INTEGRATED SYSTEM FOR OPTIMIZED DATA COLLECTION AND PROCESSING OF END OF LIFE TIRES: CASE OF GREECE

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ABSTRACT
The last decade, there is a continuously increasing number of tires that are discarded as reaching their end-of life cycle. The methods utilized for treating the used and end-of-life tires, lean towards more environmental friendly solutions such as recycling and energy utilization. However, even these treatment options do not have a zero carbon footprint, and therefore in order to completely assess and control the environmental impact of these options a precise record of many parameters needs to be done. As a matter of fact, there have been many works that present the environmental impact of each of the treatment options. For that reason an integrated system was designed and built, with the scope of optimized data collection of tires collected in the appropriate collection points. What is more, the described system will record the amounts and types of tyres gathered, the treatment options followed and the final products quantities and qualities.

Keywords: End of Life Tyres, Data collection system,

INTRODUCTION

The tires used from all types of vehicles, like private vehicles, trucks, motorbikes, bikes, construction and agricultural machinery, turn into waste at the end of their life cycle. According to European Tyre and Rubber Manufacturers Association (ETRMA, 2011), about 3.3 million tonnes of end of life tyres were gathered in Europe, of which 2.5 million tonnes were recycled or recovered. In the international scale, each year about 1 billion tyres reach the end of their life cycle. The treatment schemes followed in order to utilize the amounts of collected End of Life Tyres (ELT) vary (ETRA, 2013). As presented in figure 1, the situation in EU is led to a continuous increase of methods that are more environmental friendly than landfilling which, as shown, represents less than 10% of the total treatment methods in 2012. On the contrary, methods such as energy utilization and tyre recycling grew the past decade to such a degree, that more than 70% of the collected tyres are treated by one of these methods.

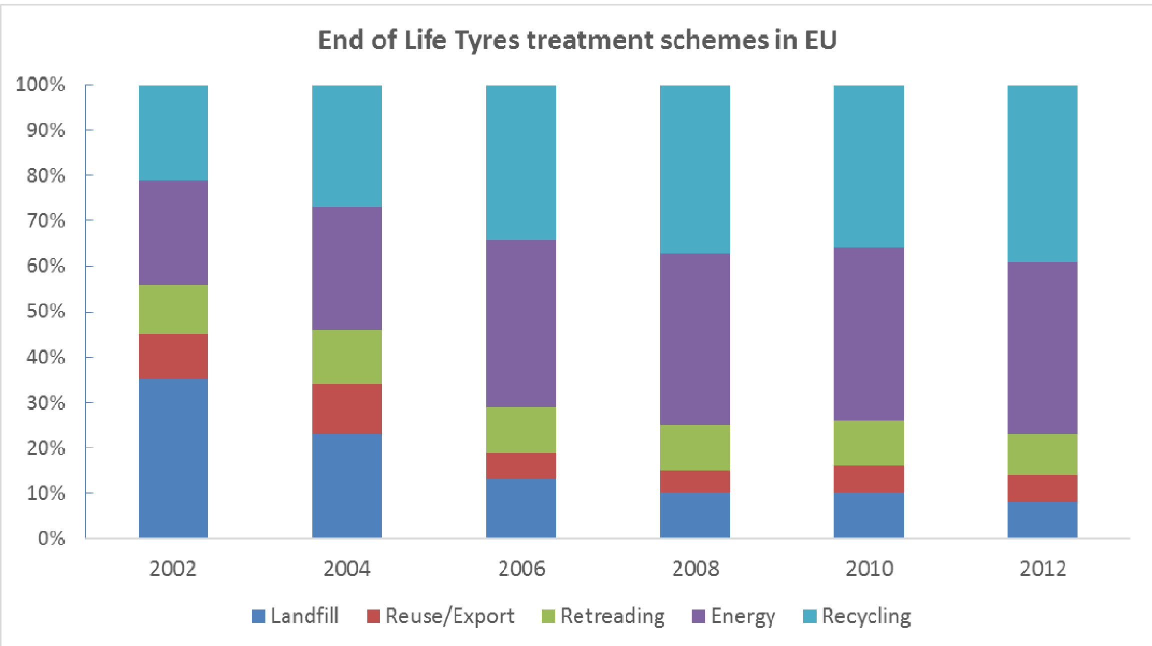

Fig.1. End of Life Tyres treatment schemes in EU.

The material recovery applications include among others the recycling of ELTs as rubber granulated and powder (83%), utilization in civil engineering works (~12%), and other applications which cover the rest of the percentage. The energy recovery options include the utilization in cement industry at a devastating percentage of 91% and the majority of the rest of the quantities are used for electricity generation (ETRMA, 2014). Likewise, as presented from the Rubber Manufacturers Association (Rubber manufacturers association, 2013) the percentage of end of life tires that is led to landfill is reduced to around 12,6%, while the percentage of tyres utilized in energy or recycling sector (as Tyre-Derived Fuel, Ground Rubber and Civil Engineering) covers more than 70%. The available data are presented in table 1.

Table 1. Market trends in U.S.

Product (thousand tons)	2005	2007	2009
Tire-Derived Fuel	2144.64	2484.36	2084.75
Ground Rubber	552.51	789.09	1354.17
Land Disposed	590.81	593.98	653.38
Used Tires	-	-	371.25
Civil Engineering	639.99	561.56	284.92
Reclamation Projects	-	132.58	130
Exported	111.99	102.08	102.1
Baled Tires/Market	-	-	27.79
Electric Arc Furnace	18.88	27.14	27.1
Baled/no market	42.22	9.31	15.57
Agricultural	47.59	7.13	7.1
Punched/Stamped	10.51	1.85	1.9
Generated	4410.73	4595.72	5170.5
Land Disposed/generated	13.39%	12.92%	12.64%

As far as the best treatment methods for ELT is concerned, it has been a case of study from many different teams around the world in terms of financial and environmental viability and sustainability. Xingfu et al. (Xingfu et. al, 2010) compared four tire treatment methods in China, were it was found that the most eco-effective ELT treatment technology is pyrolysis (with product recovery) followed by dynamic devulcanization and ambient grinding. It is noted that in future, ambient grinding for crumb rubber may be more advantageous with less energy consumption and less emissions of pollutants. Moreover, regarding the pyrolysis process, the viability depends on the variation of the prices that the products will be sold in the future. The work elaborated from Corti et al. (Corti et al., 2004) supports the aforementioned utilizing life cycle assessment (LCA) tools, they found that the use of ELT as fuel substitute in cement kilns and in Waste to Energy (WTE) processes allow better environmental behavior than other alternatives. More specifically cryogenic and mechanical pulverization of ELT for reuse as filling materials presented the worst results of environmental impact comparing to all other treatment methods. Pyrolysis was studied and is proposed as an alternative method for waste tyres treatment (Williams et al., 2013), proving that high added value products can derive from this treatment method. Sometimes the produced products may require upgrading in order to fit in specific standards for commercial use.

Samolada et al. (Samolada et al., 2012), studied the application of pyrolysis in Greece and found that it is environmentally and financial a more sound application from combustion-incineration (which is a destructive one). Specifically, pyrolysis can be considerably attractive if all of the final products are effectively used. It was also studied from Zabaniotou et al. (Zabaniotou et al., 2014), the barriers and drivers for ELT pyrolysis in industrial application, and it was noted that the current EU legislation prevents the implementation of large scale pyrolysis plants.As another means for waste ELT utilization, the production of acoustic material from tire fluff was studied (Jimenez-Espadafor et al., 2011) and it was found that it is a technically possible and sound approach.

Apart from the studying of the after use treatment methods, there have been studies for the replacement of metal parts (alumimium) of tires with other rubber or plastic parts, in order to improve the carbon footprint depending on the final treatment method that will be used. Specifically, it was found that aluminum wore is better for landfilling while plastic and rubber parts are far better for thermal utilization. (Simoes et al., 2013) However Arroyo et al (Arroyo et al., 2011) found that steel corrosion is the main source of heat production in Tires that have been landfilled or in tire derived aggregate that is actually ELT that have been reduced in size and used as lightweight fill alternative solution. This leads to possibilities of occurring uncontrolled fires in landfills. Shakya et al. (Shakya et al., 2008) studied the emissions of uncontrolled open-air burning of waste vehicle tyres, as happens in landfills. It was found that CO and SO_2 emissions were significantly higher than controlled thermal

utilization of tyres. Moreover the emission of other pollutants such as NO_2, CO_2, polyaromatic hydrocarbons and smoke were also higher than controlled utilization in specially designed facilities.
As presented from all of the aforementioned studies, all of the technologies and treatment schemes present advantages and disadvantages. It was clearly observed that despite the wide technological study for environmental and financial viability, there is not a widely accepted scheme or combination of technologies in order to achieve the optimum treatment of ELTs. There are some studies (Uruburu et al., 2013, Ene et al., 2015, Subulan et al., 2015) were the product recovery operations network as well as the final treatment for environmental optimization has been investigated. As presented in these studies the first step is data collection, in order to acquire certain parameters for processing.
Scope of the present study is to present a model for optimized data collection and processing of end of life tires produced in Greece. This will lead to an integrated system for controlling the fate of ELT, leading the treatment to most environmental friendly solutions and therefore reducing the emissions and pollution created from ELT utilization.

METHODOLOGY

In Greece the products from ELT treatment can be utilized in new products and replace in some cases other raw material with equal or better properties. In the following table (table 2) the tyres categories that are collected in Greece are presented.

Table 2. Tyres Categories that are collected in Greece

	Description	Mean Weight of each tyre
Category A'	– Passenger car tires (passenger tires and tires 4X4) – Commercial vehicle tires – Conventional (diagonal) agricultural tractor tyres for front wheels – Tyres for industrial lift trucks	8 kg
Category B'	– Commercial vehicle tires with nominal (inner) rim diameter greater than or equal to a certain diameter. – Agricultural tractor tyres for rear drive wheels – Tires for industrial lift trucks with nominal (inner) rim diameter greater than a certain diameter – Tires for earthmoving vehicles	50 kg
Category C'	– Motorcycle tires	2,5 kg

The monitoring of data from the collection, transportation and final utilization of end of life tyres is organized from ECOELASTIKA S.A. which is the Greek body responsible for tyres recovery. Afterwards, the data are registered in a designed database. Each party carrier that collaborates with Ecoelastika, completes periodically (every week) and electronic file in which the following parameters are detailed:

- Time of collection
- The collection point
- Tyre category and quantities of used tyres per collection point
- The tyre quantities carried forward to the final users

The database can afterwards provide information regarding the following points:

- The collected amounts in pieces or mass per region, for specific periods
- The frequency of transportation from certain collection points
- The collected quantities per collection point for specific periods
- The number of serviced collection points
- The amounts of tyres stored in temporary storages
- The amounts of utilized (recycled, thermal utilization) tyres in final users

The active collection points have been reduced in the latter years. From 3093 active points in 2010 only 2603 remain in operation in 2014.

The final users vary depending on the treatment method and include:

i) Mechanical grinding
ii) Recycling
iii) Utilization in construction projects, and
iv) Thermal utilization

From the above end users 51.55% end in material recovery, 28.21% end in Energy Recovery, while the rest 20.24% end as Tyre Derived Fuels (TDF). The main products from the recovered tyres include textiles, wire, shredded and crumb rubber. The percentages that derive from the mechanical grinding treatment is presented in the following figure (fig 2.).

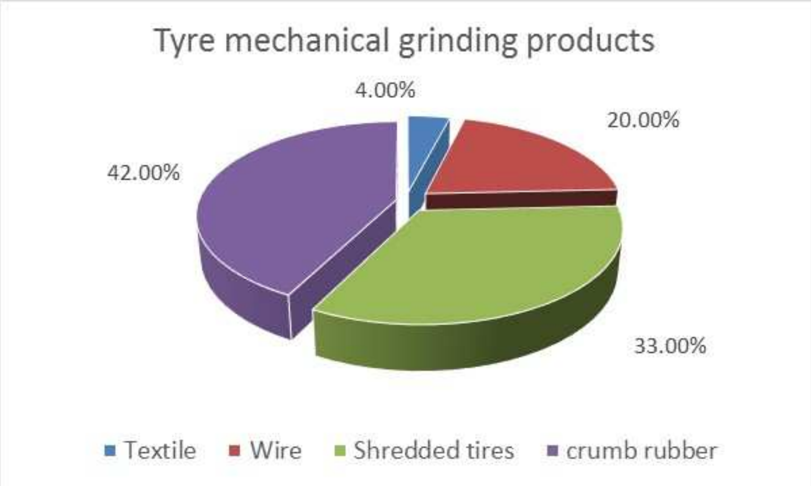

Fig.2. Products from mechanical grinding process.

However, the business as usual may present deviations between the real data and the ones collected. This produces two weaknesses. The first is that the calculations derived from the database may not fully depict the reality and the second is that it is not real time and automated. These reasons are the source for delays in processing of the data and decision making for optimum ELT treatment options.
Therefore the data collection system determines the user requirements, which include the following:

- Procedures for production and quality
- Integration of the Green Wips system with other systems
- List the number and types of relevant equipment
- System size including spare capacity e.g., number of workstations
- Requirements for data presentation, records and reports
- Any networking requirements to local/wide area networks LANs/WANs
- Communication links

An automated online system will be installed in the final users, with an automated weighing system which will continuously communicate with the central database in order to inform real time about the tyres received and about to be treated. The online system will be composed of a network of stations installed in the weight bridges of end users which will directly communicate with the server located in Ecoelastika S.A. providing detailed information on:

- Mixed, net weight and tare of each ELT load that is input or output of the final user plants for end of life tyres utilization
- Information on the trucks transporting the ELTs entering / leaving end use plant areas (e.g. registration number, net truck volume, photos)
- Time and day of each transaction

Moreover photos of the front and the rear of each truck will be taken during the first and second weighting (mixed weight and tare) of each truck that enters or leaves the final use plant areas.
Utilizing this type of systems, the capacity is provided in order to:

- Online check the quantities of whole tyres that enter or leave the end use facilities

- Check the quantities of final or intermediate products that leave from the end use facilities in order to be sold
- Crosschecking the data that are gathered through the manual system of weighting the loads and sending the data via a form to the system manager (Ecoelastika S.A.)

The loads will be registered as following:

i) Input load of whole end of life tyres
ii) Output load
    a. Shredded tyres
    b. Tyre crumb
    c. Wire
    d. Textile

Moreover information will be included for the user that will receive the load exiting the facility, and for the type of final treatment.

RESULTS AND DISCUSSION

Taking into consideration the requirements of the data collection system designed, a demonstration was implemented in an already existing tyre recycling plant located in North Greece. The incoming material (end of life tires) are brought in the plant through closed trucks. The trucks leaving the plant and carrying the products are mostly three-axle or four-axle vehicles with open or closed containers and lifting hook type vehicles with trailers (hook lifts). The plant is divided in six different modules, which are the following:

1. *Shredding module*: It is consisted of a tyre shredder and a separator for the shredding product
2. *Grinding module*: It is consisted of two grinders for the reduction of the mean size of the tyres leaving the shredder
3. *Metal separation*: It is consisted of two stage magnetic separation
4. *Module for tire crumb milling*: It is consisted of two mills
5. *Textile separation module*: it is consisted of a series of aspirators and air filters
6. *Sieving and packaging module*: It is consisted of machinery were the separation in different categories of final products takes place, according to particle size of the product

The designed system was studied in order to include 32 different requirements as they were set from the users. The more important of them were the following:

1. Potential for a detailed recording of all sensors, metering and measurement systems in the database
2. Potential for continuous and automatic recording of the measurements for the existing analogue and digital signals
3. Capability to connect with RFID readers
4. Ability to connect to message boards
5. Ability to connect to cameras for photographing vehicles
6. Capacity to connect with photocells for vehicle presence control
7. Ability to connect to traffic lights for the management of incoming and exiting vehicles
8. It must be based on internet/intranet architecture, operate in a Windows environment and be based on a GUI
9. The database in which the data will be saved and inserted will be SQL
10. It must provide the opportunity for continuous monitoring and presentation of the measurements in a PC, and give the results for all the previous periods
11. Capability to record the following data on input and output vehicles
    a. Vehicle, type, owner
    b. Date, time and system operator
    c. Mix weight, net and tare
    d. Collector

In the entrance of the plant, the control room as well as the weight bridge for weighting the vehicles is located. The weight bridge is electronic industrial type with reinforced structure, according to European Regulations. It is connected through an electronic alphanumeric weighting scale which is installed in the control room. In figure 3, the weight bridge installed is presented.

Fig.3. Weight bridge installed in plant in order to collect and transmit online data

The weight bridge was made to communicate with the system that was described before and gather, store and transmit the gathered information. In the following figures (figure 4.) the data acquisition system with the online statistic analysis is presented.

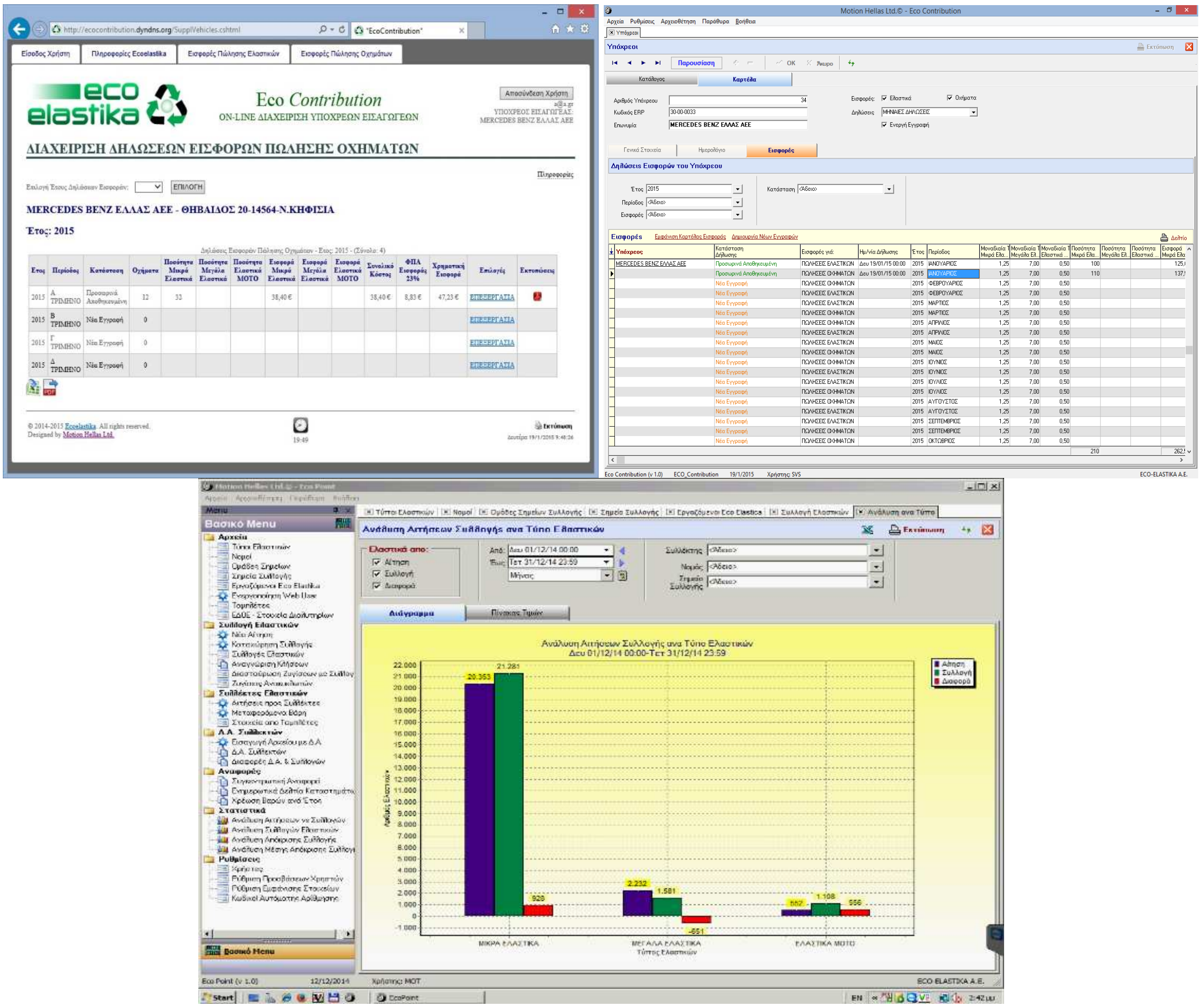

Fig.4. Weight bridge installed in plant in order to collect and transmit online data

CONCLUSIONS

The installation and operation of a data acquisition and processing system was found to be critical for the implementation of the first stage of an integrated control of End of Life Tyres treatment. As presented, the integration of a data recording system was implemented in a weight bridge located in a ELT treatment plant on the Northern Greece. Its purpose was to record and transmit data relevant with the type and quantities of the input stream for treatment, as well as the output stream, led to the final users. The first demonstration of such a holistic system was successful.

Next step is to install the same system in all of the collaborating facilities with ECOELASTIKA in order to provide a more thorough presentation of the available quantities and qualities of tyres, leading to better decision making strategies regarding their final utilization schemes.

Acknowledgement

The support of the Greek National Strategic Reference Framework 2007 – 2013 is gratefully acknowledged. More specifically the project GreenWTMS (contract number: 27-BET-2013) in the framework of the Program for Development of Industrial Research and Technology 2013.

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