waste
- MRF for packaging waste
- Mechanical biological treatment-anaerobic digestion with recyclables for 50% of the residual waste
- Mechanical biological treatment-composting with recyclables recovery for 50% of the residual waste
- Waste-to-Energy for RDF/SRF

➢ Scenario 7
- Anaerobic digestion for bio-waste
- MRF for packaging waste
- Mechanical biological treatment-anaerobic digestion with recyclables for 50% of the residual waste
- Mechanical biological treatment-composting with recyclables recovery for 50% of the residual waste
- Waste-to-Energy for RDF/SRF

The results of the application of the DSS Tool are presented in Figure 9. Based on the weights assigned to the tool the proposed scenario is number 7 followed closely by 4.

RANKING OF ALTERNATIVE SCENARIOS:

	Ranking	Net Flow
Optimum	Scenario7	0.0626
	Scenario4	0.0600
	Scenario6	0.0394
	Scenario3	0.0245
	Scenario5	-0.0477
	Scenario2	-0.0508
	Scenario1	-0.0879

PREFERENCE

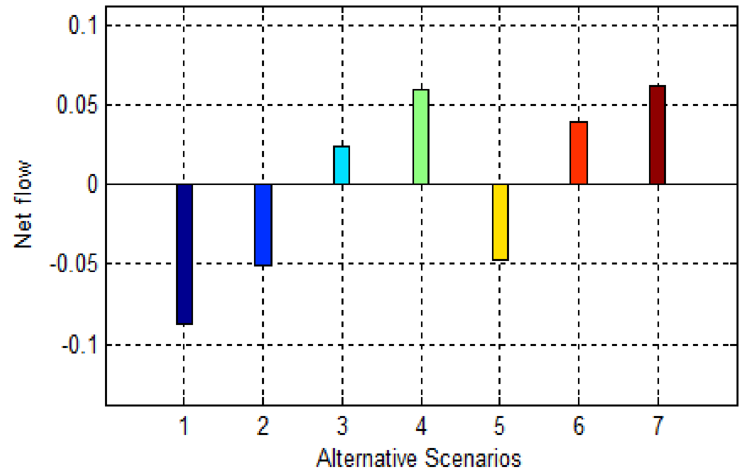


Figure 9. Results of the application of the DSS Tool

In Figure 10, the material flow analysis (MFA) and basic financial data for the best scenario are presented.

Material Flow Analysis (MFA)

...	...	...	Scenario4	...	...	Scenario7
...	AD	...	AD	...	...	AD
...	...	...	MRF	...	...	MRF
...	...	...	100%MBT-AD-Rec.	...	...	50%MBT-AD-Rec.
--	--	--	--	...	...	50%MBT-Composting-Recyc...
...	...	...	RDF/SRF-WasteToEnergy	...	...	RDF/SRF-WasteToEnergy

Mass Balance	Scenario4	Scenario7
Total RECYCLABLES:	118,696	118,696
1. Fe (tn)	2,790	2,790
2. Ai (tn)	130	130
3. PLASTIC (tn)	50,454	50,454
4. PAPER (tn)	38,301	38,301
5. Glass (tn)	27,020	27,020
6. Wood (tn)	0	0
RDF (tn)	17,397	17,397
SRF (tn)	0	0
Low Quality COMPOST (t...	9,045	9,045
High Quality COMPOST (t...	26,010	26,010
BIOGAS (tn)	18,093	15,549
LOSSES (tn)	50,096	52,640
RESIDUES (tn)	85,936	85,936
Required landfill capacity ...	89,842	89,842

Costs&Revenues		Scenario4	Scenario7
CAPITAL EXPENDITURE (euro)		92,806,729	81,047,608
ANNUAL OPERATION&MAINTENANCE COST (euro)		19,759,105	17,680,473
REVENUES FROM PRODUCTS (euro):	Plastic	11,907,261	11,907,261
	Fe	248,307	248,307
	Al	46,887	46,887
	Glass	1,080,816	1,080,816
	Paper	459,609	459,609
	Energy revenues	1,717,400	1,353,936
	Compost	245,389	245,389
	RDF/SRF Disposal Costs	521,911	521,911
	Residues Disposal Costs	2,148,401	2,148,401
TOTAL OPERATIONAL COST (euro)		6,723,750	5,008,581
LAND REQUIREMENT (m2)		150,556	162,434

Environmental Impacts	Scenario4	Scenario7
GHG (tn eq./a)	-133,865	-132,833
EMISSION TO AIR (tn SO2 eq./a)	-107	-125
CONVENTIONAL FUEL SAVINGS (toe/a)	-3,576	-3,274
WATER CONSUMPTION (m3/a)	17,531	15,452
HAZARDOUS WASTE (tn/a)	0	0

Energy Balance	Scenario4	Scenario7
ENERGY CONSUMPTION (MWh)	17,266	16,078
ENERGY PRODUCTION (MWh)	33,675	26,548
ENERGY BALANCE (MWh)	16,409	10,470

Figure 10. Material flow analysis form the first two scenarios (4 and 7)

5. CONCLUSIONS

One of the major advantages of the DSS tool is its simplicity so that non-specialists in the field of waste management can participate in designing and assessing various waste management schemes. Although minimal, the degree of involvement of decision-maker is important, as he is responsible for the setting of qualitative criteria and weighing. Moreover, the design of graphical user interface of DSS tool was given a great importance, taking into account that the user must be attracted to use the DSS tool by its user-friendliness. The application of DSS tool provides the valuable possibility to test the tool, by changing various preference parameters and visualize the influence of these parameters on final ranking. However, it must be underlined that the objective of DSS tool is not to provide absolute solutions, but assist the decision-makers to evaluate alternatives.

The application of the DSS tool on Astana demonstrated that the current planning for needs to be reconsidered and landfilling of RDF/SRF to be replaced by waste-to-energy options. The treatment technologies proposed are MRF for source separated recyclables, anaerobic digestion for source separated bio-waste, anaerobic (or combined composting-anaerobic digestion) MBT with recyclables separation for residual waste, and waste-to-energy utilization for RDF/SRF. It can be concluded that the DSS Tool can offer support for decision makers not only for planning process, but also for the assessment of adopted solutions.

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