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Selected papers (2)

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Aims and Scope

Procedia Environmental Science, Engineering and Management (P - ESEM) is a journal focusing on publishing papers selected from high quality conference proceedings, with emphasis on relevant topics associated to environmental science and engineering, as well as to specific management issues in the area of environmental protection and monitoring.

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We aim to carry important efforts based on an integrated approach in publishing papers with strong messages addressed to a broad international audience that advance our understanding of environmental principles. For readers, the journal reports generic, topical and innovative experimental and theoretical research on all environmental problems. The papers accepted for publication in *P – ESEM* are grouped on thematic areas, according to conference topics, and are required to meet certain criteria, in terms of originality and adequacy with journal subject and scope.

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GUEST EDITORS

Fabio Fava, born in 1963, is Full Professor of "Industrial & Environmental Biotechnology" at the School of Engineering of University of Bologna since 2005. He has about 130 papers on medium/high IF peer-reviewed international journals of industrial and environmental biotechnology, sectors in which he coordinated the FP7 projects NAMASTE and BIOCLEAN and participated in other 7 FP7 collaborative projects. He is vice-chairman of the "Environmental Biotechnology" section of the European Federation of Biotechnology (EFB). He is the Representative of the Italian Ministry of Education, University and Research in the "Working Party on Biotechnology, Nanotechnology and Converging Technologies" at OECD (Organisation for Economic Co-operation and Development), Paris, in the "European Strategy for the Adriatic and Ionian Region" (EUSAIR) and in the "Western Mediterranean Initiative" (WEST MED). He is member of the "Expert Group on Biobased Products" (DG GROW, European Commission, EC) and is the Italian Representative in the a) H2020 Programming Committee "European Bioeconomy Challenges: Food Security, Sustainable Agriculture and Forestry, Marine, Maritime and Inland Water Research" (SC2, DG RTD, EC), b) "States Representatives Group" of the "Public Private Partnership BioBased Industry" (BBI JU)(DG RTD, EC) and c) BLUEMED Strategic Board (DG RTD and DG MARE, EC). Finally, he is the scientific coordinator of the International Exhibition on green and circular economy ECOMONDO held yearly in Rimini (Italy).

Grazia Totaro, born in 1976, has a degree in Chemistry (University of Ferrara), a Master's Degree in Science, Technology & Management with a specialization in Environmental Chemistry (University of Ferrara) and a PhD in Materials Engineering (University of Bologna).

She worked at the R&D Centre of Basell Polyolefins in Ferrara for 2 years in the frame of a project addressed to the development of a novel methodology for qualitative and quantitative analysis of additives in polymers. She also worked at ARPA, Regional Agency for Environment in Ferrara, division Water Analysis.

Then she started working at the school of Engineering of the University of Bologna for a Ph.D. in Materials Engineering (2007-2010). After that, she had a scholarship "Spinner 2013" in cooperation with Reagens spa (San Giorgio di Piano) on novel PVC nanocomposites. Now she is post doc fellow at the same school on new polymer-based nanocomposites from renewable sources and inorganic fillers. She also worked at the laboratoire de Chimie et Biochimie Pharmacologique et Toxicologique (Université Réné Descartes) in Paris in 2001 and was visiting professor at the Ecole Nationale Superieure de Chimie (Université Blaise Pascal, Clermont Ferrand, FR) in 2012 and 2015. Dr. Totaro has about 25 scientific papers and several participations at conferences and scientific schools. She collaborates on Ecomondo from 2013.

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METALWORKING FLUID DEGRADATION ASSESSMENT BY MEASUREMENTS OF THE ELECTRICAL PARAMETERS AT DIFFERENT TEMPERATURES*

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Abstract

Metalworking fluids (MWFs) are currently used in the metal cutting industry for lubrication and to lower the temperature of both machine tools and worked pieces. Most MWFs are emulsions obtained by mixing an oil product with tap water in proper concentration (usually in the range 1% to 10%). In addition MWFs usually contain also other compounds, such as anti-microbial agents, emulsifiers and anti-corrosion products. MWFs degrade over time due to microorganism growth and contamination by processing by-products (such as tramp oil). Once worn-out the fluid must be properly disposed according to regulations using techniques such as chemical waste treatment, membrane filtration, evaporation or biological treatment.
Since MWFs disposal and replacement represent a cost and have an impact on the environment, the product life-cycle must be extended as long as possible. Thus, assessment of the MWF degradation must be carried out at regular times. This work presents a technique, based on Electrical Impedance Spectroscopy, to assess MWF degradation and estimate the fluid pH value, a parameter playing an important role in the degradation process. The proposed method is based on the measurement of fluid impedance spectrum between 20 Hz and 2 MHz at four different temperatures (15, 25, 35 and 45 °C). The data are analysed by means of Principal Component Analysis (PCA) and the results show the feasibility of fluids clustering according to the contamination level with good accuracy.

Keywords: degradation, impedance spectroscopy, embedded systems, metalworking fluids, multivariate analysis, pH, sensors, temperature

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1. Introduction

Metalworking fluids (MWFs) are used in the metal cutting industry to lubricate and lower temperature of both tools and worked pieces during different finishing processes (Stephenson et al., 2005). Most MWFs are oil-in-water emulsions with oil concentration usually in the range 1% to 10%. MWFs contain also other chemicals, such as anti-microbial compounds, corrosion inhibitors and anti-foam agents. MWFs degrade over time due to a number of different causes, such as: bacterial growth; contamination from foreign elements (metal particles, tramp oil,…) entering the product tank; alteration of the optimal oil concentration.

Contamination by bacteria and fungi is one of the most important causes of product degradation (Bakalova et al., 2007; Mattsby-Baltzer et al., 1989) since most MWFs represent a favorable environment for microorganisms replication. Microorganisms' growth produces a decrease of the product pH that, in turn, makes the environment more favorable for microbial proliferation. Excessive microorganism content makes the fluid that "rancid", resulting in bad smell, decrease of the lubricating properties, and increase of the corrosion rate and, in general, increase of the probability of tool malfunction and decrease of the quality of produced pieces. To counteract bacterial growth, a biocide is often added at regular times (Marchand et al., 2010) to lower the concentration of microorganism to an acceptable level and restore the product pH to a value (between 9 and 9.3) capable to hinder bacterial proliferation. The main drawback of using biocide is toxicity (most biocides contain formaldehyde, a well known irritant for the respiratory tract and carcinogenic agent). Since during normal plant operation, MWF particles are dispersed in the environment as aerosol, they can be inhaled by workers. This, in turn, results in respiratory problems and skin irrations for the exposed workers (Kriebel et al., 1997; Rosenman et al., 1997; Zacharisen et al., 1998.

Another important factor for fluid degradation is oil concentration (C_{oil}), whose optimal value depends on the particular oil product and the type of worked material: if C_{oil} is too low, the MWF lubricating properties decrease affecting the reliability of both machine tools and worked pieces; on the contrary, if C_{oil} is too high, foams are produced and a potential threat to workers' health is present. Since C_{oil} varies from day to day due to water evaporation, oil adhesion to metal parts and bacterial attack, it must be measured at regular intervals to timely restore its optimal value. The reference technique to measure C_{oil} in MWFs is titration with HCl, a method that is accurate and reliable but needs a laboratory and trained personnel. For this reason, the standard technique used in industrial environment is refractometry, normally carried out using an analog portable refractometer (Canter, 2011). Alternative approaches for C_{oil} determination have been proposed that are based on the measurement of viscosity (Grossi et al., 2016A), density (Navarro de Andrade et al., 1999) and ultrasound speed (Meyer et al., 1994).

Once worn-out, MWFs must be properly disposed (according to regulations) and replaced by fresh fluids. Techniques for MWFs disposal include microfiltration (Rajagopalan et al., 2004), ultrafiltration (Hesampour et al., 2008), nanofiltration (Hilal et al., 2004), electrocoagulation (Kobya et al., 2008) and biological treatment by means of bacterial inoculum to degrade the fluid chemical constituents (Van Der Gast et al., 2004).

MWFs disposal represents a cost and may have negative effects on the environment. Thus, fluid lifetime should be extended as much as possible by regular monitoring of its parameters so as to take the appropriate counteractions to prevent degradation.

This paper presents a technique, based on Electrical Impedance Spectroscopy (EIS) (Grossi et al., 2017A), for on-line monitoring of MWFs degradation. EIS is a technique used in different fields such as: measurement of microbial concentration (Choi et al., 2009; Grossi et al., 2008; Grossi et al., 2009; Grossi et al., 2010; Grossi et al., 2011A; Grossi et al., 2012A; Grossi et al., 2013A; Grossi et al., 2013B; Grossi et al. 2014A; Grossi et al., 2017B; Hardy et al., 1977; Johnson et al., 2014 ; Mancuso et al., 2016 ; Pompei et al., 2012 ; Puttaswamy et al., 2010; Settu et al., 2015; Uria et al., 2016 Wang et al., 2012) analysis of human body composition (Gudivaka et al., 1999 ; Ibrahim et al., 2005; Kyle et al., 2001; Rush et al., 2006); quality analysis in the food industry Ferrero et al., 2014; Grossi et al., 2011B ; Grossi et al., 2012B; Grossi et al., 2013C; Grossi et al., 2014B; Grossi et al., 2014C; Jackson et al., 2000; Yang et al., 2016; Valli et al., 2016) corrosion investigation of organic coatings of metal surfaces (Bonora et al., 1995; Loveday et al., 2004); measurement of oil concentration in MWFs (Grossi et al., 2017C).

This work expands on that presented in (Grossi et al., 2016B), where: a) MWF samples were clustered according to their contamination level using EIS combined with multivariate data analysis; b) and the samples pH was estimated with good accuracy. This paper investigates the effect of temperature (T) by making EIS measurements at different temperatures (15, 25, 35 and 45 °C). Furthermore, the temperature effects on the reliability of sample clustering and pH estimation is also studied.

The main result is a higher accuracy in pH estimation and fluid contamination detection that allows extending the MWF life with benefits in terms of reduced costs and less impact on the environment.

2. Materials and methods

Ten different MWF samples (oil-in-water emulsions with C_{oil} in the range 1% - 10%) have been investigated. The samples under test (SUTs) can be clustered into three different groups: fresh non-contaminated samples (from #1 to #3); samples featuring moderate contamination (from #4 to #6); strongly contaminated samples (from #7 to #10).

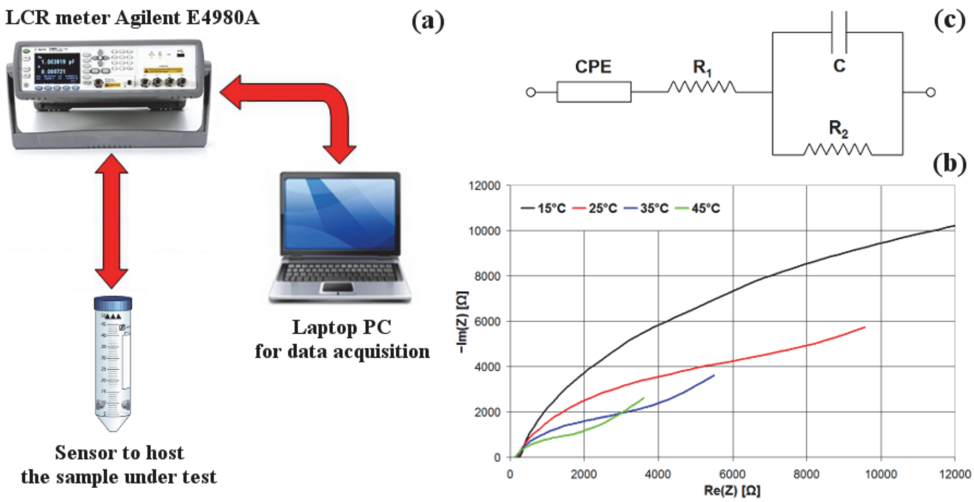

Fig. 1. Measurement set-up used in this work (a), Nyquist plot for sample #8 and different temperatures, (b), Equivalent electrical circuit for the sample-electrode system (c)

Each SUT was electrically characterized at four different temperatures (15 °C, 25 °C, 35 °C and 45 °C) and its pH measured using a portable pH-meter (HI 9811-5N). The experimental set-up for the measurements of this work is shown in Fig. 1a.

The SUTs are stored in 50 ml polyprophilene vials modified to feature a couple of stainless steel electrodes (hereafter referred to as “sensors”). The sensor is placed in an incubation chamber (Binder APT KB 53) providing target programmable temperature (T).

The SUT electrical characterization is carried out by the LCR meter Agilent E4980A: a sine-wave test voltage with amplitude 100 mV and zero DC offset is applied to the sensor electrodes and the current is measured to calculate the complex impedance Z in the frequency range 20 Hz to 2 MHz.

In Fig. 1b the Nyquist plot (representing the imaginary vs. real component of Z) is plotted in the case of SUT #8 for all tested temperatures. As can be seen the SUT electrical response is strongly affected by the value of T.

Fig. 1c shows the electrical circuit used to model the electrode/electrolyte system. In this circuit, validated in (Grossi et al., 2016B), the SUT electrical properties are modeled with the resistances R_1 and R_2 and the capacitance C, while the Constant Phase Element (CPE) models the capacitive interface between the electrodes and the electrolyte.

CPE is a non-linear circuit element with impedance expressed as Eq. (1):

$$Z_{CPE} = \frac{1}{Q \cdot (j\omega)^{\alpha}} \tag{1}$$

where: Q represents the double-layer capacitance, while α is an empirical parameter accounting for the non-ideal electrodes/electrolyte interface (the case α = 1 models an ideal capacitance).

In Fig. 2, Re(Z) and Im(Z) are plotted vs. the test frequency for all tested T in the case of SUT #8. As can be seen both Re(Z) and Im(Z) decrease with increasing temperatures.

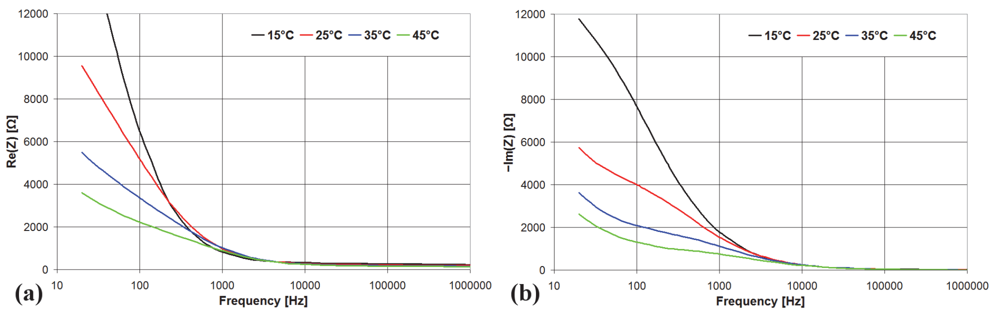

Fig. 2. Real (a) and imaginary (b) component of the impedance Z vs. frequency for all the tested temperatures in the case of SUT #8

All the statistical analysis has been carried out using Microsoft Excel and its statistical package XLSTAT (by Addinsoft).

3. Results and discussion

All measured data (i.e. Re(Z) and Im(Z) for 55 frequencies between 20 Hz and 2 MHz and four different temperatures) have been used as inputs to a Principal Component Analysis (PCA) algorithm to obtain a set of uncorrelated variables. The first two principal components (F1 and F2) accounts for more than 98% of data variations.

The scatter plots of F1 vs F2 are presented in Fig. 3 for all tested samples and temperatures 15 °C (a), 25 °C (b), 35 °C (c), 45 °C (d). From the results of Fig. 3, the three different contamination groups cannot be reliably discriminated in the case of T = 15 °C, but they can at higher temperatures, in particular at T = 35 °C and 45 °C.

Furthermore, data from PCA analysis have also been used to estimate the SUT pH. For each tested temperature a linear regression line (describing pH as linear function of the explanatory variables F1 and F2) has been calculated by minimizing the residuals (distance between measured data and model data) by means of a least squares algorithm.

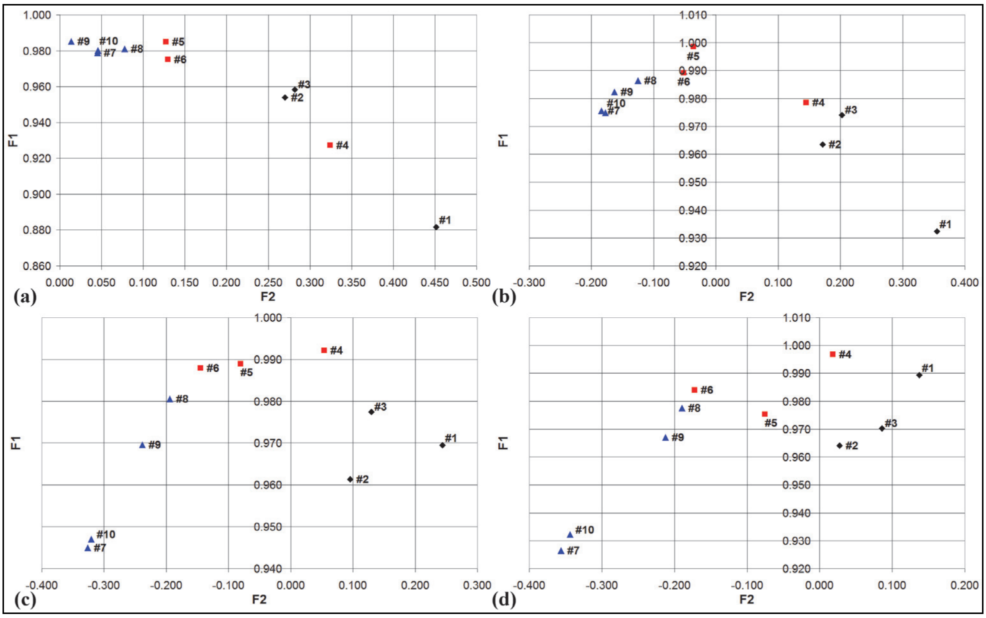

Fig. 3. Scatter plots of F1 vs F2 for all tested SUTs for temperatures 15 °C (a), 25 °C (b), 35 °C (c) and 45 °C (d). The samples are grouped in three categories: ♦ not contaminated, ■ moderately contaminated, ▲ strongly contaminated.

The linear regression lines for T = 15, 25, 35 and 45 °C are presented in Eqs (2-5) respectively:

$$pH = -7.869 + 15.376 \times F1 + 6.86 \times F2 \quad (2)$$

$$pH = 11.507 - 3.519 \times F1 + 2.847 \times F2 \quad (3)$$

$$pH = 23.752 - 15.814 \times F1 + 3.447 \times F2 \quad (4)$$

$$pH = 28.871 - 20.858 \times F1 + 5.191 \times F2 \quad (5)$$

that have been used to estimate the SUT pH from the PCA parameters F1 and F2.

Fig. 4 shows the estimated value of pH vs. the real value measured with a pH-meter in the case of temperature 15°C (a), 25°C (b), 35°C (c), 45°C (d). As can be seen the correlation, evaluated with the determination coefficient R^2 that shows how well measured data are replicated by the proposed model, increases with the incubation temperature. Thus, electrical characterization at higher temperatures (i.e. 45°C) can provide an accurate estimation of the SUT pH.

To investigate if combined data at different temperatures can improve the accuracy in pH estimation and sample clustering in the different categories, the variation of parameters F1 and F2 with T was analyzed. It was found how this relation can be modeled with a quadratic function where T is the independent variable.

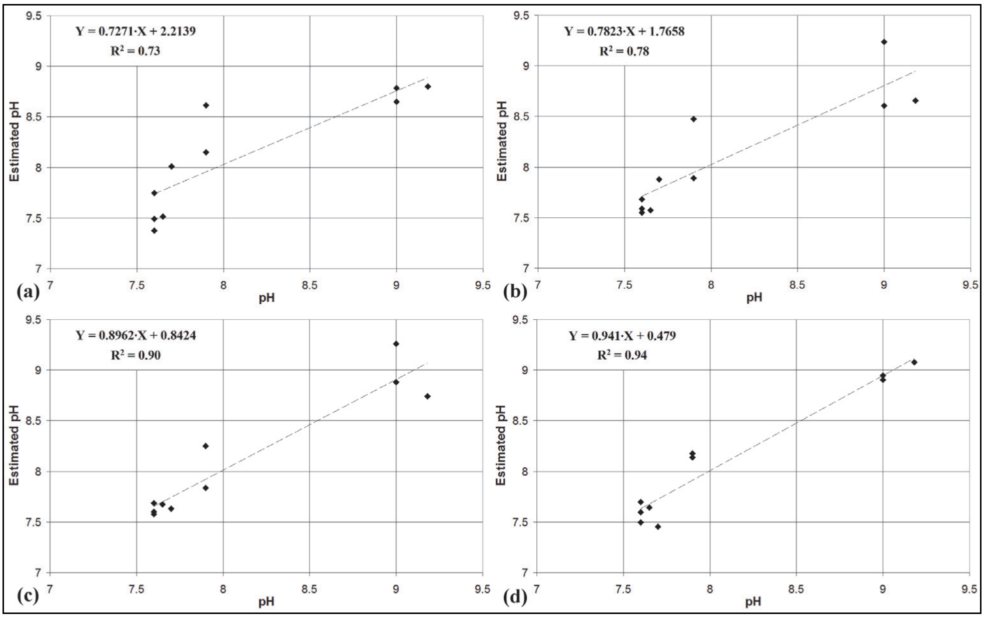

Fig. 4. Estimated SUT pH plotted vs real value measured with a pH-meter in the case of temperature 15 °C (a), 25°C (b), 35°C (c), 45°C (d).

The quadratic function, where Y can be either F1 or F2, can be expressed as Eq. (6):

$$Y = a \times T^2 + b \times T + c \tag{6}$$

The parameters (a, b, c) have been used to estimate the SUT pH using linear regression with a least squares algorithm, and the calculated regression lines are given in Eqs (7-8) for the variables F1 and F2, respectively:

$$pH = 20.761 - 1317.54 \times a - 204.774 \times b - 13.064 \times c \tag{7}$$

$$pH = 9.965 - 1312.303 \times a + 20.31 \times b - 1.183 \times c \tag{8}$$

Eqs (7-8) have been used to estimate the SUT pH for both variables F1 and F2. The results are presented in Fig. 5, where the estimated pH is plotted vs. the value measured with a pH-meter for the variable F1 (a) and F2 (b). As can be seen the variable F2 is strongly correlated with the SUT pH (more than 96% of its variance can be explained by the pH variation), while variable F1 presents only a weak correlation (less than 41% of its variance can be explained by the pH variation).

Finally, the parameters (a, b, c) modeling the temperature variation of F2 have been represented in a 3D scatter plot for each SUT and the results are shown in Fig. 6.

As can be seen the SUT can be reliably discriminated in three different categories (not contaminated, contaminated and highly contaminated), thus indicating that data at different temperatures provide higher accuracy to detect the SUT level of contamination and to estimate the pH.

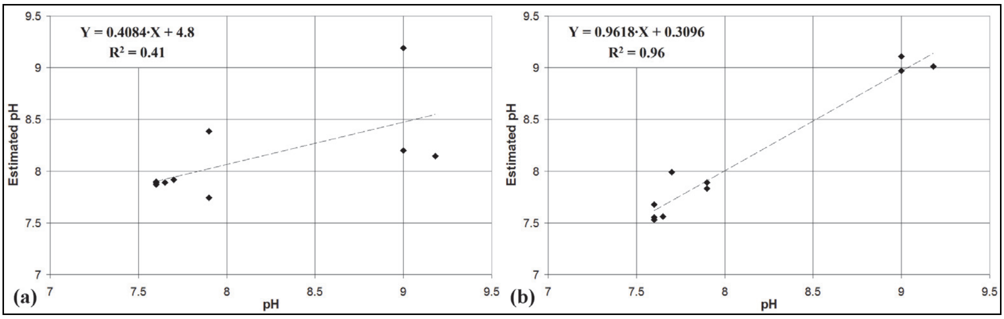

Fig. 5. Estimated SUT pH plotted vs real value measured with a pH-meter in the case of pH modeling with the temperature variation of F1 (a) and F2 (b).

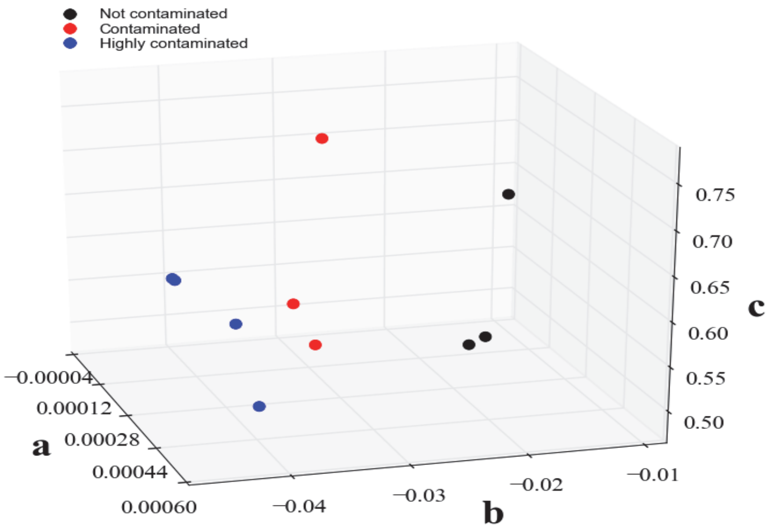

Fig. 6. 3D scatter plot of the (a, b, c) parameters modeling the temperature variation of F2

4. Conclusions

In this paper Electrical Impedance Spectroscopy (EIS) and Principal Component Analysis (PCA) have been used to characterize Metalworking fluids (MWFs) samples at four different temperatures (15, 25, 35 and 45°C).

The results have shown that it is possible to characterize the sample level of contamination as well as to estimate its pH with measurements at (relatively) high temperature (45°C). Processing measurement data at different temperature results in even higher accuracy.

The feasibility of contamination monitoring of MWFs by EIS is an important result indicating the feasibility of on-line, automated monitoring systems offering substantial advantages for regular fluid monitoring and timely detection of contamination, in the end resulting in longer fluid lifetime, lower costs and less impact on the environment.

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SWOT ANALYSIS APPLIED TO A HIGH RISK AREA AS A STRATEGY TO INCREASE SUSTAINABLE LOCAL VALUE CHAIN*

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Abstract

A SWOT analysis is a tool used in the formulation of strategic management. It identifies a firm's Strengths, Weaknesses, Opportunities and Threats. Strengths depend on a firm's skills and resources, Weaknesses on its internal failure. Opportunities and Threats are due to the exploitation or the influence of environmental elements where the business operates. A SWOT analysis can be also made comparing a firm's features and potential to a specific industrial area, analyzing the effects that it produces on the environment as well as for the social and economic context.
The aim of this paper is to describe how a company can turn the weaknesses of a high risk area into opportunities and value. The Sicilian Regional Decree 189/05 includes areas where a serious environmental damage can be caused by industrial activity. In particular, the firm observed is situated in the industrial area of Augusta – Priolo (SR), a large petrochemical industrial pole where oil is refined, petroleum products made and energy produced. Moreover, there is an important trading port in Augusta. Industrial activities in this area cause high levels of pollution, in different forms: atmospheric pollution, soil contamination, contamination of aquifers and surface water, agricultural production damage. The firm analyzed transports and incinerates special waste (industrial, naval and hospital waste). In this firm, incineration is a process where emissions are strongly controlled by innovative instruments in order to excel in the social and environmental respect. Controlled incineration allows for a significant reduction of pollution, preventing a negative impact of special waste on the environment. Therefore, in contrast to the other companies in that area, the firm plays an important role in the process of industrial reclamation. This analysis becomes a useful problem solving instrument to analyze logistic, marketing, and social responsibility, in the perspective of the optimization of eco-management material flows.

Keywords: hazardous waste, high risk area, industrial symbiosis, problem solving, SWOT analysis

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1. Introduction

High risk areas are territorial areas and sea sections characterized by serious alterations in environmental equilibrium. In these areas, environmental issues are caused by intense industrial activities that have strong impacts on the ecosystem. In Sicily there are several high risk areas: Augusta, Priolo, Melilli, Floridia and Solarino in the province of Siracusa, as well as Gela, Milazzo and Niscemi. In particular, the area analyzed in the case study is Siracusa. A firm that operates in the high risk area of Augusta is GE.S.P.I. s.r.l., specialized in the transport and incineration of hazardous waste (in particular industrial, hospital and naval waste), and also the transformation of energy from the incineration process.

Of all of the "terminal" treatment technologies, properly designed incineration systems are capable of the highest overall degree of disposal and control for the broadest range of hazardous waste streams (Oppelt, 1987). All the waste management options of reducing, reusing, recycling and recovering need to be brought into play and rejection of anything that allows the production of energy from waste incineration (EfWI) is not conducive to integrated waste management (Oppenheimer, 2000). According to the Alabama Hazardous Wastes Management and Minimization Act (AHWMMA), hazardous waste is waste that, because of its quantity, concentration or physical, chemical or infectious characteristics may cause, or significantly contribute to, an increase in mortality or an increase in serious irreversible, or incapacitating reversible illness, or pose a substantial present or potential hazard to human health or the environment when improperly treated, stored, transported or disposed of, or otherwise managed (Alabama Department of Environmental Management, 2006). Incineration allows the volume of waste to be reduced considerably and consequently its environmental impact. While thermal destruction offers many advantages over existing hazardous waste disposal practices and may help to meet the anticipated need for increased waste management capacity (U.S. EPA, 1985), public opposition to the building of new thermal incinerating plants has been strong in last decades. Risk perception is determined by the interaction of three dimensions: (a) potential damage, (b) individual risk-aversion, and (c) the way in which risk information is communicated; these factors determine individual risk acceptability, social concern, and risk-taking behaviour.

In industrial contexts where air pollution is particularly noticed by resident populations, risk perception may differ from expert-based quantitative risk assessment (Signorino, 2012). Gray (1996) analysed public controversy over the proposal for a waste incinerator in Northern Ireland. He showed that the perception of risk associated with the incinerator is a major issue for the opponents to the construction, while the safety of the technology and the benefits (jobs, elimination of waste) are stressed by the company. Communication between these two parties was difficult, because ‘‘when the company did communicate, its viewpoint was still rather remote from people’s concerns and was argued largely within a technical competence and business framework, while people wanted reassurance on a social/political level’’ (Lima, 2004). Through this paper, the firm that will be analyzed has the objective to implement a SWOT analysis to identify advantages and disadvantages linked to its activity in this particular area and to evaluate its impact on the environment and on the economic and social contest. The main aim for the company, using this analysis, is to develop strategies to make their activities more efficient and improve its symbiosis with the territory.

2. Material and methods

In order to study the business strategy and the relations between a firm and the contest where it operates, SWOT analysis is a tool that aims to identify the strengths and weaknesses of an organization and the opportunities and threats in the environment. SWOT analysis (the acronym standing for Strengths, Weaknesses, Opportunities and Threats) had its origins in the 1960s (Learned et al., 1965). In more recent years SWOT analysis has been seen as somewhat outdated and superseded by resource-based planning (Grant, 1991; Wenerfelt, 1984) and competency-based planning (Ulrich and Lake, 1990). The resource based view focuses on the internal resources, capabilities and core competencies of the organization, and advocates building strategies on these foundations to assure the competitiveness of the organization and the attractiveness of the industrial sector. Having identified these factors, strategies are developed which may build on the strengths, eliminate the weaknesses, exploit the opportunities or counter the threats (Dyson, 2004).

SWOT analysis is a commonly used tool for analyzing internal and external environments in order to attain a systematic approach and support for a decision situation (e.g. Kotler, 1988; Wheelen and Hunger, 1995). The most important internal and external factors to the enterprise's future are referred to as strategic factors and they are summarized within the SWOT analysis. The final goal of strategic planning process, of which SWOT is an early stage, is to develop and adopt a strategy resulting in a good fit between internal and external factors. SWOT can also be used when strategy alternative emerges suddenly and the decision context relevant to it has to be analyzed. When using SWOT, the analysis lacks the possibility of comprehensively appraising the strategic decision-making situation; merely pinpointing the number of factors in strength, weakness, opportunity or threat groups does not pinpoint the most significant group. In addition, SWOT includes no means of analytically determining the importance of factors or of assessing the fit between SWOT factors and decision alternatives. The further use of SWOT is, thus, mainly based on the qualitative analysis, capabilities and expertise of the persons participating in the planning process. As planning processes are often complicated by numerous criteria and interdependencies, it may be that the use of SWOT is insufficient (Kurttila et al., 2000).

Despite the advantages of SWOT in decision making, the use of conventional SWOT analysis has no means of determining the importance of each SWOT factor (Shinno et al., 2006). Generally, SWOT is a list of statements or factors with descriptions of the present and future trend of both internal and external environment; the expressions of individual factors are general and brief which describe subjective views. However, SWOT is a convenient and promising way of conducting a situational assessment (Wickramasinghe and Takano, 2009). The AHP is largely used to make the factors in SWOT analysis more measurable via providing them analytical priorities and to support the strategic planning process quantitatively (Yavuz and Baycan, 2013). As already mentioned, SWOT analysis can be applied to a firm, but also to other subjects, such as groups of firms, industrial systems, territories.

In 1992, physicist Robert Frosch introduced the concept of analogy between natural ecosystems and industrial ecosystems, called "industrial ecology". An eco-industrial system should maximize the efficient use of waste materials and end-of-life products as inputs for other manufacturing processes. Such a system can be triggered, according to Frosh, only with the interaction between a numbers of actors that contribute to solving a good number of potential problems. Through analogy with natural ecosystems, which are distinguished by their cyclical nature, the concepts of "industrial metabolism" and "industrial symbiosis" are introduced. According to Paul Hawken, industrial ecology provides for the first time an integrated, large-scale management tool that designs industrial infrastructures "as if they were a series of interconnected industrial ecosystems and interfaced with the global ecosystem". Collaboration between companies and synergy opportunities available in an appropriate geographic and economic environment are among the key aspects of industrial symbiosis. Kalundborg's case is emblematic because it does not arise from urban planning and industrial planning, but has developed over the years by the initiative of individuals who have been able to perceive the economic benefits that come from the System of synergies implemented: in fact, the industrial symbiosis mechanisms made in Kalundborg allow production costs to be reduced by accessing lower cost resources and the remunerative disposal of process waste (http://www.simbiosiindustriale.it/Simbiosi-Industriale/).

Therefore, SWOT analysis can represent a useful tool in analysing and assessing the development and the condition of a territory (in particular a high risk area) in relation to the definition of industrial symbiosis and industrial ecology. In the high risk area considered, the SWOT analysis has been carried out on the firm GESPI SRL.

3. Case study: GE.S.P.I. SRL

GE.S.P.I. SRL is a firm founded in 1984 for the management and incineration of port and terrestrial waste in the industrial high-risk area of Augusta (SR). It also offers services in this area such as transportation of personnel from the escape route of petrochemical plants and transportation of any kind of waste from shipping vessels. The core business is the disposal and incineration of special and hazardous waste and its conversion into electricity. It is technologically at the forefront in the management of fumes, ashes and dioxins. In 1999, the modern incineration plant was installed; it has been constantly updated, allowing the company to offer the various high-quality services. Since 2009, waste treatment has taken place through a first production line with a time potential of 4000 kg/h; a second line, with the same features as he first one, is under construction.

It's possible to identify the firm's most important features applying the SWOT analysis (Table 1). The internal appraisal examines all aspects of the organization covering, for example, personnel, facilities, location and services, in order to identify organization's strengths and weaknesses. The external appraisal scans the political, economic, social, technological and competitive environment with a view to identifying opportunities and threats. The firm is very fortunate to be in an extremely advantageous position: it allows costs to be minimized and privileges the closest customers; in fact, extra-regional clients represent only 15% of the total, and corresponds to the 15-20% of the plant's capacity, respecting the important aim of achieving 80% of the revenue through 20% of the clients. Public administration, represents 10% of the clients and corresponds to just 6% of the revenues. Moreover, the proximity to the harbor guarantees a rapid service for the naval waste and also allows an evacuation service of the docks in a case of accident to be performed. In fact, the firm manages different kinds of hazardous waste (naval, industrial, hospital waste) and treats the different kinds in specific proportion for the proper operation of the plant. The production process is based on a "make" structure; the technicians are at the same time the managers of the firm, which from an internal view are able to identify the best available technologies: continuous improvement is one of the pillars of G.E.S.P.I. to preserve its leadership position.

The strong points and the presence on the territory for a long time has allowed the company to increase its reputation and know how, achieving a very high level of reliability. If the position (proximity to the harbor and to the petrochemical pole) is strength for the firm, at the same time it can be considered a limit from the social point of view: historically this type of company has always been judged negatively by the society because of the lack of information. Incineration is a controversial technology. Although it has been widely used to reduce the amount of waste produced in urban areas, and so firms like the one analyzed perform a social function (problem solving function), it is associated with air pollution and its implementation always leads to social protests.

Another weakness for the firm is the distance from the most important urban centers, because of the lack of services such as airport and railways and the difficulty for the clients to reach the factory. In addition, limited spaces cause a lower risk distribution and also do not give the chance to satisfy all clients' requests. Indeed, the firm is already planning the construction of another production line. Another important issue regards the lack of appropriate infrastructures, which is a constant risk in the transport phase and a threat for the company. Finally, the growing impediment of legislation is another obstacle in recent decades: if regulatory progress has the aim to protect the environment in a more rigorous way, on the other hand it is a greater responsibility for this type of firms that have to respect increasingly restrictive limitations, moreover in a legal system full of ambiguity.

Table 1. The firm's SWOT analysis

STRENGHTS	**OPPORTUNITIES**
- Reliability - Technicians / managers - Innovative technologies - Production of energy - Different kinds of waste	- Extension of the plant - Proximity to the harbor and to other plants - Implementation of industrial symbiosis
WEAKNESSES - Proximity to the social contest - Limited spaces - Distance from important urban centers	**THREATS** - Lack of appropriate infrastructures - Regulatory progress and fragility of the legal system - Society disinformation and disturbing behaviors

3.1. SWOT analysis in high risk area

The high risk area of Siracusa involves the territories of Augusta, Priolo, Melilli, Syracuse, Floridia and Solarino (SR), for a total area of almost 550 km2. The area is characterized by a relevant variety of ecosystems and types of land. Moreover, there are lot of natural reserves such as "Cavagrande del Cassibile", "Saline di Priolo", "Grotta Palombara" and cultural heritage that are important resources for the territory. In particular, the area analyzed is the Augusta Bay, a semi-enclosed basin located on the eastern coast of Sicily (Ionian Sea, southern Italy), covering an area of approximately 4000 ha (Di Leonardo et al., 2014). A relevant element in this area is the presence of a trading port, which is source of economic value but also has social and environmental disadvantages for the local community. Indeed, coastal marine areas are sensitive environments and their natural equilibrium can often be perturbed as an effect of numerous anthropogenic stressors (Gao et al., 2014). The principal industrial activities, which make it a high-risk area, regard the industrial sectors of oil refining, chemical products and electricity, and it represents one of the most important industrial poles in the Mediterranean in term of productive capacity and it is the largest refining pole in Europe. Since the late 1950s the port of Augusta has been affected by marine pollution from industrial and petrochemical plants, but also from agriculture and urban waste, with consequent risks to the ecosystem and human health (Di Leonardo et al., 2014). These petrochemical plants are situated in the industrial pole of Priolo – Melilli, where the main activities are oil refining, petroleum products making and production of energy; these activities cause high levels of pollution.

Regarding atmospheric pollution, air quality is monitored by the C.I.P.A. (Industrial Consortium for Environment Protection). Potential micro-pollutants from combustion plants include benzene, aromatic polynuclear hydrocarbons, lead, copper, vanadium, nickel and chromium. For these micro-pollutants, it is not possible to carry out an overall assessment of the air quality status without systematic monitoring conducted with homogeneous criteria. In the petrochemical area besides the unhealthy air there is the problem of river poisoning, pollution of the aquifers and, last but not least, the seismic risk. It has been pointed out several times that many tanks in the refineries now obsolete are not capable of withstanding any earthquake to which the area is exposed. For years in the waters of Augusta, due to the production of chlorine and soda, huge amounts of mercury accumulated, such as methylmercury, entering the food chain (fish and mussels). Augusta, which together with Priolo and Melilli is part of the largest petrochemical pole in Italy, has a TSI (Standard Rate of Incidence) of 609 new cases per 100,000 inhabitants, the highest value not only of the Registry of South Italy, but also the Italian average (552.8). There are 5 main types of cancer which have a higher incidence in the industrial area, compared with the Italian average: liver and thyroid tumors in both men and women, uterine cancer in women, and pleural and bladder tumors in men.

Other weaknesses in the territory are the lack of an efficient infrastructure system, which makes transport and communications difficult; the absence of a purification plant in the municipality of Augusta, which creates serious adverse consequences for tourism; the insufficient information among citizens about the firm's activities, which often create situation of distress and dissatisfaction. Some issues analyzed could be linked to a unique major problem: Italian bureaucracy. Regional innovative patterns differ not only according to the specific strategies and technological performances of firms, but also according to the relevance of systemic interactions and the presence of contextual factors favorable to innovation. In Italy and in particular in Sicily, the slowness and ambiguity of bureaucracy and the legal system does not provide the appropriate context for the development of the territory and the innovation in a competitive industrial system.

On the other hand, the area has a lot of strong point, such as: its geographic position and the trading port that is fundamental for the economy of the territory; the proximity between the different plants and the variety of the production processes that make collaboration between the various industries possible, the creation of innovation opportunities and sustainable start-up following the principles of industrial symbiosis. Table 2 shows SWOT analysis applied to high risk area of Siracusa.

Table 2. SWOT analysis applied to high risk area

STRENGHTS - Trading port - Natural and cultural resources	**OPPORTUNITIES** - Job opportunities - Innovation opportunities - Industrial symbiosis
WEAKNESSES - Atmospheric, soil and water pollution - Lack of a developed infrastructures system - Discouragement of tourism	**THREATS** - Difficulty in legal and bureaucratic system - Insufficient information - Environmental depletion - Health risks

4. Results and discussion

By carrying out a thorough SWOT analysis, the internal and external conditions of the eastern part of Sicily were clearly present; the findings also present some major opportunities that the Sicilian area can exploit, as well as some threats that need to be mitigated in the future (Hongping, 2013).

The SWOT analysis proposed in the first part of the study identifies actors could be involved in cooperate strategy to achieve utility-maximizing measures. In particular, the legal and bureaucratic failure, the lack of infrastructure, the connection with the harbor, the proximity between the plants, the disinformation of the local community are common features in the micro and macro analysis. The two SWOT analyses could underline regional stakeholder groups involved in the process cycle analyzed. Some actors could take part in the actual implementation of the development of a regional programme: large enterprises in the petrochemical and pharmaceutical sector, other competitive sectors in waste disposal economy, sector-based administration, most important private sector employers, district units of railways and other infrastructures. These relationships could represent region's key employers and value-adding enterprises. In this area, companies perceive several obstacles which may discourage them from undertaking innovative activities or make it more difficult for them to achieve expected results from their engagement in R&D activities; in fact, during innovation development sometimes financial resources are not sufficient to cover the high level of investment required by innovation projects, as in the whole of the area of Southern Italy. Further hampering effects are related to the lack of information about technology and market that are relevant to address innovative activities but the collection of this data is time-consuming, expensive and difficult to use. Other impediments are linked to organizational rigidities within the enterprise, difficulty in receiving credits from banks and long time institutional constraints. Thus, four sets of barriers have been identified: cost factors, knowledge factors, market factors and regulation factors.

About social impact, studies of the public perception of incinerators are rare, but most of them recognize that perceived risk is an important issue in the discussion. Some authors have used the movements against incinerators to test the predictions of social movements theory (e.g., Walsh et al., 1993). There is a strong body of work which emphasizes the importance of the media as social amplifiers of risk (Kasperson et al., 1988; Pidgeon, 1999), as well as more recent work focusing on the importance of group identity and group representations on risk perception (Bonaiuto et al., 1996). This perspective allows us to understand that risk perception associated with incinerators is not consensual among the public. In fact, some authors (Petts, 1994; Freudenburg and Rursch, 1994) have stressed the importance of trust and perceived justice in risk acceptability in the case of incinerators. Due to its simplicity, effectiveness and ability to deal with qualitative as well as quantitative criteria was also indicated by the results of this study, a SWOT analysis is well-suited to dealing with the factors considered. In other areas SWOT analysis was seen as just one input in the planning process; a rich array of factors could generate a range of potential strategic initiatives, such as the development of an appropriate system of services and infrastructures, redevelopment of the area from a cultural point of view, implementation of better collaboration between companies following the logic of industrial ecology.

5. Conclusions

This study shows that SWOT approach allows formulating a considerable amount of managerial alternatives, based on intuition and subjective judgments instead of the outcomes of formal planning. It provides an effective framework for learning in strategic decision support in numerous situations; in particular it could be used as a tool in communication and education in decision making processes where multiple decision makers or judges are involved.

Moreover, by having superior intellectual resources, an organization can understand how to exploit and develop its traditional resources better than competitors, even if some or all of those traditional resources are not unique.

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RECENT DEVELOPMENTS OF BIOMETHANE SUSTAINABILITY VOLUNTARY CERTIFICATIONS: A GLOBAL OVERVIEW*

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Abstract

The EU target for renewable energy is going to reach at least 27% in the energy consumption by 2030. Biomethane is called to play an important role for climate mitigation issues thanks to the European Commission's objective to promote sustainable fuels in the transport sector. Certification of biofuels via private Voluntary Certification Schemes (VCS) has become one of the most important tools to verify compliance with Renewable Energy Directive (RED) 2009/28/EC sustainability criteria.
The objective of this paper is to provide a review on the latest development on the main initiatives and approaches for the sustainability certification of biomethane supply chain. A specific focus on Italian regulatory framework and market will be given. The expected biomethane market developments until 2020 and beyond will be discussed.

Keywords: biomethane, biowaste, sustainability, voluntary scheme

1. Introduction

The sustainability targets set by the European Union (EU) are made mandatory through the Renewable Energy Directive (RED) (EC Directive 28, 2009) and its revisions (EC Directive 1513, 2015). The RED Directive defines the main sustainability criteria for biofuels and bioliquids. The RED Directive includes a set of mandatory sustainability criteria as part of an EU sustainability scheme. Similar requirements were set in the Fuel Quality Directive (FQD) (EC Directive 30, 2009) on the specification of petrol, diesel and gas

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together with a mechanism to monitor and reduce GHG emissions. Biofuels and bioliquids are required to fulfill all sustainability criteria to count towards EU targets and to be eligible for support. With RED Directive implementation, the EU underlined the need to define the biofuel production impact and create and harmonized legal basis for biofuel certification.

A revision of the directive is ongoing and it stressed, among others topics, the importance of extending the guarantees of origin, which are currently in place for renewable electricity and renewable heating and cooling, to renewable gas; "*This would provide a consistent means of proving to final customers the origin of renewable gases such as biomethane and would facilitate greater cross-border trade in such gases. It would also enable the creation of guarantees of origin for other renewable gases such as hydrogen*" (COM(2016), 2017). Certification of biofuels via private Voluntary Certification Schemes (VCS) has become one of the most important tools to verify compliance with RED sustainability criteria. The list of officially recognized certification schemes contains 13 VCS, published in the official European Commission (EC) website. The involved stakeholders in certification schemes originate from governments and public and private sectors, like NGOs or profit-seeking corporations and academia. Currently numerous different VCS have been developed and used also for voluntary sustainability of biomethane used as transport fuel (REDCert, ISCC and NTA8080). For the purpose of certification, the whole production chain from the biowaste colleting point to the biomethane producer or trader is checked by independent auditors. However further effort need to be done at European level to harmonize the legal framework that identifies all relevant goals/targets and meaningful indicators, which are easy to measure and not ~~to~~ cost intensive.

2. Objectives

A review of the latest developments on the main initiatives and approaches for the sustainability certification of biomethane supply chain will be provided with a specific focus on Italian regulatory framework and market. The aim is to give an overview of the VCS application in the case of biomethane through case studies and best practices. Accordingly, with the perspective of the actual EU policies on renewable energy market, which suggest, as an opportunity, the option to have a VCS approach to biomethane production from biowaste for socio economic relevance of it and as a method to guarantee a third party measure.

A comparative analysis of VCS application in the biomethane supply chain as well as the expected developments until 2020 and beyond will be discussed.

3. Outline of the work

This work is divided in three main parts:

- Regulatory framework in Europe with a specific focus to Italian regulation;
- An overview of the voluntary schemes accepted by EC with focus on the objectives and procedures to demonstrate the compliance with RED Directive. GHG savings and mass balances requirements will be described;
- An overview on EU biomethane trading market: the use of international biomethane registers and the national registers. The market developments limits and the provisional step-forward will be described.

4. Discussions

4.1. Regulatory Framework and Sustainability criteria at EU level

At European Level the most important regulations containing relevant sustainability criteria for biomethane production are:

• Renewable Energy Directive (RED, EC Directive 28, 2009). On 30 November 2016, the Commission published a proposal for a revised Renewable Energy Directive (COM(2016), 2017).

• Fuel Quality Directive (FQD, EC Directive 30, 2009);

• Indirect Land Use Change Directive (iLUC – "amendments to RED and FQD", (EC Directive 1513, 2015)).

With regard to Biomethane supply chain the key policy drivers are the FQD and RED Directive which link biomethane to the principle of sustainability. Landfill directive is an indirect support to the development of biofuel, diverting biowaste from landfill, giving a potential base do the development of biomethane through anaerobic digestion. The RED sets out sustainability criteria for biofuels in its articles 17, 18 and 19. These criteria ensure that the use of biofuels (used in transport) and bioliquids (used for electricity and heating) is done in a way that guarantees real carbon savings and protects biodiversity.

The main criteria are related to the GHG savings, conservation of land with high biodiversity value, land with high carbon stock, and, only for agricultural production in EU, compliance with agro-environmental practices (See Annex 1) (da Silva e Serra, 2014). Only biofuels and bioliquids that comply with the criteria can receive government supports or count towards national renewable energy targets.

4.2. Biomethane regulatory framework and market in Italy

The Italian regulation for biomethane is very complex and totally based on the biomethane final use. There are different rules, feed-in tariffs and different designated authorities for certification and control of the production depending on the biomethane use: for transport, for power-heat cogeneration or for injection into the grid. At the moment the biomethane producers have to respect the sustainability criteria defined in the RED directive only when the biomethane introduced into the natural gas network and used for transport (http://www.biosurf.eu/en_GB/).

Italy transposed RED and FQD Directives by means of the Legislative Decree no. 28 of 3 March 2011, no. 55 of 31 March 2011 respectively (Decretto 28, 2011; Decretto 55, 2011). The cited Decree states that:

- renewable sources are to cover 17% of gross final energy consumption in 2020, at least 10% of final energy consumption in transport in the same year;
- entities bringing fuels on the market should reduce emissions of greenhouse gases per unit of energy (intensity of emissions) produced during the entire life cycle. The emission reduction target to be achieved by 2020 is 6% of current levels;
- if fossil fuels are mixed with biofuels in order to reduce emissions intensity, they must meet certain sustainability criteria (in line with those established by the EU Directive).

As a tool to monitor compliance with the obligation, 'Certificates of Release for Consumption' (CICs) of biofuels have been established, issued by the Ministry of Economic Development (MISE), which makes use of the Energy Services Operator (GSE). One CIC attests to release for consumption of 10 Gcal. Also, the Biomethane introduced into the natural gas network and used for transport is stimulated by CICs for a period of 20 years after the plant is in operation. If the biomethane plant feedstock derives from the biodegradable fraction of municipal waste after recycling there is a 'reward' of 50% more CICs (for the first 10 years of incentives) (Decretto, 2013). To fulfill the requirement, the Obligated Parties can enter into biofuel consumption or purchase CICs from Parties with a higher number than in their obligations. For this purpose, the GSE has created a specific platform (BIOCAR) through which operators can exchange certificates. For the recognition of CICs, biomethane released for consumption in transport must meet the sustainability requirements defined by RED directive, as certified by National Scheme Certification described in DM 23 January 2012 following the Guidelines of the Italian Thermal Engineering Committee (UNI / TS 11567).

The Decretto (2013), which regulate the biomethane incentives in Italy, is actually under revision. In the revised Decree draft is still reported the need of demonstrate the biomethane sustainability following the certification procedures defined in the DM 23 January 2012 and RED Directive. This mean that the biomethane supply chain economic operators still will have to certify the process under the National Certification Scheme or voluntary schemes recognized in EU to sell the biomethane for transport use.

4.3. VCS schemes in EU

According to the RED Directive economic operators in the biomass and biofuel chain must demonstrate to their Member States that the sustainability criteria have been met. This compliance effort may be carried out:

– either by providing the relevant national authority with data, in compliance with requirements that the Member States has laid down (a “national system”), or

– by using a “voluntary scheme” that the European Commission has recognized for the purpose, or

– in accordance with the terms of a bilateral or multilateral agreement concluded by the European Union with non EU countries and which the European Commission has recognized for the purpose.

One of the voluntary schemes recognized by the EC have to be used to verify the production of the biofuels in accordance to the defined sustainability requirements. In addition to these criteria, the certification schemes take into account further criteria such as soil, water and air protection as well as some social criteria. The certifications are mostly running under private organizations, where independent auditors check the whole production chain from the feedstock growers to the biofuel producer and/or trader. Besides those voluntary schemes, there exist other schemes (they are not recognized by the EC) with the aim to fulfill national requirements on sustainability (biomethane for electricity and heat production in Germany) or a stakeholder’s brand e.g. Green Gas Label in Germany (Grope et al., 2016). Differences exist in the scopes, strictness and level of detail of voluntary schemes, due to various interests, market applications and priorities. Figure 1 shows two of the many differences between these sustainability schemes: the horizontal axe indicates if a scheme is feedstock specific or not and the vertical axe indicates to which extent they cover the entire biomass chain.

Most of the schemes cover the entire biomass chain of production, conversion, trade and end-use, with exceptions of Global GAP, Red Tractor and SAN that focus on agricultural processes and hence on the first step of the biomass value chain. There are a number of schemes that are feedstock specific (Bonsucro sugarcane, RSPO palm oil). Another batch of schemes have a larger scope but do not accept all types of feedstock (Globa lGAP, Red Tractor and SAN agricultural products, REDcert biomass produced in EU-27).

Several voluntary schemes explicitly include mandatory requirements to reduce the impacts on natural resources (soil, water, air, use of chemicals) and to address human and workers rights. Biomass supply chains are diverse and differ, depending for example on the type and source of feedstock, the scale of production, and local geographical and economic conditions. REDcert, ISCC, 2Bs, HVO schemes have a specific procedure refereed to waste and residues feedstocks.

In Italy the verification of the sustainability criteria defined in the RED directive was defined through a system of traceability throughout the biofuel and bioliquids supply chain. To this end, the economic operators of the production chain of biofuels and bioliquids, whether they are produced in EU and in third countries, who intend to join this system have to be subject to initial and periodic audits by certification bodies accredited by the single certification body (ACCREDIA). Following the initial review, the certification body shall issue the company certificate compliance valid for five years against which the individual operator can release, to the next operator in the chain of delivery, the declaration of conformity that contains, for each batch of raw material or intermediate product, the information that contribute to the demonstration of compliance with the sustainability criteria. Private Voluntary Certification Schemes are still not developed in Italian context, probably due to the uncertainty of biomethane regulations and market.

4.4. GHG savings requirements

The RED Directive sets a phasing-in GHG saving reductions targets: fixing a minimum GHG emissions saving of 35% compared to fossil fuel by 2016, raising to 50% in 2017 and 60% in 2018. The GHG emission calculations are based on the entire life cycles. The only default values coming from RED for GHG calculations for biomethane are from municipal waste (23 gCO_2eqMJ - organic fraction), liquid slurry (16 gCO_2eq/MJ for biogas produced) and manure (15 gCO_2eq/MJ for biogas produced) (http://www.biosurf.eu/en_GB/). This determine a big simplification for biowaste treatment plants which produce biomethane as there is no need of calculating the actual GHG emissions of biowaste and is possible to proceed with the simplified and standardized calculation of the emissions.

However, in Italian case there is an urgent need to simplify the process by introducing default values and allowing the averaging of GHG values for other feedstocks. More in detail the Italian technical regulation UNI 11567 presents a list of other feedstocks with default values that biomethane producers could use.

4.5. Mass balance requirements

The chain of custody approach laid down in the RED is the mass balance approach. The mass balance requires a physical link between all stages and allows sustainable and other raw materials to be physically mixed as long as the sum of all consignments taken out of the mixture has the same sizes for each of the sets of sustainability characteristics that went into the mixture. All EC recognized voluntary schemes use a RED compliant mass balance. Each VS defines rules for economic operators with regard to record keeping and documentation and procedures for identification of inputs and outputs. All require that the certified volume out is not greater than the level of a geographical site in the supply chain. However, the schemes also operate certain aspects of the mass balance in different ways. The main different methods can be found for:

- double-claiming preventing: although the RED does not specify how schemes should deal with this, all schemes recognized require economic operators to put in place information systems able to keep track of the inputs and outputs to ensure the integrity of claims made under the scheme;
- different time frames over which the mass balance system operates;
- chain of custody auditing: most schemes require all actors in the chain of custody to be audited before they can start producing or trading certified material. For example, transport steps and traders in the supply chain are treated differently in different schemes and are not always required to be audited;
- waste or residue auditing: for agricultural feedstocks, it is clear that the chain of custody starts at the farm, with all farms being required to be audited by voluntary schemes (unless a group certification approach is taken, at which point it is permitted to audit a sample of farms). However for wastes and residues different approaches are currently being

taken, with ISCC currently defining the "first gathering point" for wastes as the "first melting point";

- Operation of alternative chain of custody approaches only a few of the recognized schemes actually explicitly offer more stringent chain of custody options (RSB and RSPO allow for identity preserved and segregation, ISCC allows for physical segregation).

In Table 1 are listed the key characteristic of existing mass balance methods for the main VS recognized by EC.

Table 1. Key characteristics of existing Mass balance systems (Ecofys Report, 2013)

Scheme	2BSvs	Bonsucro EU	Greenergy	ISCC EU	Abengoa	RSB EU	RTRS EU	RSPO	FSC
Prevention of double counting/claiming	YES. Through requirement for detailed internal data management and monitoring systems (principle 0) Use of internal registry.	YES – through unique ID number	YES – through the invoice (a biofuel sustainability declaration) and/or through a unique reference number	YES - through unique ID, risk analysis and random checks. Internal Registry is maintained through ISCC webpage	YES – through use of internal code and internal registry	YES - "unique identification of the product [...] unmistakable and unambiguous differentiation from all other products..."	YES-through use of an internal accounting system	YES - through a web-based Transaction Registration System (Central Registry operated by Utz)	NO centralised system.
Timeframe over which the system operates (from assessments)	Continuous	One month	2 options: (1) Periodic inventories with maximum period of 3 months ; or (2) Continuous inventories	3 months	3 months	Continuous	2 options: (1) continuous or (2) fixed inventory of 3 months (with 12 months permitted only in the first year of certification).	Continuous	Inventory period of 12 months, although exceptions are possible
Extent of supply chain covered	Entire supply chain	Entire supply chain	Entire supply chain	Entire supply chain	2 options (to conversion unit or to final economic operator)[1]	Entire supply chain	Entire supply chain	Entire supply chain	Entire supply chain
Supply chain audits	YES[2]	YES	YES	YES	YES	YES	YES	YES	YES
Chain of custody certification	YES	YES	YES	YES	YES	YES	YES	YES	YES

In Italy was issued the technical regulations UNI/TS 11567 (2014), UNI/TS 11429 (2011) and UNI/TS 11441 (2012) to clarify and outline the specific legislation in the biomethane field. The UNI/TS 11567 and 11441 define the requirements for traceability system implementation and mass balance management according to RED requirements.

The mass balance must respect these parameters:

- to allow the raw materials with differing sustainability characteristics to be mixed;
- to make sure that the information about the sustainability characteristics and sizes of the consignments remain assigned to the mixture;
- to ensure that the sum of all consignments withdrawn is described as having the same sustainability characteristics, in the same quantities, as the sum of all consignments added to the mixture.

These rules need to be applied in particular when several feedstocks are used in the anaerobic digestion plant: e.g. sewage sludge and biowaste co-digestion. The UNI/TS 11567 defines also several procedures to follow such as: process boundaries, the biomethane and biogas plant yields, define the storage area, the mass balance timeframe between 6 and 12 months, the CO_2eq associated to the input and output of anaerobic digestion plants.

4.6. EU biomethane trading and voluntary scheme market

The cross-border biomethane trade related issues have been analysed in several recent projects and reports, such as the BIOSURF project (http://www.biosurf.eu/en_GB/) and the

EBA Biomethane & biogas report 2015 (EBA, 2015). Initially, biomethane has been traded mainly at a national level only. However, gradually it becomes a cross-border commodity that is traded between EU Member States. Nevertheless, cross-border biomethane trade is still very limited. The main problem hindering cross-border trading is related to traceability requirements and in particular to the mass balancing system that was included in the RED Directive with a focus on liquid fuels, which is less suitable for the trading of biomethane that has been injected into the natural gas grid (http://www.biosurf.eu/en_GB/). Cross-border trade in biomethane is also difficult as there are a number of country specific quality requirements and verification procedures. Mandatory sustainability criteria at EU level and harmonized verification procedures would be helpful. EBA suggests international harmonization of Guarantees of Origin (GoO) certification systems to enable import and export of biomethane across Member States. Initial steps towards harmonization have already been taken by national biomethane registries in place in several countries including Germany, Denmark, Austria, France, the United Kingdom and Switzerland (EBA, 2015).

An example of international biomethane register is the BiogasRegister International which aims to complement the national biomethane registries and enable cross border biomethane trading in EU. The main ideas of Biogas Register International are:

- consider European laws and harmonizes local guidelines applicable in all European countries;
- documents legally compliant whole biomethane-supply-chain from its origin to final consumption;
- provides an European non-discriminatory access for all market players and national registers.

4.7. Regulatory Prospective with RED II Directive

On November 30, 2016, the European Commission (EC) published a formal proposal (COM(2016), 2017) to the EU Council and the European Parliament to recast Renewable Energy Directive (RED) 2009/28/EC2, which will expire at the end of 2020. The proposed new directive, called RED II, would succeed the existing regulation and enter into effect on January 1, 2021. RED II proposes a set of policy measures to achieve a 27% renewable energy share from energy consumed by the electricity, heating and cooling and transportation sectors by 2030.

With regards to biowaste, the RED II proposes a sub-target of 3.6% blending for advanced biofuels coming from these feedstocks by 2030, starting with a sub-mandate for 0.5% blending in 2021.

6. Concluding remarks

A review of the latest developments on the main initiatives for the sustainability certification of biomethane supply chain has been provided with a focus on EC and Italian regulatory framework and market. An overview of the VCS application in the case of biomethane through case studies and best practices has been given. A comparative analysis of VCS application in the biomethane supply chain as well as the expected developments until 2020 and beyond is discussed.

An overview on EU biomethane trading market also has been given with a focus on the use of international biomethane registers and the national registers. The market developments limits and the provisional step-forward is described, still further effort need to be done to harmonize the biomethane market and regulation throughout EC.

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WEB Resources

http://www.biosurf.eu/en_GB/

Procedia
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http://www.procedia-esem.eu

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THE RICIGEN FOR ECO-INNOVATION: ENERGY FROM WASTE WITHOUT COST*

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Abstract

The "Ricigen for Eco-Innovation" project was born from the idea of the Research & Development Team of the Engineering Society. Members comes from a specific university course and they have developed an alternative waste recycling chain with the implementation of special devices for generating electricity by using waste materials. The assistance phase to the companies has therefore focused over the last few years in optimizing processes that generate cost savings. Especially in the environmental sector, they need to optimize the cost of utilities that were high due to different reasons ranged from the contractual cost of subscriptions to the efficiency of installed systems to the unmanaged use of energy sources.

Keywords: environmental impact, LCA, recovery, special waste

1. Introduction

Members of this project come from a specific university course and they have developed an alternative waste recycling chain with the realization of special devices for generating electricity by using waste materials that are no longer used. The assistance phase has therefore focused over the last few years in optimizing processes that generate cost savings. Especially in the environmental sector, there was a necessity for the companies to save the cost of the utilities that were high for several reasons from the contractual cost subscribed to the efficiency of the installed systems, the unmanaged use of energy sources. In the public sector, however, the focus has become savings money and in particular in some sectors, including waste, which, in addition to being a daunting issue for a delicate solution,

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on the other hand it's a cost for public administrations and need to be revisited with a broad long-range perspective view (Rocco et al., 2017; Tricase and Lombardi, 2009).

The transition to a circular economy may be the biggest revolution and opportunity for sustainable production and consumption (UN General Assembly, 2015) in our global economy in 250 years, by recognizing that everything has a value and eliminating the very concept of "waste" (Lacy and Rutqvist, 2015). Circular economy represents a huge opportunity for companies to create a competitive advantage (a "circular advantage", Lacy and Rutqvist, 2015) and shared value (Porter and Kramer, 2011) through innovative business models and engineering, by reconceiving products and markets, redefining productivity in the value chain (olso moving from efficiency to effetiveness in the way companies manage inputs and outputs), enabling local cluster development, in partnership with institutions, academia and civil society (UN General Assembly, 2015), according the Quituple Helix model for sustainabile development and innovation (Carayannis and Campbell, 2010; Etzkowitz and Leydesdorff, 2000; Mititelu et al., 2016).

2. Objectives

The main objective of this study is to analyze the environmental sustainability of this new deal to reuse the waste. This new way of thinking about the environment, re-use and new methods for generating energy has led it to create different prototypes to generate cheap electricity. Devices created have not created new sources of energy but have innovated the thought and the conviction that energy should be generated from new constructive devices with more and more innovative materials. These are certainly useful and indispensable to achieving the most from renewable energy sources and do not compete with what we propose. Here is an unexpressed but important power in which is impossible to create a new chain and a new way of generating energy.

As specified in the premise and in the development of the design idea, every product that we use will result in an environmental impact and a relapse on global well-being. This data is often absent from design ideas and sustainable application development. Incredibly, the production of a photovoltaic panel also results in energy consumption and environmental impact balanced by its virtuous ability to return clean energy over the years. But all the other products that are produced for other uses are generated through an energetic production process followed by an energetic process at the end of life recovery. This principle in our design idea is less or at least a product that have a specific function in our everyday life (a water pump of a washing machine is produced to "pump" water by absorbing energy).

We make it a producer of energy reversing its concept for which it was produced: from energetic object to object of energy producer. This concept does not lead to an energetic process, the device has already been produced and although it will contribute for a few years to produce energy, it will have lowered the cycle of CO_2 production for its lifecycle. The appliances are easy to manufacture and easy to install and the design is aimed at making them the cheapest home accessories.

3. Outline of the work

This work is divided in three main parts:

- selection of the actual waste management of RAEE;
- evaluation the different between the current waste management systems and the new system;
- analysis of results, drawing conclusion and formulation of recommendations for policy and decision makers in the sector of C&DW.

4. Materials and methods

The generators are a prototype built entirely of waste material from industry and / or trade. Specifically, one is built using a washing pump, descendants of suitably sectioned raincoats, ferrous scrap materials, and energy storage batteries (batteries).

At this stage, using waste material, reliability is given by the integrity of the recovered products and their previous industrial life. Other generator has designed to exploit the water flows in civil homes and cities (fountains etc.) and it is built for to use the power of a bicycle.

5. Results and discussion

This paper presents an important study regarding the environmental impact of the RAEE. The production of RAEE in Italy is growing-up and the CDC RAEE are growing-up their capillarity in every city and with their activities these wastes are recovered. Thinking to another reuse of single component is a best way for improve the environmental benefit and create another possibility to reuse it. At the beginning, we study the actual waste management of RAEE and we can show the information in the Table 1. For the evaluation of the impact on the environment, we have established also the composition of this special waste in Tables 2 and 3. The impact is generated by the each component of certain type of waste. In this study, we represent the result of the application of the prototype. You can see that every material is "reuse" with an energy system. The results were normalized in accordance with each software database as to can be compared. The evaluation of the three scenarios proposed indicated the most suitable scenario to be implemented for improving the actual waste management system.

These prototype are devices that allows to create clean, efficient and low cost energy with relevant savings for customers through the use of discarded materials, actually assembled and installed alongside traditional energy supply systems. These devices are i) constructed with waste materials and ii) will serve to generate electrical energy, in alternative to the traditional supply systems, both with the connecting to the network and domestic use, with focus on metropolitan areas, new buildings, private houses, condominiums.

Table 1. Production of RAEE in Italy (WEEE Coordination Center, 2017)

Type	*Description*	*Recovered Quantity 2016 (kg)*
R1	Cold and climate	76.000.000
R2	Big White	90.000.000
R3	TV and monitor	64.000.000
R4	Vacuum cleaners, sewing machines, irons, fax, phones	30.000.000
R5	light sources such as gas lamps, energy-saving lamps	1.700.000

Table 2. Component of washing machine

Material washing machine	*%*	*kg/piece*	*Type of recovery*
Iron	37.2	24.2	Of matter with working
Plastic	13.4	8.7	Of matter with working/waste to energy
Cement	33.5	21.8	Of matter with working
Engine	10.1	6.6	Of matter with working
Aluminum and copper	1.9	1.2	Of matter with working
Cables	0.7	0.4	Of matter with working
Glass	1.1	0.7	Of matter with working
Other material	2.1	1.4	Different type
Total	100.0	65.0	

Table 3. Component of dishwasher

Material dishwasher	*%*	*kg/piece*	*Type of recovery*
Iron	63	30	Of matter with working
Plastic	12	5.8	Of matter with working/waste to energy
Cement	2	1	Of matter with working
Other	4	1.9	Different type
Tar	12	5.8	Of matter with working
Wood and plastic	6	2.9	Of matter with working
Total	100.0	65.0	

The necessities are i) demand of energy saving on electricity bill derived from private customers and builders and ii) need of low environmental impact devices by local authorities. A domestic user can save a consistent amount of money per month; condominiums and local areas as far as 12% less of current prices.

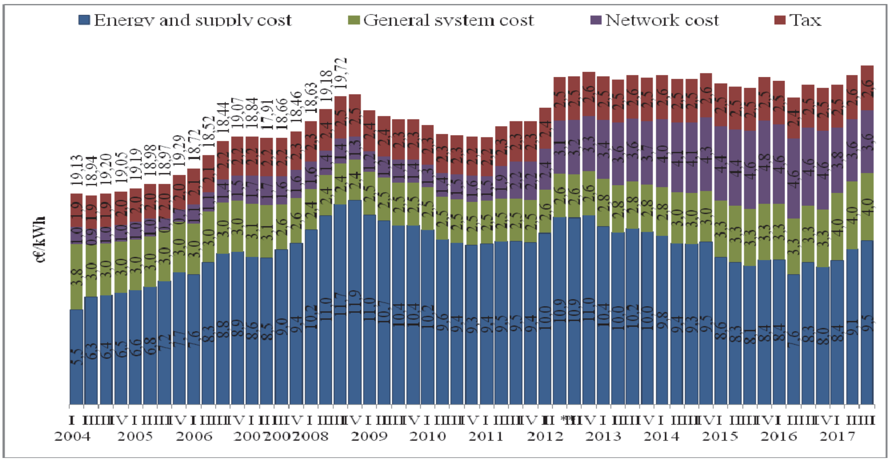

Fig. 1. Electricity price trend for the most in-home consumer (AEEGsI, 2017)

These data photograph the economic conditions for a family in Italy with 3 kW of power used and 2.700 kWh of annual consumption from 2004 to June 2017. This will be able to bring significant benefits for the consumers, providing two devices that: i) will operate on supply saving side (“green lines” on graphic), thanks to its cheapness of energy production and ensuring average savings some euros per month for private customers and until 12% for local areas; ii) will create an alternative system of energy production, replacing the traditional non-renewable resources and revolutionize the current state-of-art of design and production of renewable energy plants through this devices that can generate clean end efficient energy with waste materials; iii) will be diffused with a competitive sales and after-sale prices, including the absence of costs installation; iv) will have a less environmental impact in comparison with the other products. We have also analyzed the energy system in some house that we have shown in the Table 4 and Figs. 2, 3.

We have installed the prototype in some places where we use it for some months and we obtained good results (Tables 5, 6).

6. Concluding remarks

We strongly believe in this idea that we have until now supported all the economic and temporal costs for its realization despite being a young and trying to grow without having lenders or solid investment groups behind it. We are aware that introducing a new way of thinking about technologies and their different reuse of canonical systems is a tough and difficult challenge to carry on.

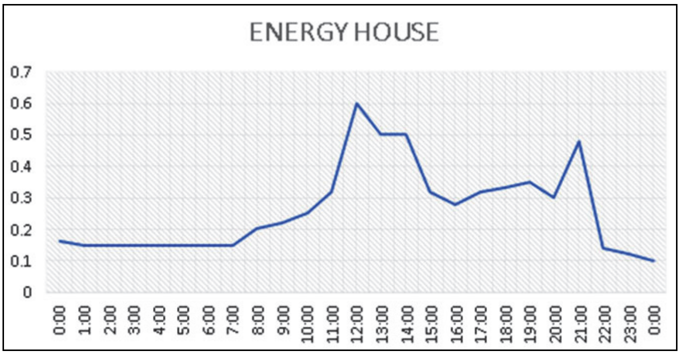

Fig. 2. Energy house system (from e-link system*)*

Table 4. Evaluation of the different concept of the two systems

Description	*Actual System*	*New System*
Environmental cost of the energy process of producing a good	Present	Absent
Environmental Cost of Disposal of RAEE	Present	Absent
Environmental benefit of having prolonged the useful life of machinery for a few years	Absent	Present
Environmental benefit of having recovered material by assembling materials and not merging some of them	Absent	Present

Table 5. Acquagen characteristics

Per capita consumption	*Average people*	*Family consumption*	*Pipe diameter*	*Pipe area*	*Velocity*	*Flow*	*Storage time*	*Storage capacity*	*Daily storage*
l/in/d	-	l/in/d	inch	m^2	m/s	l/s	s	A/h	A
50	3	150	½	0.00014	1.5	0.21	3.572	0.9	0.89

Table 6. Cyclogen characteristics

Daily consumption (kW)	*Average people*	*Number of asynchronous motors*	*Accumulation capacity (A)*	*Daily accumulation (A)*
10	3	6	36	36

We are aware that in everyday life, if we use an object, we sometimes wonder what entity was the energy process needed to realize it and how much this has impacted on the environment. When we buy an appliance we can check its consumption during operation but we never make a budget on how much energy it has been spent to produce it and how much its virtuous being in consuming less energy the generous process of generation. Now we know that in every house we can save energy and to have some benefit.

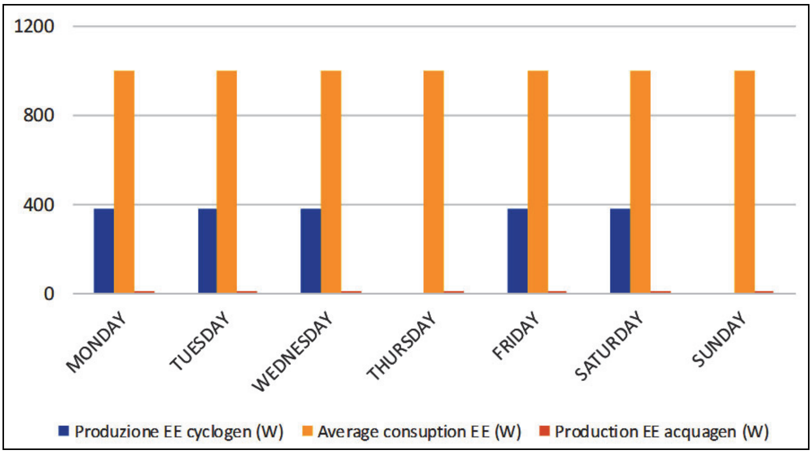

Fig. 3. Home energy chart

As shown in our paper, using only two applications a family can have 6% less of energy bill and with the use of high performance of home appliance, low consumption lamp the benefit grow-up and the reuse of something without spent energy for his regeneration give the best contribution to the environment. So having a discarded eaves gutter, printer motors, faxes or other disused household appliances, some washing machines or objects gears varies, it's possible to self-build a generator to generate electricity that supports light point installations in the house and in the cities.

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GREENHOUSE GAS EMISSIONS FROM THE INTEGRATED WASTE MANAGEMENT SYSTEM AND THE RELEVANCE AT TERRITORIAL SCALE: THE CASE OF THE PROVINCE OF GROSSETO*

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Abstract

In this study, we investigated the main emission sources of greenhouse gases from the waste management system in the Province of Grosseto (southern Tuscany - Italy). The estimation has been included in the general greenhouse gas (GHG) balance of the entire provincial territory for the year 2015. We analyzed the areal waste management system, from waste collection to specific treatment in landfill and five waste recycling plants available within the provincial boundaries. An incinerator is not installed in the area; however, we estimated the Refuse Derived Fuel (RDF) combustion in a hypothetical incinerator. Using the *"2006 IPCC Guidelines for National Greenhouse Gas Inventories"*, we calculated carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O) emissions from waste decomposition/incineration and from consumption of electricity and fossil fuels used in all waste management plants, contextualizing the results within the provincial GHG balance that includes energy, industrial and agriculture, land use & forest sectors. The study showed that the Province of Grosseto is not far from a "carbon neutral" status in 2015 and the waste sector covers a relevant part of gross emissions (15.4% of the total). Overall, this waste management system is rather fragmented and improvements in organization and plant selection and connection may help achieve 100% compensation of GHG emission for the Province. We also found that the plant with the greatest impact is the landfill (55.78% of the waste plant emissions). A bottom-up data collection approach has been adopted, generating an overall uncertainty of 14.9% for the GHG inventory. In conclusion, the GHG inventory is a tool able to suggest and validate environmental strategies to reduce the climate impact from waste management, resulting in positive feedbacks on the overall GHG balance of the territory, and influencing the environmental quality and the socio-economic infrastructure of the Province.

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Keywords: Integrated Waste Management System, greenhouse gas balance, landfill, province of Grosseto, waste treatment plant.

1. Introduction

According to the Intergovernmental Panel on Climate Change (IPCC) 5th Assessment Report (2013), at least 95% of the current greenhouse effect is caused by human activities and the waste treatment has a relevant responsibility in greenhouse gas (GHG) emissions (IPCC, 2006, 2013). Improvements in waste management can thus reduce impacts on the atmosphere and allow considering waste as a resource rather than a problem; this is also the main goal of the EU Directive 2008/98/EC. In addition, it is necessary to have a complete and realistic view of all the other sources of GHG (energy, industrial and agricultural processes) and absorption sinks of an area, to improve its environmental performance (EC Directive, 2008).

Since 2008, the Ecodynamic Group of the University of Siena, in collaboration with the provincial administration of Siena and the certification agency RINA Service S.p.A., is monitoring in time series the GHG emissions of the Province of Siena, under the REGES Project (Bastianoni et al., 2014; REGES Project, 2008-2016).

The study presented in this article is inspired by the work already done in the Province of Siena; in this case, we examined the climatic emissions of waste management plants in the Province of Grosseto and their impact on the GHG balance of the territory. In this work, we have therefore studied in detail the Integrated Waste Management System (IWMS) of the Province of Grosseto, identifying all the plants involved and all the movements of the different waste types, collected in the provincial territory.

To calculate GHG emissions, we have applied the "2006 IPCC Guidelines for National Greenhouse Gas Inventories" (IPCC, 2006) to identify which plants and management activities influence the GHG emissions of the IWMS. Moreover, to better frame the importance of the urban waste management system in the Grosseto area, we also estimated the gross emissions (including energy, industrial and agriculture activities) and the GHG balance of the whole Province. The reference year for this study is 2015.

2. Materials and methods

2.1. Description of the integrated waste management system of the Province of Grosseto

The Province of Grosseto occupies the South-Western part of the Tuscany Region and has a population of 224,481 inhabitants on January 1st, 2015, which are distributed over a territory of 4,504.30 km^2, with a population density of 49.84 inhabitants/km^2 (ISTAT, 2015). In Italy, waste recycling increased from 35.30% in 2010 to 45.20% in 2015, while in Tuscany from 36.64% to 46.10%. The Province of Grosseto, on the other hand, is the territory with the lowest level of waste recycling in Tuscany and among the lowest of Central-Northern Italy with levels that passed from 26.21% in 2010 to 30.20% in 2015 (ISPRA, 2001-2016, 2016).

The waste collection in the Province of Grosseto is implemented by a private company and the treatment plants for the different waste types are managed by many companies. Six plants operate in the provincial territory, treating the Municipal Solid Waste (MSW) produced within the area; some plants also manage waste coming from other regions of Italy, but these fractions have not been considered for the calculation of GHG emissions, because we aimed to focus only the Grosseto district (Sei Toscana, 2017).

The plants of the Province of Grosseto are (Fig. 1):
- 1 plant for the physical and biological treatment of undifferentiated MSW (SP) and 1 composting plant (CP), located on the same production site;
- 1 multi-material valorization plant (MVP);
- 2 paper/cardboard valorization plants (PVP1 and PVP2);
- 1 non-hazardous waste landfill (L), with biogas recovery plant.

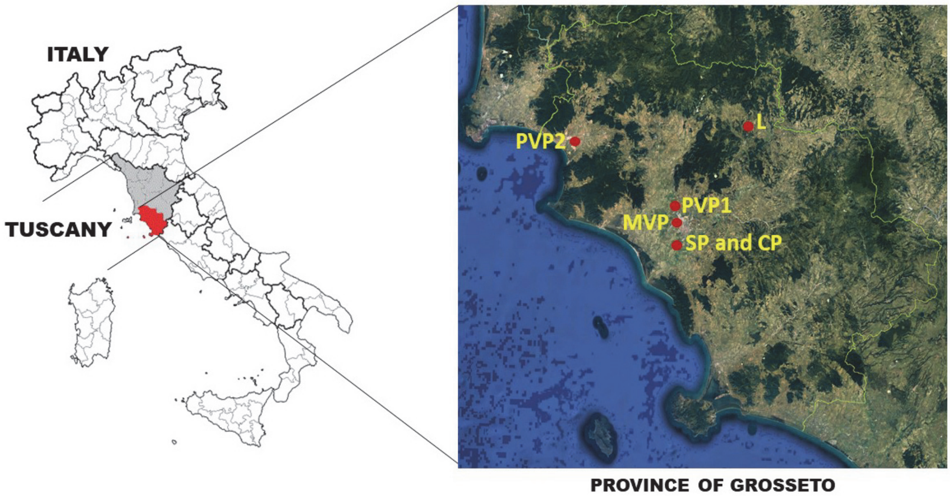

Fig. 1. Location of landfill (L), selection (SP), composting (CP) and valorization plants (MVP, PVP1 and PVP2) in the integrated waste management system of the Province of Grosseto

2.2. Estimation of GHG emissions from waste management plants

The "2006 IPCC Guidelines for National Greenhouse Gas Inventories", proposed to realize national GHG balances, have been considered for the estimation of emissions in Grosseto (IPCC, 2006). This methodology has already been successfully applied to territories at small scale, such as regions, provinces and production activities at company level (Bastianoni et al., 2014; Bosco et al., 2008; Marchi, 2014; Marchi et al., 2014; 2015; 2017; Priambodo and Kumar, 2001). The GHGs analyzed and recorded in this study are carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O); other GHG emissions considered in the IPCC guidelines have not been accounted for because not released by anthropogenic activities performed in the Grosseto area. In the 2006 IPCC Guidelines, GHG emission and removal accounting are divided into 4 activity sectors, namely: 1) Energy, 2) Industrial Processes and Product Use (IPPU), 3) Agriculture, Forestry and Other Land Use (AFOLU), 4) Waste; we focused on the Waste Sector.

Equation (1) has been used for the estimation of emissions. It includes activity data (AD, e.g. fuel consumption) multiplied by emission factors (EF, e.g. amount of CO_2 per unit fuel used), which quantify the rate of emission of a specific gas per unit of activity.

$$GHG\ Emissions = AD * EF \tag{1}$$

Most of the activity data has been collected from the companies managing the plants or other public and private bodies (e.g. Agenzia Regionale Recupero Risorse - ARRR, Siena Ambiente S.p.A. and Terna S.p.A.) involved in the system. Emission factors derive from default values contained in the 2006 IPCC guidelines, whereas in some cases we used data obtained from the handbook of national emission factors (as in the case of methane released during the oxidative degradation of the organic fraction in the composting plant) (CTNACE, 2002).

In our study, we used a geographical criterion with bottom-up approach (IPCC, 2006), when the plant operators provided the activity data; for estimating emissions related to the electricity imported from the national grid we have adopted a responsibility criterion, using the national average emission factor, which considers the GHG emission from the electricity production in Italy and that locally generated (Ridolfi et al., 2008; Terna, 2015).

Estimated GHG emissions have been divided into direct emissions, which take place within plant boundaries (decomposition and combustion of waste, use of energy generators and mobile or stationary machineries) and indirect emissions, which occur outside the plant, but that are related to the activities performed by the company (electricity consumption imported from the national grid and waste collection). Equation (2) was used to calculate the emissions from the waste collection:

$$D_c = \frac{D_i}{C_t} \frac{Q_w}{Q_t} \quad (2)$$

where:
D_c = diesel consumed for the waste collection, l; D_i = distance traveled from the municipality (where the waste was produced) to the disposal plants, km; C_t = diesel consumed by truck per kilometer, km (l) $^{-1}$; Q_w = quantity of waste treated to the disposal plant, t; Q_t = quantity of waste in the full trucks, t.

In this study, we have also supposed the presence of an incinerator to produce energy from waste. In the Province of Grosseto, the incinerator is no longer active since 2014; the incinerator of the Province of Siena has been used as a proxy to proportionate the Refuse Derived Fuel (RDF) produced in the Grosseto SP plant (Marchi, 2014). Emission produced from the RDF combustion was calculated considering the fossil carbon fraction in dry weight of different incinerated waste types.

Estimation of CH_4 emission due to the decomposition of the biodegradable matter in landfill were obtained using the IPCC Waste Model (IPCC, 2006). This model considers three basic parameters: the total served population, the annual per capita landfilled waste and the type of waste, which is divided into 7 waste types (food, garden, paper, wood, textile, nappies, plastics and other inert). This methodology is based on a first-order decay model that describes the fraction of organic matter that is degraded and transformed into CH_4 each year, decreasing over time. We have considered the waste treatment in landfill from the year 1999. For the study of the IWMS of the Province of Grosseto we only analyzed the waste managed in the sole active landfill in 2015. However, within the GHG balance at the provincial level we considered the emissions from all landfills located in the territory since 1999 (the landfill number went from 7 in the 1999 to 1 in 2015) because these continue to produce GHGs. The multi-material valorization plant emissions have been estimated proportioning the activity data of MVP, whit those of a same type plant located in the Province of Siena (Marchi et al., 2017), because of lack of local data.

All GHG emissions other than CO_2 were converted into CO_2 equivalents (CO_2-eq), using the Global Warming Potentials (GWPs), as proposed in the IPCC 5th Assessment Report, considering a 100-year horizon (IPCC, 2013).

2.3. Greenhouse gas balance of the Province of Grosseto

To highlight the relevance of the Waste Sector, we have calculated the GHG balance at the provincial scale using the IPCC 2006 Guidelines and the supplement for wetlands GHG emission (IPCC, 2014). The GHG emission balance was obtained from the algebraic sum of gross emissions, derived from all the activity sectors, and all the removals due to the annual growth of biomass of forestland and agricultural ecosystems. The emission abatement percentage was calculated by the ratio between forest absorption and gross emissions.

All the activity data were collected at provincial scale, referring to regional database and local authorities (e.g. the National Inventory of Forestland, the energy statistics of the Ministry of Economic Development and the reports of the national energy service operator).

3. Results

Table 1 shows the GHG emissions produced by the waste treatment plants involved in the areal IWMS; overall, the emissions from plants amount to approximately 126,611 t CO_2-eq. Emissions due to the decomposition of waste into landfill (L), the waste incineration, the bio-oxidation of the organic fraction in composting (CP) and selection (SP) plants are the highest values, with 106,416 t CO_2-eq, corresponding to 84% of the total. The landfill (L) is the plant with the largest level of GHG emissions (55.78%), followed by the hypothesized incinerator (34.15%); the remaining 10.07% is due to selection (SP), composting (CP) and valorization plants (MVP, PVP1 and PVP2).

Table 2 shows the GHG gross emissions of the entire Province (1,356,153 t CO_2-eq), while Fig. 2 represents the GHG balance, with an abatement percentage of 91.01%. The GHG emissions from the Energy Sector cover 54.55% of the total, followed by agricultural and breeding activities (25.27%), Waste (12.28%) and the IPPU Sector (7.90%).

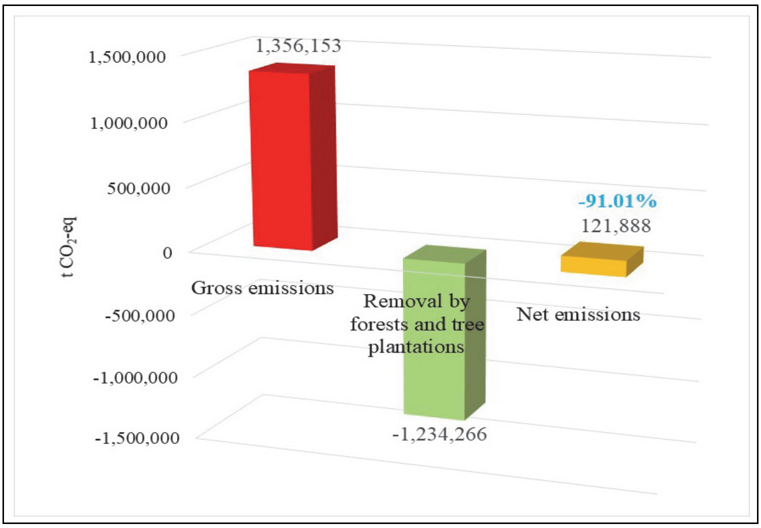

Fig. 2. GHG balance: gross emissions, removal by forests and tree plantations and net emissions. The abatment percentage is indicated with blue color.

The Energy Sector shows the highest impact, mainly due to transport (32.26%), heating (11.62%) and energy production in industries (7.56%). The combustion of RDF in the incinerator (accounted in the Energy Sector) amount to 3.11% of the total emissions; this value, added to 12.28% due to waste decomposition in landfill and bio-oxidation of organic matter in composting/selection plants, covers 15.39% of the gross emissions released from the waste management.

Table 1. Direct and indirect emissions from the waste treatment plants in the Province of Grosseto (year 2015)

GHG emission source		Direct emissions										Indirect emissions		Total
		Waste sector	Emissions from waste (stabilization, bio-oxidation and decomposition)	Wastewater treatment	Energy sector	Emissions from waste (incineration with energy recovery)	Natural gas combustion in furnaces	Machinery (mobile)	Machinery (stationary) and generator for energy	Transport of matherials	Heating	Consumption of imported electricity	Waste collection	
Composting plant (CP)	t CO_2-eq		1,240.77	0.12		/	/	59.02	2.39	1.56	/	461.8	42.89	**1,808.54**
Selection plant (SP)			4,434.89	0.83		/	/	396.63	17.88	10.39	/	3,081.17	420.09	**8,361.88**
Multi-material valorization plant (MVP)			/	/		/	/	38.36	0.04	/	0.69	77.58	1,547.84	**1,664.52**
Paper/cardboard valorization plant (PVP1)			/	/		/	/	10.48	/	/	/	11.9	691.27	**713.65**
Paper/cardboard valorization plant (PVP2)			/	/		/	/	10.79	/	/	/	12.25	180.08	**203.12**
Incinerator			/	/		42,231.96	514.01	2.5	0.68	/	/	93.07	394.43	**43,236.66**
Landfill (L)			58,498.74	7.78		/	/	207.52	/	/	/	50.89	11,857.93	**70,622.86**
Total			**64,174.41**	**8.72**		**42,231.96**	**514.01**	**686.93**	**20.95**	**11.95**	**0.69**	**3,711.08**	**13,586.70**	**126,611.23**

Table 2. GHG gross emissions of the Province of Grosseto (year 2015)

Human activity	*t CO_2-eq*	*%*
Energy sector	**739,803**	**54.55**
Trasport	437,446	32.26
Heating	157,649	11.62
Energy production in industry	102,476	7.56
Electricity production from waste	42,232	3.11
IPPU sector	**107,200**	**7.90**
Waste sector	**166,491**	**12.28**
Landfill	126,034	9.29
Wastewater treatment	34,781	2.56
Biological treatment and compost production	5,676	0.42
AFOLU sector	**342,659**	**25.27**
Forest carbon loss	110,740	8.17
Urea used	2,344	0.17
Enteric fermentation	129,647	9.56
Manure management	22,691	1.67
Nitrogen inputs to soil	73,151	5.39
Wetlands	4,087	0.30
Gross emissions	**1,356,153**	**100.00**

The AFOLU Sector plays also a key role; livestock represents 11.23% of the total emissions due to the enteric fermentation of bred animals (9.56%) and manure management (1.67%). The agricultural activities represent 5.56% of the total, due to nitrogen additions to the soil (5.39%) and the use of urea (0.17%). A relevant share of emissions is due to carbon loss caused by forest fires and harvesting products (8.17%).

At the territorial level, the emissions from the Waste Sector in the general GHG balance of the district (166,461 t CO_2-eq, as in Table 2 are slightly higher than those calculated for the IWMS (126,611 t CO_2-eq) because the former considers all the operating landfills in the area since 1999, while the latter the sole that is currently open.

4. Discussions

The results of this study can be compared with those regularly provided for the neighboring Province of Siena since 2006 (Bastianoni et al., 2014; Marchi et al., 2017); the Grosseto territory is similar to that of Siena, for number of inhabitants and type of industrial development. The most significant difference, however, is that Siena has been implementing important management policies for a decade, reducing GHG emissions and its environmental impact. In the Province of Siena, the Waste Sector (i.e. landfills, wastewater treatment and composting/selection plants) accounts for 10.60%, while the incinerator to produce energy from waste releases 2.60% of the total emissions, for an overall 13.20% (REGES, 2016). This result is better than that of the Province of Grosseto, the gap being even more evident if we consider that the population of the Province of Siena in 2015 was greater than that of Grosseto, with a difference of about 45,804 residents (ISTAT, 2015). However, we must also consider the largest tourist numbers in the Province of Grosseto compared with that of Siena, which counts 722,999 more tourists. Nevertheless, the management problems are mainly attributable to organizational inefficiency in the waste collection and treatment, performed in the analyzed territory.

During the period 2008-2011 in the Province of Siena, an average of 36,520 t of MSW were conferred to landfill, about 35.54% of the average produced waste with a trend that has been decreasing over time (Marchi et al., 2017). In the Province of Grosseto, at the end of 2015, 99,266.85 t of MSW were produced and 64,241.98 t (64.72% of the total) was disposed in landfill, which is the management solution that releases higher GHG emissions (IPCC, 2013). We also noted that, in the period 2014-2016, the amount of biogas captured by the Grosseto landfill biogas recovery plant is declining and the percentage of methane contained within biogas is also reduced; this suggests anomalies in plant management. Likewise, in the Province of Siena, the burned waste in the incinerator amounts to 57,860 t in average per year in the period 2008-2011, covering about 56.31% of total waste (Marchi et al., 2017). This solution causes high GHG emissions, but they are anyway lower than those to the traditional thermoelectric electricity generation, which in Italy still represents 68% of the national production in 2015 (Terna, 2015). In the Province of Grosseto since 2014, the incinerator is no longer operative, but the RDF produced in the MSW selection plant (SP) is sold to numerous Italian and foreign plants and companies, releasing high GHG emissions due to transport (at least 2,945.60 t CO_2-eq). Through this study, we also highlighted that the IWMS in the Province of Grosseto is not really integrated.

The various waste types are treated by plants managed by different private companies, without an organic planning; furthermore, the data availability and dissemination in some cases are not sufficiently transparent and guaranteed. To optimize waste recycling, a more organic and durable organization would be needed, also involving and educating citizens (Bartoleto and Hanaki, 2007; European Union, 2014). It is necessary to reduce waste disposal in landfills, which should be the ultimate management solution, as suggested by the Directive 2008/98/EC; the organic fraction and wood should not be disposed in landfills, to avoid CH_4 emissions for long time (EC Directive, 2008; IPCC, 2006). We calculated that if the organic waste treated in the composting plant (CP) had been landfilled, it would have emitted 10,576.69 t CO_2-eq, instead of the current 1,240.77 t CO_2-eq, with an increase of about 88%. This shows the extreme importance of a proper waste management system; in fact, a better organization of the Waste Sector could play a key role in reducing GHG emissions at territorial scale. The geographical and topographic characteristics of the Province of Grosseto are not very dissimilar to those of the Province of Siena; for this reason, it might be useful and strategic to implement a management model based on the virtuous example of Siena (Caro et al., 2014), enabling achievement of the carbon neutrality status (Bastianoni et al., 2014).

The GHG balance of the provincial territory shows that the Province of Grosseto is not far from a carbon neutrality status, in which gross emissions are offset by CO_2 absorption by forest and agricultural ecosystems. This is a goal that can be achieved through appropriate management strategies, as highlighted by the case of Siena, where the abatement percentage of emissions amounted to 109.1% in 2014 (REGES, 2016). Waste management improvement actions may help reduce the gap between gross emissions and adsorptions for the whole Grosseto territory, obtaining the carbon neutrality status also in this provincial system.

To improve the GHG balance of the territory should also be needed the development of strategic environmental policies able to decrease the GHG emissions from the key activities, as well as the waste management (such as the electricity use, transport and agriculture). The Grosseto production of electricity from renewable sources in 2015 was about 1,521,693 MWh (1,384,000 MWh of which are obtained by geothermal reservoirs) against a demand of 955,550 MWh; to improve this aspect the policy makers should increase the use of different renewable resources, in addition to the geothermal heat, with the widespread production of electricity in the overall territory. Considering the higher impact of Energy Sector due to transport a set of solutions for sustainable mobility that will disincentive the consumption of fossil fuels should be created. In the same way to reduce heating emissions a policy addressed to verify the proper boiler management as done by the Siena administration, thus reducing thermal dispersion and wastefulness, could be introduced (REGES Project 2008-2016).

To reduce AFOLU emissions, effective solutions could include the implementation of information initiatives on food and nutrition habits to optimize for instance meat production and consumption; other policy options can induce breeding systems and farms to operationalize ecological practices, such as the use of organic fertilizers, the growth of the livestock in the wild and a proper manure management. It is finally crucial to realize and optimize forest management and fires prevention plans to reduce emissions and facilitate forest absorption.

5. Conclusions

With this study, we highlighted that the IWMS of the Province of Grosseto is not really integrated and the Waste Sector covers a relevant part of the gross emissions (15.39%) at the territorial level. The highest impact is due to the landfill (55.78% of the waste plant emissions). After the realization of the provincial GHG balance, we have seen that the Grosseto area is not far from a carbon neutrality condition (with an abatement percentage of 91.01%). For this reason, through appropriate management policies the ambitious goal of the carbon neutrality status could be achieved and overcome without enormous efforts. Considering the many IWMS management gaps, we believe that a proper plan to manage the waste sector can give a relevant contribution towards the achievement of the carbon neutrality status. At the same time, acting on energy and breeding/agriculture activities will be of further help to reduce impacts.

Additional studies about the territorial activities/characteristics are needed to have a better overview of the real condition of the area; this could allow to realize strategic and sustainable management solutions to be proposed to policy makers and actively applied in this territorial system and in other regional districts around the world.

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THERMAL INCINERATION OF SOLID RECOVERED FUELS AS A STRATEGY FOR WASTE OF ELECTRICAL AND ELECTRONIC EQUIPMENT MANAGEMENT*

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Abstract

Waste incineration is a thermal treatment which allows waste volume to be greatly reduced and destroys dangerous chemicals while also producing energy. It is the best way to recover waste when, for technical and economic reasons, recycling is not profitable. The term incineration refers to an oxidation process of combustible substances which works at high temperatures, inside different kinds of incinerators through the reaction of three components: fuel, oxidizers and diluents. The heat produced during the combustion is transformed into thermal or electrical energy. It is preferable to dump disposal firstly, because it has a reduced environmental impact and furthermore because it represents the best way to avoid wasting resources. Despite this, it is not always a feasible choice due to the high costs required for building such facilities.This paper intends to analyze the features of this waste-to-energy process, focusing on the benefits and disadvantages in both economic and environmental terms, with the aim of helping the spread of this technology in southern Italy.An interesting example is a waste-to-energy plant project which will be used by a Sicilian business specialized in waste management, with a focus on the treatment and recovery of Waste Electrical and Electronic Equipment (WEEE). The 3.0 MWe plant will be exclusively powered by Solid Recovered Fuel (SRF); the technology used will be a moving grid used in the Rankine cycle. In this way the company will be able to reduce its environmental impact by recovering waste which is now disposed of in landfills (such as the polyurethane which comes from fridge treatment), and it is expected to satisfy the company's energy needs. Waste-to-energy plants can be an important part of the waste management strategy in Italy and, nowadays, the technology is advanced enough that these plants are no longer a threat for either humans or the environment.

Keywords: incineration; solid recovered fuel; waste management; waste-to-energy plant.

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1. Introduction

Thermo-chemical treatment processes are an important component of a sustainable integrated solid waste management system (Arena, 2011; Panepinto et al., 2015). The aim is the protection of human beings and the environment, and the conservation of resources such as materials, energy and space (Brunner and Rechberger, 2014). Incineration is a complete oxidation process of combustible substances contained in waste which takes place at high temperatures inside different kinds of incinerators (such as oven-grills, rotary drum furnaces, fluidised bed ovens, etc.) by the reaction of three components: fuel, oxidant (air) and diluent (nitrogen does not participate in the chemical combustion reaction but it contributes to lowering the flammability limit of fuel). This process is used for the thermal treatment of a wide range of wastes which determine the nature of the fuel used in terms of chemical composition and calorific power.

The reactions activated by a heat source: the organic substances which are in waste burn when they have reached the required starting temperature and they come in contact with the oxygen; fuel and the combustive agent must be in adequate proportions so that the combustion can take place. The reaction between fuel and agents determines the transformation of the accumulated chemical energy into thermal energy.

The process generates gas which contains most of the energy available in the form of heat; this gas contains both innocuous products such as water vapor and carbon dioxide, as well as substances which are dangerous for human beings and for the environment such as: particulate matter, HCl, SOx, PM, NO2, metals, incomplete combustion byproducts, dioxins, and furans (Hu and Shy, 2017).

The type of emissions depends on the technology used, on the nature of the fuel and on the reaction conditions; the fumes must be appropriately treated before they are released into the atmosphere in order to minimize the environmental impact. Incineration aims at waste treatment to reduce their volume and danger by destroying potentially dangerous substances (Tabasovà et al., 2012). The incineration process also allows energy recovery: in this way, it is possible to call it waste-to-energy (Tyskeng and Finnveden, 2010). In short, the waste-to-energy plant is characterized by three phases: thermal conversion, energy recovery and the treatment of gaseous effluents (Fig. 1).

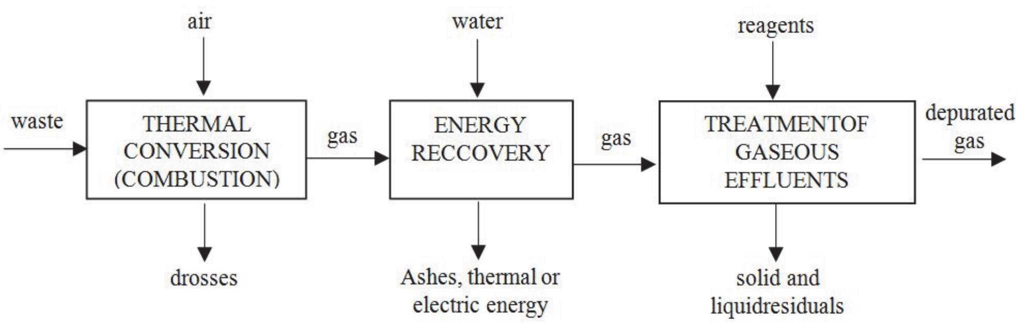

Fig. 1. Steps of waste to energy processes

Waste, before being subjected to incineration, can be exposed to treatment processes to eliminate the non-combustible materials and the humid fraction; in this way, it is possible to use the expression solid recovered fuels which is defined by SRF Technical Specification CEN/TS 15359, which represents a fundamental alternative to the use of traditional fuels such as natural gas, oil and coal, which are exhaustible natural resources (Wasielewski et al., 2011).

2. Case study

2.1. The company F.G S.r.l

F.G. S.r.l. is the leading company in Sicily in the treatment and recovery of WEEE (except for the category R5, currently untreated); it also deals with the treatment of bulky, woody and metallic waste, with the recovery of land and waste coming from ships, railways and industrial demolitions and with the reclamation of contaminated sites. FG S.r.l. is located in Belpasso (CT); in 2016 it had a turnover of €7.2 million and its staff consist in 60 employees. The company produces ferrous and non-ferrous metals by-products and other ones which are really exploitable (compressors, electronic card, hard drives etc.).

Only a few materials, since they are not recyclable, are currently sent to landfills and today they represent a cost for the company as well as causing an important environmental impact; however, the realization of waste to energy plant will allow their use as fuel for obtaining energy recovery.

2.2. The waste-to-energy plant project

The case study concerns with the creation of a waste to energy plant in F.G. S.r.l. In particular the projects foresees a small thermoelectric power plant with a nominal thermal power of 15 MWt, designed to produce a maximum power of 3.0 MWe. This plant will be powered only with solid recovered fuels obtained by wasted transformation which nowadays is disposed of in landfill by FG S.r.l. The power plant is designed to run 24 hours a day for 330 days a year and it will be able to treat about 30,000 tons of fuel per year.

The technology that F.G. S.r.l. wants to use for the production of energy is the combustion on a mobile grid with production of steam and with generation of electricity thanks to the Rankine cycle. This technology is widely used on a global scale for small plants and it allows an adequate control of the combustion parameters. Moreover, it ensures reliability and efficiency in all the operation (Quoilin and Lemort, 2009). The efficient operation of the Rankine cycle depends on two factors: the working conditions of the cycle and the thermodynamic properties of the waste (Hung, 2001).

The electricity production cycle will consist in the following steps (Figs. 2-3):

- Production of solid recovered fuel, composed firstly by polyurethane generated by the treatment of refrigerators (treatment line 1 - WEEE containing chlorofluorocarbons), secondly by waste deriving from the treatment of the mattresses and in minimum percentage by the wood (treatment line 5 – bulky waste);
- Combustion of the solid secondary fuel in an adiabatic oven on a mobile grid;
- Energy recovery of the heat of the fumes in a special boiler;
- Production of electric energy from steam Rankine cycle;
- Smoke treatment according to the NEUTREC® process and chimney drain;
- Disposal of combustion residues (cinders);

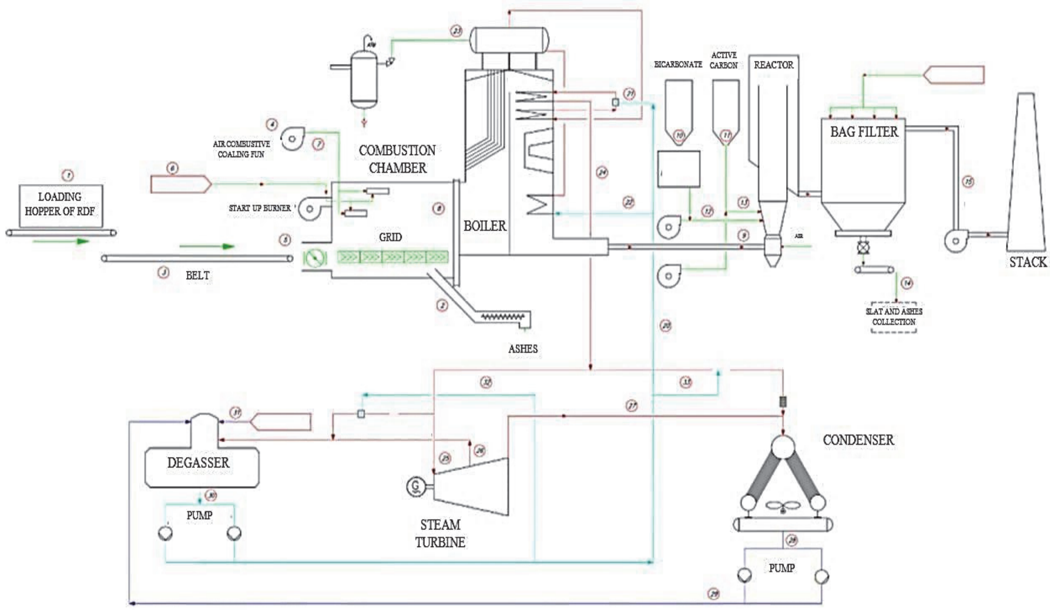

Fig. 2. Scheme of the plant

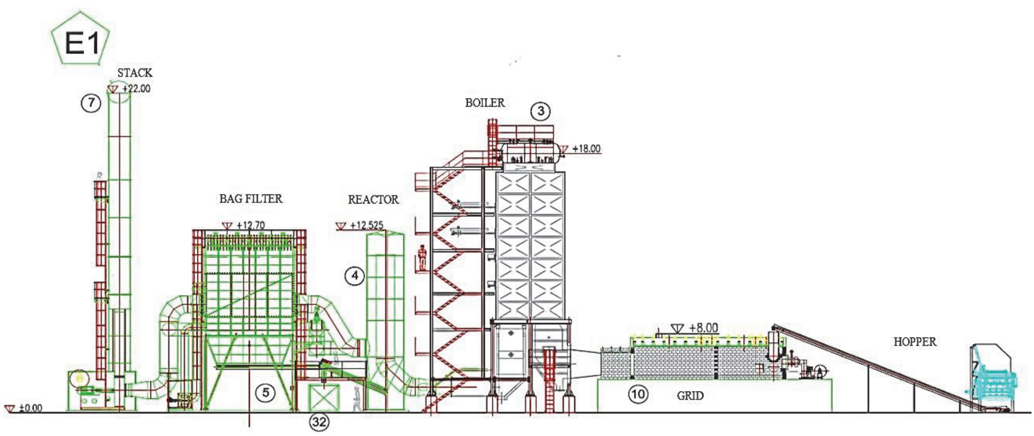

Fig. 3. Prospect of the plant

2.3. Environmental feasibility study

Thanks to an environmental feasibility study of the waste-to-energy plant, it is possible to analyze the following components: atmosphere, hydro-ambient, soil and subsoil; flora, fauna and ecosystems, landscape, noise and vibration; waste; ionize and non-ionize radiation; social and economic aspects.

In relation to the quality of the air, the most negative impacts which can occur during the plant's construction (construction period) are connected with dust production during excavating operations, transport of materials and vehicular traffic; however, they represent impacts of a low entity and they are temporary so that they are reversible. Furthermore, in the project FG S.r.l.

aims at reducing impacts by using hydrants rain in order to destroy dust, and innovative machines and tools so as to prevent and contain the polluting emissions. As regards the exercise period, it is not possible to analyze great negative impacts thanks to destruction systems and smoke purification. In addition, in order to obtains impact reduction, in relation to the road transport, the use of protection system of the load and the creation of a green barrier is envisaged.

As for the hydro aspect, there are no significant impacts in the construction and exercise step. The use of hydro-resources in the construction step is related to the consumption of water for concrete packaging, for washing the service area and for dust containment, but they represent only small quantities which do not contaminate the subterranean water. During the exercise step, the impacts on water are related to water withdrawal, and to rain waters management; also in this step, the hydro consume is low and marginal because there is a system of recycling of water process and a system of separate collection of waste effluents which are discharged in the environment only when they are completely depurated.

The most important impacts on the soil and subsoil are related to the occupation of soil, and to the possible morphological changes of the actual soil structure together with the unjustified consumption of fertile land or with pollution deriving from dangerous substances. The effects on the construction period are limited to a short period and they do not change the territory's morphology. On the other hand, during exercise period, the impacts related to land occupation, can be considered of great importance if considered according to the territory destination, which is mainly industrial.

Moreover, it is possible to analyze that there are small impacts in term of acoustic pollution, in particular noise and vibration: in the construction period the impacts are related to excavation, demolition and construction works, and to means of transport, while in exercise period they are related to plant functions, in particular to gear motors, to cooling fans, to pumps and steam turbine. Aiming at reducing all these impacts, FG S.r.l. intends to use tools for noise reduction in the construction period, and the acoustic isolation from the area in exercise period though the use of sound barriers and operation of machines encapsulation. Waste production related to this plant refers to both periods. In the former only inactive waste is expected, and a small part derives from machine packaging and from the material necessary for the process. In this way FG S.r.l. wants to reuse small quantities of excavation materials while the remaining quantities are sent to the recovery centre. In exercise period waste come from combustion process (cinders) and from maintenance operations. Cinders need to be correctly disposed of as harmless waste while a separate collection of other waste such as polluted materials from crust oils, filtering, isolating materials, plastic, rubber and similar elements is expected which are sent to special sites authorized for their treatment and disposal.

Furthermore, in relation to electromagnetic pollution, it is possible to see a positive effect deriving from the process by which electricity produced in the new plant will be used mainly inside the establishment which means an important reduction of electricity transport to the plant from the national distribution network. In addition, in the construction period, there is no production of electromagnetic radiation.

From a social and economic point of view, the new plant allows the company to reduce management costs and it gives the possibility of creating new operative units above all in exercise period. Finally, it determines positive environmental effects related to dumps and fossil sources consumption.

2.4. Economic aspects

In order to evaluate the project feasibility, a predictive analysis of costs and revenues has been made, with reference also to investment costs and cash flows. Due to an annual consumption of 20526 tons of SRF, the annual managing cost of the plant will amount to €1,258,118.00. In particular the following cost elements must be considered: industrial water used in the process of demineralized water production and during the thermal recovery process; the Igp used as auxiliary combustible; sodium bicarbonate and active carbons used in the system of treatment and depuration of smokes; soda and hydrochloric acid; oils used for the lubrification of mechanical parts; in addition it is possible to refer to disposal costs of process scraps and the relative transport cost to the disposal; other cost like insurance and extraordinary maintenance; specialized human resources costs in the new plant. On the other hand, it is possible to analyze revenues deriving from electricity sales in the amount of € 1,091,256.00 while the savings on management costs of the current establishment amount at € 2,248,444.00.

In particular it derives from resetting the costs for electric energy and from the disposal in dumps of different production residues, which will be used for the production of solid secondary combustible. In total the investment amount at € 11,120,700.00 and it includes project cost, building works, plants and machines. FG S.r.l. aims at financing the investment trough an increasing share capital of € 4,000,000.00 and through a twenty years bank loan of € 8,000,000.00. The business partners will recuperate invested share capital in the long term thanks to incomes distribution. Using the method of net present value, it is possible to show that the investment is extremely convenient if compared with buying the same amount of BTP with a 20 years deadline and with a 4% rate of return

3. Results and discussion

The analysis carried out demonstrates that, from an environmental point of view, the realization of the plant does not present risks for the environment or human health; the designed choices are aimed at reducing to a minimum all the possible negative impacts. The incineration indeed, is a technology which has a reduced environmental impact with small levels of pollution, thanks to technological progresses in combustion processes and smoke treatments achieved in recent decades. On the other hand, the plant allows energy production, avoiding the use of natural resources like coal, petrol and natural gas.

From an economic point of view, the project is extremely feasible because it will allow a good return on the investment. In this way a positive and increasing ROE will be expected with a positive net present value and finally the payback period of the investment is expected in 8 years. However, the waste-to-energy does not represent always a practicable technique due to the high investment costs necessary for the plant's realization.

6. Conclusions

With this plant FG S.r.l. can reduce the amount of waste currently disposed of in landfills, it can achieve energy self-sufficiency, it can reduce costs of the current plant and generate revenues from the sale of electricity. FG S.r.l. wants to implement a circular economy model which enables it to turn non-recyclable waste into resources to re-enter into its production process in form of electricity.

The aims of the project, in line with the policy carried out by the company, seems particularly interesting in terms of environmental protection especially if evaluated in relation to Sicily, where there are still few companies which decide to invest in this kind of plants.

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GHG EMISSIONS ANALYSIS OF SOLID WASTE PRODUCED IN A SUPERMARKET OF MASS MARKET RETAILERS (MMR)*

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Abstract

Over the years, Mass Market Retailers (MMR) have changed their different typologies of commercial spaces due to the evolution of the society, characterized by consumerism. This phenomenon has influenced a progressive increase in solid waste production within a supermarket. The aim of this study is to analyze in detail the issues related to the solid waste production in a supermarket and to highlight the possible improvements in MMR's solid waste management and disposal. A specific case study of a store, owned by *Unicoop Firenze* located in Empoli (Central Tuscany, Italy), was analyzed in order to improve the theoretical aspects, with effective and concrete experiences for the management and disposal of solid waste generated by distribution activities and marketing of food and non-food goods in the store. The analysis allowed to understand the waste quantities, typologies and collection methods, applied inside the different commercial departments of the store, as well as the disposal technologies used by the operator for the Municipal Solid Waste (MSW) management. Proposed and introduced innovations, especially in food waste and packaging reduction, have been tested. Moreover, benefits deriving from sustainable solutions have been calculated in terms of greenhouse gas (GHG) emissions, quantifying the carbon dioxide equivalent (CO_2-eq) released to the atmosphere by different waste management and disposal activities. On the basis of this analysis, similar improvement programs in the solid waste management can be adopted by other stores. For example, this study could inspire other experiences aimed at creating biogas plants powered by organic wastes produced in the MMR. The adoption of packaging reduction and eco-design improvement practices could contribute to solid waste and related GHG emission reduction.

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Keywords: GHG Emission, Mass Market Retailers (MMR), recycling, solid waste, store department.

1. Introduction

Over the years, supermarkets have reached a large diffusion in Western World also due to the spread of consumerism as a mass cultural phenomenon (AGCM, 2013). The growth of supplied goods, the increase in different typologies of products and the creation of departments with space and instruments for the internal production and/or the packaging of food (e.g. bakery, roasted goods department) or for the sale of particular foodstuffs (e.g. delicatessen, fish and butcher department) have also led, in line with the enlargement of commercial space, to the growth of quantities and variety of waste produced in every single store of Mass Market Retailers (MMR). For several years, MMR supermarkets have based their management on the modern economic system, which is developed on a linear model, although a circular model would be needed, in accordance with the physical limits of Planet, aimed to material recovery to limit the drawdowns of natural resources (Lebersorger and Schneider, 2014; Matthews, 2000).

The issue of management of different waste typologies, and their disposal, has reached over the years an always higher level of importance (Lanz and Santini, 2014). A clear and univocal definition of "waste" can be found in the 2008/98/EC European Directive; what is really important for this study is the possibility to consider the commercial waste produced in the MMR comparable to Municipal Solid Waste (MSW), both for quantity and quality (Bonafè and Franco, 2011). Several studies and researches have been performed about waste topic, especially related to packaging and food waste reduction. Actual literature often analyze specific case without consider the overall vision of a store; it is hard to find analyses aimed at estimating and examining the overall waste produced in a supermarket. Norrie et al. (1997) analyzed the waste production of a group of supermarkets located in Ontario (Canada) in order to stimulate waste recycling instead of landfill disposal. Fierro Ochoa et al. (2010) investigated the dynamics of a supermarket waste generation, in order to shown the management in time of the waste flow. Although the quantities of solid waste estimated in those studies are comparable with the waste produced in other situations, a relevant difference is present due to regulatory reasons. For example, co-products, (e.g. fish and meat scraps, which are considered special wastes in the Italian legislation), cannot be distinguished from the other supermarket solid wastes.

During the last two decades, MMR and their commercial spaces are changed extremely, thus influencing typologies and quantities of the produced waste. The supermarket waste management improvements are aimed at increasing the percentage of recycled or recovered wastes and to reduce the undifferentiated waste quantities that will be landfilled or incinerated (Davidson, 2011; Davidson and Owen, 2011).

For this reason, the first step to perform an accurate analysis of the supermarket solid waste management is to evaluate the typology and quantity of waste produced into the different store departments, while the second step is the evaluation of the environmental impacts (De Vega and Fierro Ochoa, 2011).

2. Objectives

The goal of the present study is to propose improvements for the store waste recycling We try to optimize both the supermarket economic and environmental performances through a detailed analysis of the store solid waste fluxes and the introduction of some management strategies using the DIMAIC (Define – Measure – Analyse – Improve – Control) method, proposed in the 1980s by Mikel Harry (George et al., 2005). In the present study MSW, produced inside the *Unicoop Firenze* store, located in Empoli (Florence, Central Tuscany, Italy), is examined with the aim to understand the problems related to the supermarket solid waste management to identify, where possible, some improvements, in terms of waste recycling, environmental protection and economic cost optimization.

The study proposes the evaluation of the typology and quantity of waste produced in the overall supermarket and in different store departments, comparing the status before and after the implementation of recycling measures.

Moreover, we estimated the environmental impacts of the waste produced in the supermarket, analyzing different waste disposal treatments in terms of greenhouse gas (GHG) emissions. The improvements activated in the store waste management were assessed from the environmental viewpoint to highlight the importance and the efficiency of the new adopted best practices and to promote a deeper understanding of the benefits of waste recycling against landfill disposal and incineration, with possible economic advantages in the productive system (Chartered Institute of Procurement & Supply, 2007).

3. Materials and methods

3.1. DMAIC (Define – Measure – Analyze – Improve – Control) method

Lean Six Sigma (LSS) methodology is one of the most modern and effective methods of problem solving. This approach allows, through the use of quantitative data, the identification and the elimination of the problems that are present in store waste management process (George et al., 2005). The main LSS instrument is the DMAIC (Define – Measure – Analyze – Improve – Control) method, which is structured in a series of consequential phases that help define the problem, investigate the real cause, research the possible solutions and introduce them in the operational process (Pepper and Spedding, 2010).

The first phase of DMAIC method, called "Define", includes the definition of experience goals. In the present case, the ratio between undifferentiated and separated waste (UW/SW), expressed respectively in m^3/m^3, must be lower than a target value, fixed to 0.10, in the overall analyzed store by implementing the separate waste collection. The second phase, called "Measure", provides the quantitative data collection through a first measuring session of seven working days, during which all the undifferentiated waste (UW), originated from the overall supermarket and each store department, was weighed.

The third phase, called "Analyze", classifies the waste types present in a UW sample, coming from each store department, and identifies the critical points in the waste management process. The waste classification analysis was performed by a dedicated enterprise (called *CSA S.p.A.),* on behalf of *Unicoop Firenze* store. The fourth phase, called "Improve", consists of planning future improvement actions, based on the information provided by the previous phases, through waste recycling. The fifth and last phase, called "Control", is performed by a second measuring session, which provides that all the solid waste categories produced in the entire store are weighed, in order to understand the advantages deriving from the improvement strategies previously introduced.

Eight departments have been selected for the analysis: 1) Info & Offices, 2) Bakery & Pizzeria, 3) Delicatessen, 4) Butcher, 5) Fruit and Vegetables, 6) Pastry, 7) Fish and 8) Roasted goods. As shown in Table 1, the ratio between undifferentiated and separate waste (UW/SW), expressed respectively in m^3/m^3 is 0.1614. The innovative management action was to introduce the waste recycling also in the eight store departments, where it was not currently performed.

Table 1. Waste streams of store waste categories (Publiambiente, 2015)

Solid Waste Category	***Types of container***	***N° of emptying***	***Volume of waste (m³)***	***Weight of waste (t)[a]***
Paper and Cardboard	Press container	255	10,404.33	624.26
Plastic	Press container	5	588.57	20.60
Wood	Classic container	33	960.00	28.06
Organic matter	660 l dumpster	402	265.00	92.86
Undifferentiated Waste (UW)	Press container	52	1,972.00	256.36
Total Separated Waste (SW)			12,217.90	765.78
Total			14,189.90	1,022.14
Ratio UW/SW (m^3/m^3)			0.1614	

[a] *The Organic matter weight was estimated: the dumpster refilling index is equal to 0.35 t/m³*

3.2. Environmental sustainable study: GHG emissions

Better environmental performances, achieved through recycling improvements in the store waste management, have been estimated calculating the saved GHG emissions. We evaluated the variation in GHG emission from the current waste plants, considering the quantity of waste categories generated in the supermarket before and after recycling improvements (detected, respectively, during the first and the second measuring sections). Moreover, we compared the anthropogenic emissions due to different treatment methods of various waste categories generated after the recycling implementation. Therefore, material recovery, landfill disposal and incineration of all the waste categories produced in the supermarket were considered and evaluated. GHG emissions deriving from supermarket waste disposal were estimated adopting the "2006 IPCC Guidelines for National Greenhouse Gas Inventories", proposed by the Intergovernmental Panel on Climate Change (IPCC) in 2006. The basic equation to calculate the GHG emissions is the product between a human activity (e.g. the amount of fossil fuels consumed) and an emission factor representing the emissions per unit activity (IPCC, 2006).

We estimated the amount of carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O) released to the atmosphere from the supermarket waste types treated in different waste disposal plants. All GHG emissions different from CO_2 were converted into CO_2-eq using the Global Warming Potentials (GWPs), 100 years, published on IPCC Fifth Assessment Report (2013). Every phase of waste treatment, from transport to recovery, selection and disposal, have been included in the analysis; moreover, all the material movements made by machineries powered by fossil fuels or electricity were considered. For organic, undifferentiated and the other waste types, we have also estimated the GHG emissions due to waste decomposition/degradation and incineration in specific disposal plants. The GHG emissions accounting was performed, considering the impacts of a certain year (instantaneous representation), without the Life Cycle Assessment (LCA), which is based on the approach from cradle to grave.

Organic waste, treated in composting plants, releases CH_4 by the fraction not well oxygenated, that is less than 1% of the initial carbon content. Moreover, N_2O emissions are released in a range that may change from less than 0.5% to 5% of the initial content of nitrogen (IPCC, 2006). As proposed by 2006 IPCC methodology and by Marchi et al., (2015a; 2015b; 2017), emission factors were considered equal to 0.05 g CH_4/kg of organic waste and 0.30 g N_2O/kg of organic waste treated in the composting plant. For the undifferentiated waste consigned to landfill, the CH_4 emission due to the decomposition of the biodegradable matter was estimated, applying the IPCC Waste Model (IPCC, 2006). It considers the biogas production, generated by different waste categories landfilled, which are characterized by specific decomposition parameters. The IPCC Waste Model, moreover, allowed the evaluation of the effects due to the biogas recovery by a cogeneration plant. For what concern the solid waste incineration, the CO_2 emission, derived from the burned fossil carbon fraction in the treated wastes, is estimated (Bastianoni et al., 2014; IPCC, 2006; Marchi et al., 2015a; 2017).

For organic and undifferentiated waste, the quantities of GHG emissions deriving from different waste disposal methods, has been possible to estimate, applying local activity data. We obtained emission factors from the handbook of national emission factors (ANPA CTN-ACE, 2002) and the 2006 IPCC Guidelines (IPCC, 2006). Fossil fuel quantity used for transport of these waste types from the supermarket to waste disposal plants has been estimated, considering the distance covered by trucks and a 3.4 km/l diesel consumption.

CO_2-eq emissions from two different treatment methods of organic waste were compared: composting and anaerobic digestion. Since in the district near the supermarket no anaerobic digestion plants are present, we hypothesized its installation near the existing composting plant. GHG emissions generated by this potential anaerobic digestion plant were calculated considering electricity and fossil fuel consumption of an already existing plant of the same productive capacity, presented in Marchi et al. (2015a). As reported in Reichhalter et al. (2011), we assumed that 1% of the produced biogas inside the digester is accidentally released to the atmosphere, thus, CH_4 emissions that contribute to greenhouse effect were estimated, considering the methane amount in the produced biogas (that is equal to 60%).

For plastic, multi-material (MM), paper and cardboard, treated in specific recycling and material recovery plants, we used literature parameters, taking into account transport, selection and recovery processes (Alwast and Birnstengel, 2008; Comieco, 2003). We have not found the local activity data related to these waste types because they are managed applying various treatment technologies by different enterprises. Nevertheless, the literature parameters are based on the general assumptions made in the present study and, therefore, they are comparable with those calculated in the present experience.

4. Results and discussion

As shown in Fig. 1, the separated waste collection in the eight store departments, increased of 70.48% after the recycling improvement actions and the UW produced in the departments decreased to 29.52%, when separate waste collection was done.

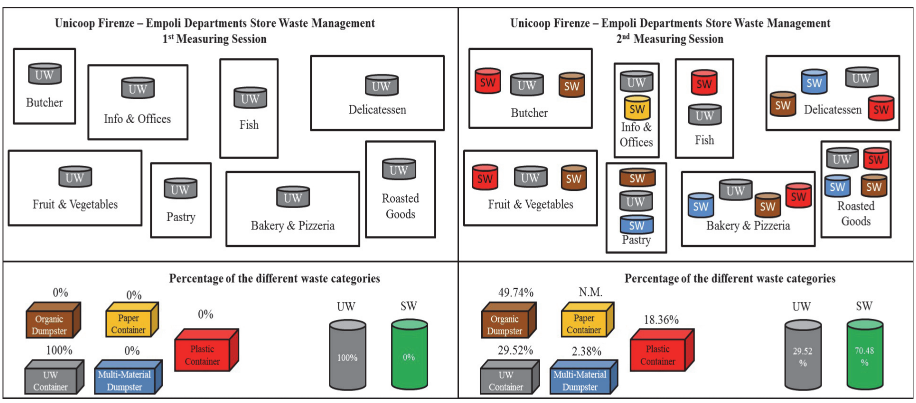

Fig. 1. Flows of wastes within the eight store departments, pre (1st measuring section) and post (2nd measuring section) recycling implementation. UW (Undifferentiated Waste), SW (Separated Waste), N.M. (not measured. Paper/cardboard coming from each of the eight store departments was not weighted for logistical and practical reasons; nevertheless, it was computed in the waste amount of the overall supermarket)

In particular, we have detected that recycled waste, coming from the analyzed departments, was 49.74% for organic matter, 18.36% for plastic and 2.38% for multi-material (MM). In Table 2, we can see that, after the recycling implementations, the ratio between undifferentiated and separated waste (UW/SW) of the overall store, is below the 0.10 threshold, and therefore the target fixed in the first phase of the DMAIC method was achieved.

Table 2. Summary of analyzed solid waste coming from the overall store, first and second measuring session (pre and post recycling implementation)

Solid Waste Category	*Pre recycling implementation*		*Post recycling implementation*	
	m^3	*kg*	*m^3*	*kg*
Organic matter	4.54	1,590	9.97	3,489
Paper and Cardboard	169.67	10,180	174.83	10,490
Multi-Material (MM)	0.00	0	2.70	81
Plastic	20.00	700	23.43	820
Wood	9.58	280	10.26	300
Undifferentiated Waste (UW)	27.69	3,600	14.15	1,840
Separated Waste (SW)	203.79	12,750	221.19	15,180
Ratio between UW/SW (m^3/m^3)	0.1359		0.0640	

As shown in Table 3, the improvement of the waste recycling in the overall supermarket led to a saving of more than 1,630 kg CO_2-eq in only seven working days.

Table 3. Summary of analyzed solid waste coming from the overall store, first and second measuring session (pre and post recycling implementation)

Activity	*Pre recycling implementation*	*Post recycling implementation*
	kg CO_2-eq	*kg CO_2-eq*
Organic matter (treated in composting plant)	**165.73**	**351.80**
Waste oxidation in composting plant	*144.85*	*317.85*
Transport	*9.93*	*9.93*
Movement machineries	*6.01*	*13.18*
Electricity consumption	*4.94*	*10.84*
Undifferentiated Waste (UW) (treated in landfill)	**4,059.93**	**2,082.45**
Waste decomposition in landfill	*4,043.0*	*2,066.4*
Transport	*15.09*	*15.09*
Movement machineries	*0.26*	*0.13*
Electricity consumption	*1.57*	*0.80*
Plastic (treated in recycling and recovery plants) (Alwast and Birnstengel, 2008)	**553.00**	**647.80**
Multi-Material (MM) (treated in recycling and recovery plants) (Alwast and Birnstengel, 2008)	**0.00**	**56.70**
Paper and Cardboard (treated in recycling and recovery plants) (Comieco, 2003)	**322.71**	**332.53**
Total emissions	5,101.36	3,471.29
Avoided GHG emission (kg CO_2-eq)	-1,630.08	

In particular, before supermarket recycling improvement, the ratio between UW/SW was much higher, with a value equal to 0.1359 versus 0.0640 obtained after the implementation of recycling practices. The total undifferentiated waste amount changed from 3,600 to 1,840 kg and the separated waste from 12,750 to 15,180 kg, before and after the implementation strategies. Comparing the situation before and after recycling improvements, we can see that the GHG emissions from organic matter composting and plastic, multi-material and paper/cardboard recovery are higher (1,041.46 vs 1,388.83 t CO_2-eq before and after, respectively). Nevertheless, the avoided waste disposal in landfill determines a much greater emission reduction in terms of unreleased CO_2-eq, than the recycling procedure. In fact, the GHG emissions from landfill passed from 4,059.93 to 2,082.45 t CO_2-eq (before and after the implementations, respectively), favoring a relevant impact reduction on the climate. The landfill emissions were estimated summing the methane released from the year 2015 until the year 2030, because the conferred waste decays slowly in time, providing the results presented in Table 3, which are referred to the waste quantity analyzed in the study period.

The benefits, in terms of CO_2-eq, of waste recycling instead of landfill disposal or incineration are always better for every analyzed waste categories. In particular, GHG emissions due to organic matter composting are lower of about 90% than landfill disposal; the recycled plastic is characterized by an emission reduction of about 70% instead of incineration, while paper/cardboard recycling determines a GHG emission decrease of 99% and 22% instead of landfill disposal and incineration, respectively; UW shows GHG emissions due to incineration lower of about 180% than landfill disposal. Organic materials have no impact in terms of GHG emissions due to incineration process because they have not fossil carbon inside. CO_2 released by the organic matter degradation in composting plants has a biogenic origin, without altering the natural greenhouse effect (IPCC, 2006). Plastic materials, that are not biodegradable, do not release GHG emissions when they have been landfilled, filling the volumes of landfill without biogas and energy production.

The hypothetical installation of an anaerobic digester suggests lower GHG emissions from anaerobic reactions (73.05 kg CO_2-eq) than composting (317.85 kg CO_2-eq). Advantages deriving from disposal of organic matter in the anaerobic digestion plant, rather than the composting one, persist, also when transport and processing phases are considered, despite that the GHG emissions due to these activities powered by electricity and fossil fuels are relevant. From an economic viewpoint, an investment equal to 1,741.31 € was needed in order to buy 20 new containers for separate waste collection and some particular typologies of waste bags. Nevertheless, results allow to obtain a big reduction equal to 9,248.00 € of the waste tax, called "TARI", established by local City Council. In this study, we have detected that paper/cardboard and organic matter were the main waste type produced in the supermarket (Table 2), as also confirmed in other works (Norrie et al., 1997).

Measurement campaigns of the waste flows in a supermarket are useful to detect waste quantity and composition, starting from the upstream production. Due to the diffusion of the same products in others firm' store, these monitoring analyses could be considered representative of other stores of the same dimension and typology, without replicate again the waste category analysis. Moreover, the measurements could suggest whether the waste collection processes and the recycling practices are performed correctly in each sector of the supermarket, highlighting wrong operations and what store departments are characterized by multiple problems in waste management. The waste measurement sections are important to understand and design proper waste management in the productive systems and reveal the crucial points to improve recycling performances.

The introduction of separate waste collection in the departments is the easiest and the best method to manage waste flows. In this way, it is possible to operate upstream, performing waste selection processes at the waste production. In order to reach the expected experience goals, it has been needed to provide to the supermarket workers both instruments and knowledge to correctly perform the waste separation. As highlighted by the New York State Department of Environmental Conservation (2017), the success of any waste management program depends on the cooperation of workers. All the workers of the enterprise, from store managers to operators, through department heads, need to be educated and stimulated towards sustainable actions. They shall be informed on the positive consequences of their actions both in terms of cost saving and resource exploitation reduction and material recovery (Dias and Junior, 2015). In fact, waste recycling determines advantages due to the raw material recovery, avoiding the consumption of other energy and matter used for the production of now materials (e.g. plastic and paper/cardboard). For this reason, before the two measuring session, a lot of preparatory meetings have been done with store manager and department heads. In addition, to facilitate the changeover to the new waste management method, workers have been supported closely in their daily work until they understand correctly the separate waste collection process. In the present study separate waste collection in store departments implicated the introduction of a greater number of containers in order to separately dispose different waste categories. In order to make more intuitive and quickly the disposal operations, in our case, 20 containers with a capacity of 70 litres and identified by the European colours-code of waste categories, were bought. Moreover, stickers, showing waste category and colours-code, were placed above all the containers. At the end, it has been suggested to dispose a little fraction of the produced waste in the UW container, if workers did not know the appropriate destination of this waste fraction, avoiding contamination of the recycled waste with impurities.

The increase in the organic matter amount, deriving from the introduction of the separate waste collection, could be the starting point of a feasibility study for the creation of a biogas plant for electricity generation (Morero et al., 2015). A possible installation of an anaerobic digestion plant equipped by technologies for the electricity production and methane upgrading from the organic matter obtained in the studied supermarket is possible, as confirmed by Alkanok et al. (2014) for different production sites. Other studies analysed, item by item, different anaerobic digestion processes and biogas generation from different types of organic waste (Ebner et al., 2016; Fisgativa et. al., 2016; Rusín et al., 2012), encouraging the application of anaerobic treatment also in the production system analysed in this study. From the environmental viewpoint, avoided GHG emission may increase over time, considering the activation of new store recycling actions. Climate impacts may further decrease, improving energy efficiency of the disposal plants and introducing a greater use of energy produced by renewable and alternative resources (Bozbas, 2008; Patrizi et al., 2013). Diesel consumption for trucks and work machineries for material movements in the waste treatment plants could be replaced with biofuels produced by biomass and wastes. Moreover, the increase in self-produced electricity could reduce the consumption of electricity, imported from the national grid, which is mainly obtained by thermoelectric technologies (Bastianoni et al., 2014). Considering that waste recycling determine an anthropogenic emission decrease, and that landfill represents the waste disposal method more impacting from the environmental viewpoint (GMI, 2011), the introduction of good practices also in the store of the MMR would avoid the landfill disposal (see Tables 3). Moreover, the installation of efficient plants for biogas recovery from landfill (GMI, 2012) and CO_2 capture from burned wastes in the incinerator (Olivares-Marín and Maroto-Valer, 2012) could be hypothesized in our productive system, in order to further decrease the GHG emissions from the store waste disposal. Replace literature emission factors with direct measurement could provide more reliable results, although the present ones are quite representative of the case study. The evaluated economic savings could come from a reduction of emptying and waste disposal of the general UW container located in the loading dock, which provides a cost equal to 100 € for every emptying/disposal. This has determined the reduction of the TARI waste tax, despite the purchase of new containers for separate waste collection and particular waste bags. Further to these easily quantifiable economic aspects, other benefits could be perceived. The decrease of material used in the manufacturing of a single package and the production of easily recyclable goods determine packaging reduction and eco-design product promotion, with a probable repercussion on economic aspects related to the waste treatment and resource depletion. Moreover, a careful analyses, from upstream, of the waste flow and the related disposal, could determine a considerable GHG emission reduction that, if verified/validated according to international standards (e.g. ISO 14064, 2012 and ISO 14067, 2013) by an independent organization, could be traded as Verified Emission Reduction (VER) credits. In this way, verified GHG emission reduction would be a further step towards implementation and validation of local environmental management policies, disseminating advantages for GHG balance at territorial level and localised (economic) benefits for the involved supermarkets/enterprises.

6. Concluding remarks

The analysis allowed to understand the importance of an optimized waste management. All the improvements introduced in the store are appropriate both from an economic and an environmental point of view. A important topic deriving from this study is the role of information and awareness campaigns. Other stores could introduce in their waste management systems the same strategies, especially related to separate waste collection, without performing again measuring sessions about waste category analyses. The adoption of quantitative and qualitative practices targeted at packaging reduction and eco-design product promotion could allow waste reduction and, therefore, a decrease in GHG emissions released to the atmosphere.

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THE NEW ISO 14001:2015 STANDARD AS A STRATEGIC APPLICATION OF LIFE CYCLE THINKING*

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Abstract

Nowadays the ISO 14001 family of standards has achieved importance: it is a fundamental voluntary tool implemented by many organizations to regulate their relationships with the environment. In a world where the term "environment" is usually seen as a term in contrast with "industry" or "development", it is possible to demonstrate that progress and the environment are not enemies. This study is aimed to prove that environment and industry can collaborate to help each other.
ISO 14001 specifically focuses on ways to implement a management system, upholding the company' environmental responsibilities. This type of certification is also used by firms to increase the stakeholders' trust. A common goal of many organizations is to be able to respect the standards of the ISO 14000 family and to combine productivity and profit with environmental management. The new ISO 14001:2015 was created by market needs, as a way to approach the circular economy and industrial sustainability. The improvements are: a better environmental performance related to proactive actions; a higher level of involvement of top management; a more specific life cycle analysis; a more developed Risk Based Thinking and a better communication strategy. "Acciaierie di Sicilia", part of the group "Alfa Acciai", which is an excellent steel producing firm and leader in Sicily, is the demonstration of a world where industry does not mean "pollution". The firm is aware of the importance of the environment and, for this reason, in 2010 installed new filtration plants and an extractor hood to reduce the levels of the emissions into the atmosphere, the soil and the water. The systems implemented by "Acciaierie di Sicilia" allow the organization to reduce the emissions levels to those imposed by the law, so as to obtain the certification ISO 14001:2015.

*Keywords: c*ircular economy, environmental performance, industrial sustainability, ISO 14001:2015, Life Cycle Thinking

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1. Introduction

As a consequence of the current globalization, firms have approached new frameworks, strategies and tools, in order to broaden their horizons to become more competitive. This is the main reason why they are focusing on two new competitive leverages: the circular economy and industrial sustainability. The former (www.ellenmacarthurfoundation.org) aims at minimizing the negative impact of wastes on the environment, reintroducing them into the production life cycle and converting them into new sources of energy (ec.europa.eu). The latter implies paying more attention to all phases of any product life cycle, now going from cradle to cradle and not from cradle to grave (Tonelli et al, 2013).

The last two decades have been marked by the development and diffusion of many industrial voluntary environmental standards. Through these private or nongovernmental regulations, firms commit voluntarily improving their environmental management practices beyond compliance. These include, for example, the international environmental management standard ISO 14001 (Magali and Montiel, 2008). Scholars analysing the factors that explain the international diffusion of voluntary environmental standards such as ISO 14001 have emphasized the role of national institutional environments and the role of forces related to trade (Corbett and Kirsch, 2001; Delmas, 2000, 2005; Klassen and Whybark, 1999; Kollman and Prakash, 2001; Petra and Taylor, 2001).

ISO 14001:2015 is a useful tool for implementing the circular economy in the perspective of an industrial sustainability, with the adoption of new business models. The point is to start thinking about the environment not as a limity but as an opportunity so as to enjoy the effects of better environmental performances in terms of competitive advantage. The news concerning ISO 14001:2015 is mainly based on the new meaning of “sustainable development”. This concept has been divided into economic, social and environmental sustainability: three different ways of satisfying the new market needs. Another remarkable change that has occurred is the compulsoriness of the Environmental Management System Manual: since the new standards have been conceived and created to fit small firms too, these small firms are not obliged to redact it any longer.

In recent years, the issue of sustainability has attracted considerable attention in the metal sector due to some specific features of metal production processes as well as some recent trends that have characterized the industry as a whole (Arena et al., 2009; Arena et al., 2012; Guo and Fu, 2009; Singh et al., 2007).

First, metal production processes imply relevant environmental impacts related to material, energy and water consumption, polluting emissions and waste disposal. Considerable costs are associated with these factors (cost of materials and energy, cost of waste and disposal, environmental taxes, etc.) that account for a large part of metal production costs. This circumstance has induced production managers and management controllers to pay particular attention to those initiatives that can potentially reduce these costs. In this context, several metal companies have implemented certified Environmental Management Systems (EMS), meaning that the metal sector has become one of the industries with a higher propensity to certificate ISO 14001 (Marimon et al., 2011). The idea at the root of an EMS is to guide companies in the evaluation of barriers and become key drivers for environmental improvement, in the definition of action plans to improve their environmental performances, in the assessment of the efficiency and effectiveness of these action plans, and in the definition of new targets. ISO 14001 is generally considered the most influential standard concerning the requirements of an EMS (Morrow and Rondinelli, 2002). It provides companies with a methodology to evaluate and monitor the environmental impacts of their processes, products and services, without defining the target values of their environmental performances (Barnes, 1996). This study aims to analyse how the new ISO 14001:2015 fits the firm “Acciaierie di Sicilia”, part of the group “Alfa Acciai”, since 1998.

2. Case study: Acciaierie di Sicilia

The organization is located in Catania (Sicily) and produces about 500,000 tons steel a year, obtained by melting scrap iron coming from all over Sicily (www.alfaacciai.it). In order to face the current crisis, it has invested money in increasing the efficiency of the production process, the effectiveness of the entire organization and the awareness of its environmental responsibilities. Thanks to the technology employed, the considerable size of the company, and the high-quality of its outputs, the firm has now a significant position in the European iron and steel industry. Since "Acciaierie di Sicilia" is part of a "polluting sector", it is fundamental for it to be noticed as an organization with superior environmental performances, able to combine productivity and profit with environmental sustainability and circular economy. According to "Federacciai", about 14% of iron and steel industry investments is directed at environmental interventions (Federacciai, 2012). This percentage rises with reference to "Acciaierie di Sicilia", which invests on eco-friendly plants and hoods. As reported by "Federacciai" (Federacciai, 2012) more than 70% of national steel production comes from companies which have the Environmental Management System Certification ISO 14001: "Acciaierie di Sicilia" is part of this percentage too and contributes to the recycling of steel and iron materials in Italy. This makes Italy the leading European country in reusing scrap iron and steel.

The principal advantages of obtaining an ISO 14001 certification are: CO2 emissions lowered by 40% (respecting the Kyoto Protocol); powder emissions lowered of 40%; water and energy saving (about 14% and 20%); improvements in the awareness about waste and consumption of resources. Moreover, the implementation of an environmental management system represents an essential advantage for "Made in Italy" products: in fact, the Italian iron and steel sector is now running the risk of being supplanted by foreign competitors (such as Chinese ones), so that the ISO 14001 Certification can make the difference. Since this sector is characterized by high investment costs, the implementation of an environmental management system also contributes to reducing the expenses related to waste and failures, entailing long-term benefits with regard to lower variable costs. More specifically, "Acciaierie di Sicilia" uses an electric furnace in order to melt scrap iron and steel present in various items (such as cars or even medical instruments and machines). After that, the product (called steel casting) is checked and analysed so as to keep the percentages of minerals and materials (that compose the casting) within the established values.

If irregularities arise, the product is melted again, to avoid the release of polluting substances into the environment: this fact shows the relevance of the firm's analysis lab. In addition, a hood has been installed to reduce and remove particles and VOC (Volatile Organic Compounds) from the air. As can be noticed, this production process perfectly fits the concept of "circular economy": the starting point is represented by waste, that then is reprocessed once, and in the case of failures once again.

3. Material and methods

ISO 14001 is a valuable tool for companies wanting to plan and achieve their objectives related to the Environmental Management System (EMS). Obtaining a sustainable development certification is one of the main aims of governments, organizations (both international and local ones) and companies. On the one hand, laws have been applied to limit pollution but, on the other hand, the unappropriated exploitation of resources and the incorrect management of waste have entailed the degradation of the ecosystems. So, the ISO 14001 has always been the best way to protect the environment and react to the environmental and social changes that have occurred. Therefore, its new version aims at being easier to understand and to apply, so that the improvement involves even its structure, in order to satisfy the "High Level Structure for Management System Standards" (HLS), a scheme expressly created to standardise the future versions of the standards. The scheme includes: a general index, involving 10 points; new contents with interdependent requisites, linked to a “systematic approach”; terms and definitions, with the possibility to add notes, with the aim to explain the concept beyond the term itself.

The ten relevant points, which can be defined as the cornerstone of the standard, are the following: scope; normative references; terms and definitions; context of the organization; leadership; planning (Plan); support (Do); operation (Do); performance evaluation (Check); improvement (Act). It is a completely different structure when compared to the previous one, the new version has twice as many main points: ten not five. Another difference between the two versions of the standard is related to the documents. The Environmental Management Systems are pointless if data are not supervised, measured, analysed and, then, explained. Nevertheless, the new standard is less rigid than the previous one about the compulsoriness of many documents. This does not mean that documents are not necessary anymore; it only means that the standards are now more flexible in order to respect the needs of small firms too, so that the documents are suitable for any kind of organization.

What is most relevant is that the Environmental Management Manual is no longer necessary when the following documents are available: the organigram, to understand who performs the different activities within the company; the risk analysis related to the environmental impacts; the list of the procedures; the management re-examination and so on. Therefore, it is clear that those documents can replace the manual. The main documents required in order to be in compliance with the ISO 14001:2015 standard are the following: the application field of the System; the Environmental Policy; the Planning Process; proof about the competences related to the activities performed within the company; evidence about the processes and the communication activities planned and performed; proof that the operation control has been performed, the preparation and reaction to emergencies have been defined and that the measurement, control, analysis and evaluation of data have been done; the document concerning the Audit; the management re-examination; a document concerning non-conformities, the linked remedial actions and results.

4. Results and discussion

The new ISO 14001:2015 can only be implemented through a careful analysis of the 43 already existing procedures, and it allows the new objectives that must be achieved to be identified. This is why major importance is given to the Environment Manager: this figure has earned a primary role in the definition of what has to be done in order conform with the new ISO 14001. The Environment Manager has to take care of the production plants, organizing the daily maintenance and checking that outside and inside areas meet the standards. As in the past, the Environment Management should deal with the carefully selected suppliers and it is their duty to check them.

The procedure P06 explains that suppliers should fill in a “Questionnaire for the qualification of suppliers/ sub suppliers of scrap” on their own and then they should send it to the Environment Office. If the document is approved, the Environment Office passes it on to the Administration Office that will register it, as can be read at point 9 of the procedure. After the approval of the Questionnaire, the supplier undergoes an audit to check if the Questionnaire is truthful and to give the supplier technical environmental support. Moreover, another main responsibility of the audit is to check that the supplier respects the protocol for the acceptance and management of ferrous and nonferrous metals.

The Environment Manager should check periodically (at least once a year) that the supplier fulfils all the requisites envisaged in the protocol. Furthermore, the Environment Manager must check all the devices and, specifically, must accomplish these goals: defining the necessary metrological features of the needed tools, together with the Establishment

Management; defining the entity of the controls for each accepted tool; planning the setting of the tools and to check the fulfilment and the registration of this activity; finding out and evaluating the measures carried out; registering the accepted tools on the "ALFAGEST" system; supervising the effectuation of the controls and settings; registering the calibration and updating the list of the accepted tools on the ALFAGEST system; checking that the tools are employed and stored correctly. The procedure P03, related to the maintenance of the tools belonging to the plant, is one of the updated procedures. Specifically, it now includes a new term: outsourcing. Nowadays an organization is required to check all the activities performed outside the company itself (so, the activities performed by other firms) and that could have a significant impact on the environment. This means that, currently, a new activity has to be added to the ones already performed by the Environment Manager: the Manager should include all the areas involved in the production cycle in the monitoring module. The concept of "outsourcing" also emerges when we think about the audit concerning the company's suppliers. As a matter of fact, the procedure P06 has been updated, including a new periodical documental and a strict control over suppliers and sub-suppliers. Thanks to this new procedure, the company can face any consequence coming from unexpected modifications, limiting any negative effects and have the possibility to prove that the activities have been performed as previously planned.

Another relevant fact concerning the ISO 14001:2015 are the documents: all the workers responsible for Quality, Environment or Safety have to guarantee the easy identification of the documents, so as to improve their traceability. Moreover, the ISO 14001:2015 entails greater importance to the Product Life Cycle, taking into account unexpected conditions, changes or emergency situations that could influence it. But the most most relevant novelty is that the ISO considers the concept of "analysis of the external business context" for the very first time. To satisfy this requisite, it is necessary to focus on the new concepts of the life cycle and analysis of the external context. The Environment Manager, in collaboration with others (for instance, work groups), identifies the aspects and the factors that could affect a product in terms of environmental impact, taking into account its life cycle. The analysis of the contest is represented by a sort of check list, updated every year or at any time needed. It is a common knowledge that the steel and iron sector is seen as a high impact sector in terms of emissions and this is the reason why being proactive is fundamental for a company which is active in this sector. Thus, the respect of the environment represents a strategic choice for "Acciaierie di Sicilia", which has described the external context and underlined the relevant perceptions of people from outside the firm. The analysis of the context starts with the identification of indicators and criteria specified in the procedure P21 "Environmental aspects and impacts". As a matter of fact, the document representing the environmental analysis, called "Aspects and Impacts Register", and the control of objections have gained great importance.

To focus our attention on the external context, it is relevant to notice that, apart from the warehouses and the office buildings owned by "Acciaierie di Sicilia", other structures and elements must be taken into account: Ikea, Buttaceto River and the beach near to the establishment. Moreover, other data that have been collected by "Acciaierie di Sicilia" refer to the landscape, the site and its evolution, the previous environmental accidents, the socio-economic context and the socio-cultural one. As a result, the firm pays much more attention than others to the following factors: the presence of polluting mists, dangerous emissions or unpleasant smells; the excess of limits concerning the sewage; the presence of loud noises; the contamination of the ground and the subsoil.

The reasons leading to the implementation of ISO 14001 have been analysed and the perceived benefits associated with its implementation in the metal industry. The core objective of ISO 14001 is to provide companies with a pro - active and systemic approach to manage 'environmental variables', reducing the negative impact of their business activities on the environment. The implementation of a certified EMS may contribute to the improvement of the environmental performance, fostering compliance with all applicable environmental regulations; supporting the documentation and analysis of the plant's environmental impacts. Moreover, the adoption of systematic, written and standardized checklist type procedures is aimed to reduce and prevent pollution (Barla, 2007). Empirical work carried out in different settings and industries has highlighted the potential contribution of ISO 14001 to reducing toxic emissions (Arimura et al., 2008; Prakash and Potoski, 2011; Russo, 2009; Szymanski and Tiwari, 2004), the reduction of materials and energy consumption and the reduction of waste (Ammenberg et al., 2002; Kuryllowicz, 1996). Moreover, empirical work provides evidence of the association of ISO 14001 with the reduction of costs related to materials and energy (Ammenberg et al., 2002; Kuryllowicz, 1996), management of both hazardous and non-hazardous waste (Ammenberg et al., 2002), recycling (Jump, 1995), material storage, handling and packaging costs (Kuryllowicz, 1996), and insurance premiums (Kuryllowicz, 1996). The ten items used to assess the aims and benefits associated with the achievement of ISO 14001 are the following: 1. Improvement of environmental performance; 2. Cost reduction; 3. Response to client requests; 4. Implementation of a green marketing strategy; 5. Improvement of corporate image; 6. Improvement in the relationship with local communities; 7. Improvement in the relationship with regulators; 8. Fund raising; 9. Improvement of product quality; 10. Competition with certified competitors (Arena, 2012).

The implementation of ISO 14001 standard is widely recognized has having a positive impact on a firm's relationships with its stakeholders and, in particular, with local communities (Arnaboldi and Spiller, 2011; Coulson and Monks, 1999; Delmas, 2001). To ensure their legitimacy, companies need to recognize their responsibility in relation to the environment and the society, and communicate this both inside and outside the organization (Gavronski et al., 2008). ISO 14001 supports companies in demonstrating to external stakeholders the quality of their environmental systems and in communicating their commitment to preserve the environment, making it clear that the conservation of the areas where they operate is an important part of the corporate strategy. As with the previous issue, the implementation of ISO 14001 can contribute to the improvement in the relationship with the government policy makers, and ensure compliance with environmental regulations (Arnaboldi and Spiller, 2011). Thanks to the implementation of a certified EMS, companies can demonstrate that they take all necessary precautions to prevent environmental accidents and limit the impact of business activities on the environment, minimizing their environmental liability. This can result in less frequent inspections and more flexible enforcement of command and control regulations (Arnaboldi et al., 2004; Potoski and Prakash, 2004; Scholz and Gray, 1997). In addition, ISO 14001 could help companies to enhance their reputation, providing them with opportunities for "green" lobbying, joining government projects and international scientific committees (Potoski and Prakash, 2005). It is important to note that the ability of a company to achieve well identified environmental quality standards can become a necessary element when competing in certain markets and entering new segments (Turner C.R. et al., 2000). In such cases, the adoption of an EMS becomes a critical element to surviving in a market where the status of "green company" is a prerequisite to compete with other companies (Donaldson, 1996).

Thus, the firm will enjoy the consequences of its integrated Environmental-Quality-Safety System: what has been done paves the way to integration, considering that the ISO 9000 standards have been updated too.

5. Concluding remarks

The importance "Acciaierie di Sicilia" gives to the meaning of an Environmental Control System has entailed a detailed analysis of the ISO 14001:2015. The main aim was to analyse the differences between the old and the new ISO 14001, with the intention of creating guidelines for the definition of an Environmental Management System.

The advantages of implementing the ISO 14001:2015 can be summed up as follows: economic advantages related to a better market share; financial benefits related to viable suretyships or favourable access to credit; legal advantages related to the respect of law and the proactive behaviour of firms.

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BIOGAS PRODUCTION BY MEANS OF LIVESTOCK COMPOST*

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Abstract

The concept the "circular economy" focuses on the conscious and sustainable management of waste products, to reuse them in a more efficient way, re-introducing them into the production cycle as "secondary raw materials", instead of adopting a simple waste disposal treatment. In this way, the products' lifecycle is extended to ensure a new use. The aim of this paper is to analyze the anaerobic digestion techniques used to obtain small-scale biogas, with the purpose of incorporating together the production, industrial collection and management systems' and the amount of the sewage produced by the livestock company "Azienda Agricola Mulinello Srl", located in the Sicilian hinterland. The company owns a close-loop pig farm of 5,000 livestock units (ranging from 110 to 120 Kilograms), its own slaughterhouse, a meat processing laboratory, a production plant for cured meat, a feeding system and a composting plant for processing effluents. The entire establishment has got a circular economic system. The anaerobic digestion system becomes particularly important in the "circular" view, as it allows the re-use of processed effluents and organic waste by their transformation into biogas and bio-fertilizers. This is the reason why the company plans to install an anaerobic fermentation plant for the autonomous production of electricity and heat to be re-used within the factory itself, and also to redeploy processed sewage as organic fertilizer. The company could obtain several positive results from this plant, such as: the reduction of waste products, a decrease in disposal costs, possible income from the sale and exploitation of the so-called "digestate", and the participation in European incentive plans for the production of renewable energy. In the long run this method, which exploits effluents, will not only provide the company with savings, but it will also represent benefits both in terms of financial earnings and health.

Keywords: biogas, circular economy, sustainable production, zootechnical waste, zootechnis

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1. Introduction

The Circular economy represents a theoretical concept whose purpose is to create an industrial system thought to self-regenerate (Genovese et al., 2017). Infact recyclable materials are reintegrated into the production system as second raw materials. As Ellen McArthur said: *"There are two types of material flows: biologic ones, which can be reintegrated into the biosphere, and technical ones, which are destined to be revalued without entering into the biosphere"*. The economic system is becoming more and more aware of the issue because it considers circular economy as an instrument to get a competitive edge (Genovese et al., 2017). In this scenario biomasses and derived biofuels represent an alternative energy source. Biogas can be obtained from a wide variety of processes such as the decomposition of urban and industrial waste, landfills, co-digestion of livestock and agricultural waste. Biogas can be considered as one of the most well-known and widely used biofuels (Cipitı et al., 2016). Through the optimization of these wastes, the use of recyclable materials and the use of energy from renewable sources, such as biogas, it is possible to activate a virtuous circle of production and a sustainable consumption that can improve the environmental conditions of our planet and the life of its inhabitants (La Via et al., 2016).

In addition to the production of energy from a renewable source and the related reduction of fossil fuel consumption, there are other benefits such as (Ciancaleoni et al., 2011):

- the use of digestate as fertilizer in place of chemical ones. This allows the reduction of the risk of pollution and eutrophication of surface and waters;
- a more efficient assimilation of nutrients by plants, especially organic nitrogen;
- the reduction of emissions of methane gas, other climate-altering gases and substances which generate odors, that are collected in biogas or metabolized by microorganisms during the digestion process and subsequently burnt in energy conversion;
- the reduction of potentially pathogenic or parasitic agents in the sewage.

The aim of this paper is to analyze the anaerobic co-digestion techniques that will be used to obtain biogas by the livestock company “Azienda Agricola Mulinello Srl”. The company deals with light Mediterranean pig products and has a breeding of 5000 pigs for the supply of sewage to be reused. The company’s plant for biogas production will have an anaerobic fermenter in which, without oxygen and at a controlled temperature, the bacteria will degrade the organic matter. In this way, the company will obtain biogas, heat and digestate: biogas will be used to produce electricity in a waste-to-energy plant; heat will be used to heat the company’s offices and in the fermentation process; digestate will be used as a natural fertilizer in farm crops, whose quality is far superior to manure. (http://www.biolectricitalia.it/i-nostri-impianti.html)

2. Material and methods

In the perspective of circular economy, the construction of biogas digesters is a key program to increase the supply of clean energy, achieve emission reduction and promote sustainable development (Dai et al., 2015). The overall pollution prevention targets, the objectives of the Kyoto agreement recently important issues related to human and animal health and food safety require increasingly sustainable solutions for handling and recycling of animal manure and organic wastes, where biogas from anaerobic co-digestion of animal manure, combined with pre- and post-treatment technologies, play an increasingly important role (COM, 2015)

The large amounts of animal manure and slurry produced today by the animal breeding sector as well as the wet organic waste streams represent a constant pollution risk with a potentially negative impact on the environment, if not managed optimally. To prevent emissions of greenhouse gases (GHG) and leaching of nutrients and organic matter to the natural environment it is necessary to close the loops from production to use by optimal recycling measures. Biogas can be produced from nearly all kinds of biological feedstock types, within these from the primary agricultural sectors and from various organic waste streams from the whole society. The largest resource is represented by animal manure and slurry from cattle and pig production units as well as from poultry, fish, fur, etc. In the EU-27 alone, more than 1500 mil. tonnes of animal manure are produced every year. European agriculture handles more than 65% of livestock manure as slurry, a liquid mixture of urine, feces, water, and bedding material (Holm-Nielsen et al., 2009).

The energy- environmental scenario, recently seen in Italy, has been marked by the development and upgrading of renewable energy sources through the incentive tools provided by the relevant rules deriving from the European Union (EU) guidelines. Plant and animal biomass is a resource that the agricultural and livestock breeding world, in Italy, is very interested in, for the various economic and environmental repercussions resulting from its transformation into energy (Lombardi et al., 2008).

Mulinello farm s.r.l. boasts a closed-loop big-breeding, of animals from 110 to 120 kg born and raised in Sicily, its own slaughterhouse, a meat processing workshop and a factory for the production of sausages. The company has the ISO 22000 certification; this norm has had great impact on the world of certification because it allows the use of a valid reference known world-wide. The standard is applicable to the various sectors of the production chain divided into categories. Starting from the fact that a consumer health risk may occur at any stage of the production/distribution chain, ISO 22000 has been designed to be applicable to all actors in the agri-food chain (Di Martino, 2014). In addition, the plant to be implemented by the company will have an anaerobic fermenter where, in the absence of oxygen and at controlled temperature, the bacteria will degrade the organic substance; this way biogas, heat and digestate will be obtained.

Anaerobic digestion is a solid and widely applied biochemical process for the energy conversion of biodegradable organic substances (Gardoni et al., 2016). Biogas can be used to produce heat and electricity as well as motor fuel. In addition, the digestate from biogas production, when used as fertilizer, can reduce the use of chemical fertilizers that are produced by fossil energy sources. Increasingly, various industrial sectors (e.g., utilities, transportation, waste management, and agriculture) have begun to use biogas technology as a way to meet social and environmental responsibilities as well as to increase resource efficiency (Karlsson et al., 2016).

In the European Community, biogas represents the most widespread fuel obtained from biomass in recent years, thanks to the specific legislative tools aimed at increasing production in the various economic sectors involved: ranging from livestock breeding to agro-industrial. In particular, biogas deriving from animal waste constitutes an ever increasing commodity in some EU Member States (such as, Germany, Denmark, Sweden and Austria) and also great potential in other states (such as Italy). Greater use of animal sewage, as raw material in the production of biogas, was strongly encouraged by the new guidelines for energy-environmental and agricultural policies set out in the various norms issued to this regard (such as Regulation 1774/2002 concerning disposal procedures and use of animal origin by-products as well as the subsequent temporary and implementation norms, such as Regulation 810/203 EC, 92/2005/EC, 208/2006/EC, 209/2006/ EC, 185/2007/EC, Directive 91/676/EEC regarding the spreading of nitrates, Directive96/92/EC. There are various final objectives to be achieved: a decrease in air and soil pollution linked to their disposal; the production of an amendment as a debris by-product (for fertilization or as a colloidal humus); and an increase in the amount of energy deriving from renewable sources, using simple technology already present on site (Tricase et al., 2009).

In the national, particularly regional, legislative decree of January 17, 2007, no. 10, the approval of the regional ruling concerning the use of livestock effluent and waste water from comapnies in agricolture was included referred to in art. 101, paragraph 7, letters a), b) and c) of Legislative Decree no. 152, and from small agri-food companies, issued in pursuance of the Decree of the Ministry of Agricultural and Forestry Policies of April 7, 2006.

Annex 2, which contains the main features of the discipline, is structured as follows:

- Title I: Scope;
- Title II: Livestock effluents;
- Title III: Waste water from the companies referred to in art. 101, paragraph 7, letters a), b) and c) of Legislative Decree no. 152;
- Title IV: Waste water from small agri-food companies;
- Title V: Communication and transport;
- Title VI: Agronomic use in areas vulnerable to nitrates;
- Title VII: Additional requirements and controls.

3. Experimentals

The Mulinello Farm is a small enterprise that has 44 employee and is located in the middle of Sicily, in particular in the province of Enna. It was founded in 1976 as a closed-loop farm for pigs.

This company is the only one in Sicily it has got a crossbreed process between *big white* and *pietrain* species, thanks to the collaboration between the Universities of Messina, the University of Turin and the University of Lyon. On average, within a year, 15,000 head of livestock pass through this company.

In addition to the breeding of closed-loop pigs, the company has, over the years, been integrated into other related sectors (Decree 22, 1997):

- The feed sector, with the integration of a grinding mill and a feed mill (powered by grain products) for the production of livestock feed for animals. This plant is characterized by a special technology which consists in inserting a microchip into the animal, which allows the system to recognise the animal and provide it with a customized feed; The production consists of four types of feed for the different phases of the pig's life: pig under nursing, weaning 1 (up to 30 kg), weaning 2 (up to 60 kg) fattening; The company also deals with the commercialization of local food businesses, the "Biovit", produced in special plants located in Emilia Romagna;
- Slaughter industry, which took effect on 10 July 2001;
- Transformation and freezing, with attached tunnel of abatement;
- Laboratory annex for production of fresh sausage and chopped meats;
- Laboratory for the production of meat-based foods;
- Wastewater treatment plant for compost production.
- In 2018 a biogas plant powered by swine-derived slurries will also be operating.

The products are distributed both in Italy and abroad, particularly in England, Ireland and France as regards salami, and Holland for meat. Recently the company has also opened up to foreign trade, creating a line of exports to Japan, where mainly Nebrodi black pork is marketed. The company is also looking for additional markets to invest in, looking particularly at the US market, and also intends to expand its plant with a further sales outlet.

Today, thanks to the implementation of the biogas production plant, the company aims at being autonomous in every stage. The slurry intended to feed the plant will be exclusively derived from the plant. The heat and the energy produced by the plant will be reused within the company's production processes, allowing for a reduction in wastewater management costs, reducing the cost of electricity needed for production.

4. Results and discussion

The livestock company “Mulinello srl” will employ a biogas plant using the anaerobic digestion techniques of livestock wastes. The Bioelectric NV has offered a 44 kW biogas plant with a turn-key formula which produces energy only from effluents. It is an aerobic fermentation plant, controlled by an Internet system, for the autonomous production of electricity, heat and digestate effluents. The Bioelectric NV plant presents a rated power of 44 kW, a heat rated power of 152 kW, a productivity of 8000 hours and an annual electric energy production of 352.000 kW. The initial investment is € 310,000 with an amortization period of 4.2 years, an estimated annual revenue of € 72,994.24 and a state incentive of € 0.233/kWh. The plant can deliver the calculated output provided that the fed sewage has sufficient gas production capacity. The potential is identified in a range of 25-30 cubic meters of biogas per ton of sewage. “Mulinello srl” can supply sewage from about 5,000 pigs. Therefore, assuming that the available sewage will make 20 cubic feet of biogas per ton of sewage, the company will require about 22,000 tons of sewage per year to produce 440,000 cubic meters of biogas annually to fuel the plant.

The Bioelectric offer includes a container, with:

- pump to send the digestate to a storage tank;
- heat exchanger for water heating, using the co-generator’s excess heat;
- two biogas engines with indication of the power and heat recovery from the engine block and exhaust fumes;
- gas line with filtration and air injection adjustable to the gasometer;
- electronic driving device (BMC) which monitors the whole plant;
- flow gauge which allows the BMC to measure the amount of fresh effluents pumped into the system;
- digester, sufficiently isolated and equipped with radiators for the heating of the digestion material;
- sealed inner covering;
- gas extraction system, connected to the reactor;
- insulation of the pipes between the reactor and the container, to avoid the damp condensation produced by the biogas;
- mixer, inside the reactor, to ensure sufficient mixing in the reactor vessel;
- dual-membrane gasometer system and the fan required to blow air into the cavity;
- boiler for heating the reactor during startup;
- crushing pump that transfers fresh sewage to the reactor;
- installation and electrical connection of the pump for fresh sewage;
- installation of pipes which connect the plant to the pump and to the storage of effluents.

The plant will collect a certain amount of sewage daily from the reactor and send it to the digestate storage. Later, it will fill the volume of sewage removed with fresh sewage collected from the sewage tank. For an optimal operation of the sewage collection process from the tank, the sewage introduced must be as cool as possible without contaminants such as sand or stones, and it is necessary that any medicines and sanitizing substances are not present in high concentration in order to avoid a negative effect on fermentation and biogas production. Sewage has a yield performance of 18-22 cubic meters of biogas produced every 1,000 liters, depending on both its density and its freshness. Depending on the composition 28-40 cubic meters of sewage is needed daily. In order that the fresh sewage gas potential is not lost, contact between fresh material and digestate must be avoided. The fermentation of the sewage takes place inside the reactor at a temperature of about 35-38°C (mesophilic fermentation process). The reactor consists of a digester with a diameter of 15.60 meters and a height of 2.5 meters, whose covering is made up of a double membrane while all its perimeter is covered by an insulating layer that allows a constant temperature to be maintained inside the reactor. The external sides of the silo are covered with stainless steel plates.

The biogas produced by the process of fermentation is purified by gasometers, then flows through an activated carbon filter that retains the remaining impurities. The gas produced consists of 55% methane gas, which supplies the engine. The heat produced by the engine is then transferred to the reactor by means of a heat exchanger and a radiator to reach the desired temperature. To ensure the maximum performance of this process, the green container, where the engine is located, is installed near the reactor. For a correct functioning of the biogas plant, waste heat is dispersed to avoid problems derived from excessive temperatures, above 42°C. The control of the various processes is carried out by using the BMC (Bioelectric Master Control) system, which ensures that the digester's environmental conditions are always optimal to allow the colony of bacteria present in the organic matter to complete digestion and develop methane gas. The process is monitored by a series of sensors that communicate constantly with the BMC. Finally, the company will be able to control its power production through the Internet 24/7.

5. Conclusions

Over the years, there is an increasing spread of management practices that try to integrate environmental protection and achieve operational efficiency, minimizing the negative externalities of production and consumption processes. The use of livestock waste for the production of biogas stand out to the traditional method of applying soil slurry, reducing greenhouse gas emissions and saving fossil fuel.

The aim of this paper was to analyze the application of the biogas production method in a Sicilian enterprise that is highly aware of environmental issues with its proactive use of environmental policy tools throughout the production chain.

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