# Greece confronted with the new Waste Framework Directive

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**Abstract**
This study assessed greenhouse gas emissions of different municipal solid waste treatment technologies currently under assessment in the new regional plan for Attica in the frame of addressing the country's contemporary waste management challenges.

**Keywords**
Greenhouse gas emissions, waste management scenarios.

# 1 Introduction

Waste management (WM) activities and especially disposal of waste in landfills that generates methane ($CH_4$) contribute to global Greenhouse Gas (GHG) emissions approximately by 4%. In Greece, the main method of solid WM remains landfilling; apart from this, 22 Material Recovery Facilities (MRF) are in operation for source segregated recyclables, 5 Mechanical-Biological Treatment (MBT) plants exist in 2010 (4 operating) and 8 more MBT are planned and expected to be constructed in the period between 2010 and 2020. In Attica Region (Greater Athens area) 2,200,000 t Municipal Solid Waste (MSW) (wet weight) were generated in 2008, of which 12% were recycled and 350,000 t were treated in the existing MBT plant (Figure 1). Taking into account the current Hellenic WM policy, the forecasted population growth and the anticipated waste growth, 2,800,000 t MSW are expected to be generated annually by 2030 (Figure 1). Considering the above, new WM infrastructure is necessary in order to meet the targets of the Landfill Directive 99/31/EC. The aim of the present study is to assess the GHG emission impacts of the proposed technologies for the Integrated Waste Management Centre (IWMC) in W. Attica in the context of different scenarios. The waste treatment technologies include Mass-Burn Incineration-Waste-to-Energy (WtE), Mechanical Treatment (MT) and MBT. The MBT process may be either aerobic composting or anaerobic digestion (AD) or bio-drying. Within this study MBT with aerobic composting is defined as MBT(C), MBT with AD as MBT(AD) and MBT with bio-drying MBT(BioD). Within this study, the term Solid Recovered Fuel (SRF) is used for fuels derived by MBT(BioD) while the term Refuse Derived Fuel (RDF) is used for fuels derived by MT, MBT(C) and MBT(AD) plants.

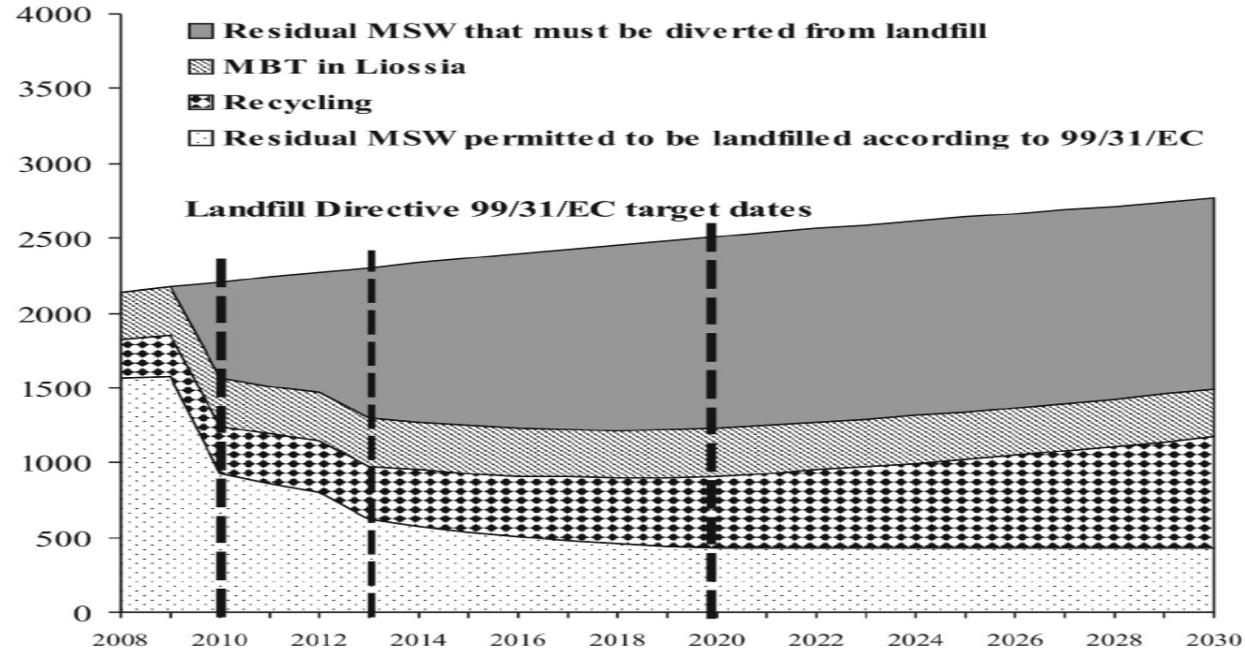


*Figure 1* *Foreseen MSW management in Attica until 2030 according to existing facilities*

## 2 Materials and methods

The present study aimed to quantify Carbon Dioxide ($CO_2$), Methane ($CH_4$) and Nitrous oxide ($N_2O$) emissions from WM activities in 5 Attica scenarios under assessment. For the quantification of GHG emissions from the treatment of MSW in each of the scenarios, a validated methodology (Papageorgiou et al, 2009) was adopted and Emission Factors (EFs) were sourced from previous studies that assessed the GHG emissions impact of MSW treatment technologies and were applied in this study adjusted to the Hellenic MSW composition. Five scenarios described next were compiled. The MSW management system for each of the scenarios is presented in Figure 2.

**Scenario 1:** 400,000 t of residual MSW are treated in a MBT(C) plant and 700,000 in a WtE. MBT(C) outputs include ferrous and aluminium metals, bio-stabilised output, residues and RDF. Metals are recovered for recycling, while the bio-stabilised output and residues are disposed in a landfill, whilst RDF substitutes coal in a cement kiln. In the WtE plant, the ferrous metals recovered from the bottom ash are sent to a reprocessor for recycling, whilst the bottom ash and the APC ash are both landfilled in a sanitary and a hazardous landfill cell respectively. The WtE plant recovers electricity only with a net electrical efficiency of 22,6 % (related to the NCV of waste), in order to be qualified as recovery operation according to the requirements new Directive on Waste (2008/98/EC) (Karagiannidis et al, 2009)

**Scenario 2:** 400,000 t of residual MSW are treated in a MBT (AD) and 700,000 t in a WtE. MBT(AD) outputs are ferrous and aluminium metals, residues and bio-stabilised output that are disposed to landfill, RDF that substitutes coal in cement kilns and biogas combusted for electricity generation with efficiency 37%. It is assumed that 33% of the produced electricity is used in-house for plant operation and 65% is exported to the grid.

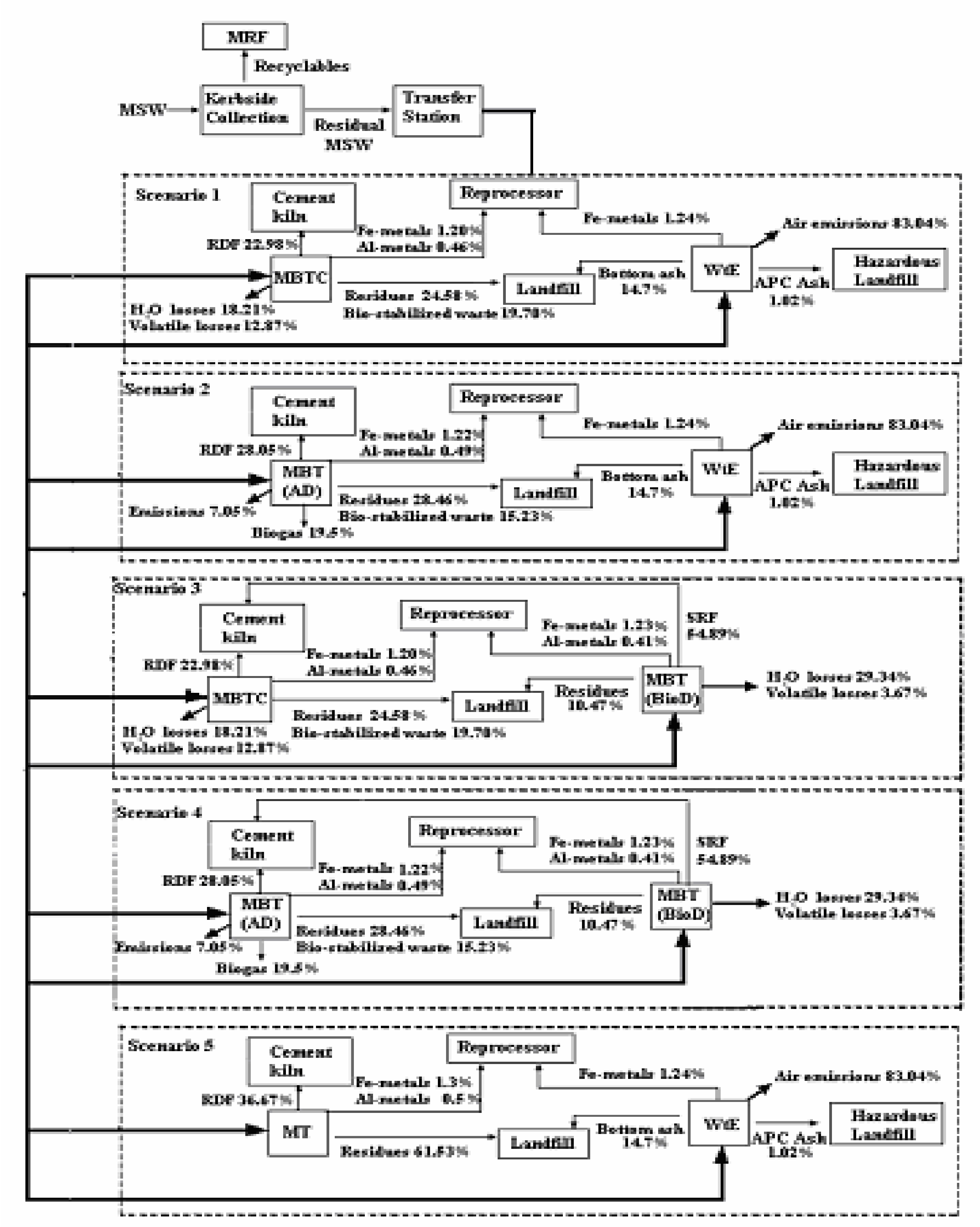


*Figure 2 Waste management scenarios for the IWMC in west Attica.*

**Scenario 3:** 400,000 t of residual MSW are processed in a MBT(C) (like Scenario 1) and 700,000 t in a MBT (BioD). MBT (BioD) outputs are metals sent for recycling, residues disposed to landfill and SRF that substitutes coal in a cement kiln. Ash from SRF combustion in the cement kiln is included in clinker production.

**Scenario 4:** 400,000 t of residual MSW are treated in a MBT(AD) (like Scenario 2) and 700,000 in a MBT(BioD) (like Scenario 3).

**Scenario 5:** 250,000 t of residual MSW are processed in a MT plant and 850,000 in a WtE. MT outputs are metals sent for recycling, RDF and residues that are landfilled.

In this study it was assumed that the treatment plants in each scenario treat residual MSW, after kerbside collection. For the estimation of the future residual MSW composition, it was assumed that the targets set by the Packaging Waste Directive (99/42/EC) would be met and hence 60% w/w of packaging glass, 60% w/w of paper and cardboard, 50% metals w/w, 22,5% w/w plastic and 15% w/w wood would be recycled. The residual MSW is taken as the input to the WM system of each scenario. MSW in Greece consists of: 29% paper and card, 40% kitchen and garden waste, 14% plastic, 3% inert, 2% leather wood, textiles and rubber, 3% glass, about 3% ferrous metals, 0,5% non-ferrous metals and 6% other materials. Based on the residual MSW composition, mass balances for each of the examined scenarios were compiled and are shown in Figure 2. For the quantification of GHG emissions from the treatment of residual MSW in each scenario the methodology presented in Papageorgiou et al, 2009 was applied. The EFs (kg $CO_2$-eq/t of MSW treated) were estimated for all activities involved in the WM system of every examined scenario and converted to $CO_2$-eq using global warming potentials for a 100-year time frame.

*Table 1 Direct and indirect emission impacts included in the model*

| Process | Indirect-up-stream impacts | Direct impacts | Indirect–down-stream- impacts |
|---|---|---|---|
| **MBT (C)** | $CO_2$ emissions ($E_{CO2)}$ associated with electricity provision | 1. $E_{CO2}$ from fossil fuels combustion for waste treatment<br>2. $CH_4$ and $N_2O$ from composting<br>3. $E_{CO2}$ from combustion of fossil carbon in RDF<br>4. $CH_4$ emissions ($E_{CH4}$) (landfilling)-$CO_2$ from fuels consumption–no $CH_4$ | 1. $CO_2$ savings from metals recycling and from substitution of fossil fuels (coal) by RDF in cement kilns |
| **MBT (AD)** | Electricity for the operation of plant is provided by the electricity generated by the combustion of biogas | 1. $E_{CO2}$ from fossil fuels combustion<br>2. Efficient recover of $CH_4$ from digestion - no leakage takes place<br>3. $E_{CO2}$ from combustion of fossil carbon in RDF<br>4. $E_{CH4}$ from residues landfilling-$CO_2$ from fuels consumption-biostabilized output does not generate methane | 1. $CO_2$ savings from electricity substitution (biogas combustion)<br>2. $CO_2$ savings from metals recycling and coal substitution by RDF in cement kilns |

| | | | |
|---|---|---|---|
| **MBT (BioD)** | $E_{CO2}$ associated with electricity provision | 1. $E_{CO2}$ from fossil fuels combustion<br>2. $E_{CO2}$ from the combustion of fossil carbon in SRF<br>3. $E_{CH4}$ from landfilling of residues - $CO_2$ from fuels consumption | 1. $CO_2$ savings from metals recycling and from substitution of fossil fuels (coal) by SRF in cement kilns |
| **WtE** | Electricity for the operation of plant is provided by the electricity produced on-site | 1. $E_{CO2}$ from the combustion of waste fossil fraction and fossil fuels for WM<br>2. $N_2O$ emissions<br>3. $E_{CO2}$ from fuels consumption for landfill operation where ash is disposed | 1. $CO_2$ savings from electricity substitution and from recycling of ferrous metals recovered from bottom ash |
| **MT** | $E_{CO2}$ associated with electricity provision | 1. $E_{CO2}$ from fossil fuels combustion<br>2. $E_{CO2}$ from the combustion of fossil carbon in RDF<br>3. $E_{CH4}$ from residues landfilling-$E_{CO2}$ from fuels consumption and electricity | 1. $CO_2$ savings from metals recycling and coal substitution by RDF in cement kilns |

# 3 Results and discussion

From figure 3, it can be seen that all scenarios under assessment in this study could generate GHG emission savings. Scenarios 3 and 4 perform better, followed by 2, 1 and 5. Scenario 3 incorporates MBT(C) with RDF production and MBT(BioD) with SRF production. Both fuels were assumed to substitute coal in cement kilns or paper mills. In general, the performance of all scenarios and especially scenarios 3 and 4 are strongly dependent on the existence of a market for the produced RDF and SRF. However the market for these fuels is extremely volatile and there many cases where these fuels end up in landfills instead of being utilized for energy recovery.

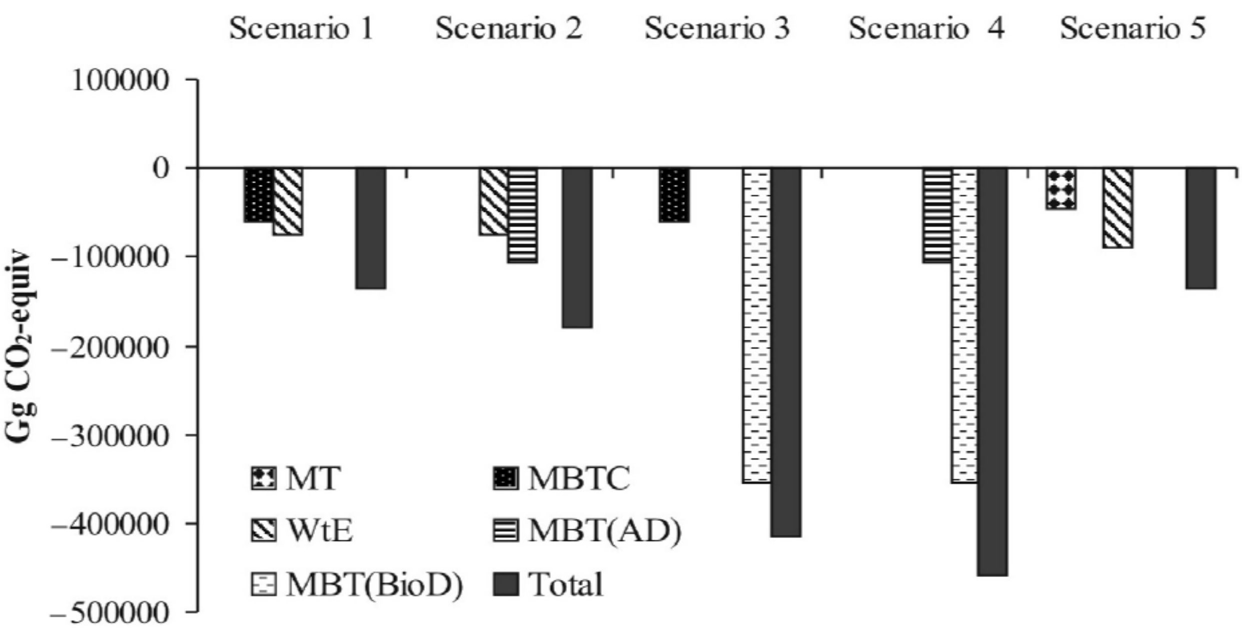


*Figure 3 GHG emissions (kg CO2-eq.) for all five scenarios*

The sensitivity analysis aimed to evaluate what would be the GHG emission impact in the case where there is no end market for the produced RDF and SRF from the MT, MBT(C), MBT(BioD) and MBT(AD) plants in the assessed scenarios. In this case the GHG emission savings from the recovery of energy from these fuels should not be taken into account, whereas potential $CH_4$ production from the degradation of the biodegradable content of these fuels should be assessed, if they are finally disposed in a landfill. Especially a MBT(BioD) plant incorporates a bio-drying process, that does not reduce the biodegradable content of the waste or it reduces only a small amount of it, about 10% (Archer et al, 2005) and thus the disposal of SRF in landfill will surely generate $CH_4$. Moreover, RDF in the MBT(C) and MBT(AD) plants is recovered before the biological process and thus the biodegradation of their organic fraction due to disposal in landfills will generate $CH_4$ as well. In the analysis it was assumed that the WtE facilities in scenarios 1, 2, 5 will increase their capacity and finally combust the surplus RDF from the MBT(C), MBT(AD) and MT respectively. On the other hand in scenarios 3 and 4, where no thermal treatment plant is foreseen, it was assumed that the produced RDF and SRF will finally end up in landfill. The performance of all scenarios depends strongly on the existence of an end market for the recovered RDF and SRF. Especially scenarios 3 and 4 generate net GHG emissions and thus the treatment of residual MSW in these scenarios, offers no benefit, at least on GHG emission savings. Therefore, in the event that a SRF market does not exist, then probably further aerobic treatment for RDF and SRF will be necessary in order to reduce its biodegradable content, since they will be disposed in landfills. On the other hand, scenarios 1, 2 and 5 can provide GHG emission savings as they incorporate WtE and MBT(AD) which recover electricity for which the demand is constant.

# 4 Conclusions

The presented study has shown that all scenarios under assessment could save GHG emissions provided that there is an end market for the recovered RDF and SRF. In this case the co-incineration (e.g. in cement kilns or paper mills) of SRF from MBT (BioD) mainly and RDF from MBT(C), MBT(AD) and MT can generate significant emission savings. It should be also commented here that waste policy and planning in Greece for the moment does not promote waste minimization measures neither poses high recycling targets and instead promotes technologies and plants of large capacity that will treat mixed residual waste. Thus, the potentials of waste minimization measures such as home composting and Pay-As-You-Throw schemes in conjunction with new waste treatment plants should be utilised, combined with maximised recycling and reuse.

# 5 Literature


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