Proposal for Recycling and Energy Usage of Municipal Wastes in Greece

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Executive Summary

Greece is the only country out of the EU15 which has not applied yet energetic exploitation of Municipal Solid Wastes (MSW). Even though first steps in recycling are done, the resistance of the Greek communities and environmental organizations against Waste to Energy (WTE) installations is extremely strong. The EU community set in 2020 a deadline for the usage of landfilling as an accepted method for handling wastes. In addition, only in Attica within the next decade for the handling of the predicted 35-45 mio t municipal wastes, 7-8 additional landfilling areas of 500.000 m^2 each will be necessary! Even the operation of the already approved landfilling areas in Keratea and Grammatiko are blocked. Thus, WTE remains the only realistic solution!

Additionally, in the region of Attica 800 t/d dried sludge from biological sewage treatment plants (STP) are produced, temporarily landfilled and recently partially utilized in cement production.

The three biggest Greek cities, Thessaloniki, Patra and Volos face the same difficulties with their waste handling. The problem becomes even bigger when moving to the islands. Touristic regions like Rhodos, Kos, Patmos, Mykonos, Santorini, Kreta etc. have to handle an extraordinary waste amount during the summer period. Landfilling, is most of the times in the islands inapplicable due to the lack on free land. Thus, uncontrollable burning is performed in most cases, e.g. in Kos where, besides the side effects on public health, the Asklipeiion of the father of Medicine Ippocrates is frequently covered by thick smoke.

Solutions in the frames of WTE implementation and STP sludge utilization, including sun drying of the sludge in the islands, taking into consideration the geographical and population distribution in Greece are proposed. Furthermore, regarding the STP sludge management, the feeding of the sludge to hard coal electrical power generation units to be installed in coastal areas in eastern and western part of Greece is described.

The fact that according to initial discussions the mayors of Ano Liosia (landfill of Attica), Patras, Rhodos, Kalymnos trust the WTE technology and are willing to proceed with such investments is very encouraging.

A pre-feasibility study for each WTE case is provided.

INTRODUCTION

MSW and STP Sludge Management in Greece Today

The main characteristic of MSW management in Greece is that over 90% results in landfilling as presented in **Figure 1,** significantly higher than the average landfilling level in EU 27, which reached 62% in 1995 and decreased to 40% in 2007 [1]. Unfortunately, the MSW landfilling in more than 1300 cases has been preformed illegally (2005 data) [2]. In the meantime progress due to strict EU environmental legislations and foreseen penalties by disobedience has been accomplished. Special program for the rehabilitation of the illegal landfills, **Figures 2a,b** has been issued by the

Greek Ministry of Environment. By April 2006 almost 90% of the total number of sites of the condemnatory decision of the Court of Justice of the European Communities was decided to cease their operation [3].

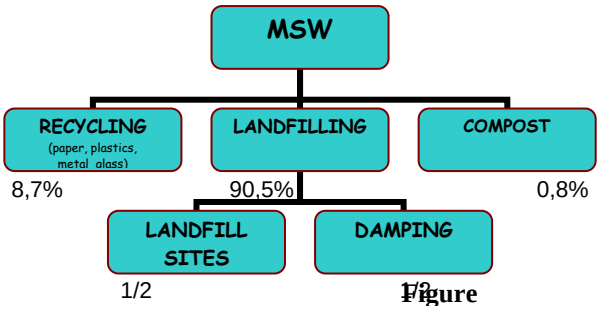


Figure 1: Breakdown of the MSW management in Greece

However, the Greek authorities are still hesitating to apply modern technologies for alternative to landfill management of MSW like WTE. This ineffective policy due to lack of information in conjunction to the observed considerable opposition by the local communities to the construction of new necessary landfill sites makes the situation even more complicated. Only in Attica, within the next decade the handling of predicted 35-45 mil. tons municipal wastes, taking a production of 7000t/d MSW, will require 7-8 additional landfill sites of 500.000m^2 area and ~20m height each, while the operation of the already approved landfilling areas in Keratea and Grammatiko have been blocked!

Figures 2a, b: Non conforming landfill sites

The three biggest Greek cities, Thessaloniki, Patras and Volos face the same difficulties with their waste handling. In example in 1993 Patras constructed one of the first modern landfills, which was designed to have a life 20 years at the time that the rate of generated MSW (Municipal Solid Waste) was 65000 t/y; however in the meantime the landfilling rate increased to 100000 t/y, so that this landfill will have to be closed by 2011 based on the present rate. In Western Greece and the Ionian Islands, solid waste disposal causes significant environmental pollution problems. Outside Patras, most garbage disposal sites are poorly designed and managed. A tiny amount of the area's waste is recycled, while most of it is left to rot in garbage dumps, or burned in open air pits.

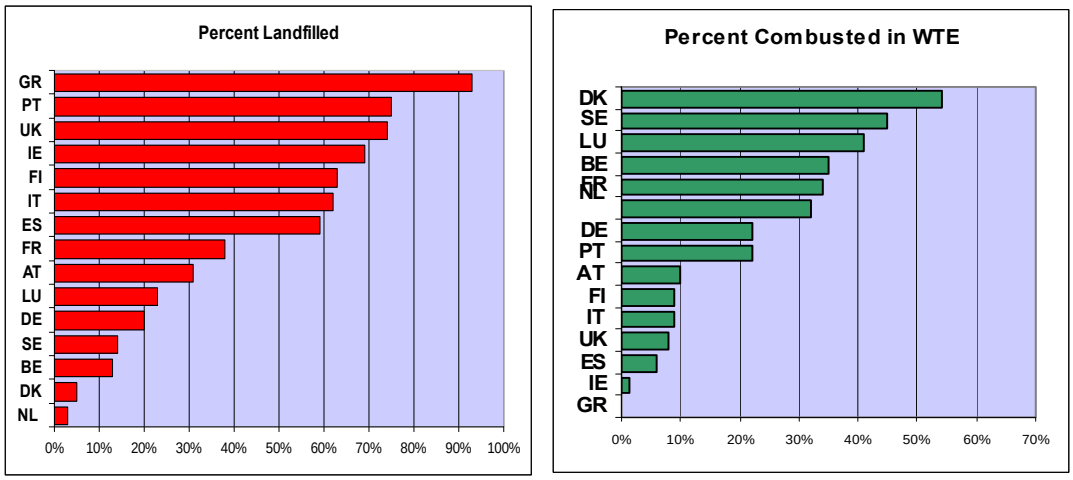
The problem becomes even bigger when moving to the islands. Tourist regions like Rhodos, Kos, Patmos, Mykonos, Santorini, Crete, etc have to handle an extraordinary waste amount during the summer period, while there is no integrated program for their safe management. Each ton of waste, that is burned in open pit produces considerable emissions of heavy metals, methane and chlorine compounds. Moreover the consequences are harmful for the historical monuments of the Islands. In example, in Kos the smoke resulting from the uncontrolled burning of MSW covers the historical holy Asklipio, where Hippocrates the founder of medical science was teaching and practicing medicine.

Another major environmental problem in the region of Attica is the marine pollution caused by urban wastewater. In the frames of resolving this problem the small historical from the sea fight of

Salamina, island of Psyttalia (~600.000m^2 area), near Piraeus port has been sacrificed. The biological sewage treatment plant (STP), which is operating there, **Figure 3**, serving the district of Athens and Piraeus treating 850.000m^3/d wastewater, Figure 3, produces ~800t/d of sludge, dried and recently utilized as fuel in cement production plants. No provision has been taken so far for the re-utilization of the "clean" outlet water stream, which is distributed in the Saronicos bay.

Figure 3: Biological STP on Psyttalia

The lag of Greece in the environmental management of MSW compared to the other EU 15 countries is presented in Figures 4a,b where no further comments are necessary to describe the status [4].



Figures 4: MSW environmental management in EU 15, a) Percent landfilled, b) percent combusted in WTE

Incorporation of EU Environmental Directives in Greek Legislation

The huge pile of strict EU environmental directives published the last two decades and their mandatory incorporation in the national legislation has set the baseline for environmental projects of sustainable development enhancing recycling, promoting renewable energy sources and conservation of natural resources not only in the industrial sector but also in the local communities at the levels of municipalities and prefectures. A list of some characteristic environmental directives is given below.

- Council Directive 1999/31/EC of 26 April 1999 on the landfill of waste; incorporated in Greek legislation with min.dec. 29407/3508/2002 (FEK 1572/B/2002).& min. deci.9268/469/2007 (FEK 286/B/2.03.07) Greece has to reduce the amount of waste lead to landfills by 1/3 until 2010, by half until 2013 and above 2/3 by 2020.
- European Parliament and Council Directive 94/62/EC of 20 December 1994 on packaging and packaging waste and its amendments; incorporated in Greek legislation with law 2939/2001 (FEK 179/A/2001) Greece has to accomplish the following targets by 2011:

    - Total recovery: 60% by weight of the packaging waste
    - Recycling targets: total recycling 55-80%
        - Glass 60%, paper/cardboard 60%, metals 50%, plastic 22,5%, wood 15%
- Directive 2000/76/EC of the European Parliament and of the Council of 4 December 2000 on the incineration of waste and its amendments; incorporated in Greek legislation by min.dec. 22912/1117/2005 (FEK 759/B/2005)
- Council Directive 86/278/EEC of 12 June 1986 on the protection of the environment, and in particular of the soil, when sewage sludge is used in agriculture; incorporated in Greek legislation by min. dec. 80568/4225/1991(FEK 641/B/1991)
- Kyoto protocol according to which Greece has to reduce the CO_2 emissions by 8% in 2008-2012 compared to 1990 levels. The change in MSW management from landfill to WTE reduces the CO2e by a factor of 1,3.
- Directive 2001/77/EC of the European Parliament and of the Council of 27 September 2001 on the promotion of electricity produced from renewable energy sources in the internal electricity market; incorporated by law 3468/2006 (FEK 129/A/2006).

The Solution of WTE

A modern and promising solution for the aforementioned problems could be the erection of Waste-To-Energy units, in proper locations taking into consideration the geographical and population distribution in Greece, i.e. serving Attica, Western Region & Ionian Islands, the Dodecanese Islands, etc. Such units would burn the MSW and/or sewage sludge from waste water treatment plants of the regions under controlled conditions producing electricity and steam. In addition the bottom ash of the facility, which comprises 10-15% of the initial MSW mass undergoes treatment for the recovery of metals while the rest is landfilled or smelted in the special furnaces for the production of mud-bricks. The most common technology for the WTE unit is Martin hearth technology as shown in Figure 5. Very impressive is the high volume of gas cleaning systems installation, **Figure 6**, so that the gas outlet is completely clean and air pollution is prevented especially from dioxins.

The advantages of the WTE units compared to landfill are well known and apparent through the more than 600 WTE plants that operate worldwide. A characteristic example of WTE installation is the one operating successfully in Brescia, Italy, **Figure 7**, serving the needs of 500000 people. The sewage sludge from the waste water treatment plant of the city is also incinerated in the plant. The unit produces 50 MW and the producing steam is used for central thermal supply in the city.

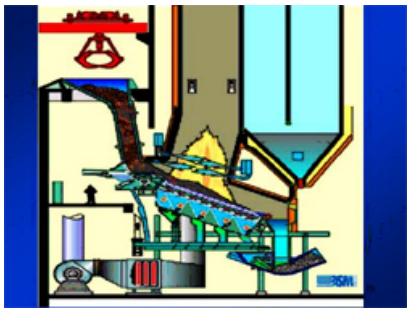


Figure 5: Martin burner hearth of WTE unit

Figure 6: Integrated WTE installation

In EU 15, above 50 mil. t/y of MSW out of 200 mil.t/y have been thermally treated in some 420 plants, **Figure 8** [4]. The largest number of WTE plants is located in France, **Figure 9** [4], while concerning the MSW treated quantity Germany comes ahead, Figure 10 [4].

Figure 7: WTE facility in Brescia

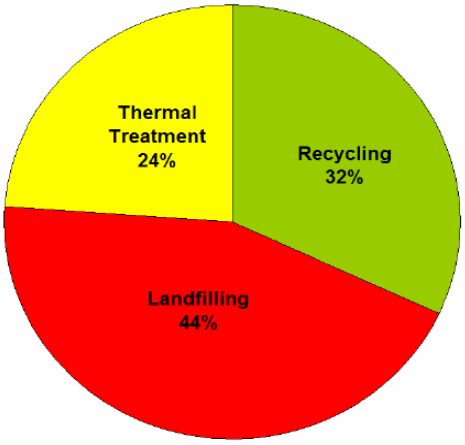


Figure 8: MSW management in EU 15, 2005 data

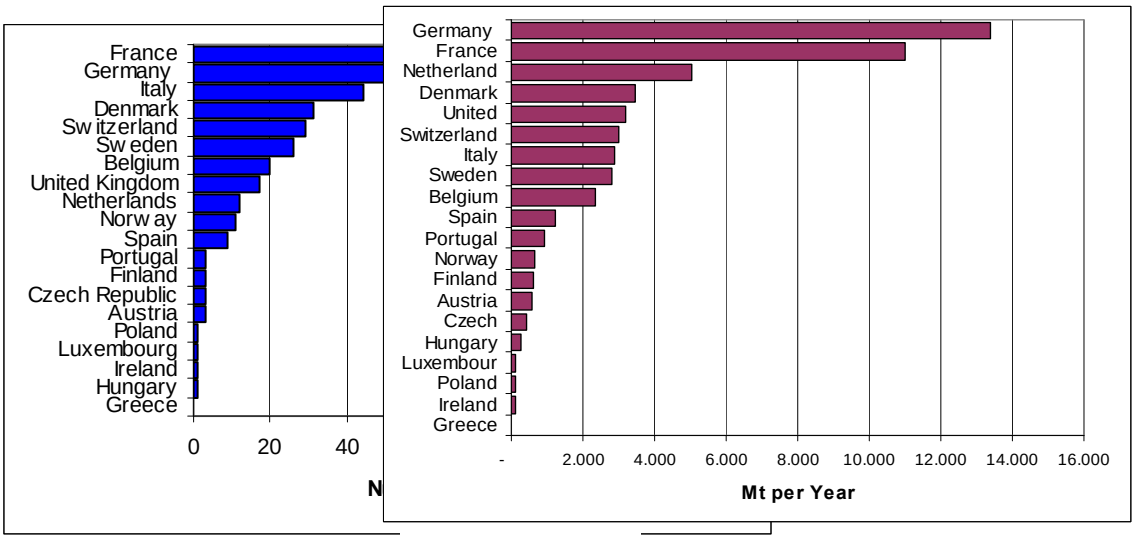


Figure 9: WTE plants in EU 15, 2005 data

Figure 10: MSW treatment qualtity in EU 15, 2005 data

MSW MANAGEMENT PROPOSALS FOR THE GREEK REGIONS

Three characteristic regions of Greece that have significant problems in MSW management have been selected to demonstrate examples of WTE implementation solutions: Athens-Attica, terrestrial Western Greece & Ionian Islands and Dodecanese islands. A brief description and a pre-feasibility study for each case follow.

The Case of Attica

The treatment of the MSW from the whole region of Attica could be directly processed in two big WTE units of 3300t/day capacity each in order to reach a total capacity of 6600t/d to cover all district, with the perspective for adding a third one as well. The total investment cost would be 850 mil. € for two units with a power of 180 MW. Around 1330 GWh of electrical energy would be annually produced. The investment cost for two units decreases down to 450 mil. € taking advantage of EU-grants, as shown in **Figure 11**, where the dependence of the WTE – installation cost from the MSW load required is presented. The estimated tipping fee for such installation reaches 30€/t of MSW, which is at the same levels or even less than the one required for landfilling, **Figure 12**. The income for the WTE plant besides the tipping fee would come from the selling of the produced electricity either with the normal price of the Power Public Corporation (A150) or partially with the price established for electricity produced from renewable energy sources. Moreover, incomes would be collected from the selling of steam for industrial or urban use aw well as of the recovered metals.

Alternative scenarios for exploitation of the MSW energy content have been also studied for the regions of Attica: i) treatment of MSW to produce RDF and then incineration of the RDF to power/WTE/cement plant, ii) combination of WTE plant with a natural gas power plant in the region of Eastern Attica (the energy content of the off gases from the natural gas turbine is used for superheating the steam from the WTE boiler) producing 20% more electrical power than the two units separately. The comparison among different scenarios for MSW management for the regions of Attica is summarized in **Table 1** where the advantages of the WTE scenario are clearly shown, evaluating the relative criteria.

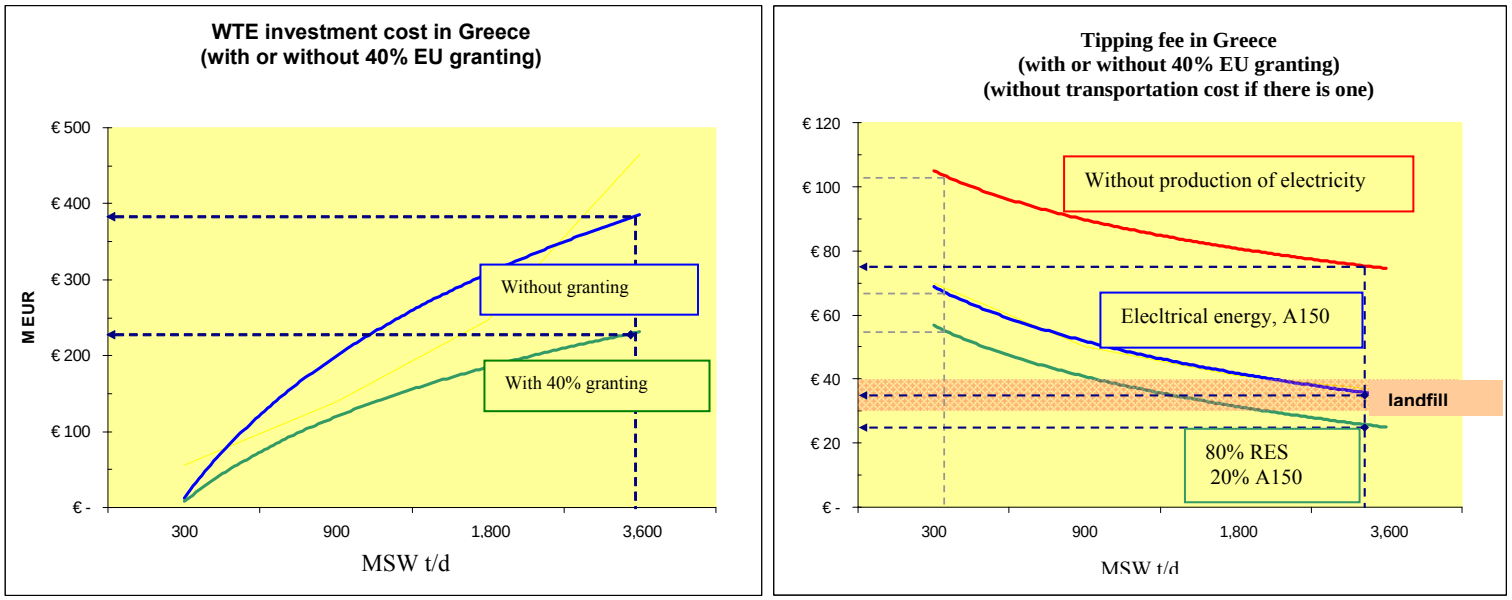


Figure 12: Tipping fee estimations for WTE installation

Table 1: Comparison among MSW management alternatives for the regions of Attica

	Landfilling	**Treatment of MSW to RDF & inc. in WTE (whole Attica)**	**Direct incineration to WTE (whole Attica)**	**Combination of natural gas and WTE (Eastern Attica)**
Compliance with the EU directives	X	? Necessity to examine an environmental safe incineration of RDF concerning the emissions levels	√	√
Tons/day	6000	3000	3300	550
Electricity production (kWh/t)	150	500	600	700
Number of units	NA	10-20	2	1
Foreseen tipping fee with 40% EU grants	30-40€/t	? 80€/t	30€/t	30€/t
Benefit for the municipality where the units will be constructed	X	Small	High	Medium

Western Greece & Ionian Islands

A WTE facility could be constructed in or near Patras to service the residents of Patras as well as those living in neighboring prefectures & the Ionian Islands (i.e. Zakynthos, Kefalonia, Lefkada and Ithaki). A MSW collection station could be designed on each of the Islands and a container-ship could collect the waste and transport them to the WTE facility in Achaia, as shown in the

correspondent map, **Figure 13** [2]. The MSW of Achaia, Aitoloakarnania and Ilia regions could be managed. Especially after the construction of Rio-Antirio bridge numerous ferry-boats that are idling could be used for the transportation of the MSW containers. A preliminary estimate is that a plant to economically handle the MSW produced by 400000 residents and related commercial enterprises will be able to process 200000 t/y of waste. The erection cost of such a facility is estimated ~50-60 mil. € with 20MW turbine power. About 100GWh/y of electricity would be produced from such unit enough to cover 1/4 to 1/3 of Patras households. In addition the unit would be self-sustaining financially, generating over 10 mil. €/y revenues from electricity sales, steam sales, tipping fees and scrap metal recycling. Creation of job vacancies and economic development in a region of high unemployment rates would also benefit significantly the involved local communities.

Figure 13: WTE facility in/near Patras serving close municipalities and Ionian islands

Dodecanese Islands

A WTE facility could be constructed on the Island of Gyali serving the needs of Dodecanese: Kos, Rodos, Karpathos, Astypalaia, Patmos, Kalymnos, Nissyros, Tilos, Symi, Leros, Halki, Leipsoi, Kastelorizo, Kasos, Farmakonisi, Agathonisi, Telendos, Pserimos, Arkoi and Gyali [5]. Gyali has the infrastructure for the erection of such a facility, due to the fact that a station for the exploration of 800000 t/y of pumice operates on the Island, as shown in **Figure 14**. Waste collection stations could be planned on each of the Islands of the region. A special container-ship could pass periodically and transport the waste of the North and South Complex of Dodecanese to Gyali, as shown in the correspondent map, **Figure 15**. The WTE facility could be able to incinerate around 200000 t/y of waste. The electricity produced could be transferred through the existing interconnection of Kos-Nissyros-Kalymnos-Leros contributing to the needs of the North Dodecanese Complex. The Prefecture of Samos (Samos, Ikaria, Fournoi), distanced 60-70 nm from Gyali, as well as the Islands of Amorgos and Anafi could also be served. The additional electrical energy produced would be substantial for the summer period, while the ash from the WTE unit could be used for the rehabilitation of Gyali Island from the mining. Moreover the recovery of valuable metals from the bottom ash i.e Al, Cu which is in abundance in beverage cans, food packing etc, would also be high. In contrary to landfilling, the proposed WTE solution relieves the islands long-term from the emissions of the wastes and of the sewage sludges that are opposite to the traditions and the civilization of Ionia in which the Islands belong.

Figure 14: Pumice exploitation station on the island of Gyali

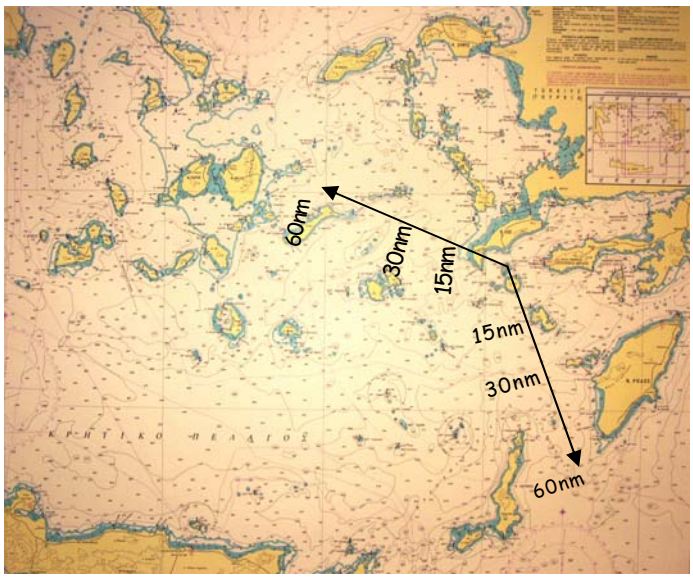


Figure 15: WTE facility on Gyali serving Dodecanese islands

ALTERNATIVE STP SLUDGE MANAGEMENT PROPOSALS

The composition of Biological Sewage Treatment Plant sludge, like the one produced on the island of Psyttalia, Table 2, renders it a very promising solid fuel compared to solid fossil carbonaceous fuels, as lignite, used for electrical energy production due to its high energy content. The disintegrated sludge with thermal capacity of 500-700kcal/kg can be fired in a solid fuel fired boiler for power generation without any previous treatment. The dry sludge is fired nowadays in cement production units. In case a WTE unit existed for the management of MSW the sludge could be easily co-fired to the unit as well. Provided that as already mentioned there are no such installations in Greece today, the sludge could be co-fed to one of the existing coal power plants after proper modifications of the relative units. The No 3 unit of PPC in Aliveri was selected as a possible solution for co-firing the sludge with solid fuel (steam coal) due to its geographical position, which enalbes the short marine transportation (~70nm) of the sludge in special ships, **Figure 16**, from the port of Psyttaleia to the port of Aliveri [6].

Table 2: Composition of Plyttalia sludge compared to lignite

	Psyttalia sludge		Lignite of Megalopolis
	Dewatered	Dry	
Humidity (%)	**68**	**-**	**60**
Inorganic (Ash) (%)	**10**	**60-35**	**14**
Organic Matter (%)	**21**	**40-65**	**26**
Energy content (kcal/kg)	**500-750**	**2200-3200**	**900**

Once the sludge arrived to the power plant in Aliveri the process described in the flow chart of **Figure 17** would follow. Certain modifications of the unit would be necessary in order to co-fire the sludge as presented in **Figure 18** [7]. The transformation, gas cleaning systems and sludge drying (optional) expenses were estimated 55 mil. €, which could be depreciated in 2-3 years from the difference in the fuel cost. This proposal for Aliveri was not realized by PPC. However similar transportation of the sludge and co-firing to a hard-coal fired power station placed on the coast, with maximum distance from Psyttaleia 70-130nm, to be constructed in the near future could be examined. The sludge can be pneumatically charged to the hard-coal mills as shown in **Figure 19** [7].

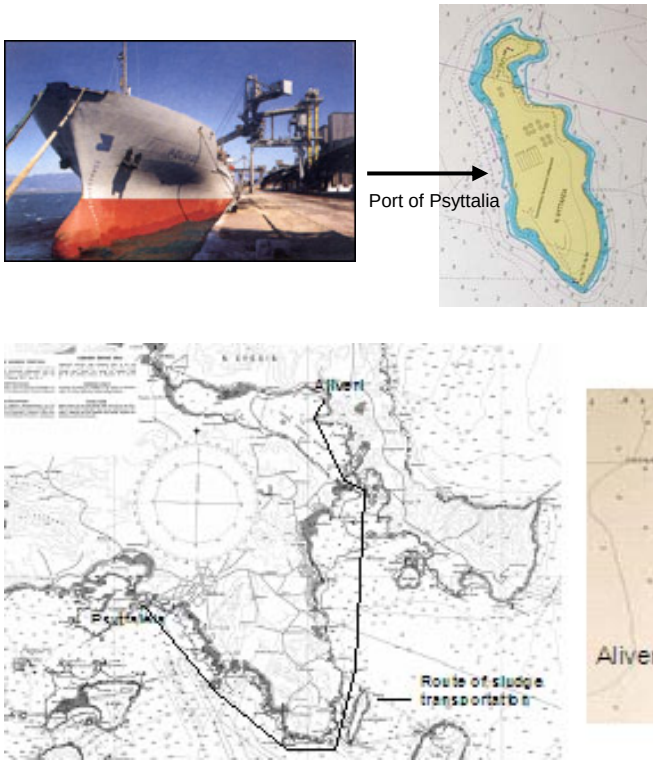


Figure 16: Transportation of STP sludge from Psyttalia to Aliveri by special ships

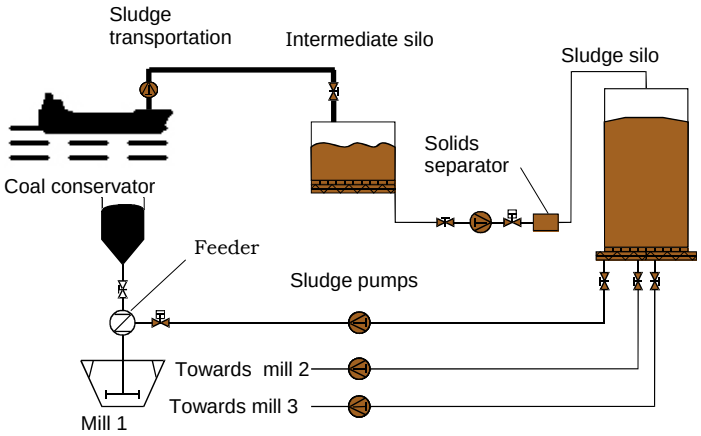


Figure 17: Flow chart of sludge management in the power plant of PPC in Aliveri

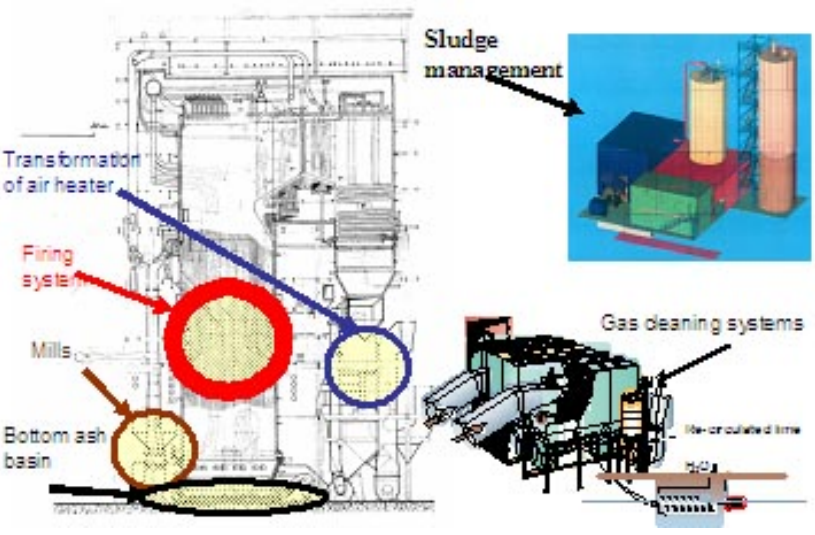


Figure 18: Transformation areas of No 3 power plant unit in Aliveri

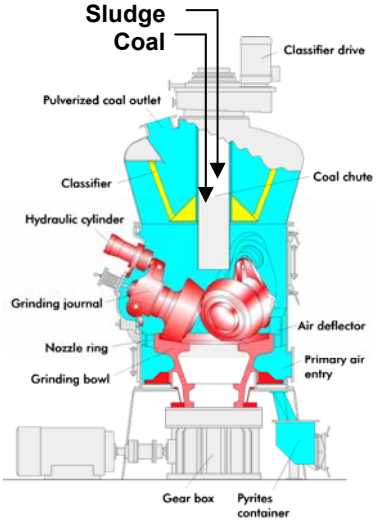


Figure 19: Co-firing of sludge & hard-coal in hard-coal fired power station

CONCLUSIONS

Greece faces severe problem with the MSW management in the urban regions especially in big cities like Athens, Thessalonica, Patras and Volos. In addition the Greek islands with the well developed tourism have also difficulties with MSW management, which increase significantly during the summer period. The main route causes of MSW environmental management problems are: 1. The implementation of landfilling above 90% as MSW management solution, which also creates resistance in acceptance by landfill-region local neighboring communities 2. Poor scientifically documented information regarding modern MSW treatment technologies 3. None alternative to landfilling technique for the exploitation of the MSW energy content has been implemented in Greece until nowadays. Drastic and effective MSW management measures and technologies should be applied in order to resolve these problems in the spirit of the described proposals for the regions of Attica, Western Greece & Ionian Islands and Dodecanese islands.
Moreover, the wastewater management due to the EU environmental legislation for the protection of the Mediterranean Sea made a considerable progress the last decades applying modern STP technology. Additionally the following measures are proposed for the utilization of the two outlet streams of the STP units the "cleaned" water and the STP sludge.: 1. Use of the STP sludge as humus carrier in the reforestation 2. Expanding of the use of the STP "clean" water in the reforestation as it has been already performed in the Island of Kos. 3. In the future fire the STP sludge in solid fuel (steam coal) power generation units placed at the coast. A proposal for applying this technology at the Aliveri 150MW power generation unit was not accepted by PPC.
Greece should get closer to the MSW and STP Sludge modern management techniques applied successfully in the other EU countries. The significant advantages from the implementation of such techniques for human health, the environment and local communities have been elaborated in the presented examples.

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