A NEW FATE FOR THE DEMOLITION WASTE – A CASE STUDY

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Abstract. The conflict between anthropic civilization and environment must be solved as fast as possible, if both are to survive. Industrial development, extensive use of land for agriculture and for urban expansion, accumulated pollution are trends that aggravate the global crisis, making the respite difficult. New approaches are needed to face these challenges. The paper presents a case study included in a LIFE+ Project (ECOREG) carried out in Suceava County, in the 2009-2011 period. It established a symbiotic link among various generators of demolition and construction waste in Suceava County and the TERMICA power plant. Instead of using virgin soil, the reconstruction of the fly ash landfill of the power plant was carried out using demolition waste with no economic value that would otherwise be sent to the municipal landfill. The economic, environmental and social benefits are quantified and the contribution to the waste management problem in Romania, analysed. Waiting for more innovative approaches for the use of fly ash or demolition waste, the solution presented may be straightforwardly applied in many polluted areas across Romania.

1. The solid waste problem in EU and Romania

The paragraph presents a synthesis of the situation of two major categories of solid waste in EU and Romania. The power generation and the construction sector are two of the most important generators of waste. The environmental impact of these two sectors comes from:

- the large quantities of solid materials processed (coal, concrete, gypsum, metal, limestone, etc.) that, at the end of their lives, are sent to landfills;
- the large amounts of greenhouse gases (CO_2) generated during the production and processing of the raw materials (upgrading and burning coal, cement production in energy intensive kilns, etc.);

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- the large amounts of process water needed by these two sectors (steam generation, cooling towers, concrete preparation, etc.);
- the little interest still shown for re-using, recycling fly-ash or demolition waste;
- the limited environmentally sound alternatives at hand that could replace coal or cement. Nuclear energy shows its limits and risks. The use of traditional building materials like wood would gravely affect the forests still covering the Earth.

The amount of demolition and construction waste in several EU countries is presented in Table 1 (Nisbet, 2012).

Table 1. Construction and Demolition Waste in EU

Member State C&D Waste	**Generated (million tonnes, rounded)**	**% Reused or recycled**	**% Incinerated or landfilled**
Germany	59	17	83
UK	30	45	55
France	24	15	85
Italy	20	9	91
Spain	13	<5	>95
Netherlands	11	90	10
Belgium	7	87	13
Austria	5	41	59
Portugal	3	>5	>95
Denmark	8	81	19
Greece	2	<5	>95
Sweden	2	21	79
Finland	1	45	55
Ireland	1	>5	>95
Luxembourg	0	n/a	n/a
EU-15	180	28	72

At the same time, the amount of waste generated by coal-fired power plants in EU is (ECOBA, 2012):

- 40400 tons of fly ash;
- 6100 tons of bottom ash;
- 1800 tons of boiler slag;
- 940 FBC ash.

Though the quantity of demolition and construction waste is more than 3 orders of magnitude higher than the quantity of ash or similar products generated in power plants, the environmental impact of both is significant and asks for swift action. Unlike construction and demolition waste, ashes from power plants contain important amounts of heavy metal. A typical composition (particular coals could present large variations around the values below) of fly ash collected in the cyclone section of the flue gas duct is (Voina, 1981):

- As = 24 ppm;
- Ba = 1010 ppm;
- Cr = 480 ppm;
- Mn = 250 ppm;
- Pb = 355 ppm.

The particulate matter (PM), especially that of small dimensions (PM10, PM2.5), transported by wind spreads all these hazardous substances in the atmosphere, increasing the risks for public health.

In Romania, the situation of solid waste collected, reused or sent to landfill is presented in Table 2 (ANPM, 2012).

Table 2. Solid waste generation in Romania (2007). Data in metric tons.

Waste category	**Collected**	**Reused**	**Sent to landfill**
Values at National level			
Domestic waste	5243185	64391	5178794
Municipal waste (street, park, public garden, market cleaning)	944758	1350	943408
Construction and demolition waste	733717	6825	726892
Total	6921660	72566 (1.05%)	6849094
Values for the NE Region (incl. Suceava County)			
Domestic waste	639934		
Municipal waste	73542		
Construction and demolition waste	110347	30000 tons recycled at TERMICA (27.2%)	

As it can be seen, the share of solid waste sent to landfill is ca. 99%. The amount of construction and demolition waste reused is of the same order of magnitude. A simple comparison of these figures to the levels of construction and demolition waste recycled in The Netherlands, Belgium or UK illustrates the need for decisive action to narrow the gap between Romania and its EU partners.

The paper details the results of an EU financed project (ECOREG, in the mainframe of the LIFE+ Programme) (ECOREG, 2012), trying to apply the principles of industrial symbiosis to business companies or public authorities in the Suceava County. Industrial symbiosis strives to create partnerships among various companies that may take resources not used by one partner or offer it resources it needs, in the same way living organisms are interconnected in nature.

2. Ways of recycling and reuse

There are a lot of alternatives for using the solid waste coming from power plants or from the construction sector. Some figures are given in the subsequent paragraphs. The characteristics of the fine material (particle shape, fineness, particle-size distribution, density, melting point, chemical composition) influence the use properties of end products. Fly Ash produced at different power plants or at one plant with different coal sources may have different characteristics. Particle size distribution and shape characteristics of fly ash are dependent upon the source and uniformity of the coal, the degree of pulverization prior to burning and the type of cyclones and collection systems used.

Technologies that rapidly cool the ash from the molten state as it leaves the flame cause fly ash to be predominantly glassy with minor amounts of crystalline constituents, such quartz, Fe minerals like magnetite (or ferrel spinel), and hematite. Other constituents which may be present in high-calcium fly ash include periclase, anhydrite, limestone, alkali and calcium sulphates, melilite, merwinite, nepheline, sodalite, etc.

The particles are generally smaller than 250 micrometers in size, more or less spherical, have a high mechanical strength, densities from 600 to 3000 kg/m3, present a melting point in general larger than $1000^{o}C$, exhibit low thermal conductivity and are mostly chemically inert.

Each ton of fly ash replacing 1 ton of cement saves almost 1 barrel of oil and approx. 1 ton of CO_2 emitted in the atmosphere. The main uses of fly ash are as a component of cement and concrete and as substitute for clay, limestone, gravel, etc.

As for the case of construction and demolition waste, the trend in the EU (SYMONDS, 1999) and US is to give up the term *demolition* and speak of *deconstruction* (Hegyesi and Yeoman, 2011).

The main idea is that, at the end of their lives, buildings and constructions of any kind should not be turned to rubble and sent to landfill but processed to recycle panels, gypsum, iron bars, asphalt, shingles, etc., as much as possible, in new buildings or construction projects (Nisbet et al, 2012). Cement and concrete could be recycled in the cement industry, after minimal processing. The rest of such waste (which should amount to no more than 10%) should be used as filling materials (in road, bridge or dam construction, for example) (Venta and Nisbet, 2000).

The reuse, recovery and recycling of fly ash or demolition waste in Romania are very limited.

3. The ECOREG project

The philosophy of the Project was to identify and reinsert in the economic and value chain all kind of resources that are not currently used or are not used at full capacity. Resources were not limited to waste, but also included production capacities (equipment, workshops), transport fleets, expertise, laboratory facilities, energy flows, training, experts, etc.

During a number of workshops, where 40-60 company managers participated in each of them, they were asked to complete special forms with their available resources that could be given or shared with symbiotic partners and the resources they needed. Subsequently, the Project team identified the most promising links and contributed to the materialization of the symbiotic partnerships created between companies that had resources to give and those that needed the resources offered. The ECOREG Project was more than a brokerage facility because of the portfolio of resources involved, but also because an important scientific and technical contribution was brought to the Project (evaluating the composition and characteristics of waste that could be exchanged between symbiotic partners, evaluating the environmental impact of the partnerships, deriving cost-benefit analyses, helping local managers to find optimal ways to add value to their resources).

An important step in the ECOREG Project was the set-up, in a very early stage, of a Project Advisory Board (PAB). It included representatives of major local economical units, representatives of local authorities (administrative, environmental), representatives of the academic environment, etc. They all had the legitimacy and expertise that allowed them to critically evaluate every stage of the Project. As they came from local entities, they were in the best position to know what the priorities and capacities of local business community were and what could be the sustainability of a specific issue. The members of the PAB were in no way remunerated for their contribution, but their role was essential in guiding and censoring the Project team, in generating ideas for symbiotic partnerships, in finding appropriate partners for a given symbiotic link, etc.

The paper details the case study of the TERMICA power plant that has to reconstruct the environment at its fly-ash landfill. This case led to a successful symbiotic link between TERMICA and a number of local companies that generate construction and demolition waste that otherwise would have been sent to the municipal landfill.

The original idea of this Case Study represents the result of an initiative of one of the project Advisory Group (representing the Suceava TERMICA Power Plant) that worked together with the LIFE+ ECOREG partners to identify new opportunities for using construction and demolition waste and turn it in a valuable resource that could spare important amounts of virgin soil.

Because of the dimension of the problem (the environmental impact generated by the ash land fill, the large quantities of construction and demolition waste generated by the local companies), the detailed study and the evaluation of the potential symbiotic link was the subject of a special workshop reuniting delegates of TERMICA, representatives of the LIFE+ ECOREG partners, managers of companies generating construction and demolition waste and key members of the local Administration.

The workshop was organized by the Suceava City Hall in July 2010. It constituted an opportunity of information, communication and it led to constructive ideas and suggestions for putting the idea in practice.

3. The termica ash landfill

The TERMICA Power Plant of Suceava is the main power and heat provider for the Suceava City.

It has 3 sectors of landfill, operated in different period of times. They all have severe environmental problems (Fig. 1).

A special Project, starting in 2010, was meant to rebuild the environment at the location of the landfill. The need for action at the TERMICA landfill came from legal acts. According to the EU Directive 1999/31/CE and its Romanian equivalent, HG no. 349 / 2005 concerning waste landfills, TERMICA had to address the (non-compliant) ash landfill problem in the time frame specified by the *acquis communautaire*, signed when Romania joined the EU. Works started in January 2010 and were directed to close down the non-compliant landfill and to reconstruct the environment at the landfill location as well its surroundings. Each of the 3 sectors of the landfill had a separate method of reconstruction.

The 3 compartments of the TERMICA landfill totalize 7.3+11.6+11.7 = 30.6 ha.

In some paces, the landfill is excavated up to 8-10m down. These excavations need lots of filling material to be levelled.

The main components of the original solution considered:

1. levelling the terrain (see why in Fig 2. below),
2. installing synthetic protective membranes stopping water infiltration
3. creating a controlled 2-3 ‰ slope enabling drained water to be directed toward special collecting trenches
4. covering the ash material with earth (30cm thickness) taken from unpolluted areas;
5. adding virgin topsoil (15cm thickness) with perennial grass.

As mentioned above, the reconstruction Project asked for huge quantities of virgin soil or of earth taken from unpolluted areas. This solution has the following shortcomings:

1. It affects the soil and ground at the site where earth and topsoil are taken from to cover the landfill at TERMICA; practically, it moves the location of

affected soil from TERMICA to the area from where the earth and topsoil are taken since each hectare covered with topsoil at TERMICA landfill means a hectare of topsoil taken from other areas, affecting the local environment;

Fig. 1. Seriously affected environment at TERMICA landfill (April 2010)

Fig. 2. Highly uneven terrain at TERMICA ash landfill. (April 2010)

2. Transporting the large amounts of earth and topsoil requires important consumptions of fossil fuel and generates large quantities of greenhouse gases (CO_2).

The estimated quantity of filling material needed to carry out the work at TERMICA landfill is 30000 tons.

4. The symbiotic partnership

The idea was to use construction and demolition waste generated by the Suceava County Construction Companies as well as by other Utility Companies (Gas, Water and Electricity) or private construction companies.

Before accepting the idea, a study was carried out to check its feasibility and to ascertain that the solution will not add to the environmental impact of the ash landfill at TERMICA.

It was found that the construction and demolition waste consists of:

1. Wood: timber, stumps, plywood, laminates, scraps;
2. Drywall: concrete slabs, gypsum, plaster, mortar fragments (up to 40%);
3. Some metal debris: Pipes, rebar, flashing, steel, aluminium, copper, brass, stainless steel;
4. Plastics: Vinyl siding, doors, windows, floor tile, pipes;
5. Roofing: Asphalt & wood shingles, slate, tile, roofing felt;
6. Rubble: Asphalt, concrete, cinder blocks, rock, earth;
7. Bricks and decorative blocks;
8. Glass: Windows, mirrors, lights;
9. Miscellaneous: Carpeting, fixtures, insulation, ceramic tile;
10. Soil from excavations (up to 30%).

Neither of these materials represents a high hazard for the environment. They all come from buildings, roads, excavations and do not require treatment before being sent to the landfill.

Instead of sending them to the landfill, the proposed symbiotic partnership would mean collection of such waste from where it is generated and use of this waste instead of earth to level up and cover the ash landfill at TERMICA.

The importance of getting rid of demolition waste in a responsible way comes from the following considerations:

- the large amounts of such waste generated at local or national level; figures in Table 2 refer only to the Romanian population covered by waste collection services. As this represents only 54% of the Romanian population, the aforementioned figure is probably twice as large;
- the absence of ways of recycling it, as it is recycled in other EU countries
- the unacceptable situations in which large amounts of such waste is simply disposed of on some road edge (Fig. 3).

In order to carry out a very promising synergy, the next step was to convince the local Administration and the Construction Companies to deliver the demolition waste to TERMICA.

This was done by a presenting the cost/benefits analyses, the environmental impact assessment and by presenting similar cases in other EU countries.

Once TERMICA and the symbiotic partners accepted the solution and once it was certified that it would not add to the environmental problems already present at the ash landfill, 30000 tons needed to level off the TERMICA landfill would not be taken anymore from virgin land but would be replaced with construction and demolition waste provided by local Companies.

This way, the amount of demolition waste reused at TERMICA and saved from the municipal landfill represents almost half of the entire demolition waste recycled in Romania in an entire year!

Fig. 3. Demolition waste irresponsibly left at a roadside (Dec 2010).

5. Economic, social, environmental benefits

For TERMICA, the estimated savings by replacing virgin earth with demolition waste to carry out the environment reconstruction of the ash landfill are 60000RON (15000 Euros).

For the Construction and Utility Companies: reducing the amounts needed for fuel consumption and truck maintenance since, instead of carrying the demolition waste to the Botosani landfill (the only nearest legal landfill available in the Suceava County), they simply shuttle the waste inside the Suceava City, to the TERMICA landfill. The two-way road from the local companies to TERMICA landfill is only approx. 3-5km.

The same two-way road from Suceava to the Botosani legal landfill area is approx. 110km (including the intra-city roads).

This gives an approx. 100 km saved for every transport of the waste.

So, the 30000 tons of waste that, instead of being shuttled to Botosani are landfilled at TERMICA give 100x30000=3000000ton.km.

Using data from the literature (Carbon Fund, 2012), Table 3 includes calculations of fossil fuel (Diesel) saved and of GHG emissions avoided (CO_2).

As seen in Table 3, the solution led to important amounts of virgin resources saved.

The amount of saved fossil fuel is 6435.8 litres (Diesel).

Expenses for drivers' salaries, truck maintenance, road maintenance, etc. cannot be estimated, but they are real and important.

Replacing virgin earth with construction and demolition waste leads to 30000 tons of earth left undisturbed.

More than 17 tons of greenhouse gases will not be emitted by trucks shuttling waste to Botosani.

In addition, 11.6ha of land is reconstructed and reclaimed, becoming ready for future use.

As the TERMICA is located very near to the City Centre, the value of this land will increase considerably in the following years, becoming available for residential areas or shopping centres.

Table 3. Fuel saved and CO_2 emissions reduced by the symbiotic partnership.

Calculation Item	**Value**	**UM**
Distance	100	km
Quantity	3000	metric tons
Ton.kilometre	300000	ton.km
Truck capacity	20	tons
Number of trips needed	150	trips (2-way)
Large trucks fuel consumptions	42.91	liters/100km
Total fuel saved	6435.8	litres Diesel
	1700.2	US gallons
CO2 emitted	22.384	lb CO2/gallon consumed
	38056.76	lb CO2 saved
	17262.54	kg CO2 saved
	17.26254	tons CO2 generated (saved)
1 US Gallon	3.7854	litres
1 lb	0.4536	kg

A number of social benefits also came out of the symbiotic partnership.

For partners, the synergy should become an example of responsible co-operation of Administration and business companies to serve the community and the environmental objectives.

It just gives an example of how the problem of construction and demolition waste should be treated in Romania so that not only 1% of that waste is recycled.

The synergy creates an important intangible value: a network of mutually beneficial cooperation among Administration and companies that could be activated whenever necessary.

For communities, the synergy saves important quantities of fuel, avoids large quantities of GHG emissions, lets a large area of earth undisturbed (from which the earth needed at TERMICA would have been extracted) and reclaims a large area of land for future residential Projects or other development Projects.

A question of principle is if the solution detailed by this paper is sustainable. It certainly is, since attaining the level of Construction and Demolition waste recycled in other EU countries (90% in The Netherlands, 87% in Belgium) represents a very long way to go for Romania. Yet, the ECOREG Project showed that the things are very simple wherever there is awareness and responsibility and where specialists can be sufficiently convincing.

As there will always be construction needed, there will always be construction waste – thus the completed case is fully sustainable in the long term.

In addition, apart from using construction and demolition waste to reconstruct landfills, it may be used in road construction, dams, bridges, in riversides consolidation, in reclaiming land of the former mining areas, etc., adding to the sustainability of the solution described here.

Conclusions

The paper presented a way to address the important problem of environmental reconstruction of a site seriously affected by ash with heavy metals in its composition and which was continually dispersed on a large area and affected the public health.

During the implementation of the solution, a cooperation link, similar to the symbiotic links encountered in nature, has been established between the local power plant and a number of companies generating construction and demolition waste.

The economic, environmental and social results constitute arguments for the replication of the solution, in similar cases.

The absence of a dedicated National or Regional Office that could provide information about available waste, potential waste uses, location and quantities is the main impediment toward using construction and demolition waste at large scale.

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